ISSN: 1813-4890

Short-term effectiveness and safety of sleeve gastrectomy with transit bipartition: a single-arm meta-analysis of global patients

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Abstract

While bariatric surgery remains the most effective approach to address obesity and its associated metabolic conditions, there is an ongoing debate concerning the optimal surgical technique. Recently, the combination of sleeve gastrectomy with transit bipartition surgery has garnered attention for its potential benefits. The purpose of this meta-analysis is to assess the short-term effectiveness and safety of this combined procedure in individuals dealing with obesity. Systematically searched PubMed, Embase, Scopus, Cochrane Library, Web of Science, CNKI, and WANFANG databases for relevant studies. For further analysis, the extracted outcomes included BMI, FPG, HOMR-IR, HbA1c LDL, Vit B12, and postoperative complications. Stata/SE 12.0 was used for data analysis and a meta-analysis was conducted to combine health indicator data from various studies. Summary estimated effects were calculated using a random effects model, if fixed effects were not applicable. Additionally, sensitivity analysis was performed and potential publication bias was assessed using a funnel plot. This meta-analysis, including 12 studies with 2,221 patients, found significant weight loss postoperatively. The reduction in BMI at 1, 3, 6, and 12 months was 4.34 kg/m2, 7.00 kg/m2, 9.96 kg/m2, and 13.53 kg/m2, respectively. Additionally, reductions in FPG and HbA1c% were observed at various follow-up time points. Postoperative complications related to SG-TB included gastroesophageal reflux (0.294-14.286%), gallstones (1-12.941%), and leaks/fistulas (0.340-1.133%). This meta-analysis provides evidence that the sleeve gastrectomy with transit bipartition holds considerable promise in terms of effectiveness and safety for patients dealing with obesity and accompanying metabolic disorders.

Keywords

Sleeve gastrectomy with transit bipartition(SG-TB); Bariatric surgery; Adverse events; Effectiveness; Weight loss.

1. Introduction

Bariatric and metabolic surgery is widely accepted as the gold standard for treating obesity and metabolic diseases due to its superior effectiveness and sustained weight loss outcomes. The most popular procedures globally are Sleeve Gastrectomy and Roux-en-Y Gastric Bypass(RYGB)[1]. RYGB was introduced in the surgical treatment of patients with obesity in the early 1960s, and due to its significant weight loss effects, it has been regarded by most bariatric surgeons as the "gold standard" procedure for obesity treatment[2]. A more challenging learning curve and the potential for postoperative malnutrition, diarrhea, and other risks have resulted in sleeve gastrectomy gradually surpassing it in terms of surgical volume[3].

From a 5-year perspective on weight loss, sleeve gastrectomy (SG) shows weight reduction effects not inferior to RYGB, and it is more in line with the human physiological structure[4]. However, the probability of weight regain is relatively high when relying solely on the excision of the greater curvature of the stomach, and the increased gastric cavity pressure restricts SG application due to postoperative reflux esophagitis.

In recent years, bariatric surgeons have conducted extensively explored improving weight loss procedures. On the one hand, subtraction has been performed based on gastric bypass surgery, such as one anastomosis gastric bypass (OAGB) and biliopancreatic diversion with duodenal switch (BPD-DS). On the other hand, additions have been made to sleeve gastrectomy, and these procedures are collectively referred to as sleeve gastrectomy plus (SG-plus)[5]. SG-plus involves the addition of foreign materials or additional interventions on the small intestine and/or gastric fundus after the completion of SG. Just like SG, the SG-plus procedure does not leave behind a remnant gastric pouch, making it a preferred choice for patients with a family history of gastric cancer or precancerous lesions. Combining sleeve gastrectomy with transit bipartition (SG-TB), which combines intake restriction with reduced absorption, is a promising procedure among SG-plus.

In 2006, Santoro and colleagues reported this procedure, which combines sleeve gastrectomy with transit bipartition (SG-TB), involving Roux-en-Y gastrojejunostomy of the stomach pouch located 260 cm from the ileocecal junction. This procedure does not include narrow anastomoses, exclusion segments, or prostheses[6]. Besides, SG-TB is also suitable for patients with obesity and type 2 diabetes (T2DM). Nevertheless, nearly all studies on SG-TB for the treatment of obesity with or without metabolic diseases are non-randomized controlled trials with small sample sizes, inconsistent modifications of this procedure, and uncontrolled statistical analyses, potentially resulting in a lack of effective measures for evaluating the efficacy and safety of SG-TB. Hence, this paper aims to review relevant research on SG-TB in treating obesity with or without metabolic diseases and assess its effectiveness and safety through a meta-analysis.

2. Methods

2.1. Search Strategy

In accordance with the MOOSE (Meta-analysis of Observational Studies in Epidemiology) guidelines[7], we conducted a comprehensive literature search across seven electronic databases (PubMed, Web of Science, Cochrane Library, Scopus, Embase, CNKI, and WANFANG), to identify 12 studies from January 1, 2004, to September 8, 2023. No language restrictions were applied. We used the following combination of text and MeSH terms: “SG” and “transit bipartition”. The full search query for PubMed was: (LSG[Text Word] OR SG[Text Word] OR sleeve gastrectomy[Text Word]) AND (transit bipartition[Text Word] OR intestinal bipartition[Text Word]). Queries for other databases were adapted from this search strategy. We attempted to identify additional articles that may have needed to be included in the initial search strategy by reviewing the reference lists of all included studies, personal collections, and manual searches. This study was registered in the PROSPERO.

2.2. Selection Criteria

Inclusion criteria are as follows: 1) Population: Adult patients with BMI≥35 kg/m2 or BMI≥30 kg/m^2 accompanied by one or more comorbidities, such as T2DM, OSAS, dyslipidemia, hypertension, arthritis back pain/joint pain, etc., regardless of subtypes; 2) Intervention: Patients undergo SG-TB; 3) Study type: Prospective or retrospective controlled studies or cohort studies; 4) Outcomes: Report weight related indicators at follow-up time such as BMI and metabolic disease related indicators like homeostasis model assessment for insulin resistance (HOMR-IR), fasting plasma glucose(FPG), glycated hemoglobin, or occurrence of postoperative complications. Exclusion criteria are outlined as follows: 1) Study subjects: Animal experiments or non-human studies; 2) Literature type: Reviews, meta-analyses, abstracts, editorials, letters, expert opinions, commentaries, or case reports; 3) Other diseases that could potentially affect the prognosis; 4) Other modified surgical procedures such as SASI, SASJ, isolated intestinal partition (IT), and surgeries involving additional rings; 5) Or appropriately exclude studies with fewer than 10 patients. Two researchers (FQ Zhou, SL Dong) screened all titles and abstracts relevant to the study and independently reviewed the full texts of relevant studies. Any discrepancies regarding including studies were resolved between these two individuals or the third researcher (WH Chen). In cases where multiple articles targeted the same cohort with identical exposures and outcomes, the article with the largest sample size or most comprehensive follow-up was retained.

2.3. Data Extraction And Quality Assessment

Two researchers independently extracted all the required data from the included studies, followed by a quality assessment of the studies. The summarized features extracted include (1) first author, (2) publication year, (3) country, (4) study design, (5) study duration, (6) sample size, (7) patient demographic data such as gender, age, and BMI (mean±[SD]), (8) median or maximum follow-up period, (9) BMI, percentage of excess weight loss (%EWL), FPG (mean±[SD]), HOMA-IR, HbA1c, LDL (mean±[SD]), and Vit B_{12} (mean±[SD]) at different follow-up time, and (11) postoperative complications. When published information was insufficient or only reported in figures, attempts were made to contact the corresponding authors to obtain additional data, and WebPlotDigitizer was used for data extraction when necessary[8]. In addition, two researchers independently assessed and extracted the required data from all included studies. The Newcastle-Ottawa Scale (NOS) was used for the quality assessment of non-randomized trials[9]. Moreover, retrospective studies were evaluated using the JBI Case Series Critical Appraisal Checklist[10].

2.4. Statistical Analysis

They analyzed the data using Stata/SE 12.0 (StataCorp LP4905 Lakeway Drive College Station, TX 77845 USA). Baseline data was employed as the control group. Meta-analysis was performed to aggregate the effect sizes, as well as 95% confidence interval (CI), for the reductions in BMI, FPG, HbA1c, HOMR-IR, LDL, and Vit B_{12} at various follow-up time points (the difference between baseline and follow-up values) and employed a random-effects model to present the summarized estimated effects using weighted mean differences (WMD) and utilized I^2 and heterogeneity tests to evaluate the heterogeneity among the studies. Significance in statistical heterogeneity was determined when I^2 exceeded 50% in the studies. Data pertaining to complications were documented when they were involved in the studies. Furthermore, a sensitivity analysis was performed to assess the stability and reliability of the combined outcomes. Finally, potential publication bias was assessed through a funnel plot.

3. Results

3.1. Study Selection

The initial search across seven databases (PubMed=46, Embase=77, Web of Science=75, Scopus=55, Cochrane Library=8, WANFANG=20, and CNKI=10) resulted in 291 published relevant studies. After removing duplicates and screening titles and abstracts, 110 studies were retained. Subsequently, a thorough assessment of the full-text articles led to excluding 98 studies for reasons such as animal experiments, article types, lack of relevant outcome reporting, repetitive reporting from the same cohort, and small sample size studies. Countries with a higher research volume include Turkey, Brazil, China, France, and Russia. Finally, 12 studies met the inclusion criteria[11–22], with a total of 2,221 patients included in this meta-analysis, of which 10 were retrospective studies. The flowchart of the selection process is depicted in Figure1. Detailed information for each included study is presented in Figure1.

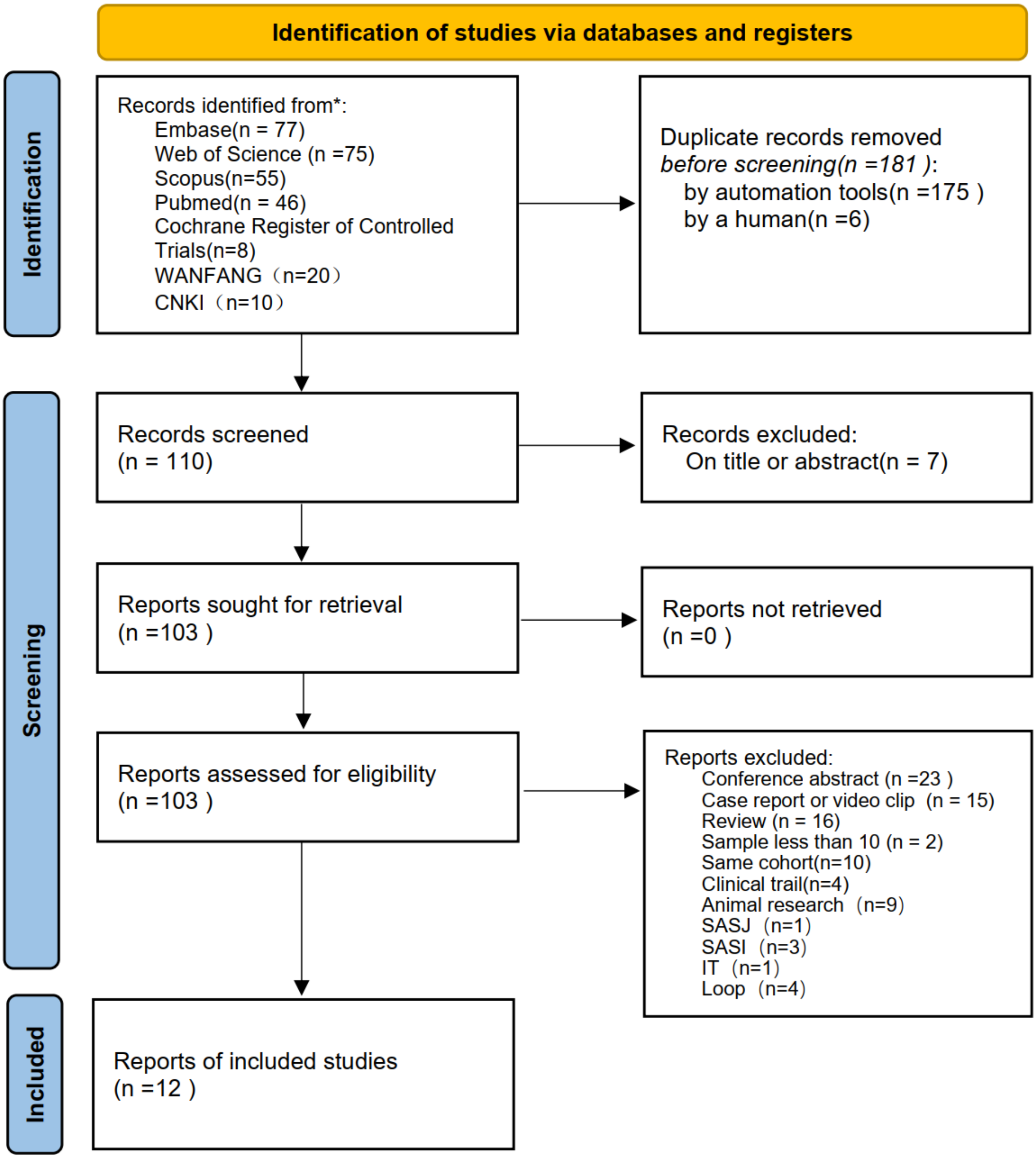

Figure1: The flowchart of the selection process

*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers)

*if automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

ISSN: 1813-4890

Table 1: Key Features of Studies Incorporating the SG-TB Procedure in the Meta-Analysis.

Author(Year)	Design	Data Period	Nation	Sample size	Female	Age(year)	Baseline BMI* (kg/m2)	HbA1C	FPG*	Home-IR*	Vitamin B_{12}	follow-up time(Mo)
Okuyan et al.(2023)	Retrospective	2019-2020	Turkey	21	13	46.6±9.1	43.7±4.9	-	-	-	-	12
Al et al.(2022)	Retrospective	2015-2019	Turkey	883	516	51.8±9.0	34.1±5.0	9.70±1.5	-	-	-	12
Shan et al.(2022)	Retrospective	2020-2021	China	13	12	29.0±11.4	35.67±3.11	7.90±1.88	8.47±3.21	6.60±4.78	-	6
Gulaydin et al.(2022)	Retrospective	2018-2019	Turkey	24	16	46.13±9.96	41.38±3.16	-	-	-	-	12
Calisir et al.(2021)	Retrospective	2014-2017	Turkey	32	17	43.5±10.18	44.70±9.34	9.25±1.86	12.7±3.1	6.95±1.40	337.79±45.70	30.22±6.74
Ece et al.(2021)	Retrospective	2013-2018	Turkey	26	20	47.3±6.1	43.8±2.1	9.0±1.2	10.75±1.172	11.8±8.1	462.4±41.6	16.6±5.1
Yao et al.(2021)	Retrospective	2019-2021	China	41	32	34.6±7.0	37.3±5.7	8.8±2.2%(39)	10.6±4.3	-	482.3±148.8	12
Karaca et al.(2020)	Retrospective	2017-2018	Turkey	45	22	51±8.06	38.05±8.7	9.1±1.35	12.222±4.278	14.6±23.1	393±197	12
Topart et al.(2020)	Retrospective	2017-2018	France	71	47	42±18.7	53.5±4.6	-	-	-	-	24
Bilecik et al.(2019)	prospective	2016-2017	Turkey	35	35	48.8±6.0	42.0±1.3	9.1±1.0	10.42±2.6	-	-	14.3±2.8
Azevedo et al.(2018)	RCT	2014-2015	Brazil	10	0	45±10	33.4±2.6	9.3±2.1	12.06±5.72	-	-	24
Santoro et al.(2012)	Retrospective	2004-2011	Brazil	1020	695	42±13.25	42.2±9.75	-	-	-	-	60

*BMI：Body mass index

FPG: Fasting plasma glucose

Home-IR :Homeostatic model assessment of insulin resistance, HOMA-IR = FPG（mmol/L）× FINS（μU/mL）/22.5

3.2. Quality Assessment

The NOS was used to assess five controlled studies, which categorized the research into three dimensions based on eight items, including population selection, comparability, and assessment of outcomes (cohort studies) or exposure (case-control studies)[9].The quality of included studies was rated as moderate or high, with NOS scores ranging from 8 to 9.Seven retrospective studies were assessed using the JBI Case Series Critical Appraisal Checklist, which comprises ten items evaluating the quality of case reports, including case selection, disease or health issues, and presentation of case data. The JBI score still has a high quality ranging from 8 to 10.

3.3. Patient Characteristics

This systematic review included 12 studies involving 2221 patients (Table 1). Among the 12 studies, there were 796 (35.84%) male patients and 1425 (64.16%) female patients, with two studies reporting data for a unified gender[12,13]. The patients' ages ranged from 29.0±11.4 years to 51.8±9.0 years. Baseline BMI ranged from 33.4±2.6 kg/m^2 to 53.5±4.6 kg/m^2.

3.4. Effect of SG-TB on BMI

Nine studies, which included BMI reduction values (baseline BMI - follow-up BMI) and underwent meta-analysis, were divided into four groups based on follow-up time. In the 1M group (4 studies), the follow-up duration was one month, with a baseline BMI range of 34.1±5 to 44.7±9.34 kg/m^2. This range decreased significantly during the follow-up from 30.5±5.7 to 41.04±5.37 kg/m^2. In the 3M group (7 studies), the follow-up duration was three months, with a baseline BMI range of 33.4±2.6 to 44.7±9.34 kg/m^2. A significant reduction from 26.7±6.3 to 37.33±4.84 kg/m^2 was observed at follow-up.

In nine studies (n = 2057), the overall mean weighted average BMI reduction at follow-up was 9.13 kg/m^2 (95% CI: 7.92-10.33). The BMI reduction effect sizes at 1, 3, 6, and 12 months post-surgery were 4.34 kg/m^2 (95% CI: 2.37-6.31), 7.00 kg/m^2 (95% CI: 5.46-8.54), 9.96 kg/m^2 (95% CI: 6.96-12.96), and 13.53 kg/m^2 (95% CI: 9.49-17.57), respectively.

Heterogeneity testing using a random-effects model revealed significant heterogeneity in BMI reduction among all eight studies (I^2 = 96.2%, $p < 0.001$). The 1-month postoperative group exhibited relatively lower heterogeneity (I^2 = 70.8%, p = 0.017), whereas the heterogeneity in BMI reduction at 3, 6, and 12 months post-surgery was notably significant (I^2 = 80.4%, $p < 0.001$; I^2 = 93.7%, $p < 0.001$; I^2 = 97.0%, $p < 0.001$), as depicted in Figure 2 and Table 2.

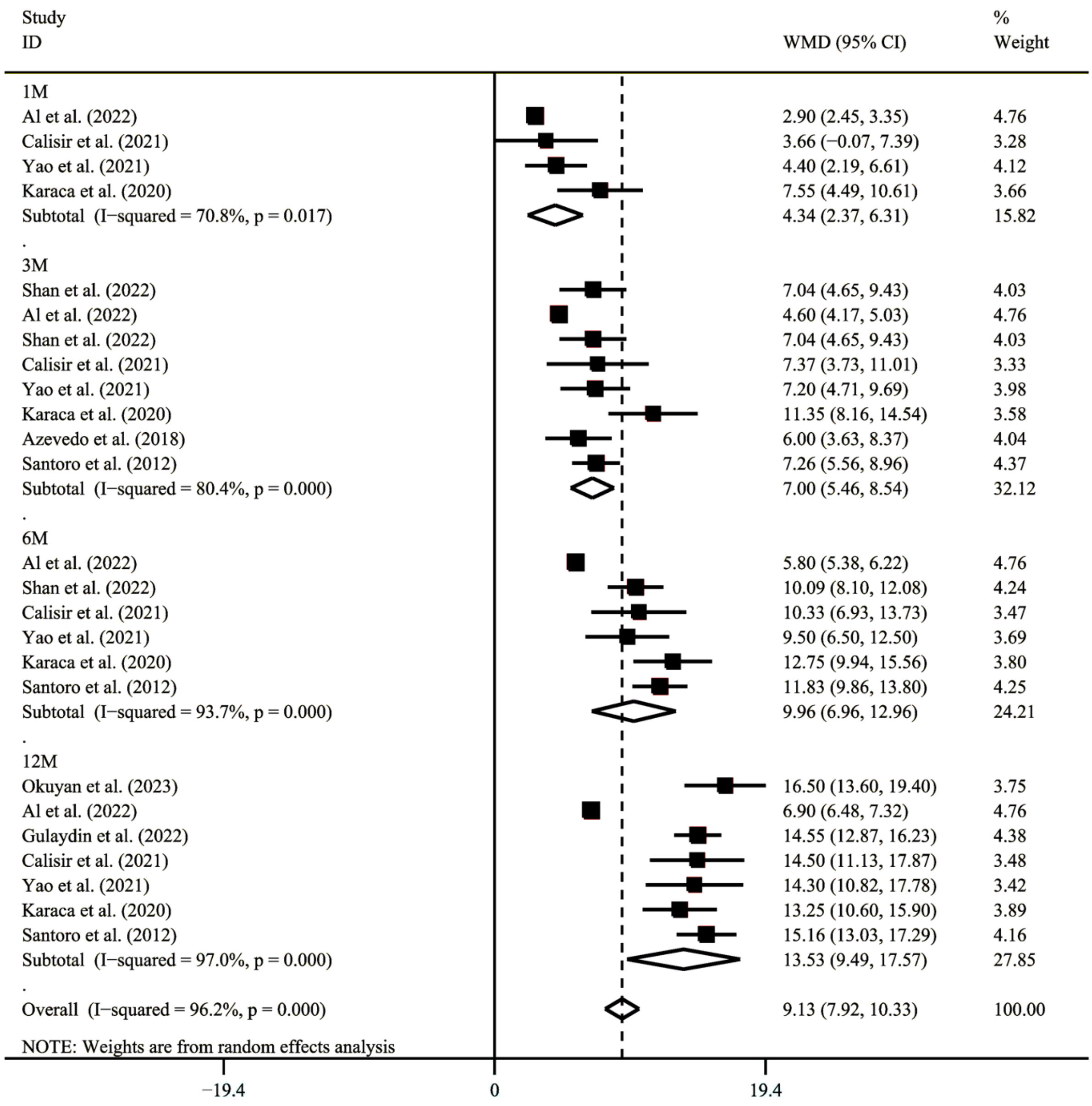

Figure 1 Forest plot of WMD mean of BMI loss (BMI at follow-up – BMI at baseline) with its 95%CI.

Table 2 Subgroup Meta-Analysis Findings for the SG-TB.

	Model	Follow-up	No. of studies	I^2	P value for heterogeneity	Pooled WMD (95%)	P value for pooled
BMI	Random						
		1M	4	70.80%	0.017	4.34(2.375,6.307)	<0.01
		3M	7	81.90%	<0.01	7.01(5.313,8.709)	<0.01
		6M	6	93.70%	<0.01	9.96(6.964,12.961)	<0.01
		12M	7	97%	<0.01	13.53(9.491,17.569)	<0.01
				96.40%	<0.01	9.21(7.98,10.448)	<0.01
FPG	Random						
		1M	4	90.30%	<0.01	4.017(2.228,5.807)	<0.01
		3M	6	0	0.427	4.839(4.283,5.394)	<0.01
		6M	5	74.00%	0.004	5.515(4.314,6.717)	<0.01
		12M	3	1.20%	0.363	6.973(6.124,7.822)	<0.01
				87.60%	<0.01	5.1(4.228,5.972)	<0.01
HbA1C	Fixed						
		1M	5	4.90%	0.379	2.066 (1.951,2.181)	<0.01
		3M	7	71.90%	0.003	3.190(3.086,3.293)	<0.01
		6M	7	0	0.715	3.322(3.221,3.423)	<0.01
		12M	5	0	0.814	3.399(3.295,3.504)	<0.01
				94.80%	<0.01	3.042(2.989,3.095)	<0.01
LDL	Fixed						
		1M	4	49.50%	0.114	20.931(12.455,29.406)	<0.01
		3M	4	68%	0.025	24.19(14.384,33.995)	<0.01
		6M	3	0	0.620	35.92(32.204,39.636)	<0.01
		9M	2	0	0.336	38.35(34.547,42.154)	<0.01
		12M	2	17.80%	0.270	41.614(34.977,48.251)	<0.01
				83.60%	<0.01	30.591(25.622,35.56)	<0.01
Vit B_{12}	Random						
		1M	4	78.20%	0.003	6.008(-54.164,42.148)	0.807
		3M	2	29.30%	0.243	18.662(-4.255,41.578)	0.110
		6M	2	63.30%	0.065	34.522(1.4,67.643)	0.041
		12M	3	78.30%	0.003	26.975(-26.417,80.367)	0.322
				74.80%	<0.01	20.732(0.899,40.566)	0.040
HOMR-IR	Fixed						
		1M	3	32.20%	0.229	2.946(0.919,4.973)	0.004
		3M	3	59.60%	0.084	5.149(2.751,7.546)	<0.01
		6M	3	52%	0.125	5.572(3.51,7.633)	<0.01
		12M	2	83.10%	0.015	8.394(0.268,16.52)	0.043
				84.30%	<0.01	4.78(3.749,5.811)	<0.01

*BMI：Body mass index, FPG: Fasting plasma glucose, HbA1C: Hemoglobin A1C, LDL: Low-Density Lipoprotein, Vit B_{12}: Vitamin B12, Home-IR: Homeostatic model assessment of insulin resistance, HOMA-IR = FPG（mmol/L）× FINS（μU/mL）/22.5

3.5. Effect of SG-TB on Blood Glucose Metabolism

Analysis of the 7 included studies reported changes in FPG (FPG reduction = baseline FPG - FPG at follow-up) after SG-TB surgery using a random-effects model, with an overall weighted mean FPG reduction of 5.10 mmol/L (95% CI: 4.23-5.97). Subgroup analysis based on follow-up time revealed FPG reductions of 4.02 mmol/L (95% CI: 2.23-5.81), 4.84 mmol/L (95% CI: 4.28-5.39), 5.52 mmol/L (95% CI: 4.31-6.72), and 6.97 mmol/L (95% CI: 6.12-7.82) at 1, 3, 6, and 12 months postoperatively, respectively. Notably, there was no substantial heterogeneity in FPG reduction at three months (I^2=0.0%, P=0.427) and 12 months (I^2=1.2%, p=0.363) post-surgery within the two subgroups.

Concerning the reduction in glycated hemoglobin (HbA1c %) after surgery compared to baseline, a total of 8 studies were included. Compared to baseline, HbA1c% during short-term postoperative follow-up decreased (WMD=3.04, 95% CI: 2.99-3.09; I^2=94.8%, p <0.001). Subgroup analysis by follow-up duration showed significant heterogeneity at three months postoperatively among the four subgroups (I^2 = 71.9%, p = 0.003), while no significant heterogeneity was found at 1, 6, and 12 months postoperatively, with I^2 values of 4.9%, 0.0%, and 0.0%, respectively, along with the use of a fixed-effects model. The WMDs for HbA1c% reduction at 1, 3, 6, and 12 months post-surgery were 2.07 (95% CI: 1.95-2.18), 3.19 (95% CI: 3.09-3.29), 3.32 (95% CI: 3.22-3.42), and 3.40 (95% CI: 3.29-3.50), respectively (Figure 3 and Table 2).

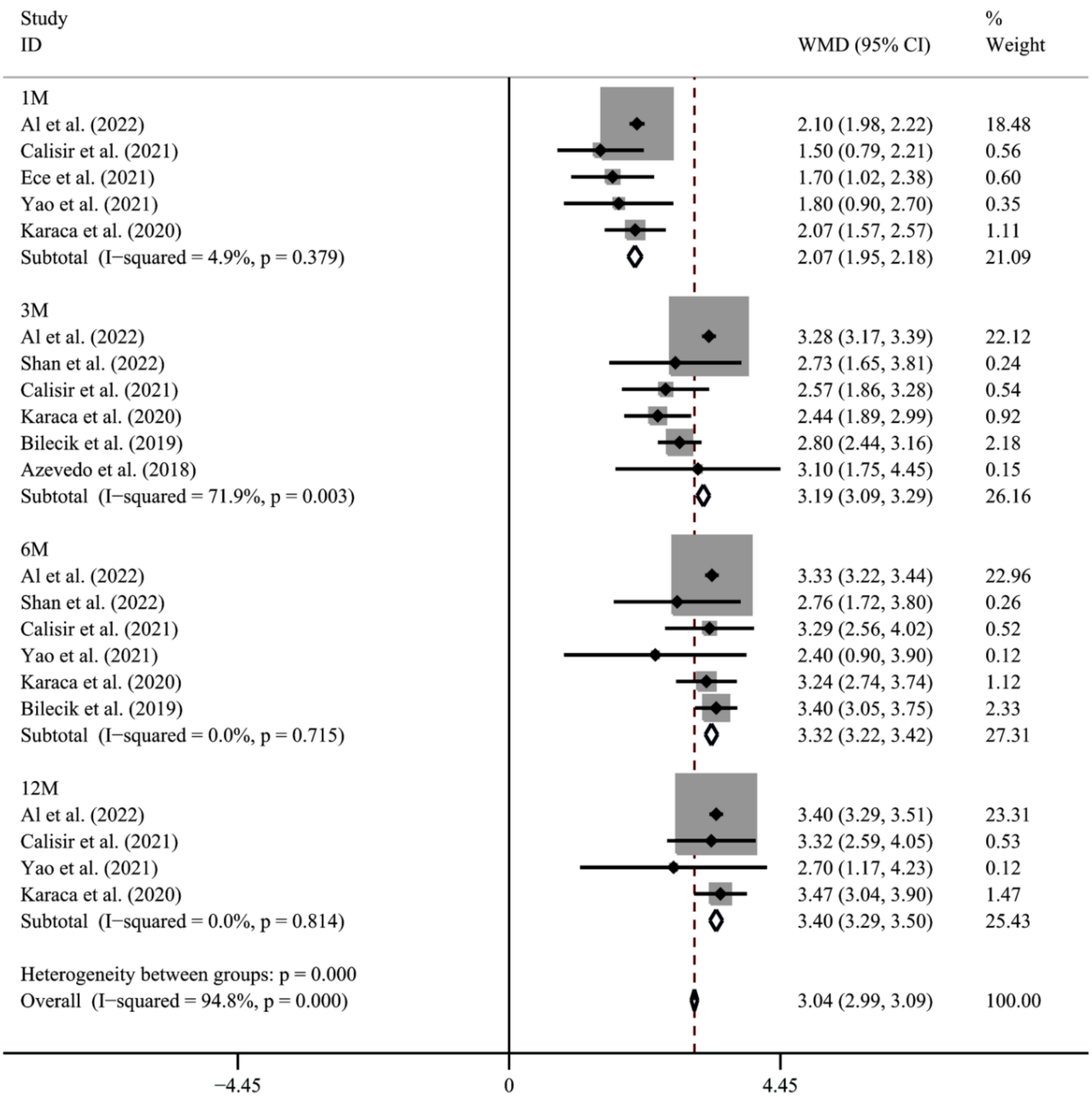

Table 2 includes a total of four studies that assess the reduction in Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) values, specifically comparing baseline HOMA-IR with follow-up HOMA-IR values. The overall weighted mean reduction in HOMA-IR was 4.78 (95% CI: 3.75-5.81), with significant heterogeneity (I^2 = 84.3%, $p < 0.001$). A random-effects model was employed. Postoperatively at 1, 3, 6, and 12 months, there were varying degrees of reduction in HOMA-IR, with combined reductions of 2.95 (95% CI: 0.92-4.97; I^2 = 32.2%, p = 0.229), 5.15 (95% CI: 2.75-7.55; I^2 = 59.6%, p = 0.084), 5.57 (95% CI: 3.51-7.63; I^2 = 52.0%, p = 0.125), and 8.39 (95% CI: 0.27-16.52; I^2 = 83.1%, p = 0.015), respectively.

3.6. Effect of SG-TB on Lipid Metabolism

We extracted data from four studies in the literature regarding laboratory measurements of low-density lipoprotein cholesterol (LDL) for analysis displayed in Table 2. Using a fixed-effects model, the overall summary effect size for LDL reduction was 32.62 mg/dL (95% CI: 30.95-34.30; I^2 = 83.6%, $p < 0.001$). After 1, 3, 6, 9, and 12 months post-surgery, LDL levels decreased by 22.10 mg/dL (95% CI: 18.40-25.79; I^2 = 49.5%, p = 0.114), 27.62 mg/dL (95% CI: 24.05-31.20; I^2 = 68.0%, p = 0.025), 35.92 mg/dL (95% CI: 32.20-39.64; I^2 = 0.0%, p = 0.620), 38.35

mg/dL (95% CI: 34.55-42.15; I^2 = 0.0%, p = 0.336), and 40.81 mg/dL (95% CI: 36.88-44.75; I^2 = 17.8%, p = 0.270), respectively.

3.7. Nutritional Indicators

We retrieved information from four studies in the literature on laboratory measurements of vitamin B_{12} (Vit B_{12}), for a total of four studies included in the analysis shown in Table 2. Utilizing a random-effects model. Compared to baseline, vitamin B_{12} levels at 1, 3, 6, and 12 months post-surgery decreased by -6.01 (95% CI: -54.16-42.15; I^2 = 78.2%, p = 0.003), 18.66 (95% CI: -4.25-41.58; I^2 = 29.3%, p = 0.243), 34.52 (95% CI: 1.40-67.64; I^2 = 63.3%, p = 0.065), and 20.73 (95% CI: 0.90-40.57; I^2 = 78.3%, p = 0.003), respectively.

3.8. Postoperative Complications

We included ten studies (n=2162) that explicitly reported complications, as summarized in Table 3. Only one study reported a mortality rate (0.196%)[23]. Five studies reported gastroesophageal reflux (0.294-14.286%), four studies reported gallbladder stones (1-12.941%), and three studies reported leakage/fistula (0.340-1.133%). Incisional hernia (0.113-1.863%) was mentioned in two studies.

Table 3 Postoperative complications in the 10 included studies.

			Okuyan et al.(2023)	Al et al.(2022)	Shan et al.(2022)	Calisir et al.(2021)	Ece et al.(2021)	Yao et al.(2021)	Karaca et al.(2020)	Topart et al.(2020)	Azevedo et al.(2018)	Santoro et al.(2012)
Digestive system (n=358)	PONV					3(9.375%)	1(3.846%)	6(14.634%)		1(1.408%)		
	Reflux		3(14.286%)			4(12.500%)		2(4.878%)	6(13.333%)			3(0.294%)
	Abdominal pain		5(23.810%)							1(1.408%)		
	Flatulence		16(76.190%)									
	Diarrhea		6(28.571%)	25(2.831%)	2(15.385%)			4(9.756%)				
	Constipation		1(4.762%)					1(2.439%)				
	Gallstone					1(3.125%)			1(2.222%)		1(1.000%)	132(12.941%)
	Foul-smelling stool			15(1.699%)								
	Exhaust odor							2(4.878%)				
	Non-obstructive long-term intestinal obstruction											7(0.686%)
	Intestinal occlusion			15(1.699%)								23(2.255%)
	Anostomosis or fistula (n=22)	Marginal ulcer		3(0.340%)								
		Anastomotic stricture		10(1.133%)								
		Fistula										9(0.882%)
	Bleeding (n=23)	Delayed gastrointestinal bleeding		1(0.113%)								
		Other Bleeding				1(3.125%)				1(1.408%)		
		Bleeding requiring surgery		12(1.359%)								8(0.784%)
	Incision rupture or hernia (n=26)	Dehiscence of incision		1(0.113%)								4(0.392%)
		Incision hernia										19(1.863%)
		Approach hernia		2(0.227%)								
Nervous system (n=3)	Peroneal neuropathy											
	Compressive nerve palsy								1(2.222%)			2(0.196%)
Circulatory system (n=2)	Cardiac complications											2(0.196%)
Respiratory system (n=8)	Symptomatic atelectasis			3(0.340%)								5(0.490%)
Infection (n=5)	Infection at the surgical site						1(3.846%)					
	Urinary tract infections						1(3.846%)					
	Abdominal or unknown origin infection											3(0.294%)
Thrombus (n=6)	Pulmonary embolism											1(0.098%)
	Portal vein thrombosis											5(0.490%)
Other(n=10)	Clinical significance: rhabdomyolysis											1(0.098%)
	Acute urolithiasis			3(0.340%)								5(0.490%)
	Anemia and hypoalbuminemia										1(1.000%)	
Death(n=2)												2(0.196%)

*PONV: Postoperative Nausea and Vomiting

3.9. Sensitivity Analysis

Sensitivity analysis was conducted by omitting one study at a time to assess its impact on the combined results. The analysis results indicated that the summary results of the five indicators, FPG, HbA1c, HOMR-IR, LDL, and Vit B_{12}, with 95% CI, were not significantly affected by any individual study. However, in the sensitivity analysis regarding BMI, the exclusion of two studies further reduced heterogeneity. Through analysis, we found that the main reason was that both of these studies used web tools to extract data from images, resulting in lower data quality, and both of these studies had large sample sizes (n>800)[18,20]. In conclusion, the results of this meta-analysis are relatively reliable.

3.10. Publication Bias

This study's summary analysis of six indicators exhibits significant publication bias, with many studies falling outside the expected range. Consequently, subgroup analysis was performed based on follow-up duration to mitigate heterogeneity. It should be noted that this study is a single-arm rate meta-analysis, and the presence of publication bias is still acceptable.

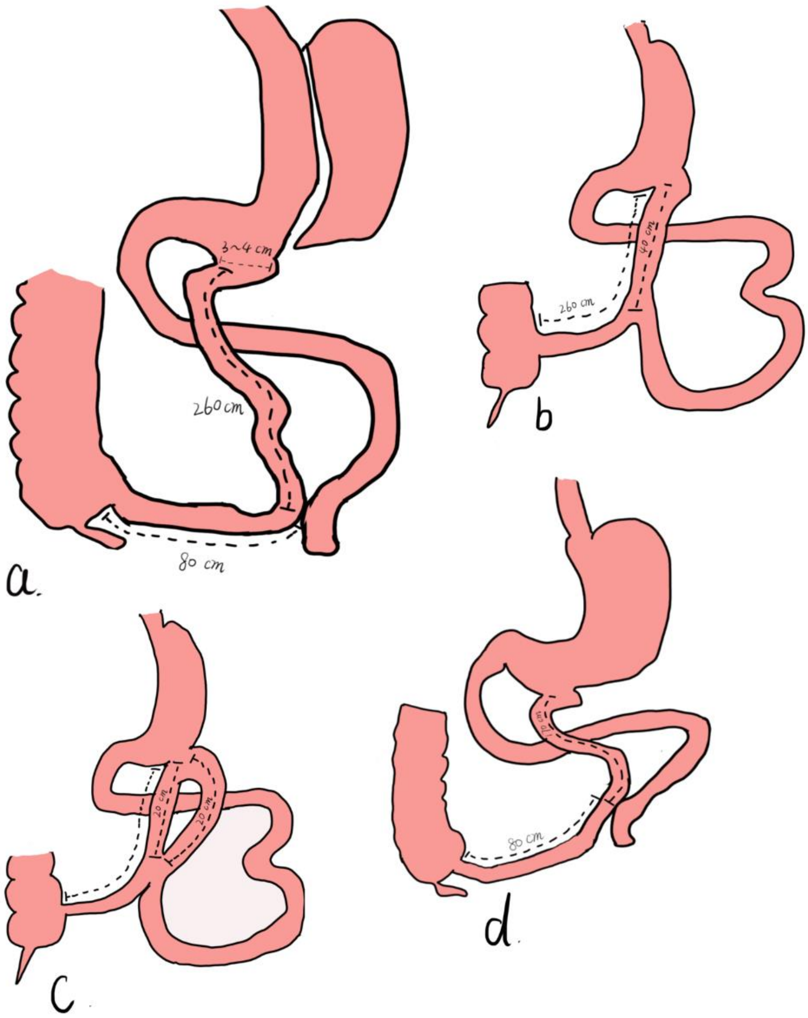

Figure4: The development of SG-TB surgical procedure across various studies.

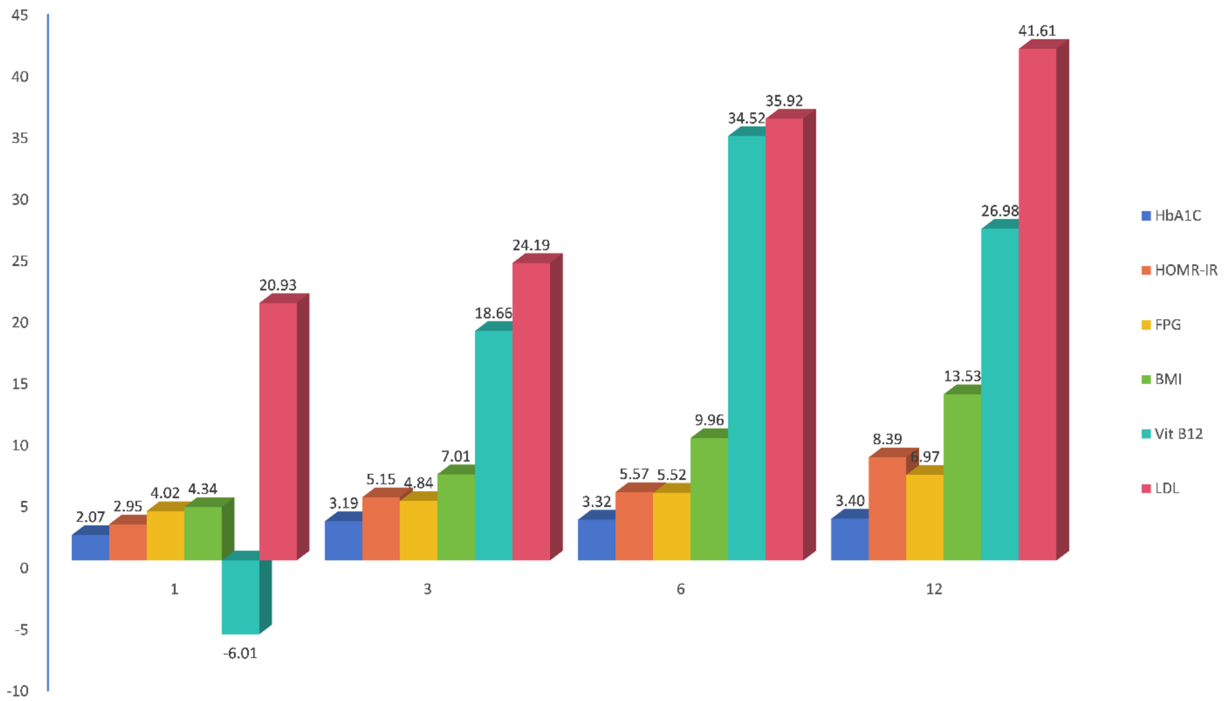

Figure5: The improvement of BMI and various metabolic indicators by SG-TB

*BMI：Body mass index

FPG: Fasting plasma glucose

Home-IR :Homeostatic model assessment of insulin resistance, HOMA-IR = FPG（mmol/L）× FINS（μU/mL）/22.5

4. Discussion

We only included peer-reviewed published studies to ensure that the meta-analysis is based on valid data and is conducive to comparing surgical follow-ups. Although numerous studies have reported the application of SG-TB surgery, only 12 studies met the anticipated inclusion criteria and reported follow-up data. In this paper, meta-analysis was used for the first time to aggregate the postoperative effects of SG-TB surgery, and the results indicate a significant reduction in body weight among patients with mild to severe obesity, along with the alleviation of metabolic-related comorbidities, while simultaneously maintaining an acceptable rate of postoperative complications.

Since its first proposal by Santoro, the SG-TB(a) procedure has undergone various modifications by subsequent researchers (Figure 4). The first type is the single anastomosis sleeve ileal bypass (SASI) with simplified surgical steps, as first reported by Mahdy et al.[24], where the small intestine is not individually disconnected (omitting the side-to-side anastomosis of the ileum). An anastomosis is performed between the stomach and the small intestine at 250 cm from the ileocecal junction. The second type(b) is essentially similar to SASI, where the anastomosis of the gastric pouch is relocated from the ileum to the jejunum (i.e., gastrojejunostomy, SASJ). A retrospective study with a 2-year duration involving 150 cases of this procedure was reported in 2020 [25]. The third type(c), developed by Professor Zhu Xiaocheng's team in China [26], involves creating a side-to-side anastomosis at both ends of the small intestine, each 20 cm away from the anastomosis between the stomach and the ileum in SASI, resulting in a Braun Anastomosis, to reduce biliary reflux and thereby establishing a new procedure, B-TB. The fourth type of SG-TB procedure does not involve resection of the greater curvature of the stomach but only partitions the intestines. Compared to the previous

ISSN: 1813-4890

procedures, it(d) appears to have a reduced weight loss effect, termed Isolated Intestinal Transit Bipartition (IT) [27]. In this meta-analysis, the mentioned modified procedures are excluded from the analysis to mitigate heterogeneity and explore the effectiveness of the initial procedure.

In 12 studies, SG-TB demonstrated a significant decrease in BMI and improvement (Figure 5) with follow-up exceeding six months. Multiple literature reports indicate that this procedure still has a substantial effect on weight loss one year after, with the longest postoperative 5-year excess BMI loss percentage (EBMIL%, EBMIL % = preoperative BMI − current BMI ×100/preoperative BMI − 25) being 74% ± 22.5%[23], indicating that SG-TB has a sustained and effective weight loss effect.

Obesity and metabolic surgery, while treating obesity, often draw considerable attention for their potential to alleviate comorbidities, particularly in terms of benefits related to blood glucose control. Our meta-analysis also included major diabetes-related indicators such as HOMR-IR, FPG, and HbA1c. At all follow-up time points(Figure 5), these three indicators exhibited a decreasing trend compared to baseline, suggesting that SG-TB surgery has a beneficial effect on reducing insulin resistance and postoperative blood glucose levels in patients with obesity-related metabolic diseases. Yormaz et al. [28] conducted a retrospective analysis and found that the advantage of SG-TB in alleviating diabetes was more pronounced than that of SG patients one year postoperatively. Another study, lasting for two years, compared SG-TB and RYGB and observed no significant difference in the alleviation of comorbidities between the two procedures [12]. Santoro also described the potential mechanisms of blood glucose regulation during the early reporting of the procedure, promoting the rapid transit of undigested chyme to the distal small intestine to stimulate neuroendocrine hormones like glucagon-like peptide 1 (GLP-1) and peptide tyrosine tyrosine (PYY)[29]. In addition to diabetes, obesity-related comorbidities, including sleep apnea syndrome, hyperlipidemia, and hypertension, have also experienced considerable improvement [12,14,19,20].

In evaluating effectiveness, we also included lipid metabolism-related indicators LDL and trace element indicator Vit B_{12}. LDL decreased steadily within one year after SG-TB surgery, indicating some relief of hyperlipidemia while losing weight. Up to 50% of obese individuals undergoing weight loss surgery have concurrent lipid abnormalities[30]. Patients undergoing weight loss surgery exhibited substantial improvements in lipid metabolism indicators after surgery, sometimes occurring before weight loss. Calisir et al.[14] found that some patients no longer required lipid-lowering medications three months after SG-TB surgery. Generally, malabsorptive and mixed procedures have a more significant impact on lipid metabolism compared to restrictive procedures, with potential mechanisms including mobilization of fat redistribution, changes in intestinal anatomy, endocrine alterations, alterations in inflammatory substances, and procedure-related intestinal hormone metabolism [31].

The supplementation of trace nutrients after weight loss surgery is emphasized in various guidelines, and the supplementation of multiple vitamins after surgery has already become a standard clinical practice. Vit B_{12} deficiency is associated with neurological discomfort and anemia, and clinical symptoms often take 3-5 years to become apparent due to liver reserves. Therefore, the significant decrease in short-term Vit B_{12} levels after weight loss surgery is likely due to pre-existing deficiencies in corresponding trace elements. In this study, besides an increase in Vit B_{12} levels in the first month after surgery, follow-up assessments indicated a decline compared to pre-surgery levels. This is consistent with previous literature indicating post-LSG vitamin deficiencies; hence, targeted oral vitamin supplementation after SG-TB surgery is necessary [32]. It's worth noting that in several studies included, the data from researchers showed that there was no statistical significance in this value before and after surgery[9,11,13,15]. Furthermore, the forest plot summarizing the effect sizes of postoperative

Vit B_{12} compared to preoperative values is relatively close to the null line. However, no related research currently reports whether this procedure significantly differs in the absorption of trace nutrients compared to RYGB or SG.

In this meta-analysis, none of the included studies reported intraoperative complications. Postoperative complications were relatively minor. Among the postoperative complications of more significant concern, the incidence of leaks or fistulas after SG-TB surgery ranged from 0.340% to 1.133%, which is generally consistent with the previously reported rates of 0.8% for RYGB and 0.7% for SG[33]. SG-TB, due to having two outlets, results in relatively lower pressure at the gastrojejunal anastomosis, which may lead to a lower occurrence of leaks compared to RYGB, which is more prone to leaks at the gastrojejunal anastomosis, as supported by some studies[20]. Compared to SG techniques, the surgical procedures included in this meta-analysis frequently perform the anastomosis 1-3cm to the left of the His angle, thus avoiding injury to the high-risk site for leaks at the His angle associated with SG. Santoro et al. reported two mortality cases but did not elaborate on the specific causes of death. Notably, half of the surgeries at this center were performed using an open surgical approach, and the utilization of modern laparoscopic techniques is expected to reduce mortality rate.

Owing to the scarcity of data, the studies are predominantly observational It is advisable to conduct additional randomized, double-blind controlled studies to evaluate the effectiveness of SG-TB and compare its complications. The included studies were single-arm, with only some comparing SG-TB to other weight loss procedures, and there is needs to be more cross-sectional comparative research results. Reporting of postoperative outcome measures needs further standardization and diversification. Regarding weight loss, most studies only describe changes in BMI. Safety indicators, such as reporting postoperative complications, need additional categorization, including long-term and short-term postoperative complications, and the grading of postoperative complication severity. Although our current research results suggest an apparent weight loss effect and sufficient safety of SG-TB, further evidence from randomized controlled trials (RCTs) and long-term follow-up is required to support its routine use in patients with obesity or metabolic comorbidities.

5. Conclusions

SG-TB has demonstrated the capacity to significantly reduce the weight of patients with obesity while also providing relief from insulin resistance and diabetes, all with safety levels comparable to those of RYGB or SG. However, further substantiating evidence from randomized controlled trials and long-term follow-up is necessary to firmly establish its suitability for use in patients with obesity.

Acknowledgments:

We sincerely thank our teams of the First Affiliated Hospital of Jinan University.

Declarations

Ethics Approval

For this type of study, formal consent is not required.

Consent to Participate

Informed consent does not apply.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] 7 IFSO Global Registry Report on https://www.ifso.com/pdf/ifso-7th-registry-report-2022.pdf

[2] W.C.Maclellan and J.M. Johnson: Laparoscopic Gastric Bypass: Still the Gold Standard? The Surgical clinics of North America, Vol. 101(2021) No. 2, p.161–175.

[3] A. Vitiello, G. Berardi, N. Velotti, et al: Learning curve and global benchmark values of laparoscopic sleeve gastrectomy: results of first 100 cases of a newly trained surgeon in an Italian center of excellence. Updates Surg, Vol. 73(2021) No. 5, p. 1891–1898.

[4] B. K. Wölnerhanssen, R. Peterli, S. Hurme, et al: Laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy: 5-year outcomes of merged data from two randomized clinical trials (SLEEVEPASS and SM-BOSS). The British journal of surgery, Vol. 108(2021) No. 1, p. 49–57.

[5] C-K. Huang and A. Katakwar: Sleeve plus procedures: need of time. Surgery today, Vol. 50(2020) No. 4, p. 419–422.

[6] S. Santoro, C. Malzoni, M. Velhote, et al: Digestive Adaptation with Intestinal Reserve: A Neuroendocrine-Based Operation for Morbid Obesity. Obes Surg, Vol.16(2006) No.10, p. 1371–1379.

[7] D. F. Stroup, J. A. Berlin, S. C. Morton, et al: Meta-analysis of observational studies in epidemiology: a proposal for reporting. Jama, Vol. 283(2000) No. 15, p. 2008–2012.

[8] Rohatgi A. Webplotdigitizer: Version 4.6 on https://automeris.io/WebPlotDigitizer

[9] A. Stang: Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. European journal of epidemiology, Vol. 25(2010) No. 9, p. 603–605.

[10] Z. Munn, T. H. Barker, S. Moola, et al: Methodological quality of case series studies: an introduction to the JBI critical appraisal tool. JBI evidence synthesis, Vol. 18(2020) No.10, p. 2127–2133.

[11] M. Al and H. E. Taskin: Sleeve gastrectomy with transit bipartition in a series of 883 patients with mild obesity: early effectiveness and safety outcomes. Surg Endosc, Vol. 36(2022) No. 4, p. 2631–2642.

[12] F. R. Azevedo, S. Santoro, M. L. Correa-Giannella, et al: A Prospective Randomized Controlled Trial of the Metabolic Effects of Sleeve Gastrectomy with Transit Bipartition. Obes Surg, Vol 28(2018) No. 10, p. 3012–3019.

[13] T. Bilecik: Metabolic Effects of Sleeve Gastrectomy with Transit Bipartition in Obese Females with Type 2 Diabetes Mellitus: Results After 1-Year Follow-up. Obes Surg, Vol. 29(2019) No. 3, p. 805–810.

[14] A. Calisir, I. Ece, H. Yilmaz, et al: The Mid-Term Effects of Transit Bipartition with Sleeve Gastrectomy on Glycemic Control, Weight Loss, and Nutritional Status in Patients with Type 2 Diabetes Mellitus: a Retrospective Analysis of a 3-Year Follow-up. Obes Surg, Vol. 31(2021) No. 11, p. 4724–4733.

[15] G. Ç. Okuyan and D. Akkuş: Assessment of Exocrine Pancreatic Function Following Bariatric/Metabolic Surgery: a Prospective Cohort Study. Obes Surg, Vol. 33(2023) No. 1, p. 25–31.

[16] I. Ece, H. Yilmaz, S. Yormaz, et al: The Short-Term Effects of Transit Bipartition with Sleeve Gastrectomy and Distal-Roux-en-Y Gastric Bypass on Glycemic Control, Weight Loss, and Nutritional Status in Morbidly Obese and Type 2 Diabetes Mellitus Patients. Obes Surg, Vol. 31(2021) No. 5, p. 2062–2071.

[17] N. Gulaydin, F. Ersoz, N. Derici, et al: Comparative evaluation of efficiency for gastroileostomy anastomosis in laparoscopic transit bipartition with sleeve gastrectomy between linear and circular staplers. Videosurgery Miniinvasive Tec, Vol. 17(2022) No.1, p. 199–206.

[18] F. C. Karaca: Effects of Sleeve Gastrectomy with Transit Bipartition on Glycemic Variables, Lipid Profile, Liver Enzymes, and Nutritional Status in Type 2 Diabetes Mellitus Patients. Obes Surg, Vol. 30(2020) No. 3, p. 1437–1445.

[19] S. Santoro, L. C. Castro, M. C. P. Velhote, et al: Sleeve gastrectomy with transit bipartition: A potent intervention for metabolic syndrome and obesity. Ann Surg, Vol. 256(2012) No. 1, p. 104–110.

ISSN: 1813-4890

[20] P. Topart, G. Becouarn and J. B. Finel: Comparison of 2-Year Results of Roux-en-Y Gastric Bypass and Transit Bipartition with Sleeve Gastrectomy for Superobesity. Obes Surg, Vol. 30(2020) No. 9, p. 3402–3407.

[21] L. B. Yao, Y. Shao, J. Hong, et al: Short term clinical results of SG-TB in 41 cases. Chinese Journal of Practical Surgery. Vol. 41(2021) No. 9, p. 1024–1028.

[22] X. D. Shan, Y. Yan, Y. W. Chen, et al: Short-term clinical efficacy of laparoscopic sleeve gastrectomy with transit bipartition. Chinese Journal of Obesity and Metabolic Disease(Electronic Edition)， Vol. 8(2022) No. 2, p. 87–92.

[23] S. Santoro, L. C. Castro, M. C. P. Velhote, et al: Sleeve Gastrectomy With Transit Bipartition: A Potent Intervention for Metabolic Syndrome and Obesity. Annals of Surgery, Vol. 256(2012) No. 1, p. 104–110.

[24] T. Mahdy, A. Al Wahedi and C. Schou: Efficacy of single anastomosis sleeve ileal (SASI) bypass for type-2 diabetic morbid obese patients: Gastric bipartition, a novel metabolic surgery procedure: A retrospective cohort study. INTERNATIONAL JOURNAL OF SURGERY, Vol. 34(2016), p. 28–34.

[25] A. M. Sewefy, A. M. Atyia, M. M. Mohammed, et al: Single anastomosis sleeve jejunal (SAS-J) bypass as a treatment for morbid obesity, technique and review of 1986 cases and 6 Years follow-up. Retrospective cohort. Int J Surg, Vol. 102(2022), p. 106662.

[26] J. Widjaja, X. Sun, Y. Chu, et al: Sleeve Gastrectomy with Braun Anastomosis Transit Bipartition (B-TB): a Potential Midway Between Single Anastomosis and Roux-en-Y Transit Bipartition. Obes Surg, Vol. 31(2021) No. 12, p. 5500–5503.

[27] E. P. de Godoy, S. S. D. S. Pereira, D. Coelho, et al: Isolated intestinal transit bipartition: A new strategy for staged surgery in superobesity. Rev Col Bras Cir, Vol. 46(2019) No. 5, p. e20192264.

[28] Y. Serdar, Y. Huseyin, E. Ilhan, et al: Laparoscopic Ileal Interposition with Diverted Sleeve Gastrectomy Versus Laparoscopic Transit Bipartition with Sleeve Gastrectomy for Better Glycemic Outcomes in T2DM Patients. Obesity surgery, Vol. 28(2018) No. 1, p. 77–86.

[29] S. Santoro, C. Malzoni, M. Velhote, et al: Digestive Adaptation with Intestinal Reserve: A Neuroendocrine-Based Operation for Morbid Obesity. obes surg, Vol. 16(2006) No. 10, p. 1371–1379.

[30] S. P. Heffron, B-X. Lin, M. Parikh, et al. Changes in High-Density Lipoprotein Cholesterol Efflux Capacity After Bariatric Surgery Are Procedure Dependent. Arteriosclerosis, Thrombosis, and Vascular Biology, Vol. 38(2018) No. 1, p. 245–254.

[31] M-E. Piché, I. Tardif, A. Auclair, et al: Effects of bariatric surgery on lipid-lipoprotein profile. Metabolism, Vol. 115(2021), p. 154441.

[32] L. Dong, H. Suh, W. Karantanis, et al: Evaluation of Micronutrient Status Post Laparoscopic Sleeve Gastrectomy: an Australian Perspective. Obes Surg, Vol. 31(2021) No. 3, p. 1099–1104.

[33] ASMBS. ASMBS Position Statement on Prevention, Detection & Treatment of Gastrointestinal Leak | American Society for Metabolic and Bariatric Surgery on https:// asmbs.org/ resources/ prevention-and-detection-of-gastrointestinal-leak