Original Article

The Prevalence of Vitamin B12, Hemoglobin, and Ferritin Deficiency in Patients with Morbid Obesity and Changes in their Blood Levels after Bariatric Surgery

Abstract

Background: Obesity and its complications are becoming a global concern. Assessing hemoglobin (Hb), vitamin B12, and ferritin deficiencies is crucial for morbidly obese patients due to the significant implications these deficiencies can have on their overall health and well-being. Studies indicate that individuals undergoing bariatric surgery are at a high risk of developing deficiencies in essential nutrients such as vitamin B12, iron, and folate, which can have profound health implications. One of the most effective treatments for morbidly obese patients is bariatric surgery. By understanding the process of these surgeries, several micronutrient deficiencies are anticipated. The lack of data about how bariatric strategies may affect these micronutrient levels provoked us to examine these changes closely. **Methods:** In the current retrospective cohort study, we submitted 224 morbidly obese patients (body mass index (BMI) ≥ 40 kg/m2 or BMI = 35-39.9 kg/m2 with a risk factor, e.g. diabetes mellitus) who were candidates to bariatric surgeries at the obesity center of Rasoul-e-Akram Hospital from December 2018 to December 2019. Participants were divided into three groups of bariatric surgeries: sleeve gastrectomy (SG), mini-gastric bypass, and Roux-en-Y gastric bypass (RYGB). Demographics and clinical features and hemoglobin, ferritin, and vitamin B12 were recorded preoperatively and compared with postoperative follow-up periods at three, six, and 12 months after the operation. **Results:** The mean age was 39.17 ± 10.60 years, and preoperative BMI was 46.13 ± 5.83 kg/m2. The prevalence of anemia was 7.1% before the surgery and 28.1% one year after. The results showed that hemoglobin level had been reduced within 12 months postoperatively, and the changes were statistically significant ($P < 0.001$). We were unable to find significant differences in the preoperative and postoperative proportions of anemia among different types of surgeries. Ferritin levels increased in the first three months after the operation and reduced as time went on. Preoperatively, 32.6% of the cases were ferritin deficient, which rose to 44.6% at the end of the 12-month follow-up. Vitamin B12 level was corrected by supplement therapy, and it did not reduce over follow-up periods (25% preoperatively vs. 21.9% at the end of the 12th month). We found no meaningful differences among various types of surgery in examining vitamin B12 deficiency. **Conclusions:** Bariatric surgery probably can increase the prevalence of anemia and ferritin deficiency. Vitamin B12 deficiency is expected after the surgery; however, it can be prevented by encouraging patients to use intramuscular or oral supplements during postoperative periods. Although micronutrient deficiencies can develop years after the surgery, a more significant study population must be designed with extended follow-up periods to determine more specific changes.

Keywords: *Bariatric surgery, deficiency, ferritin, hemoglobin, obesity, vitamin B12*

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Introduction

Obesity, a result of an imbalance between energy intake and calorie burn, is turning into a worldwide issue among nations. It is generally characterized as BMI ≥ 30 kg/m2 and can be a consequence or a cause of metabolic syndrome.[1] The term "morbid obesity" is characterized by body mass index (BMI) ≥ 40 kg/m2 or BMI = 35-39.9 kg/m2 with a critical underlying disease, e.g. diabetes.[2] Based on what WHO claimed, there were more than 500 million obese around the world in 2015.[3] A vast study that calculated BMI in 19.2 million people in 200 countries found that BMI has increased over the decades. This study represented that 2.3% of men and 5% of women are severely obese, and it is anticipated that these numbers are going to be doubled by 2025.[4] Significant complications of morbid obesity are

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cardiovascular events, cerebrovascular attacks, diabetes mellitus, dyslipidemia, some cancers, and hypertension.[5,6] Although there are non-invasive treatments for overweight and even obese individuals, in morbid obesity, bariatric surgery is proven to lower mortality and comorbidities.[2,7-11]

Bariatric strategies that are pure restrictive types like gastric banding (GB) and sleeve gastrectomy (SG) reduce the stomach size, increase gastric emptying, and cause early satiety, resulting in less calorie intake.[12,13] On the other hand, pure malabsorptive procedures such as biliopancreatic diversion (BPD) change the gastrointestinal tract's normal anatomy by excluding and bypassing some parts of it.[12] Restrictive-malabsorptive procedures, including mini bypass and Roux-en-Y gastric bypass (RYGB), are considered the "gold standard" choice.[2,10,11,14] Early satiety, reduced amount of food, decreased secretion of hydrochloric acid and intrinsic factor, the remarkable reduction of secretory and absorptive surface, and dietary restriction after surgery are the main ways patients end up with micronutrient deficiencies.[12,13,14-16]

Cyanocobalamin, well known as "vitamin B12," is a water-soluble vitamin essential for deoxyribonucleic acid (DNA) synthesis.[17-19] The human body receives adequate cobalamin from vitamin B12-rich food, such as red meat.[20] An average-aged adult can store vitamin B12 in the liver for three years in case of deprivation.[17,18] Vitamin B12 is bound to food proteins. As food is digested in the stomach, pepsin and hydrochloric acid cleave vitamin B12 from food protein. After B12 is released from protein, it binds to intrinsic factor (IF) to safely transmit via the GI tract until it reaches the terminal ileum.[21] The daily need for vitamin B12 is considered to be about two μg. Although hepatic storage of an ordinary person has restored nearly 2000 μg of B12, it is crucial to prevent B12 hypovitaminosis after bariatric surgery. The minimum compensatory amount of B12 is estimated at 350 μg/d, and for better outcomes in neurologic and hematologic issues, a higher dosage of vitamin is needed.[22,23] Studies reported that 1000–2000 μg/d of cyanocobalamin could provide an optimal serum level of B12 when administered orally.[23,24] However, the administration can be both orally and parenterally.[23]

Cyanocobalamin is vital for many nuclear processes. B12 deficiency symptoms are fatigue, shortness of breath, numbness, neuropathy, and ataxia. Megaloblastic anemia, thrombocytopenia, leukopenia, and glossitis are other hematologic manifestations of B12 deficiency.[25-27] Patients who underwent malabsorptive operations are more likely to become B12 deficient in 1–9 years than restrictive surgeries.[21,28] Overall, three main ways lead to B12 depletion[29]:

1- limited food intake, especially animal protein, because of intolerance;
2- decreased gastric acid and pepsin secretion, which leads to decreased B12 cleavage;
3- inadequate secretion and altered function of IF, which is necessary for B12 transmission.

Serum ferritin is generally an inflammatory factor and an indicative marker for Iron content in the human body.[30,31] There is strong evidence that obesity is related to insulin resistance and high ferritin levels.[30-34] Abril-Ulloa V *et al*.,[35] in a meta-analysis study, reported that high ferritin levels and metabolic syndrome are correlated with each other in a positive direction. Thus, morbidly obese patients are expected to have higher ferritin levels. On the other side, after bariatric surgery, many anatomical and physiological alterations can develop iron deficiency anemia (IDA) over the years after the operation. Consequently, ferritin, as an indicator of iron content, will be decreased over time. Due to this sequence, ferritin and hemoglobin are anticipated to be lower than the normal limit or before the surgery.

This study has been designed to determine the prevalence of anemia, ferritin, and vitamin B12 deficiency after a bariatric procedure and examine the effect of different types of bariatric surgery on vitamin B12, ferritin, and hemoglobin levels in morbidly obese patients among the Iran population.

Methods and Material

Study design and participants

The present study is a retrospective cohort study performed at the obesity center of Rasoul-e-Akram Hospital from December 2018 to December 2019. We submitted 224 patients who qualified for bariatric surgery (BMI ≥ 40 kg/m2 or BMI 35–39.9 kg/m2 with a risk factor, e.g. DM). People were between 18 and 65 years old and did not use alcohol or illicit drugs actively. Cases with a history of bariatric surgery or other malabsorption disease were excluded. The Ethics Committee has approved the current study of Iran University of Medical Sciences under the number IR.IUMS.REC 1396.31919.

We arranged patients into three groups based on the type of surgery (mini bypass, RYGB, and SG). 171 (76.3%) of patients underwent mini-gastric bypass, 38 (17%) RYGB, and 15 (6.7%) SG. Vitamin B12, ferritin, and hemoglobin have been recorded preoperatively and compared with three, six, and 12 months after the operation. Anemia was considered hemoglobin < 12 mg/dL in females and less than 14 mg/dL in males. Vitamin B12 < 211 pg/mL was defined as B12 deficiency, and ferritin < 30 ng/mL was assumed as deficiency. We measured ferritin and vitamin B12 levels by Abbott (Abbott Diagnostics, Delkenheim, Germany), and normal ranges were defined as 30–150 ng/mL and 211–946 pg/mL, respectively. Patients were recommended to use mineral supplements and multivitamins after the surgery. Each tablet contained 500 µg of vitamin B12 in combination with other micronutrients, which was supposed to be taken once a day orally. Patients were encouraged to take supplements from the first post-operation visit. Further information is listed in Table 1.

Statistical analysis

Quantitative variables with normal distribution were described by mean ± standard deviation (SD). We reported categorical variables by frequency and percentages. Chi-square or Fisher's exact tests compared categorical values, and for continuous variables, independent sample *t* test was performed. We conducted a repeated measures ANOVA test to assess the changes in hemoglobin, vitamin B12, and ferritin across different follow-up periods, provided that the assumption of sphericity (Mauchly's sphericity test) was met. For the evaluation of non-normally distributed variables, a non-parametric test (Friedman) was used. This study determined the significance level to be less than 0.05 (P value < 0.05). We analyzed the data using IBM SPSS statistics version 26.

Table 1: Supplement's constituent recommended to bariatric patients

Supplement ingredients	Amount per serving
Vitamin A	2250 µg
Vitamin B_1	3 mg
Vitamin B_2	3.4 mg
Vitamin B_3	20 mg
Vitamin B_6	4 mg
Vitamin B_{12} (Cyanocobalamin)	500 µg
Vitamin C	90 mg
Vitamin D	75 µg
Vitamin E	40.2 µg
Vitamin K	160 µg
Folate	800 µg
Iron	45 mg
Copper	2 mg
Zinc	30 mg
Magnesium	400 mg
Iodine	150 µg
Manganese	2 mg
Selenium	70 µg
Pantothenic acid	20 mg
Biotin	600 µg
Molybdenum	75 µg
Chromium	120 µg

Results

Demographics and clinical characteristics

A total of 224 patients were included in the study. Table 2 shows the demographic and clinical features of the participants. There were 190 (84.8%) females in the survey. The mean age (± SD) was 39.17 ± 10.60 years, and the mean preoperative BMI (± SD) was 46.13 ± 5.83 kg/m2. Males and females were statistically similar in age or BMI (P = 0.410 and 0.171, respectively). More patients had undergone mini-gastric bypass than RYGB or SG (171 vs. 38, 15, respectively). Dyslipidemia, followed by hypothyroidism, was the most frequent comorbidity among all underlying diseases. Further information is shown in Table 2.

Hemoglobin level and anemia

Changes in hemoglobin, ferritin, and vitamin B12 levels have been described in Tables 3 and 4. The preoperative average hemoglobin was 13.69 ± 1.43 mg/dL. Our findings confirm that hemoglobin level was continuously decreased during three-, six-, and 12-month periods (12.85 ± 1.42 mg/dL at the end of the 12th month; P < 0.001) [Figure 1]. However, the repeated measure of the ANOVA test for hemoglobin deficiency was not significant among different types of surgery. Hb < 12 in females and Hb < 14 in males were defined as anemia. By this definition, 16 cases had anemia before the bariatric surgery. Our results highlight that the number of hemoglobin-deficient cases has increased during all three follow-up periods [16 vs. 63 at the end of the 12th month].

Serum level of ferritin; before vs. after

Evaluating ferritin level showed that despite an increase in the first three months after the surgery, ferritin level drops as time goes on (67.75 ± 74.97 vs. 55.85 ± 56.30 ng/mL at the end of the 12th month; P < 0.001) [Table 5]. Interestingly, our study proved that ferritin levels had decreased significantly over the third and sixth months when people submitted to RYGB compared to other types of surgery (P = 0.038 and 0.028, respectively). The number of ferritin-deficient cases was 32.6% before the surgery, which reached 44.6% in 12 months after the operation. Compared with the preoperative period, RYGB patients were found to be 57.9% deficient cases after the first year (57.9% vs. 41.2%). The incidence of deficient cases was significant in the third and sixth months (P = 0.042, 0.017, respectively) [Figure 2].

Vitamin B12

The results of this study represented that vitamin B12 has been remarkably increased after 12 months of follow-up. Vitamin B12 levels had almost doubled in patients who recommended taking supplements during the first three months (285.68 ± 97.45 vs. 477.61 ± 3 65.29 pg/mL). Although it began to drop after the third month, the vitamin B12 level was still higher 12 months after the surgery than the baseline (285.68 ± 97.45 vs. 298.90 ± 106.59 pg/mL; $P < 0.001$) [Table 5]. As we considered vitamin B12 less than 211 pg/mL as vitamin B12 deficiency, there were 56 (25%) deficient cases preoperatively, which dropped to 49 (21.9%) patients 12 months after the operation [Figure 3]. The changes in hemoglobin, ferritin, and vitamin B12 levels within the follow-up periods are demonstrated in Figures 4–6. Table 6 presents an overview of the identified deficiencies.

Discussion

Recently, the American Society of Hematology stated that anemia is highly anticipated in people undergoing bariatric surgeries.[36] Based on what the American Society of Hematology claimed, 33%–49% of patients submitted to bariatric surgery develop anemia over two years.[36,37] We conducted this study to examine the hemoglobin

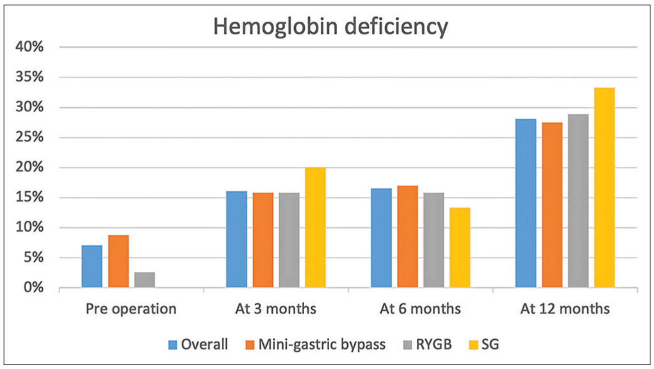

Figure 1: Hemoglobin deficiency among bariatric patients before surgery and within three, six, and 12-month follow-up periods and in different types of operation. RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy

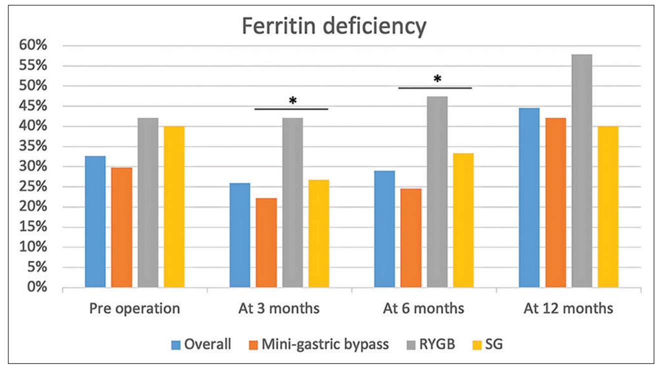

Figure 2: Ferritin deficiency among bariatric patients before surgery and within three, six, and 12-month follow-up periods and in different types of operation. RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy. ****P* **< 0.05**

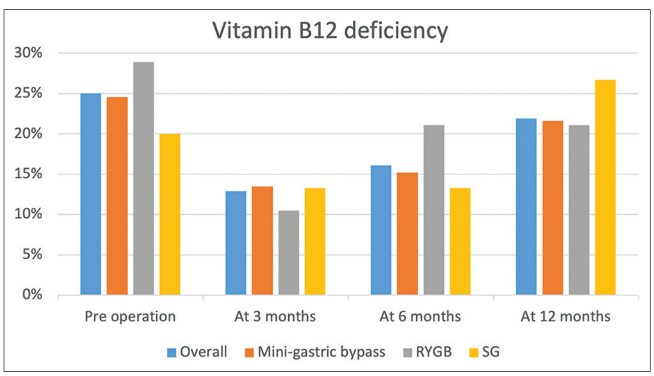

Figure 3: Vitamin B12 deficiency among bariatric patients before surgery and within three, six, and 12-month follow-up periods and in different types of operation. RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy

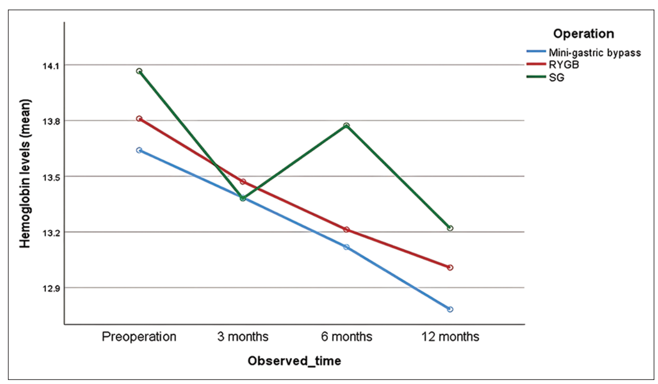

Figure 4: Hemoglobin levels decrease within follow-up periods. RYGB: Roux-en-Y gastric bypass. SG: sleeve gastrectomy

Table 2: Demographics and clinical features of the participants

Characteristic	Overall	Type of surgery			$P^{\dagger}$
		Mini-bypass	RYGB	SG	
Females	190 (84.8)	146 (76.8)	32 (16.8)	12 (6.3)	0.851
Age (year)	39.17±10.60	38.88±10.85	41.29±8.60	37.20±12.16	0.175
Preoperative BMI (kg/m^2)	46.13±5.83	46.39±6.05	45.16±4.44	45.56±6.45	0.655
Comorbidities					
HTN	38 (17)	24 (63.2)	12 (31.6)	2 (5.3)	0.031
DM type II	36 (16)	30 (83.3)	6 (16.7)	0	0.207
Dyslipidemia	97 (43.3)	74 (76.3)	18 (18.6)	5 (5.2)	0.649
Hypothyroidism	43 (19.2)	36 (83.7)	6 (14)	1 (2.3)	0.336

**n* (%), mean±SD, †Chi square test, Kruskal–Wallis test. BMI: body mass index, RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy, HTN: hypertension, FBS: fasting blood sugar, DM: diabetes mellitus

Table 3: Hemoglobin, serum ferritin, and vitamin B12 levels before the surgery and during follow-up periods

Variable	Surgery type	Preoperation	Postoperation			*P**
			3 months	6 months	12 months	
Hemoglobin (mg/dL)	Overall	13.69±1.43	13.40±1.33	13.17±1.14	12.85±1.42	<0.001
	Mini-gastric bypass	13.64±1.42	13.38±1.26	13.11±1.15	12.78±1.45	-
	RYGB	13.81±1.57	13.47±1.31	13.21±1.01	13.01±1.29	-
	SG	14.06±1.27	13.38±2.02	13.77±1.34	13.22±1.39	-
Ferritin (ng/mL)	Overall	67.75±74.97	87.01±78.62	80.11±74.01	55.85±56.30	<0.001
	Mini-gastric bypass	66.69±79.29	91.20±79.03	84.27±73.98	55.76±55.64	-
	RYGB	58.84±61.34	64.03±63.88	59.23±63.78	46.71±53.65	-
	SG	68.29±54.51	97.46±100.26	85.58±92.78	80.03±66.61	-
Vitamin B12 (pg/mL)	Overall	285.68±97.45	477.61±365.29	423.78±299.47	298.90±106.59	<0.001
	Mini-gastric bypass	287.12±90.85	478.69±367.06	419.10±297.63	292.69±105.44	-
	RYGB	266.82±110.02	474.82±397.60	414.44±244.40	330.90±107.38	-
	SG	317.06±130.34	472.34±267.40	500.72±433.73	288.75±110.22	-

*Greenhouse-Geisser. RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy

Table 4: Effects of time and type of the surgery on hemoglobin, ferritin, and vitamin B12 levels following bariatric surgery

Source	Df	Hemoglobin			Ferritin			Vitamin B12		
		F	*P**	η^2	*F*	*P*	η^2	*F*	*P*	η^2
Time (within-subjects)	3	17.61	<0.001	0.074	6.391	<0.001	0.028	14.82	<0.001	0.063
Type of the surgery (between-subjects)	2	0.884	0.414	0.008	1.507	0.226	0.013	0.223	0.800	0.002
Time-Surgery	6	0.979	0.433	0.009	1.391	0.226	0.012	0.412	0.806	0.004

*Greenhouse-Geisser. df: degree of freedom, *F*: *F*-statistics, *P*: *P*, η^2: Eta squared

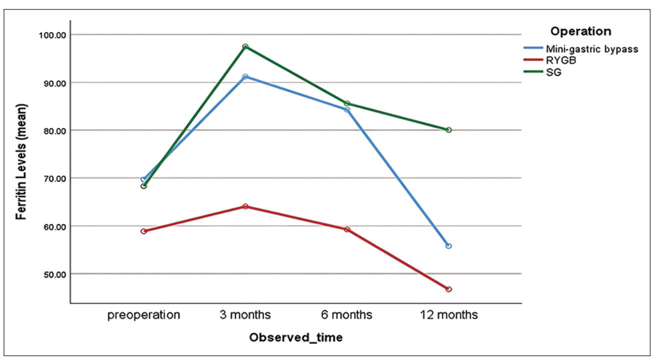

Figure 5: Ferritin levels change within follow-up periods. RYGB: Roux-en-Y gastric bypass. SG: sleeve gastrectomy

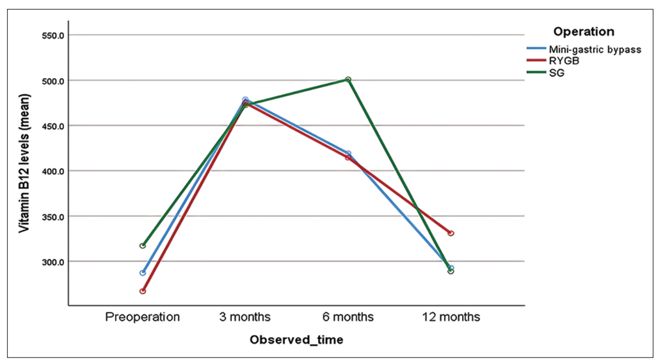

Figure 6: Vitamin B12 levels alteration within follow-up periods. RYGB: Roux-en-Y gastric bypass. SG: sleeve gastrectomy

levels preoperatively and after bariatric surgery. Our data suggested that anemia increased from 7.1% before the surgery to 28.1% after a 12-month follow-up. Despite the meaningful difference between the different procedures, hemoglobin level was significantly reduced at every three evaluation moments. This result supports the possible mechanism of developing anemia after bariatric surgery. In these cases, anemia is often a result of iron deficiency and B12 hypovitaminosis. However, several cases were already hemoglobin deficient before submission; thus, we highly recommend evaluating hemoglobin baseline levels before examining anemia's incidence.

Our data supports what Andreas Alexandrou *et al.*[38] claimed in 2014. According to this survey, anemia has been reported in nearly half of the patients who have undergone bariatric procedures. However, SG and RYGB had the same effect on hemoglobin levels (*P* = 0.418). Toh SY *et al.*[39] Conducted a study to compare micronutrients before and after bariatric surgery in 2009. This study claimed that the prevalence of anemia has risen from 6.2% to 17.2% in people who have undergone RYGB one year after the surgery (*P* = 0.04). Annette von Drygalski and Deborah A. Andris mentioned the main mechanisms leading to hemoglobin deficiency in bariatric candidates in a review published in 2009.[40] These factors include:

1- Bypassing duodenum and proximal jejunum, as main sites of iron absorption.
2- Reduced acid production, which leads to hypofunction of iron transporters and lowers iron bioavailability.
3- Dietary restriction after the operation: more than 50% of cases are intolerant to red meat.
4- Iron demand and intake imbalance will deplete iron storage.

Our study supports this hypothesis that although vitamin B12 deficiency is inevitable after a bariatric procedure, it is sufficiently correctable by administering oral or intramuscular supplements.[41-43] Based on what we analyzed, we found that regardless of the type of surgery, vitamin B12 levels remarkably increased three months after the surgery (25% deficient cases vs. 12.9%). Despite a reduction in vitamin B12 level after the third month, it was still higher in the 12th month compared to the baseline (285.68 ± 97.45 vs. 298.90 ± 106.59; $P < 0.001$). These results propose the potential effect of supplements in the postoperative period. However, Simone Gehrer *et al.*[43] claimed that intramuscular cyanocobalamin was more capable of correcting vitamin B12 levels than oral supplementations. This statement favorably fits with previous surveys. Clement RH *et al.*, in a prospective study, examined 493 RYGB patients and confirmed that after one year of follow-up with evaluation moments every three months and treatment with 1000 µg intramuscular cyanocobalamin, only 3.6% of cases were reported as vitamin B12 deficient.[44] In another study conducted by Brolin RE *et al.*, oral supplements suffice normal plasma levels of vitamin B12. High doses of oral vitamin B12 (more than 500 µg daily) are needed to correct deficiencies.[41] It emphasizes the importance of cobalamin treatment during the postoperative period. Our study has some similarities with Ferraz ÁA *et al.*'s findings. After administering vitamin B12, results showed no significant decrease in vitamin B12 level or the type of surgery.[12] As formerly mentioned, there are many ways in which bariatric surgery contributes to B12 hypovitaminosis. since vitamin B12 deficiency is a significant cause of postoperative anemia; thus, correction of cobalamin level is a crucial issue to prevent both neurologic complications and developing anemia.

By measuring serum ferritin level, we examined how obesity and bariatric procedures will change its level. By analyzing the values, it was understood that serum ferritin level would be higher a couple of months after the surgery (preoperative: 67.75 ± 74.97 vs. 87.01 ± 78.62 and 80.11 ± 74.01 ng/mL; three and six months after the surgery, respectively). At the end of the one-year follow-up, this level dropped to 55.85 ± 56.30 ng/mL, supporting the hypothesis that bariatric patients will end up with ferritin deficiency years after the surgery ($P < 0.001$).

Table 5: Pairwise comparison of hemoglobin, ferritin, and vitamin B12 levels among different follow-up periods

	Month	Mean difference	95% CI		P*
			Lower bound	Upper bound	
Hemoglobin					
Preoperative	3	0.427	0.082	0.772	0.007
	6	0.471	0.145	0.797	0.001
	12	0.836	0.510	1.161	<0.001
3-month	6	0.044	-0.202	0.290	1.000
	12	0.409	0.088	0.729	0.005
6-month	12	0.365	0.098	0.631	0.002
Ferritin					
Preoperative	3	-18.62	-37.32	0.073	0.052
	6	63.96	43.01	84.90	<0.001
	12	4.77	-13.01	22.55	1.000
3-month	6	82.58	60.80	104.36	<0.001
	12	23.39	8.60	38.18	<0.001
6-month	12	-59.19	-74.77	-43.60	<0.001
Vitamin B12					
Preoperative	3	-184.94	-288.31	-81.58	<0.001
	6	-154.42	-242.69	-66.142	<0.001
	12	-13.77	-52.13	24.58	1.000
3-month	6	30.52	-90.13	151.18	1.000
	12	171.17	68.16	274.17	<0.001
6-month	12	140.64	59.22	222.06	<0.001

*Bonferroni, CI: confidence interval

Table 6: Hemoglobin, ferritin, and vitamin B12 deficiency, compared preoperatively, three, six, and 12 months after the surgery

State	Type of the surgery	Preoperation	Postoperation		
			3 months	6 months	12 months
Hemoglobin deficiency	Overall (*n*=224)	16 (7.1)†	36 (16.1)	37 (16.5)	63 (28.1)
	Mini-gastric bypass (*n*=171)	15 (8.8)*	27 (15.8)	29 (17)	47 (27.5)
	RYGB (*n*=38)	1 (2.6)	6 (15.8)	6 (15.8)	11 (28.9)
	SG (*n*=15)	0 (0)	3 (20)	2 (13.3)	5 (33.3)
Ferritin deficiency	Overall (*n*=224)	73 (32.6)	58 (25.9)	65 (29)	100 (44.6)
	Mini-gastric bypass (*n*=171)	51 (29.8)	38 (22.2)	42 (24.6)	72 (42.1)
	RYGB (*n*=38)	16 (42.1)	16 (42.1)	18 (47.4)	22 (57.9)
	SG (*n*=15)	6 (40)	4 (26.7)	5 (33.3)	6 (40)
Vitamin B12 deficiency	Overall (*n*=224)	56 (25)	29 (12.9)	36 (16.1)	49 (21.9)
	Mini-gastric bypass (*n*=171)	42 (24.6)	23 (13.5)	26 (15.2)	37 (21.6)
	RYGB (*n*=38)	11 (28.9)	4 (10.5)	8 (21.1)	8 (21.1)
	SG (*n*=15)	3 (20)	2 (13.3)	2 (13.3)	4 (26.7)

†*n* (% of total), **n* (%within operation). RYGB: Roux-en-Y gastric bypass, SG: sleeve gastrectomy

Serum ferritin's importance is in distinguishing whether the anemia is iron deficiency-related or due to chronic inflammation. Ferritin will be lower in IDA as an indicator of body iron storage. On the contrary, as an acute phase reactant, ferritin can be much higher due to chronic inflammation. In morbidly obese patients, insulin resistance and obesity will mimic an inflammatory-like state, leading to ferritin elevation. As previously discussed, there are many ways in which bariatric patients tend to become iron deficient. However, a low serum ferritin level is anticipated after surgery.

On the other hand, both obesity as a chronic inflammatory factor and surgery as an acute process elevate serum ferritin. Our finding demonstrated that considering both mechanisms simultaneously, the outcome after a one-year follow-up is more likely to reduce serum ferritin level in total (32% deficient cases vs. 44.6%). Toh SY *et al*.[39] conducted a study to assess nutritional deficiencies after bariatric surgery. According to this study, ferritin deficiency was remarkably more frequent in the RYGB method after one year of follow-up. About two percent of participants were already ferritin deficient, and at the end of the first year, 15% of cases became ferritin deficient after RYGB ($P < 0.01$). Although there were changes in the SG group's ferritin level, this reduction was not significant and did not result in iron deficiency.[39]

Ferraz ÁA *et al*.[12] reported that ferritin deficiency was 3.5% and 2.9% in patients undergoing SG and RYGB, respectively ($P = 0.687$). After 24 months of follow-up, RYGB patients became more ferritin deficient than SG (23.7% vs. 13.8%).[12] In another study, Alexandrou A *et al*.[38] compared ferritin deficiency between SG and RYGB methods. Contrary to our results, they found no significant differences between SG and RYGB methods (30% vs. 36.4%; $P = 0.635$).

Limitations

Our study faces the following limitations. A small sample size limits our survey. A more extensive study population will provide more reliable conclusions. In addition to that, being a retrospective study can lower the predictive values of the analysis. The next issue is follow-up duration. Since examined items such as vitamin B12 deficiency and anemia can occur after the first year, follow-up periods should be extended to more postoperative years to determine the precise changes. Another limitation of our study was incomplete data which impaired our conclusion. We did not measure folate, iron level, Alb, CRP, MCV, and other confounding elements, which helped us make better and more accurate judgments. After all, we need to determine whether the participants used the supplementations correctly as ordered. Furthermore, some micronutrients are affected by dietary habits and food cultures which may disturb our evaluations.

Conclusions

To summarize our findings, we investigated bariatric surgery's effect on developing anemia, ferritin, and vitamin B12 deficiency and evaluated whether bariatric strategies make any difference in the outcome. We outlined that even with supplement therapy after the surgery, anemia and ferritin deficiency had significantly increased within the first postoperative year. Despite this, the serum level of vitamin B12 had been remarkably elevated during this period. Different types of surgery did not make any significant differences in vitamin B12 deficiency and anemia. Supplementation therapy can favorably maintain vitamin B12 levels, but further interventions should be considered to prevent anemia years after the surgery.

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Conflicts of interest

There are no conflicts of interest.

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