Effect of laparoscopic mini gastric bypass versus laparoscopic single anastomosis sleeve ileal bypass on serum iron and calcium levels

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Background
Although bariatric surgery techniques are very effective in the treatment of obesity, they are usually associated with evident nutritional deficiencies. Such operations require ongoing medical care along with vitamin (Vit) and nutrition supplements.
Aim
Is to determine and compare the effect of Laparoscopic mini gastric bypass (MGB) versus laparoscopic single anastomosis sleeve ileal bypass (SASI) on serum iron and calcium levels.
Methodology
The current prospective Randomized controlled study included 62 patients who were randomly allocated into one of two equal groups. Group A (n=31) underwent MGB while group B (n=31) underwent SASI. Follow-up was designed for 6 and 12 months in both groups for the serum iron profile, serum folate, Vit B12, Vit D, parathyroid hormone, and calcium level.
Results
There was a statistically significant decrease in Excess weight loss (EWL)% in both groups after 1, 6, and 12 months and a significant EWL % in group A more than group B (P=0.045*). There was a statistically significant drop in the Iron profile components' levels in both groups after 1, 6, and 12 months in comparison with the corresponding baseline levels. There was a statistically significant decrease in the calcium level as well as Vit D3 within both groups at 1, 6, and 12 months follow-up with a significant increase in Parathyroid hormone in both groups at the same interval of follow-up.
Conclusion
Both MGB and SASI are effective methods for the treatment of morbid obesity. However, adherent follow-up for the Iron profile, Vit B12, Vit D3, parathyroid hormone, and calcium levels are mandatory.

Keywords:
calcium level, iron profile, mini gastric bypass, single anastomosis sleeve ileal

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Introduction

The most effective method for treating morbid obesity that can produce and maintain significant weight loss for an extended period is bariatric surgery, according to research. Such operations, which use restrictive, malabsorptive, or combined techniques, have been demonstrated to achieve positive and encouraging weight loss results [1]. However, such operations require ongoing medical care along with vitamin (Vit) and nutrition supplements. Furthermore, due to anatomical limitations, these are commonly accompanied by dysphagia and vomiting and can cause major metabolic disorders [2,3].

Due to improvements in diabetes and heart disease and a decreased risk of cancer, patients who have surgery are likely to live longer. An interdisciplinary approach and focus on numerous elements of care are necessary for long-term bariatric follow-up. The most crucial component of follow-up is nutrition if you want to safely maximize weight reduction and avoid weight gain. Exercise supports weight reduction maintenance. Early detection of problems is essential because they can arise from poor behavior or postoperative complications [4,5].

Following malabsorptive bariatric surgeries, nutritional disturbances caused by shortages of micronutrients such as iron, vit B12, and folate are particularly prevalent so iron and B12 supplementation is advised in addition to general multivitamin and mineral supplements [6,7].

Since it had been introduced in 2001, mini gastric bypass (MGB) is considered an important bariatric technique with a marvelous outcome in the treatment of obesity and its related comorbidities. In 2018, the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) approved MGB as a mainstream bariatric procedure. MGB is associated with nutritional deficiencies in most patients including serum calcium abnormalities and secondary hyperparathyroidism at 1 year after surgery [8,9].

Laparoscopic single anastomosis sleeve ileal bypass (SASI) and MGB challenge laparoscopic Roux en Y gastric bypass (LRYGB) even though LRYGB was discovered to be the gold standard treatment at the beginning of the 21st century. This is partially due to the fact that both treatments have been reported to be quicker, simpler, and more effective at reducing body weight than LRYGB with superior postoperative profiles [10].

The SASI method based on Santoro's operation, which involves sleeve gastrectomy and gastro ileal loop anastomosis, developed as a revolutionary metabolic and bariatric surgery. Such a method preserves the natural food channel, allowing only a small portion of the meal to be absorbed, while the majority of the food is bypassed and goes directly into the ileum, producing the desired metabolic effect with a low-risk of postoperative nutritional problems and enabling comprehensive endoscopic visualization of the biliary system [11,12].

Since it does not rely on the omission of any component of the digestive system and thus does not interfere with crucial digestive functions, SASI has come to be recognized as a novel and simple surgical technique that can overcome some of the limitations previously mentioned, most importantly malabsorption. However, there are several drawbacks to these surgical methods that may result in malabsorption and diarrhea [13].

The aim of this study is to determine and compare the effect of laparoscopic MGB versus laparoscopic SASI on serum iron and calcium levels.

Patients and methods

Study design and subjects

The current prospective Randomized controlled study was conducted after the approval of ethical and research committees, Benha University following ethical consideration of the World Medical Association Declaration of Helsinki.

The current study included 62 morbidly obese patients of age 18–60 years, BMI greater than 40 kg/m^2, BMI greater than 35 kg/m^2 with comorbidities. Diabetic or pre-diabetic or heavy sweet eaters. Exclusion criteria included patients with uncompensated cardiovascular disease, Hepato-renal insufficiency, Uncontrolled endocrinology disease, or Pulmonary dysfunction. Patients who refused to be included in the study were also excluded. Eligible patients who were recruited and operated on from the General Surgery Department, Benha University Hospital June 2021 to December 2022.

Randomization

The included Patients were randomly allocated into two equal groups using specific software (Random Allocation Software 1.0, 2011). This block randomization was done by an independent investigator.

The study included 62 male patients who were randomly allocated into one of two equal groups.

Group A (n=31) underwent MGB while group B (n=31) underwent SASI. Written informed consent was obtained from all patients included in the study. For all included patients, complete history taking and physical examination and investigations were done, and the procedure was done under general anesthesia.

Procedure

Group A (MGB)

A closed pneumoperitoneum was made by Veress needle insufflation, optical 12 mm port insertion and two additional 12 mm and one 5 mm port were placed as functional ports in the upper abdomen. A subxiphoid track was created using a 5 mm opening to insert the Nathanson liver retractor. A long, thin gastric pouch using the Medtronic Tristapler (Medtronic Inc., Dublin, Ireland). The pouch started slightly lateral to the angle of his and extended beyond the crow's foot. The last staple was positioned directly lateral to the gastroesophageal fat pad Fig. 1a. At that point, the Duodeno-jejunal (DJ) flexure was referring to the instrument marks. Our standard length when we first started utilizing this method was 200 cm. The 45 mm Medtronic (Medtronic Inc., Dublin, Ireland) linear stapler was used to create a gastrojejunostomy Fig. 1b, and the stapler entry opening was then closed with sutures Fig. 1c. The gastrojejunostomy was made in a similar fashion for both groups. At the end, a leak and patency test was performed using a diluted methylene blue solution. No nasogastric tubes or drains were utilized.

Group B (SASI)

A a 10 mm umbilical visiport was used to produce pneumoperitoneum. To insert the liver retractor, a 5 mm trocar was inserted under the xiphoid process. For the surgeon's instruments, 12- and 15 mm trocars were inserted on the right and left middle clavicular lines, respectively. On the left anterior auxiliary line, a second 5 mm trocar was inserted for support. In order to decompress the stomach, an oral Ryle's tube was inserted. Dissection then began on the larger curve, 5 cm from the pylorus up to the cardio esophageal junction, and continued until the gastric fundus was fully mobilized. The stomach was then resected using linear staplers Fig. 2a. Methylene blue was used to examine the leakage and staple line. The patient was placed in the trendelenburg position following the construction of the sleeved gastric tube. The patient's transverse mesocolon was pulled back towards his or her head, and the small intestine's distance from the ileocecal junction was measured at 250 cm Fig. 2b. Then, using a 45 mm linear stapler, an antecolic side-to-side gastro-jejunostomy was performed at the posterior wall of the region between the antrum and the body of the stomach Fig. 2c. An uninterrupted Vicryl 2/0 stitch was used to seal the gastroentrotomy staple Fig. 2d r. The leak test was carried out by injecting 50–100 ml of methylene blue into the gastric pouch. Drains were left in place for 24 h.

Starting four weeks after surgery, all of our patients must follow the following regimen: ferrous fumarate (210 mg) once daily, Adcal D3 chewable tablets twice daily, 400 units of vit D and B12 injections every 12 weeks, and one daily multivitamin tablet.

Evaluation and follow-up

Follow-up was designed for 1, 6, and 12 months in both groups for Excess weight loss (EWL)%, the serum hemoglobin, serum ferritin, serum folate, Vit B12, Vit D, parathyroid hormone, calcium level as well as EWL%.

Outcomes

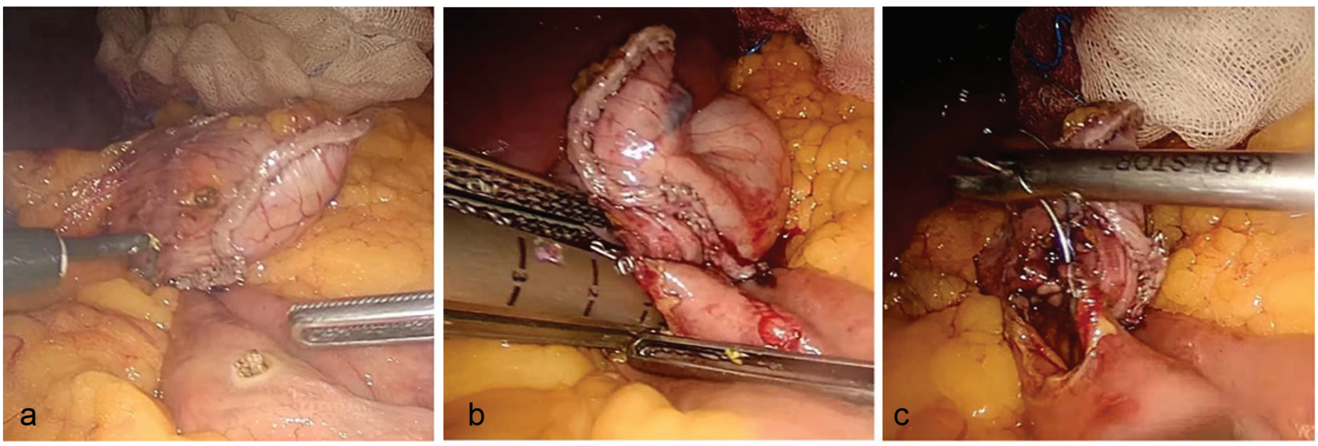
The primary outcome was the successful mal absorptive bariatric procedures with proper estimation and comparison of postoperative levels of the serum hemoglobin, serum ferritin, serum folate, Vit B12, Vit D3, parathyroid hormone, and calcium level in both groups.

The secondary outcome was proper estimation and comparison of EWL% in both groups.

Statistical analysis

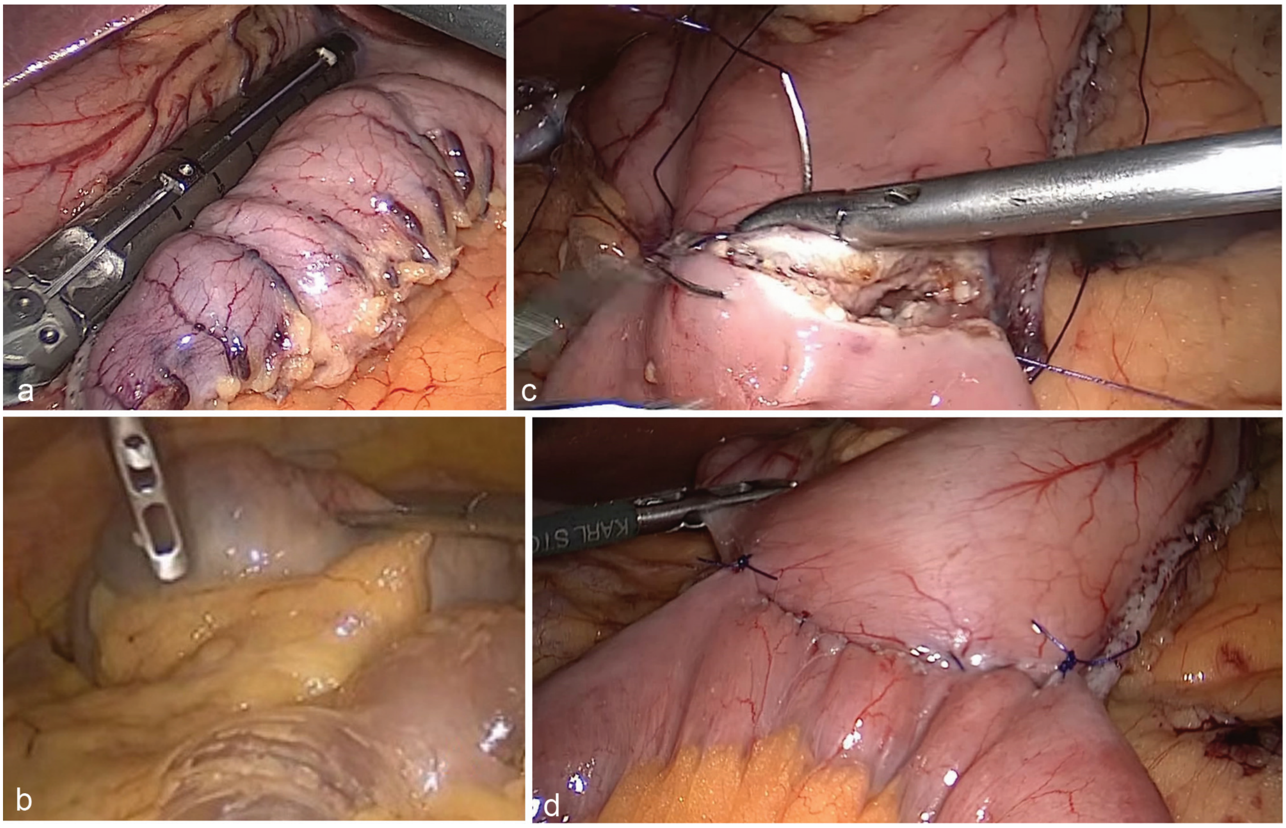
The sample size was calculated depending on the incidence of 24 months follow-up postoperative complications and long term nutritional deficiencies which are the primary and 2ry outcomes of this study with the incidence of 10% loss in follow-up. A sample size of 62 was considered with a power of 80%, *P* value

Figure 1



(a) Creation of pouch. (b): Side to side gastrojejunostomy. (c): Closure the site of stapler entry. Figure 1b: Side to side gastrojejunostomy. Figure 1c: Closure the site of stapler entry

Figure 2



(a): Stabling of the stomach. (b): Identification of the Caecum. (c): Side to side Sleeve ileal anastomosis. d: Closure the site of stapler entry. Figure 2b: Identification of the Caecum. Figure 2c: Side to side Sleeve ileal anastomosis. Figure 2d: Closure the site of stapler entry.

of 0.05, and an effect size of 0.7 using G*power 3.1 software (Universities, Dusseldorf, Germany).

SPSS, version 25 (IBM Corp., Armonk, New York, USA) was used for statistical analysis. Student t-test was used for quantitative parameters that were described using mean and SD. The χ^2 test was used for qualitative parameters that were described as the frequency with percent. *P* values of less than 0.05 were considered significant.

Results

The current study included 62 morbidly obese patients who were randomly allocated into two equal groups, group A (*n*=31)who underwent MGB while group B (*n*=31)underwent SASI procedure. The mean age was 37.89±5.22 and 36.22±5.87 years in group A and B, respectively. There was no statistically significant difference in The base line BMI between both groups (*P*=0.389).other base line values of Iron profile, Vit B12, Folate, Calcium, Vit D3, and parathormone in the study were reported in Table 1. Table 2 demonstrated that there was statistically significant decrease in the mean BMI within both groups after 1, 6, and 12 months follow-up however significant difference in EWL% was reported between both groups only after 12 months (*P*=0.045*) more in MGB group.

As regarding the iron profile, a statistically significant decrease in serum Iron and serum Ferritin in group A more than what was reported in group B after 1, 6, and 12 months while there was statistically significant drop in the serum hemoglobin, serum ferritin, serum Iron, Serum transferrin Saturation and total iron binding capacity levels in both group A and group B after 1, 6, and 12 months in comparison with the corresponding baseline levels Tables 3 and 4. There was a statistically significant decrease in the calcium level as well as Vit D3 within both groups at 1, 6, and 12 months follow-up with Significant Increase in Parathyroid hormone in both groups at the same interval of follow-up Table 5.

Discussion

According to the technique used to lose weight, bariatric procedures can be classified as using restrictive, malabsorptive, or mixed processes. Due to changes in nutrient absorption across the gastrointestinal system and decreased stomach capacity during gastric bypass, nutritional

Table 1 Sociodemographic data and baseline BMI, iron profile, Vitamin B12, folate, calcium, vitamin D3, and parathormone level

Variable	Group A mini gastric bypass *N*=31	Group B single anastomosis sleeve ileal *N*=31	*P* value
Age Mean±SD	37.89±5.22	36.22±5.87	0.389
Sex *N* (%)			
Female	22 (71%)	23 (74%)	0.973
Male	9 (29%)	8 (26%)	0.926
Baseline BMI Mean±SD	45.23±4.89	44.12±4.22	0.356
Baseline Hb Mean±SD *N*=12–16 gm/dl [14,15].	13.45±1.12	13.22±1.23	0.561
Baseline Serum Iron Mean±SD *N*=60–170mic/dl [14,15].	98.36±12.34	101.65±11.86	0.341
Baseline Serum Ferritin Mean±SD *N*=30–250 ng/ml [14,15].	113.2±31.4	115.32±29.23	0.254
Baseline Serum transferrin Saturation Mean±SD *N*=15–50% [14,15].	27.23±3,22	28.29±2.97	0.423
Baseline Total iron binding capacity Mean±SD *N*=250–450 mic/dl [14,15].	323.72±16.48	328.46±17.92	0.239
Baseline Serum Vit B12 Mean±SD *N*=160–800 pg/ml [16].	368.45±23.29	372.22±26.21	0.12
Baseline Serum Folate Mean±SD *N*=6.2–38.5 nmol/l [16].	15.19±2.01	14.88±2.44	0.412
Baseline Serum Total Calcium Mean±SD *N*=8.50–10.8 mg/dl [14,15].	9.44±0.89	9.33±0.77	0.87
Baseline Serum Ionized Calcium Mean±SD *N*=1.16–1.4 mmol/l [14,15].	1.27±0.08	1.24±0.06	0.64
Baseline Serum 25 OH Vit D Mean±SD *N*=4.42–42.7 ng/ml [14,15].	23.23±5.67	24.44±4.32	0.27
Baseline Parathormone Mean±SD *N*=5–65 pg/ml [14,15].	59.24±4.65	58.11±5.22	0.116

deficiencies may develop. Therefore, taking additional vits and minerals like iron, folic acid, vit B12, calcium, and vit D3 is advised for patients.

In the current study, there was no statistically significant difference within each group as regarding the BMI at 1, 6, and 12 months, respectively and this matched the results of Moustafa *AA et al.* [4]. However, the same study reported a statistically significant decrease in the BMI in between the same group and this is against what had been reported in the current study where there was no statistically significant difference In the BMI in both groups along the 12 months follow up and this is assumed to be due to the difference in the baseline BMI reported by Moustafa AA *et al.* [4] in their study.

The proximal jejunum and duodenum are the key sites for iron absorption, which is influenced by the physical state of the iron atom. Iron is found in the oxidized, ferric (Fe^{3+}) state at physiological pH. Iron needs to be ferrous (Fe^{2+}) or bonded to a protein like heme in order to be absorbed. The proximal duodenum's low pH of stomach acid enables the transformation of

Table 2 Pair wise comparison within and in between groups as regarding BMI and EWL% at 1, 6, and 12 months

Variable	Groups	Base line	1 month	*P* value
BMI Kg/m^2 Mean±SD	**Group A**	45.23±4.89	40.34±2.24	**0.001***
	Group B	44.12±4.22	40.21±2.88	**0.001***
	***P* value**	0.356	0.298	
EWL %	**Group A**		24.4	
	Group B		20.1	
	***P* value**		0.072	
Variable	**Groups**	**Base line**	**6 month**	***P* value**
BMI Kg/m^{2}Mean±SD	**Group A**	45.23±4.89	33.54±3.24	<**0.001**
	Group B	44.12±4.22	34.08±3.12	<**0.001**
	***P* value**	0.356	0.786	
EWL %	**Group A**		57.32	
	Group B		50.87	
	***P* value**		0.053	
Variable	**Groups**	**Base line**	**12 month**	***P* value**
BMI Kg/m^{2}Mean±SD	**Group A**	45.23±4.89	28.94±1.84	<**0.0001**
	Group B	44.12±4.22	28.91±2.18	<**0.0001**
	***P* value**	0.356	0.97	
EWL %	**Group A**		86.52	
	Group B		76.45	
	***P* value**		0.045*	

Table 3 Comparison between the two groups regarding, iron profile, Vitamin B12, folate, calcium, vitamin D3, and parathormone at 1, 6, and 12 months follow-up

Variable	Follow-up	Group A mini gastric bypass	Group B single anastomosis sleeve ileal	*P* value
Hb Mean±SD *N*=12–16 gm/dl [14,15].	1 month follow-up	11.23±2.12	12.28±2.11	0.076
	6 months follow-up	11.12±2.16	11.69±2.07	0.812
	12 months follow-up	10.98±1.09	11.25±1.94	0.463
Serum Iron Mean±SD *N*=60–170 mic/dl [14,15].	1 month follow-up	87.43±9.88	94.66±9.82	0.01*
	6 months follow-up	84.29±6.35	91.89±8.97	0.01*
	12 Months follow-up	81.89±6.82	90.12±6.34	0.01*
Serum Ferritin Mean±SD *N*=30–250 ng/ml [14,15].	1 month follow-up	103.34±22.38	109.24±27.68	0.032*
	6 months follow-up	100.21±24.66	107.12±25.22	0.047*
	12 months follow-up	96.11±21.89	101.25±22.37	0.042*
Serum transferrin Saturation Mean±SD *N*=15–50% [14,15].	1 month follow-up	25.22±2.66	26.65±1.99	0.512
	6 months follow-up	24.63±2.78	26.12±1.68	0.263
	12 months follow-up	21.39±2.76	25.24±1.88	0.024*
Total iron binding capacity Mean±SD *N*=250–450mic/dl [14,15].	1 month follow-up	312.67±17.22	322.16±14.89	0.352
	6 months follow-up	311.22±14.23	317.29±11.88	0.437
	12 months follow-up	305.13±12.67	311.25±12.56	0.236
Serum Vit B12 Mean±SD *N*=160–800 pg/ml [16].	1 month follow-up	354.25±28.98	361.28±22.14	0.186
	6 months follow-up	349.26±22.76	357.66±19.88	0.27
	12 months follow-up	332.39±18.66	352.39±23.84	0.031*
Serum Folate Mean±SD *N*=6.2–38.5 nmol/l [16].	1 month follow-up	17.09±1.06	**16.66±1.92**	0.163
	6 months follow-up	19.38±1.66	18.97±2.21	0.287
	12 months follow-up	20.01±2.39	19.89±3.22	0.98
Serum Total Calcium Mean±SD *N*=8.50–10.8 mg/dl [14,15].	1 month follow-up	9.14±0.68	9.26±0.92	0.067
	6 months follow-up	8.92±0.75	9.16±0.64	0.026*
	12 months follow-up	8.74±.45	8.97±0.55	0.01*
Serum Ionized Calcium Mean±SD *N*=1.16–1.4 mmol/l [14,15].	1 month follow-up	1.1±0.13	1.16±0.09	0.96
	6 months follow-up	0.99±0.07	1.1±0.13	0.043*
	12 months follow-up	0.91±0.12	1.06±0.11	0.039*
Serum 25 OH Vit D Mean±SD *N*=4.42–42.7 ng/ml [14,15].	1 month follow–up	21.89±6.33	22.46±4.66	0.24
	6 months follow–up	20.34±4.21	21.37±5.22	0.068
	12 months follow-up	18.11±3.22	19.65±3.67	0.41
Parathormone Mean±SD *N*=5–65 pg/ml [14,15].	1 month follow-up	64.22±3.66	61.23±4.36	0.078
	6 months follow-up	67.35±2.68	63.27±3.56	0.062
	12 months follow-up	72.32±4.23	68.22±4.27	0.038*

insoluble ferric (Fe^{3+}) ions into absorbable ferrous (Fe^{2+}) ions. Similar to how calcium ions are mostly absorbed from the duodenum, pH affects how well calcium is absorbed. Vit D and parathyroid hormone (PTH) are crucial in maintaining calcium homeostasis [8,17].

In the current study, the iron profile including the Hb %, serum ferritin, serum iron, serum transferrin Saturation, and total iron binding capacity was adherently monitored postoperatively for 12 months in both groups as well as Vit B12 and folate.

Many previous studies [3,18,19] reported evident both microcytic and macrocytic anemia after MGB. In this study, the components of iron profile were affected throughout the 12 months follow-up period where the was statistically significant decrease in the Hb %, serum ferritin, serum iron at 1, 6, and 12 months, respectively within both groups and this matched the results of Mokhber S *et al.* [20] and Gowanlock Z *et al.* [21] and this can be explained as the fact that the proximal small bowel is skipped by a one anastomosis gastric bypass, ingested iron cannot interact with the gastric acid produced in the bypassed stomach. This interferes with the process. This mechanism is further impacted by the use of proton pump inhibitors and shortened contact times with the acid in the gastric pouch [9].

Although anemia and changes in the iron profile occurred in both groups there was a statistically significant decrease in Hb %, serum ferritin, and serum iron in MGB more than SASI and this is assumed to be due to the longer time of contact of iron with the relatively larger remnant of the stomach

Table 4 Mean difference and 95% confidence interval and pairwise comparisons values of the iron profile, vit B12 and FolateLevels in both groups at 1, 6, and 12 months follow-up

	Group A MD (95%CI)	*P* value	Group B MD (95%CI)	*P* value
Hb				
Baseline vs post 1 M	2.22 (1.11–3.33)	0.01*	0.94 (0.47–1.41)	0.01*
Baseline vs post 6 M	2.33 (1.17–3.49)	0.01*	1.53 (0.76–2.29)	0.01*
Baseline vs post 12 M	3.47 (1.73–5.2)	<0.001*	1.97 (0.99–2.95)	0.01*
Post 1 M vs post 6 M	0.11 (0.06–0.16)	0.24	0.57 (0.28–0.86)	0.057
Post 1 M vs post 12 M	0.25 (0.125–0.375)	0.063	1.03 (0.52–1.54)	0.03*
Post 6 M vs post 24 M	0.14 (0.07–0.21)	0.056	0.44 (0.22–0.66)	0.724
Serum Iron				
Baseline vs post 1 M	10.93 (5.46–16.4)	0.001*	6.99 (3.49–10.48)	0.01*
Baseline vs post 6 M	14.07 (9.38–28.14)	0.001*	9.76 (4.88–14.64)	0.01*
Baseline vs post 12 M	16.47 (8.23–24.7)	0.001*	11.53 (5.76–17.29)	0.01*
Post 1 M vs post 6 M	3.14 (1.5–4.71)	0.006*	2.77 (1.38–4.15)	0.534
Post 1 M vs post 12 M	5.54 (2.77–8.31)	0.031*	4.54 (2.27–6.81)	0,213
Post 6 M vs post 24 M	2.4 (1.2–3.6)	0.213	1.77 (0.88–2.65)	0.319
Serum Ferritin				
Baseline vs post 1 M	9.86 (4.93–14.79)	0.01*	6.08 (3.04–9.12)	0.128
Baseline vs post 6 M	12.99 (6.5–19.48)	0.01*	8.2 (4.1–12.3)	0.02*
Baseline vs post 12 M	17.09 (8.55–25.63)	0.01*	14.07 (7.03–21.10)	0.01*
Post 1 M vs post 6 M	3.13 (1.65–4.7)	0.068	2.12 (1.06–3.18)	0.055
Post 1 M vs post 12 M	7.23 (3.61–10.85)	0.007*	7.99 (3.99–11.98)	0.009*
Post 6 M vs post 24 M	4.1 (2.05–6.15)	0.348	6.87 (3.43–10.30)	0.244
Serum transferrin Saturation				
Baseline vs post 1 M	2.01 (1.0–3.01)	0.01*	1.64 (0.82–2.46)	0.01*
Baseline vs post 6 M	2.6 (1.3–3.9)	0.01*	2.17 (1.08–3.25)	0.01*
Baseline vs post 12 M	5.84 (2.92–8.76)	0.01*	3.05 (1.52–4.57)	0.01*
Post 1 M vs post 6 M	0.59 (0.30–0.88)	0.16	0.53 (0.27–0.79)	0.005*
Post 1 M vs post 12 M	3.83 (1.91–5.74)	0.043*	1.41 (0.71–2.11)	0.015*
Post 6 M vs post 24 M	3.24 (1.62–4.86)	0.831	0.88 (0.44–1.32)	0.812
Total iron binding capacity				
Baseline vs post 1 M	11.05 (5.52–16.57)	0.01*	6.3 (3.15–9.45)	0.01*
Baseline vs post 6 M	12.5 (6.25–18.75)	0.01*	11.17 (5.58–16.75)	0.01*
Baseline vs post 12 M	18.59 (9.29–27.88)	0.01*	17.21 (8.60–25.81)	0.01*
Post 1 M vs post 6 M	1.45 (0.73–2.17)	0.127	4.86 (2.43–7.29)	0.053
Post 1 M vs post 12 M	7.54 (3.77–11.31)	0.012*	10.91 (5.45–16.36)	0.011*
Post 6 M vs post 24 M	6.08 (3.04–2.21)	0.632	6.04 (3.02–9.06)	0.30
Serum Vit B12				
Baseline vs post 1 M	14.2 (12.1–36.3)	0.231	10.94 (5.47–16.41)	0.275
Baseline vs post 6 M	19.19 (20.59–61.78)	0.076	15.56 (7.78–23.34)	0.834
Baseline vs post 12 M	356.06 (–2.37–0.79)	0.024*	19.83 (9.91–29.74)	0.082
Post 1 M vs post 6 M	16.99 (8.49–25.48)	0.214	3.62 (1.81–5.43)	0.19
Post 1 M vs post 12 M	21.86 (10.93–32.79)	0.062	8.69 (4.34–13.03)	0.26
Post 6 M vs post 24 M	14.87 (7.34–22.30)	0.458	5.27 (2.63–7.90)	0.107
Serum Folate				
Baseline vs post 1 M	–1.95 (–2.92–0.98)	0.18	–1.78 (–2.67–0.89)	0.43
Baseline vs post 6 M	–4.24 (–6.36–2.12)	0.047*	–4.09 (–6.13–2.09)	0.039*
Baseline vs post 12 M	–4.87 (–7.3–2.43)	0.02*	–5.01 (–7.51–2.5)	0.027*
Post 1 M vs post 6 M	–2.29 (–3.36–1.12)	0.214	–2.31 (–3.96–1.15)	0.19
Post 1 M vs post 12 M	–2.92 (–4.38–1.96)	0.042*	–3.23 (–4.84–1.61)	0.028*
Post 6 M vs post 24 M	–0.63 (–0.95–0.31)	0.458	–0.92 (–1.38–0.46)	0.928

than the pouch left in MGB. None of the included patients in both groups suffered from severe anemia because of adherent postoperative iron supplementation.

The causes of a vit B12 shortage are probably complex in nature. An antrectomy performed as part of MGB causes patients to lose the physiological function of parietal cells in the antrum. Both the glycoprotein gastric intrinsic factor and the stomach synthesis of hydrochloric acid originate from parietal cells. While gastric intrinsic factor forms a complex with vit B12 that is typically absorbed through a particular receptor

Table 5 Mean difference and 95% confidence interval and pairwise comparisons values of the calcium, vit D3 and parathormone Levelsin both groups 1, 6, and 12 months follow-up

	Group A MD (95%CI)	*P* value	Group B MD (95%CI)	*P* value
Serum Total Calcium				
Baseline vs post 1 M	**0.3** (0.15–0.45)	**0.042***	0.07 (0.03–0.11)	**0.34**
Baseline vs post 6 M	0.52 (0.26–0.78)	**0.01***	0.17 (0.08–0.25)	**0.01***
Baseline vs post 12 M	0.7 (0.35–1.05)	**0.01***	0.36 (0.18–0.54)	**0.01***
Post 1 M vs post 6 M	0.22 (0.11–0.33)	**0.01***	0.1 (0.05–0.15)	**0.459**
Post 1 M vs post 12 M	0.4 (0.2–0.6)	**0.01***	0.29 (0.14–0.43)	**0.024***
Post 6 M vs post 24 M	0.24 (0.12–0.36)	**0.056**	0.17 (0.08–0.25)	**0.721**
Serum Ionized Calcium				
Baseline vs post 1 M	0.17 (0.08–0.26)	**0.03***	0.08 (0.04–0.12)	**0.23**
Baseline vs post 6 M	0.28 (0.14–0.42)	**0.01***	0.14 (0.07–0.21)	**0.01***
Baseline vs post 12 M	0.36 (0.18–0.54)	**0.01***	0.18 (0.09–0.27)	**0.01***
Post 1 M vs post 6 M	0.11 (0.06–0.16)	**0.16**	0.06 (0.03–0.09)	**0.53**
Post 1 M vs post 12 M	0.2 (0.1–0.3)	**0.01***	0.1 (0.05–0.15)	**0.021**
Post 6 M vs post 24 M	0.08 (0.04–0.12)	**0.213**	0.04 (0.02–0.06)	**0.319**
Serum 25 OH Vit D				
Baseline vs post 1 M	1.34 (0.67–2.01)	**0.03***	1.98 (0.99–2.97)	**0.017***
Baseline vs post 6 M	2.89 (1.45–4.33)	**0.01***	3.07 (1.53–4.60)	**0.01***
Baseline vs post 12 M	5.12 (2.56–7.68)	**0.01***	4.76 (2.38–7.14)	**0.01***
Post 1 M vs post 6 M	1.55 (0.77–2.32)	**0.016***	1.07 (0.53–1.60)	**0.04***
Post 1 M vs post 12 M	3.78 (1.89–5.67)	**0.043***	2.81 (1.40–4.21))	**0.015***
Post 6 M vs post 24 M	2.24 (1.12–3.36)	**0.831**	1.72 (0.86–2.58)	**0.812**
Parathormone				
Baseline vs post 1 M	−4.98 (−7.47– −2.49)	**0.01***	−3.12 (−4.68– −1.56)	**0.01***
Baseline vs post 6 M	−8.11 (−12.16–4.0)	**0.01***	−5.16 (−7.74–2.5)	**0.01***
Baseline vs post 12 M	−13.33 (−19.99–6.65)	**0.01***	−10.11 (−15.16–5.05)	**0.01***
Post 1 M vs post 6 M	−3.13 (4.69–1.56)	**0.027***	−2.04 (−3.6–1.2)	**0.053**
Post 1 M vs post 12 M	−8.1 (−12.15–4.05)	**0.012***	−6.99 (−10.48–3.49)	**0.011***
Post 6 M vs post 24 M	−4.97 (−7.48–2.48)	**0.032***	−4.95 (−7.42–2.47)	**0.042***

in the distal ileum, stomach acid increases the bioavailability of vit B12 in food [22].

Human vit B12 stores can last up to 3 years, and a vit B12 deficit can become clinically significant for a very long time and this matched the current results where Vit B12 deficiency manifested after 1 year in MGB group with a significant decrease in MGB group (*P*=0.24*) and more than SASI group (*P*=0.031*) and this may be due to the larger remanent of the stomach left including part of the antrum and this the normal pathway of Vit B12 absorption and this also explains why there was no statistically significant loss of Vit B12 in SASI group after 1 year follow-up (*P*=0.107).

Surprisingly the level of Folic acid increased over time following bariatric surgery [23] and this is assumed to be due to intestinal bacterial overgrowth and this matched what had been reported in the current study.

Preoperative Vit D3 in the current study was 23.23 ±5.67 and 24.44±4.32 in group A and B, respectively and this border line values in the current study matched the findings of Wei JH *et al.* [24] who documented Vit D3 deficiency before surgery. this preoperative low normal or even Vit D3 deficiency can be explained by an increased uptake of the vit D3 by adipose tissue, and limited exposure to sunlight due to inactivity. In some cases steatosis associated with obesity may cause crucial impairment in Vit D3 synthesis [25].

In the current study, there was a statistically significant decrease in Vit D3 within both groups at 1, 6, and 12 months, respectively however there was no statistically significant difference in Vit D3 deficiency between patients who underwent MGB and SASI after 1 year follow-up and this matched the results of Ducloux *P et al.* [26] and Suter *M et al.* [27] who reported postoperative Vit D3 deficiency in different bariatric procedures that may extend up to 5 years. Therefore, an aggressive vit D3 insufficiency treatment before and after bariatric surgery is highly recommended.

In the current study there was a statistically significant decrease in both total and ionized calcium levels with in both groups at 1, 6, and 12 months follow-up as well as between MGB group and SASI group after 6 and 12 months and this is assumed to be due to impaired calcium absorption after MGB and this matches the results reported by Wei JH *et al.* [24] who reported significant decrease in the calcium level after 1 year follow-up following gastric bypass surgery. However, Worm *et al.* [28] reported significant increase in the calcium level in both sexes after 6 months following MGB and this may be due to excess postoperative supplementation. Another study including a 3 years follow-up following SASI operation [29] reported a drop in the calcium level after 1-year follow-up. Kessler *et al.* [18] recommended Adherent follow-up of the calcium level with optimized supplementation.

Emerging evidence has shown that secondary hyperparathyroidism (SHPT) is a common consequence of bariatric surgery. This is assumed to be due to alternations in the hypothalamus pituitary-parathyroid (HPP) axis through its effects on calcium absorption. Furthermore, different types of bariatric surgery have different effects on body weight and calcium absorption However, long-term data are lacking, and differences in the prevalence of SHPT with different procedures are not clear [30,31].

In the current study, there was evident SHPT noticed in both groups manifested by an increase of the parathormone level over time matching the results of Wei *et al.* [24] and this is assumed to be due to the reported Vit D3 and calcium deficiencies in this study.

Conclusion

According to the current results, both MGB and SASI are effective methods for treatment of morbid obesity, However adherent follow-up for the Iron profile, Vit B12, Vit D3, parathyroid hormone, and calcium levels is mandatory.

Recommendations

Aggressive nutritional supplementation for Iron, Vit B12, Vit D3, parathyroid hormone, and calcium is highly recommended following both SASI and MGB.

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