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Ten-Year Outcomes Following Sleeve Gastrectomy With and Without Ring Augmentation: A Single-Center Observational Study

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Abstract

Background:
Long-term data comparing sleeve gastrectomy (SG) with ring-augmented sleeve gastrectomy (Ra-SG) remain limited. This study evaluated 10-year weight loss, revisional surgery, reflux-related outcomes, and nutritional status after SG and Ra-SG.

Methods:
Patients undergoing primary SG or Ra-SG between January 2012 and December 2013 at a single tertiary bariatric center were invited for 10-year follow-up. Clinical assessment included anthropometric measurements, comorbidities, revisional surgery, reflux symptoms, gastroscopy, and micronutrient status. Long-term weight loss was analyzed using a linear mixed-effects model. Patients who underwent revisional surgery were excluded from the primary weight-loss analysis.

Results:
Of 121 eligible patients, 79 completed follow-up (SG n=50; Ra-SG n=29). Among patients without revisional surgery (SG n=33; Ra-SG n=15), 10-year total weight loss (%TWL) was 22.1% (95% CI 18.8–25.6) after SG and 26.3% (95% CI 21.5–32.2) after Ra-SG. Suboptimal response (%TWL <20%) occurred in 51.5% after SG compared with 20.0% after Ra-SG. Revisional surgery was required in 31 patients (39.2%), occurring in 34.0% after SG and 48.3% after Ra-SG. The most common indications after SG were weight regain (38.7%), reflux (22.6%) and insufficient weight loss (16.1%). Regurgitation (12.9%) was the most common indication for revisional surgery after Ra-SG.

Conclusions:
Both SG and Ra-SG achieved durable long-term weight loss 10 years after surgery. Ra-SG provided superior weight-loss maintenance and reduced the proportion of patients with suboptimal response. Ring-related complications predominated after Ra-SG, whereas revisions were performed more frequently for weight-loss-related indications following SG. The use of a 6.5 cm ring circumference with a low ring position is associated with a high rate of regurgitation requiring revisional surgery.

Introduction

Sleeve gastrectomy (SG) is the predominant bariatric procedure performed world-wide (1). Retrospective studies indicate that suboptimal clinical response and weight regain remain major concerns after SG and are among the leading indications for revisional surgery (2–5). An analysis of a large German bariatric cohort demonstrated that patients with SG are at higher risk of experiencing poor primary response, defined as < 20% total weight loss (%TWL) within the first year following MBS (6). Reported weight regain following SG ranges from 5.7% at 2 years to 75.6% at 6 years postoperatively (7). To improve long-term weight loss and reduce weight regain, ring-augmented sleeve gastrectomy (Ra-SG) was introduced. Multiple clinical studies have evaluated this procedure, with most reporting significantly greater short- and mid-term weight loss of up to 11.6% TWL and reduced weight regain (8–14). However, to date long-

term data on Ra-SG remains scarce. This observational study evaluated 10-year long-term weight loss outcomes in patients undergoing sleeve gastrectomy with and without silicone ring augmentation.

Study Design

All patients who underwent SG with and without ring augmentation between January 2012 and December 2013 at our institution were screened and contacted for an in-person follow-up. Follow-up examinations were performed in 2023. Written informed consent was obtained from all patients. Data collection included anthropometrics, associated comorbidities, complications and vitamin deficiencies.

A screening gastroscopy was offered to patients after 10 years, at 10 years if they had not previously undergone gastroscopy during follow-up or if they reported reflux or regurgitation. The study was approved by the local Ethics Committee (22-1193-S1) and conducted in accordance with the Declaration of Helsinki.

Surgical technique

Sleeve gastrectomy was undertaken under preservation of the antrum using a 35Fr. bougie. For Ra-SG, a silicone ring (MiniMizer®, Bariatric Solutions, Switzerland) was placed using a perigastric approach and positioned 6 cm below the gastroesophageal junction. The ring was closed to a circumference of 6.5 cm and fixed to the anterior gastric wall.

Outcome measures

Continuous variables were characterized using mean and standard deviation. Categorical variables were presented as frequencies and percentages. Weight loss was expressed as percentage total weight loss (%TWL) for primary SG or Ra-SG without surgical revision. Type 2 diabetes (T2D) was defined by the use of antidiabetic medication or insulin therapy. Arterial hypertension was defined by the use of anti-hypertensive medication. The presence of obstructive sleep apnea (OSAS) was subjectively assessed through a questionnaire. Patients experiencing dysphagia, reflux or regurgitation (defined as postprandial convulsive regurgitation of undigested food) were recorded as either not present or present, with symptom frequency categorized as $\geq$ 1 episode/week and $\geq$ 1 episode/month. Reflux symptoms were additionally assessed using the Reflux Symptom Index (RSI) and the Gastroesophageal Reflux Disease–Health-Related Quality of Life (GERD-HRQL) questionnaire. Laboratory tests included complete blood count, ferritin, selenium, zinc, vitamin B1, B12 and D, folic acid, and albumin levels. Deficiencies were defined as serum concentration below the laboratory-specific reference range.

Statistical analysis

A linear mixed effects model was used to compare weight loss between SG and Ra-SG. Only patients who had not undergone revisional surgery 10 years postoperatively were considered for final analysis. ‘Patient’ was included as a random effect, while surgical procedure (SG vs. Ra-SG, excluding revisional

procedures), gender, age and time point (1-,2-,5-,10 years) were included as fixed effects. An unstructured, within-patient covariance matrix was assumed. Confidence intervals (CI) were calculated at the 95% level. Statistical analysis was performed using SPSS Version 29.0. Figures were generated by Excel and R.

Results

Overall patient characteristics

A total of 121 patients underwent screening. The final cohort consisted of 79 patients (SG = 50 patients (63.3%) Ra-SG = 29 patients (36.7%). Figure 1 illustrates the study flowchart, baseline characteristics are summarised in Table 1.

Table 1
Patient demographics and characteristics of total cohort according to surgical procedures

Gender (%)		**SG**	**Ra-SG**
		(n = 50)	**(n = 29)**
	male	**36.0%**	**34.5%**
	female	64.0%	65.5%
Age at operation (mean ± SD)		42.5 ± 11.23	40.6 ± 10.8
Mean preoperative weight (kg) (mean ± SD)		148.1 ± 22.1	160 ± 18.0
Mean preoperative BMI (kg/m^2) (mean ± SD)		50.7 ± 7.3	55.8 ± 7.5
Preoperative comorbidities (%, n=)	No medication-dietary only	6% (n = 3)	10.4% (n = 3)
	NIDDM	30% (n = 12)	10.4% (n = 3)
	IDDM	12% (n = 6)	0 (0%)
	Arterial Hypertension	76.0% (n = 38)	65.5% (n = 19)

Weight loss

Weight loss trajectories were modelled in patients undergoing primary SG or Ra-SG who did not require revisional surgery (SG n = 33, Ra-SG n = 15). Suboptimal response (TWL < 20%) at 10 years postoperatively was recorded in 51.5% (n = 17) following SG and 20% (n = 3) following Ra-SG. At 10 years postoperatively, %TWL was 26.3% for Ra-SG (95% CI 21.5–32.2), and 22.1% for SG (95% CU 18.8–25.6), as shown in Fig. 2. At 2, 5, and 10 years postoperatively, %TWL was greater following Ra-SG compared to SG, with differences of 4.2%, 7.3%, and 4.2%, respectively. The linear mixed effects model demonstrated

weight loss nadir at 1 year postoperatively with subsequent weight regain in the SG group, compared to a sustained weight loss up to 5 years following Ra-SG. However, patients following Ra-SG experienced a similar degree of weight regain in the time period of 5 to 10 years after surgery.

Revisional procedures

In total, 39.2% of patients (n = 31) underwent revisional procedures within 10 years. The revision rate was 34% following SG (n = 17) and 48.3% after Ra-SG (n = 14). Indications included weight regain 38.7% (n = 12), insufficient weight loss 16.1% (n = 5), reflux 22.6% (n = 7), regurgitation 12.9% (n = 4) and ring slippage 3.2% (n = 1). Weight regain was the main reason for revisional surgery following SG. Regurgitation was the leading indication for revisional surgery after Ra-SG. Conversion to RYGB was the most frequently performed revisional procedure, especially in patients after SG. All patients with primary insufficient weight loss were converted to malabsoprtive procedures. On average, revisional surgery was performed five years after SG or Ra-SG. Four rings were removed due to isolated regurgitation between 10 months and 8 years after surgery. One slippage was noted in this cohort. Figure 3 illustrates indications for revisional surgery and the type of procedure chosen

Reflux & Regurgitation

Out of the initial 79 patients, 58 patients underwent a gastroscopy (73.4%). In 31 cases, gastroscopy was performed due to symptomatic reflux, regurgitation, weight regain or other medical conditions, which subsequently led to a surgical revision. In the remaining 36 patients, gastroscopies were offered as part of the recommended follow-up 10 years after MBS (SG = 23, Ra-SG = 13). Results of these screening gastroscopies for primary SG and Ra-SG without revisional surgery are summarised in Table 2. Sleeve stenosis was seen in 1 patient after SG and 2 after Ra-SG. Sleeve dilatation was recorded in 5 patients following SG compared to none in the Ra-SG group.

The use of PPIs significantly increased after 10 years. Nevertheless, recorded reflux symptoms remained frequent. Although patients after Ra-SG were more likely to experience reflux symptoms and presented with a higher rate of reflux esophagitis, the RSI score suggested a better outcome compared to patients after SG. The reflux-related quality life was, compared to SG, worse. The most striking difference between the two groups is the frequency of regurgitation, which is far more common after Ra-SG.

Table 2
GERD and Gastroscopy results preoperatively and 10 years after bariatric surgery, excluding patients with revisional surgery

	Preoperatively		**10 years postoperatively**	
	SG (n = 33)	**Ra-SG (n = 15)**	**SG (n = 33)**	**Ra-SG (n = 15)**
No GERD	N = 19 (57.6%)	N = 10 (66.7%)	N = 21 (63.6%)	N = 6 (40%)
Symptomatic GERD	N = 14 (42.4%)	N = 5 (33.3%)	N = 12 (36.4%)	N = 9 (60%)
No PPI Use	N = 24 (72.7%)	N = 14 (93.3%)	N = 12 (36.4%)	N = 8 (53.3%)
PPI Use	N = 9 (27.3%)	N = 1 (7.7%)	N = 21 (63.6%)	N = 7 (46.7%)
No Regurgitation			N = 29 (87.9%)	N = 5 (33.3%)
Regurgitation			N = 4 (12.1%)	N = 10 (66.7%)
RSI			5.8 (0–25)	4.5 (0–13)
GERD HRQL			5.7 (0–35)	6.8 (0–20)
			10 years postoperatively	
Gastroscopy			**SG (n = 23)**	**Ra-SG (n = 13)**
Esophagitis			n = 8 (34.8%)	n = 8 (61.5%)
Gastritis			n = 10 (43.5%)	n = 7 (53.8%)
Hiatal hernia			n = 9 (39.1%)	n = 7 (53.8%)
Sleeve Stenosis			n = 1 (4.1%)	N = 2 (15.4%)
Sleeve Dilatation			n = 5 (21.7%)	0

Comorbidities & Complications

Overall mortality was 7.4% within 10 years (n = 9) of MBS (n = 8 SG, n = 1 Ra-SG), with one surgery related mortality due to sepsis after staple line insufficiency after SG. 2 patients suffered from pulmonary embolism, 2 patients were diagnosed with lung carcinoma, one patient had amyotrophic lateral sclerosis. In 4 patients the cause of death could not be determined in this study.

The incidence of arterial hypertension remained high within both groups. Symptoms of OSAS improved in 3 out of 4 (75%) patients following Ra-SG and 9 out of 17 (52.9%) following SG at 10 years postoperatively. Preoperativ assessment of T2DM revealed a large heterogeneity between the groups. Overall, improvement was seen in 11 out of 21 patients after SG, and 4 out of 6 patients after Ra-SG.

Vitamin and micronutrient deficiencies were recorded 10 years following MBS. Zinc, folic acid and vitamin D deficiencies were prominent, despite general recommendations for respective supplementation. Figure 4 represents vitamin- and micronutrient deficiencies for patients after SG and

Ra-SG, excluding revisional procedures. Adherence to vitamin supplementation was not recorded in this study.

Discussion

This study evaluated clinical outcomes of patients up to 10 years following sleeve gastrectomy with and without ring augmentation at a single bariatric centre.

Despite the increasing focus on patient-centered outcomes in modern metabolic and bariatric surgery, weight-loss maintenance remains crucial, as it is associated with the degree of metabolic improvements (15, 16). However, suboptimal clinical response and weight regain are prominent difficulties following SG (17–20). A considerable body of evidence comprising retrospective and prospective clinical trials has demonstrated that ring-augmentation of standard SG can lead to a weight loss benefit that is comparable to the weight loss gap between SG and RYGB (8–10, 13, 19, 21–23). However, most studies is limited to a follow-up period of 5 years. The current study demonstrates a sustained weight loss benefit in Ra-SG compared to SG up to 10 years postoperatively. The number of patients with suboptimal response (< TWL 20%) is considerably higher 10 years following SG compared to Ra-SG (n = 17 vs n = 6). Compared to 5 years postoperatively, the overall additional weight loss effect of Ra-SG diminished at 10 years. The mixed effects model was primarily used to characterize the magnitude of weight loss in this explorative analysis. The effect size is comparable to existing data on mid - to long-term outcome (9, 10, 14, 22).

In the Ra-SG group, 17% of patients underwent revisional surgery due to ring-related complications. At the same time, 66.7% of patients in the remaining “per protocol” population of Ra-SG experienced regurgitation. In response to these findings, the surgical technique was later adapted aiming at more proximal ring placement (4 vs 6 cm below GE-junction) and larger diameter (7.5 cm vs 6 cm) (8, 10, 24). Prospective data adopting this ring placement reveal a considerably lower rate of frequent regurgitation of 13% after 3 years and 37% after 5 years (8, 10). More proximal placement also correlated with a ring removal rate of 2.2% due to slippage, while no rings were removed due to regurgitation 3 years after surgery (8). These data suggest that complication and revision rates can be lowered by optimal ring placement, as reflected by a recent summary of expert opinions (25).

This is the first trial showing a higher rate of symptomatic reflux and PPI use in Ra-SG compared to SG. These findings correlate with a higher rate of reflux esophagitis in Ra-SG in screening gastroscopy 10 years following surgery. Reflux associated quality of life was similar, indicating adequate control of symptoms. Earlier studies observed fewer reflux symptoms and subsequently hypothesized that the ring may act as an antireflux barrier (8, 26). However, distal ring placement may act as a barrier for acid clearance, especially in a dilated proximal sleeve, leading to higher rates of reflux. Proximal ring placement in turn may reduce reflux symptoms as it could diminish acidic reflux from the antrum to the cardia (25). Overall rates of reflux esophagitis were comparable to those reported in the SleevePass trial (21).

A high rates of deficiencies for micronutrients and vitamins was detected 10 years afetr MBS, which clearly highlights the need for strict adherence to long-term supplementation. Of note, there was no vitamin B12 deficiency, although this is common even among the general population (3%-43% in older adults) (27). Compared to SG, a higher rate of iron deficiency has been previously reported for Ra-SG and has been attributed to a lower tolerance of meat in these patients (28). The current data demonstrated an overall low rate of iron deficiency, which may reflect adaptation of eating habits to include alternate iron sources.

A surprisingly high Zinc deficiency was detected in both groups (50% after SG and 64% after Ra-SG). Symptoms specific for zinc deficiency (e.g. frequent infections, hair loss, gastrointestinal symptoms) were not collected. A recently published meta-analysis demonstrated a zinc deficiency in only 9.4% of patients 1 year after SG, with increasing rates after 2 years (29). With respect to longer term-follow-up, a study analyzing nutritional deficiencies in adolescents revealed a Zinc deficiency in 50% 7 years after surgery for a small sample size (30). Long-term data remain scarce. Long-term data on zinc deficiency are limited because routine zinc assessment is not recommended by current European and American guidelines (DGAV und ASMBS, (31, 32)). Although a Zinc supplementation of 15mg/d (BOMMS Guidelines) or 8-11mg (ASMBS guidelines) is recommended after SG, data suggest that this is not preventive of clinically relevant zinc deficiency (31, 32). The high rate of Zinc deficiency in the current trial (despite unknown supplementation adherence) in combination with data demonstrating a decrease of Zinc absorption by 72% after SG may not only warrant strict life-long supplementation, but also regular screening for Zinc deficiency following SG.

This study has several limitations. The nature of this cohort study is purely explorative and descriptive. No sample size calculations were performed. Overall sample size was small, and the groups were not evenly matched with regard to size and baseline characteristics, limiting the ability for statistical comparison.

Furthermore, patients were treated within the learning curve and standardisation of Ra-SG. Observed effects may therefore differ from current Ra-SG techniques.

Conclusion

This study reports long-term outcomes after SG and Ra-SG. Overall weight loss outcomes after 10 years remained satisfactory in both groups (%TWL > 20%). Ra-SG was associated with superior long-term weight loss compared with SG, with a clinically relevant effect size that warrants further long-term investigation. Overall revision rates were high in both groups. Ring-related complications predominated after Ra-SG, whereas revisions were performed more frequently for weight-loss-related indications following SG. The use of a 6.5 cm ring circumference with a low ring position is associated with a high rate of regurgitation requiring revisional surgery.

Declarations

Author Contribution

M.F., G.M., G.S. J.F. initialised the study idea. M.F., J.F. wrote the main manuscript and were responsible for statistical analysis. Statistical Analysis was checked by S.H. and N.W. C.W. was responsible for patient recruitment and data collection. All authors reviewed the manuscript.

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Figures

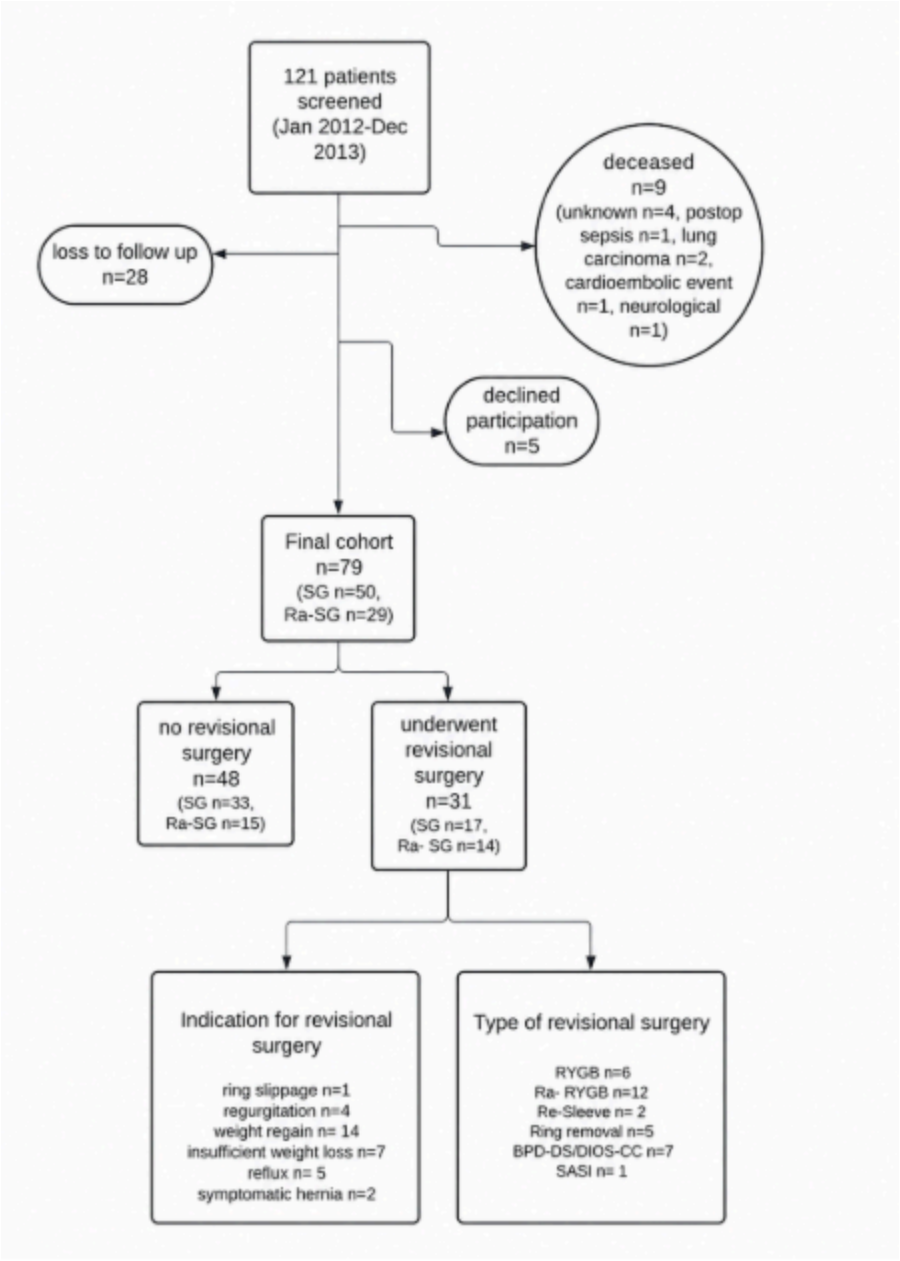

Figure 1

Cohort selection and study flow chart

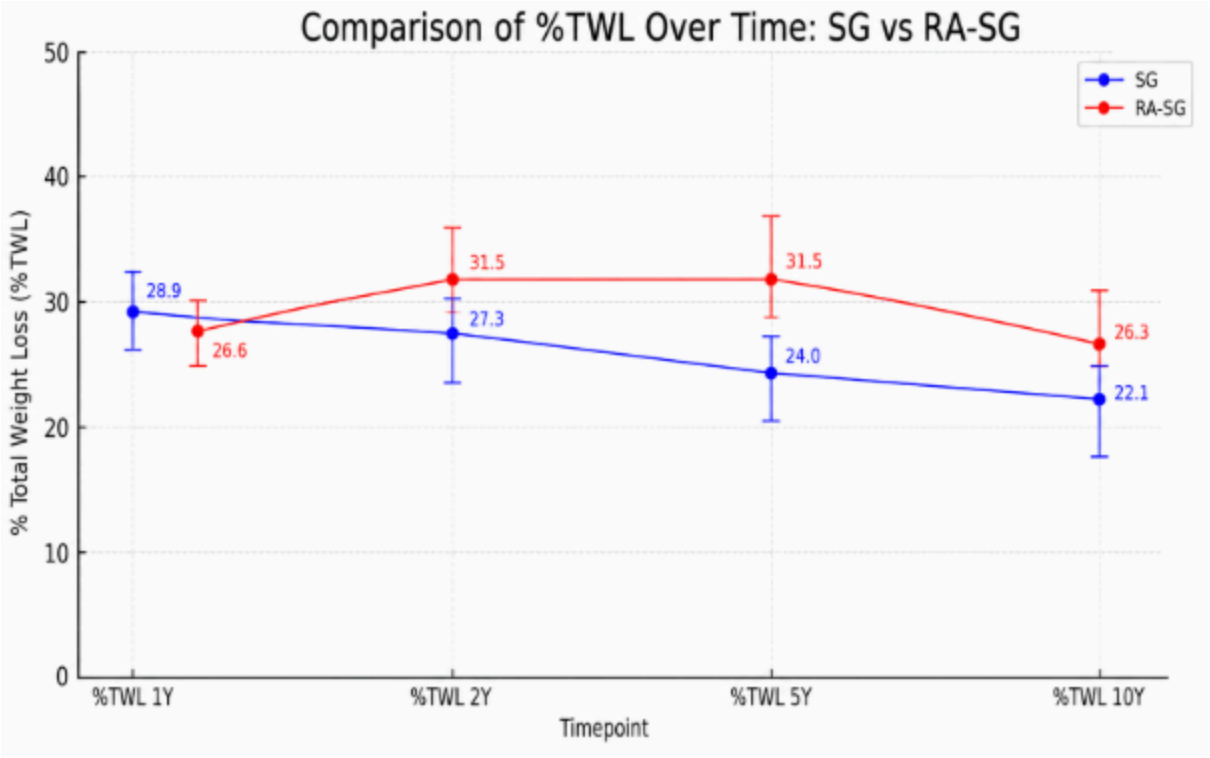

Figure 2

Mean percentage total weight loss (%TWL) over 10 years after SG and Ra-SG. Error bars depict 95% CI

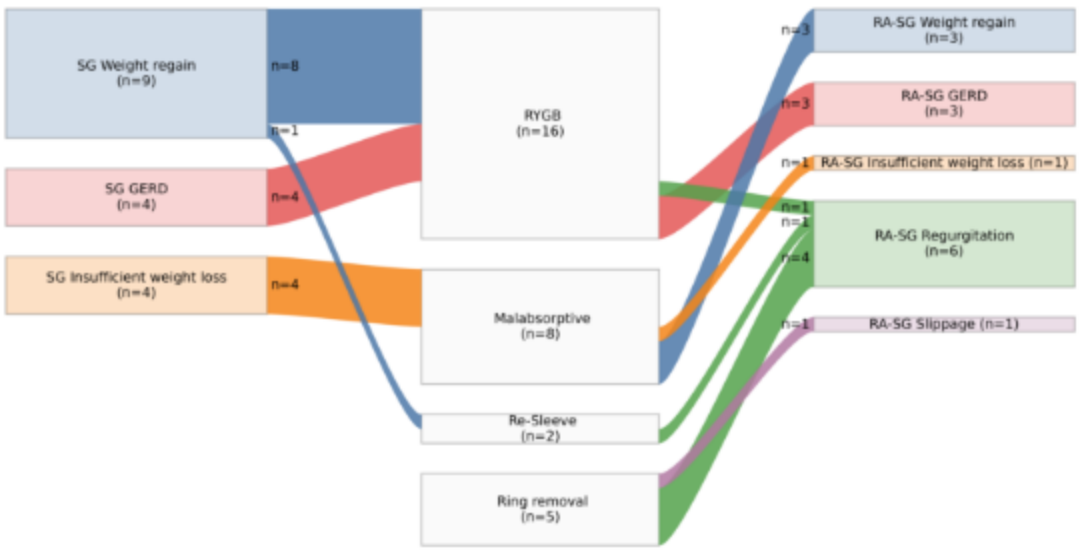

Figure 3

Indication and type of revisional procedure 10 years after primary SG or Ra-SG

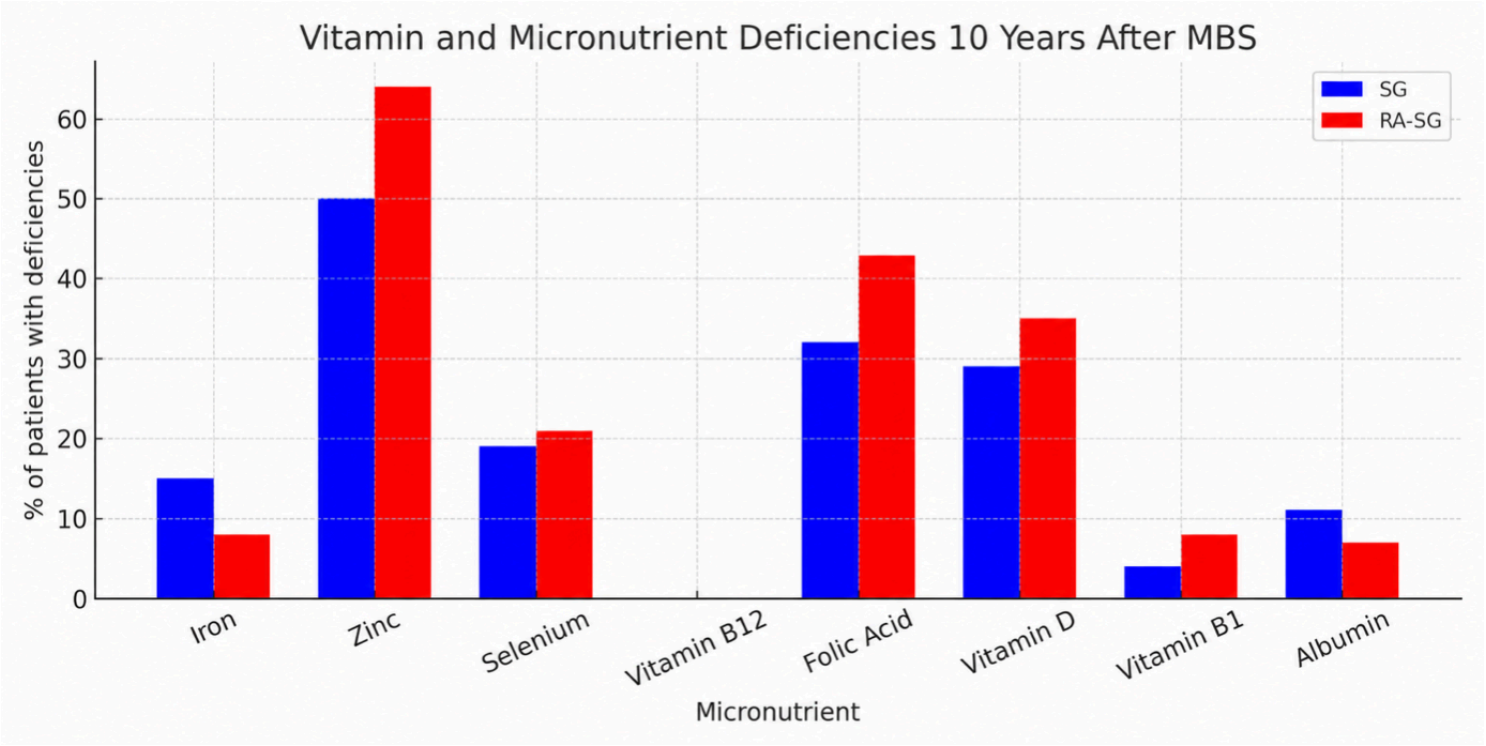

Figure 4

Vitamin – and micronutrient deficiencies 10 years after SG and Ra-SG