Effect of Two Bariatric Procedures on Macro- and Micronutrient Levels Inspite of Multivitamin Supplementation

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ABSTRACT

Background: *Bariatric surgery is getting popular especially for patients with body mass index (BMI) >35kg/m^2. Consequent alterations in micronutrient absorption may lead to undesired metabolic side effects.* ***Objective:*** *To compare changes in nutritional status after 2 bariatric surgical techniques in a period of 24 months.* ***Patients and methods:*** *A prospective double armed randomized clinical trial was conducted at the Surgical Department of Ain Shams University hospitals. 69 patients (BMI >35kg/m^2) were allocated to either vertical sleeve gastrectomy (VSG) as group 1 or mini-gastric bypass (MGBP) as group 2. Micronutrient and vitamins levels were followed up for 24 months. Clinical data collected at 3, 9, 18 and 24 months were tabulated and analyzed.* ***Results:*** *Out of 69 surgically treated patients, 67 completed the 2 year follow-up period. Microcytic anemia was significant in both study groups but significant in MGBP patients by 3, 6 and 18 months postoperative, but normalized by the end of 24 months. Macrocytic anemia was significant during the 3 and 6 postoperative months in the VSG compared to MGBP, but again improved following appropriate vitamin supplementation by the end of the study period. Vitamin D concentrations declined at 6 months postoperative in MGBP patients compared to VSG patients. There were no significant changes in mean serum calcium levels during the postoperative period in both groups.*
Conclusion: *Comparing the effect of MGBP and VSG on nutritional deficiencies postoperatively, showed micronutrient and vitamin deficiencies which require different monitoring and supplementation regimens in the following years after surgery.*
Key words: *Bariatric surgery, Sleeve gastrectomy, Mini gastric bypass, Nutritional deficiencies.*

INTRODUCTION

Global obesity rates have steadily risen and nearly doubled since the 1980s, posing a major public health crisis and contributing to premature death.[1] Bariatric surgical procedures are popular and clinically effective intervention for obesity (BMI ≥35 kg/m^2) and morbid obesity (BMI ≥40 kg/m^2).[2,3] They alter the gastrointestinal tract to reduce caloric intake or absorption. The burden of severe obesity and comorbid cardio-metabolic disease, including type 2 diabetes,[4] atherosclerosis and hypertension, is lifted from most of these individuals.[5] Decreased prevalence of arthropathy, depression, poor quality of life and mortality,[6,7] following bariatric surgery is well documented. They are classified by the mechanism of action for promoting weight loss as: restrictive or malabsorptive. Restrictive procedures reduce the volume or capacity of the stomach and thereby limit caloric intake by promoting early satiety. Vertical sleeve gastrectomy (VSG) represents the most commonly performed restrictive procedure nowadays. Malabsorptive procedures reduce the amount of calories absorbed by altering the flow of food to limit contact with pancreatic secretions and bile acids and/or bypass the absorptive regions of the duodenum and proximal jejunum. The Mini-gastric bypass (MGBP) represents the most commonly performed malabsorptive procedure.[8]

In view of surgical alteration of the gastrointestinal tract to restrict energy intake, particularly purely restrictive procedures, the concern has been that vitamin deficiency and nutritional complications may arise postoperatively. *Risk factors* include: ***1)*** preoperative malnutrition (e.g. vitamin D, iron); ***2)*** decreased food intake (due to reduced hunger and increased satiety, food intolerances, frequent vomiting); ***3)*** inadequate nutrient supplementation (due to poor compliance with multivitamin/multimineral regimen, insufficient amounts of vitamins and/or minerals in supplements); ***4)*** nutrient malabsorption; and ***5)***

Lack of appropriate follow-up, (insufficient monitoring, difficulty in recognizing symptoms of deficiency).[9] The altered anatomy, impaired gastric acidity & intrinsic factor may affect B12 absorption in VSG.[10]

In our practice, we found different clinical presentations that might be related to nutritional deficiencies namely bony aches and tiredness, hair loss, skin eczema, and many other presentations that only appeared following surgery. Accordingly, for two years postoperative, we studied the effects of both VSG and MGBP on the macro- and micronutrients deficiencies.

Objective:

Our objective was to investigate the patients' nutritional deficiencies following two bariatric surgical procedures: vertical sleeve gastrectomy and mini-gastric bypass during a two-year postoperative follow-up period.

PATIENTS & METHODS

This prospective double armed randomized clinical trial (equally 1:1 to either surgeries) study was held at the surgical department of Ain Shams university hospital over a period of 30 months. From March 2014 to October 2016, all consecutive patients who underwent VSG and MGBP were enrolled in the study. The first patient enrolled in the study was on March 12th, 2014 & the last was on October 28th, 2014. The endpoints of the study were the BMI and %EWL after two years follow up, rate of complications & occurrence of nutritional deficiencies. A written informed consent was obtained from all patients prior to inclusion in the study. Patients were informed about the purpose of the study, the benefits, risks and side effects associated with the surgical intervention.

Patient selection:

We included patients with BMI >35, aged between 21- 55 years who had failed to achieve sustained weight loss by nonsurgical measures. These criteria are in-line with the recommended indications for bariatric surgery.[11] Patients were excluded from the study if they had nutritional deficiencies, previous bariatric or major abdominal surgery, severe cardiopulmonary disease, malignancy, oral steroid treatment, drug abuse or severe psychiatric illness. Patients were randomly allocated (through a coin flip technique) to either group according to the type of surgery performed: Group (1) underwent VSG & Group (2) who had MGBP. Each patient was attended by a consultant nutritionist and a bariatric surgeon at least once before surgery and in the immediate postoperative period.

Patients follow up:

Patients were followed up regularly every three months during the first year and bi-annually during the second year at the outpatient clinics of Ain Shams university hospital. Data was collected and tabulated at periods of 3, 9, 18 and 24 months. During the first preoperative visit, each patient had the body weight and height measured and BMI was calculated. Height was measured with the use of a stadiometer. Body weight was measured during pre- and each postoperative visit thereafter using a Detecto bariatric scale. The %EWL was calculated according to the ideal body weight.[12] Patients were also counseled for comorbidities, namely hypertension, diabetes mellitus, hyperlipidemia and arthritis.

Biochemical Analysis:

Blood sample measurements included complete blood count (CBC), random and fasting blood sugar (RBS, FBS). Serum levels of BUN (mmol/l) and creatinine mmol/l), albumin (g/dl), ALT (IU), AST (IU), lipid profile (cholesterol, triglycerides, high, and low density lipoproteins), serum calcium (mg/dL), vitamin A (umol/l), vitamin C (mmol/l), vitamin D (nmol/l), iron (umol/l), ferritin , Folate (nmol/l), Thiamin (vitamin B1, nmol/l), Pyridoxine (vitamin B6, nmol/l) and Cobalamin (vitamin B12, pmol/l) were measured. Microcytic anemia or low hemoglobin level (<10.5 mg/dl) was diagnosed on basis of a low serum iron (serum Fe<50ugm/dl), low serum Ferritin (<18 ng/ml) and macrocytic anemia was diagnosed by macrocytic red cells (fl) in blood film. Additionally, prothrombin time and partial thromboplastin time were measured preoperatively. Blood was collected by venipuncture. All samples were immediately sent for biochemical analysis at Ain Shams University hospitals central laboratories. Samples were left to clot 30 min at room temperature, serum was separated by centrifugation, and aliquots were stored in freezer -70^{o}C (after acidification for vitamin C measurement). We used mass spectrometry to analyze serum levels of vitamins which was carried out in the National Nutrition Institute, Cairo. Ionized calcium measured with a Rapidlab 348 analyzer.

The immediate perioperative complications were recorded. The %EWL, BMI and the effect on macro and micronutrients serum levels in each group were compared at 3, 9, 18 and 24 months postoperatively.

Postoperative medications:

Medications were prescribed postoperatively, Omeprazol 40 mg once daily for 2 months to prevent ulceration of the staple lines and remaining stomach, and 0.5 mg/kg body weight of Enoxaparine subcutaneous once overnight postoperatively to prevent thrombosis together with the use of elastic stockings, we encouraged every patient for early ambulation starting from the first postoperative night. Patients also received 2 intravenous 12 hourly doses of Ceftriaxone.

Postoperative nutrient supplements:

A standard multivitamin and micronutrient rich preparation was started 1 week postoperatively in all patients,[19] made available free of charge at the local hospital pharmacy, to encourage the use of the same brand (includes 60 mg Iron Sulfate, 1200 mg Calcium Citrate and 5000 IU vitamin D3) during study period, and recommended for life. A B12 substitute was also provided. Once a deficiency was identified at any follow up visit, it was treated accordingly.

Statistical analysis:

The collected data was revised, coded, tabulated and managed by SPSS version 2.0. Quantitative (mean and SD), qualitative variables (frequencies and percentage), **Student t** test to compare continuous variables (A ***P-value*** <0.05 was considered statistically significant) and **Chi square test** to examine the relationship between categorical variables.

RESULTS

From January 2014 to October 2016, a total of 69 patients (female: male = 37:32) were included. Two patients with VSG failed to maintain regular follow up, and were excluded from the study. The mean age was 36.99 ± 7.31 (minimum 24 and maximum 55 years). The mean weight was 136.07 ± 20.04 (95 - 185 kg). The mean calculated BMI was 47.82 ± 6.91 kg/m^2 (Table 1). Preoperatively, patients in both group were matched for age, gender, %EBW & BMI. Thirty-seven (37) patients underwent sleeve gastrectomy, 16 males & 21 females. Mini-gastric bypass was offered to 32 patients, 13 males &19 females. Baseline characteristics were not statistically significant among both surgical treatment groups as regards sex distribution, mean age, weight and BMI, Table (2). Mean BMI in the VSG and MGBP was 48.35±7.41 kg/m² and 47.21±6.70 kg/m² respectively, (p 0.502).

Table (1): Preoperative demographic & anthropometric measures of study groups.

Parameter (Mean ± SD)		**Mean**	**±SD**	**Minimum**	**Maximum**
Age (years)		36.99	7.31	24.00	55.00
Height (cm)		1.69	0.07	1.55	1.89
Weight (kg)		136.07	20.04	95.00	185.00
BMI (kg/m^2)		47.82	6.91	34.79	61.81
		No.		%	
Gender	**Male**	28		40.6%	
	Female	41		59.4%	
Operation	**VSG**	37		53.6%	
	MGBP	32		46.4%	

Collectively, the comorbid conditions: hypertension, type 2 diabetes, hyperlipidemia and arthritis were present in 36.28 % of cases in both groups; 58% versus 49% in VSG and MGB patients respectively. Some 37% of patients had more than one comorbid condition (Table 2).

There was no statistically significant difference between both study groups regarding serum iron, ferritin, vitamins B1, B6, B12, A, C, D and serum calcium preoperatively.

Six patients in VSG group were anemic, two microcytic and four normocytic, versus five in MGBP patients, three had microcytic anemia and two normocytic. The mean operative time was shorter in the VSG group compared with the MGBP group (112 ± 10.3 min vs 138 ± 12.8 min, P < 0.15).

Major perioperative complications were reported in 33.3 % (23 cases) of patients in both groups; 14 in VSG group and 9 in MGBP group.

Table (2): Preoperative anthropometric parameters and comorbidity in each study group

Parameter (Mean ± SD)		Group 1 n= 37 (VSG)	Group 2 n= 32 (MGBP)	p-value	
Gender N (%)	**Males**	16 (43.2%)	12 (37.5%)	0.628**	NS
	Females	21 (56.8%)	20 (62.5%)		
Age (years)		36.27 ± 6.41 (24.00 – 48.00)	37.81 ±8.26 (25-55)	0.395*	NS
Weight (Kg)		140.03 ± 22.19 (98.00 – 185.00)	131.50±16.41 (95.00-167.00)	0.078*	NS
Height (cm)		1.70 ± 0.07 (1.55 – 1.89)	1.67±0.06 (1.59-1.81)	0.061*	NS
BMI (Kg/m2)		48.35±7.41 (34.79 – 61.81)	47.21±6.70 (36.32 – 61.71)	0.502*	NS
Diabetes Type 2		6 (8.7%)	8 (11.6%)		
Hypertension		7 (10.1%)	6 (8.7%)		
Hyperlipidemia		4 (5.8%)	3 (4.34%)		
Arthritis		8 (11.6%)	5 (7.2%)		

(*student t test,**Chi-Square Tests).

These included gastritis, heartburn, stomach ulcer and leaking from the staple line. Heart burn and gastritis occurred in 11 cases in VSG group; 1 case with gastric ulcer and 2 cases with staple line leakage which was clipped endoscopically and resolved after a few weeks; versus 7 cases in MGBP group had heart burn and gastritis, 1 case with gastric ulcer and 1 case in the same group with leakage in the staple line at the gastro-esophageal junction which was over-sewn during reoperation.

Table (3): Post-operative anthropometric parameters during the follow up visits.

	3 months				P*	9 months				P*	18 months				P*	24 months				P*
	VSG		MGBP			VSG		MGBP			VSG		MGBP			VSG		MGBP		
	Mean	±SD	Mean	±SD		Mean	±SD	Mean	±SD		Mean	±SD	Mean	±SD		Mean	±SD	Mean	±SD	
Weight (kg)	119.6	19.0	110.8	15.0	.03	101.5	17.9	93.7	12.5	.03	84.0	11.9	78.5	9.0	.03	73.6	8.1	68.8	6.6	.008
BMI (kg/m^2)	41.3	6.2	39.8	5.9	.29	35.0	5.7	33.6	4.8	.27	29.0	3.7	28.1	3.3	.31	25.4	1.8	24.6	1.2	.03
EWL %	14.6	2.5	16.2	3.1	.01	27.6	3.6	28.6	4.7	.31	39.8	3.9	40.0	4.7	.07	46.7	6.5	47.0	7.8	.88

*student t test P<0.05(significant), P<0.01(highly significant).

Postoperative %EWL and BMI:

Table 3 shows the mean %EWL achieved at 3, 9, 18 and 24 months postoperatively. By the end of 3 months, %EWL was statistically significantly higher in the MGBP versus the VSG (16.2± 3.1 % and 14.6 ± 2.5% respectively; p <0.01). However, the rate of mean %EWL in the MGBP group was higher than in the VSG patients, gradually during the second postoperative year, but did not show statistical significance.

The mean BMI at 3, 9 & 18 months postoperative was lower in MGBP group than in VSG group, but it only showed statistical significance at 24 months (24.6 ± 1.2 kg/m^2 & 25.4 ± 1.8 kg/m^2 respectively; p <0.03) Table (3).

There was a steady statistically significant decrease in weight of patients in MGBP compared to VSG patients at 3 (p<0.03), 9 (P<0.03) & 18 (p<0.03) months and was highly significant at 24 (p<0.008) months postoperatively. Comorbidities showed improvement in 5 (71.4%) patients with hypertension in VSG versus 6 (100%) patients in MGBP, 4 (66.6%) patients showed resolution in diabetes in VSG and 5 (62.5%) in MGBP, (100%) improvement in hyperlipidemia in both groups; (87.5 %) & (100%) improvement in arthritis in both groups respectively.

Nutritional status:

Anemia:

Preoperatively, six (16.2%) patients were anemic of which two had microcytic red blood cells (5.4%) and four were normocytic (10.8%) in VSG group versus five (15.6%) patients in MGBP group, three microcytic (9.4%) and one (3.1%) with normocytic anemia. All patients adhered to the prescribed multivitamin preparation advised postoperatively and through the 48 month follow up period.

Table (4): Postoperative laboratory values among the two study groups during the follow up visits.

	3 months					9 months					18 months					24 months				
	VSG		MGBP		P*	VSG		MGBP		P*	VSG		MGBP		P*	VSG		MGBP		P*
	Mean	±SD	Mean	±SD		Mean	±SD	Mean	±SD		Mean	±SD	Mean	±SD		Mean	±SD	Mean	±SD	
Hb	11.6	0.9	10.5	1.5	**.001**	11.6	0.8	10.5	1.3	**.001**	11.6	0.5	11.1	0.6	**.001**	11.9	0.3	11.8	0.3	.068
MCV	86.5	6.6	79.6	10.9	**.003**	86.9	4.6	80.5	7.6	**0.001**	86.3	3.5	83.1	3.7	**0.01**	89.0	2.6	89.6	1.8	.306
Ferritin	84.6	12.0	70.6	31.9	**.017**	87.4	11.2	77.6	26.6	**.045**	88.6	11.910.8	86.3	10.8	.395	89.3	8.6	88.7	7.5	.723
Ca	9.3	0.4	9.2	0.5	.756	9.2	0.3	9.2	0.4	.990	9.2	0.3	9.2	0.3	.732	9.3	0.2	9.3	0.2	.403
Vit.C	0.33	0.1	0.36	0.2	.864	0.35	0.2	0.38	0.1	.881	0.36	0.16	0.39	0.22	.871	0.42	0.11	0.44	0.21	.801
Vit D	32.2	11.0	37.1	7.3	**.031**	37.3	11.6	43.8	6.0	**0.035**	45.9	10.0	44.2	7.9	.433	50.9	11.4	49.2	12.1	.550
Folate	15.9	4.1	17.3	4.5	**0.04**	17.8	5.3	20.3	6.3	**0.014**	24.9	8.1	26.3	7.1	.834	28.8	7.3	30.1	8.5	.799
Vit.B1	2.7	.31	2.9	.11	.834	2.9	.28	3.2	.46	.691	3.1	.45	3.3	.87	.702	4.5	1.1	4.7	1.2	.899
Vit.B6	25.5	10.2	28.8	9.7	.591	36.9	8.6	39.9	9.8	.587	40.8	12.9	41.5	13.3	.792	42.8	8.1	44.3	5.8	.609
Vit.B12	313.2	141.1	379.0	178.2	.092	361.4	155.6	377.0	172.9	0.695	690.8	168.0	681.3	174.3	.819	693.4	139.2	698.6	148.9	.880
Vit A	55.5	14.2	58.7	18.9	.689	66.7	16.9	67.8	13.8	.880	82.5	19.5	83.8	18.2	.871	92.8	29.4	93.6	23.2	.691

*student t test.

Nutritional deficiencies were reported in both groups postoperatively. **Microcytic anemia** was reported in both groups, VSG & MGBP, during the first 3 & 9 months follow visits. Microcytic anemia was significantly higher in the MGBP as reflected by statistically significant decrease in serum ferritin levels at 3 months ($p<0.017$) and 9 months ($p<0.045$) and improved after supplementation. Hemoglobin concentration significantly decreased at 3, 9 and 18 months, more in the MGBP versus the VSG patients ($p< 0.001$, 0.001, 0.001 respectively). In all microcytic anemia patients, both pre- & postoperatively hemoglobin concentrations improved markedly by 24 month after adequate iron preparations ($p=0.068$).

Macrocytic anemia (MCV and folate) as monitored by increased MCV and low serum folate levels, developed in both groups of patients. Significantly higher MCV and lower serum folate levels were seen in VSG patients, (86.5 ± 6.6, 15.9 ±4.1 respectively) versus (79.6 ± 10.9, 17.3 ± 4.5; $p<0.003$, $p< 0.04$ respectively) in the MGBP patients at 3 months; and 9 months postoperative, (86.9 ± 4.6, 17.8 ± 5.3) compared to MGBP patients (80.5 ± 7.6, 20.3 ± 6.3; $p< 0.001$ & $p<0.14$). Although the serum folate levels was not significantly different among both study groups at 18 & 24 months postoperative, the MCV continued to be significantly higher in the VSG group (86.3 ± 3.5 versus 83.1 ± 3.7; $p< 0.01$) at 18 months and leveled at 24 months (89.0 ± 2.6 versus 89.6 ±1.8; $p=0.306$). **Vitamin B12**, although levels were lower in the VSG group at all follow-up visit screening, but did not show statistical significant difference among both groups. **Thiamine** and **pyridoxine** ($p=0.899$, $p= 0.609$ respectively), **vitamin A** and **C** ($p = 0.691$, $p=0.801$ respectively) concentrations did not change significantly among both study groups before and after surgery, both at the end of all follow up visits. Only one case of vitamin A deficiency was reported at 3 months postoperative, and corrected at 6 months after proper supplementation.

Vitamin D concentrations decreased significantly among VSG patients compared to the MGBP patients at 3 and 6 months postoperative (32.2±11.0 and 37.1 ± 7.3, $p<0.031$; 37.3 ± 43.8 ± 6.0, $p<0.035$) and did not show significant difference thereafter up to the end of the study period. **Serum calcium** levels were within low levels for normal ranges, when corrected for albumin, in both study groups during the study period. There was no significant change for vitamin E by 1 and 2 years postoperative. There was no mortality in both study groups.

DISCUSSION

Bariatric surgeries have gained overgrowing popularity during the recent years as a treatment for obesity which fails to be corrected by dietary measures alone. The most relatively common surgical bariatric procedures are VSG and the mini-gastric bypass (MGBP). Several studies reported one or more nutritional deficiencies in these patients postoperatively. Therefore, careful postsurgical monitoring and surveillance help patients avoid problems caused by such deficiencies.

In this study, we concentrated and compared the effect of VSG and MGBP on %EWL, BMI and their impact on the nutritional status in two groups of patients after a two-year follow up period. The mean BMI was lower at 3, 9 & 18 months postoperative in MGBP group compared

to the VSG group, but it only showed statistical significance at 24 months visit. By the end of 3 months, %EWL was statistically significantly higher in the MGBP versus the VSG. Although, the rate of mean %EWL in the MGBP group continued to be gradually higher during the second postoperative year than in the VSG patients, but did not show statistical significance. These findings are in accordance with the 3rd International Summit on the Current Status of VSG which shows durable weight-loss outcomes.[13] Bypassing the intestine produces a malabsorptive aspect that effectively reduces calorie consumption and effectively reduces weight faster in MGBP.

We spotted several preoperative **comorbidities** which showed improvement in the first 6 months postoperative, (71.4%) patients with hypertension in VSG versus (100%) patients in MGBP, (66.6%) patients showed diabetes resolution in VSG and (62.5%) in MGBP, (100%) improvement in hyperlipidemia in both groups; (87.5 %) & (100%) improvement in arthritis in both groups respectively.

Nutritional deficiencies in macro- and micronutrients are well known to the surgeons and other key practitioners (dietitians, primary care doctors, and endocrinologists) who provide postoperative support to the patients themselves. Micronutrients are essential dietary factors that function in various biochemical pathways and metabolic processes. Patients treated by VSG have significantly less nutritional deficits compared to MGBP patients.

Anemia: Cable,[14] reported that anemia is seen in 36% of patients around one year after RYGB, and in 5% of patients 1 year after VSG. Because VSG is a restrictive procedure and therefore lacks the malabsorptive component, the risk for developing deficiencies after surgery is considered low. Hemoglobin concentration significantly decreased at 3, 9 and 18 months in the MGBP versus the VSG patients. Iron deficiency is an important postoperative cause of anemia. In our study, we reported microcytic anemia in both groups during the first 3 and 9 months postoperative, but significantly higher in the MGBP patients as reflected by the significantly low serum ferritin levels at 3 and 9 months postoperative. With appropriate iron supplementation, anemia reverted to normal by 18 month follow up, in both groups, and remained within normal ranges of hemoglobin for the rest of study period. Several mechanisms support the finding of iron deficiency following bariatric surgery. Marceau et al,[15] found abnormal ferritin levels (<20ug/L) preoperatively in 4% of the total sample, and up to 25%-40% at follow-up. The iron deficiency can be partially explained by peri-operative iron deficiency anemia which occurs in approximately 9–16% of bariatric surgery patients, and may account for some of the post-operative deficit,[16] but also by the procedure itself. Because of the resection of the fundus, iron is less likely to be absorbed.[17] Gastric acid improves absorption of non-heme iron, the quantity of hydrochloric acid produced in the stomach is reduced and nutrients may pass the stomach faster after a MGBP, thus reduce iron absorption.[18] In addition, bypass of the duodenum and proximal jejunum isolates segments in which improved absorption of iron occurs.[19] Post-surgery patients have reduced iron intake secondary to a considerable reduction of their meat intake to almost a 50% net reduction.[18]

MCV, folate and vitamin B12: are typically evaluated together, as deficiencies of either can lead to macrocytic megaloblastic anemia. B12 deficiency can also lead to neurological sequelae; folate deficiency may present with a wide variety of systemic symptoms, including diarrhea, anorexia, weight loss, weakness, headaches, and behavior changes. **Folate deficiency** following bariatric surgery is reported to be rare. Mallory and Macgregor, in a study of a large number of patients, reported only a 1% prevalence of folate deficiency. This study, showed a significant reduction in mean serum folate at 3 and 9 months postoperative in the VSG group compared to the MGBP group. This reflected as significant increase in the **MCV** at 3, 9 and 18 months follow up visits. Corrected serum folate level at 18 and 24 months postoperatively lead to improved MCV by the end of the study period. These changes are explained by the supplementation with 1 mg of folic acid daily.

Vitamin B12 deficiency is one of the most common nutritional deficiencies occurring after bariatric surgery. These patients are at an increased risk of developing vitamin B12 deficiency because their digestive tracts have been altered in such a way as to interfere with the natural absorption of this vitamin.[22] Studies have estimated the prevalence of vitamin B12

deficiency at one-year follow up after gastric bypass surgery to be as high as 30%.[23] The long-term prevalence ranges widely, from 36–70%.[24] In our study, we did not find significant vitamin B12 deficiency in VSG & MGBP patients at the 18 months follow-up post-surgery. This may be due to the short follow up period, considering that B12 deficiency requires long term depletion. The average store of vitamin B12 in a normal individual is estimated to be 2mg, which should last for approximately 2 years if intake is insufficient. Most authors recommend 350-500g/day of oral cobalamin, and some patients will require monthly intramuscular B12 injections (1,000-3,000g/dose),[25] which we supplemented in our study. Reduced production of intrinsic factor by limited number of parietal cells with consequent decrease in cobalamin-intrinsic factor complex formation and absorption is the main mechanism for B12 deficiency following bariatric surgery.[22,24] The lower production of hydrochloric acid which is needed to release bounded vitamin B12 in food is an added factor.[24]

V**itamin A:** We reported only one case of vitamin A deficiency at 3-month follow up visit due to non compliance with supplementation. Treatment was given and response was seen at the 9 month follow up visit. The incidence of vitamin A deficiency after gastric bypass surgery varies widely in published reports. Clements et al, [21] noted an incidence of vitamin A deficiency of 11% and 8.3% of patients at one- and two-year follow up, respectively. They hypothesized that intestinal absorption may adapt, thereby overcoming the decreased surface area. Even with supplementation, vitamin A deficiency may still occur. Brolin et al,[25] reported a vitamin A deficiency rate of 10% in post-RYGBP patients despite supplementation. Slater et al, reported an incidence of vitamin A deficiency of 69% at four year follow up after biliopancreatic surgery. They recommend at least 10,000 international units (IU) daily. Routine measurement of vitamin A levels pre- and post- surgery is warranted.

Bone metabolism: vitamin D and Ca are inter-related and both affect bone health. Normal levels of vitamin D are essential for an adequate intestinal calcium uptake. Vitamin D deficiency is common after bariatric surgery, which further exacerbates calcium malabsorption, causing an increase in parathyroid hormone (PTH) and, eventually, osteoporosis. In this study, we reported significantly low levels of vitamin D in both study groups, at 3 and 9 month postoperative. Calcium levels were almost within normal levels at all post-operative follow up visits, in both study groups and showed no significant difference. Our results are in agreement with those reported by other authors.[27] Slater et al, [26] found vitamin D deficiencies in 57% of patients at one-year follow up and 63% at four-year follow up. Brolin et al, [25] found that 51% of postoperative patients had significant vitamin D deficiencies at two-year follow up. Currently, most authors recommend supplementing post bariatric patients with 800–1,200 IU of vitamin D and 1,200 –1,800 mg of calcium citrate daily. Careful monitoring is needed to maintain homeostasis and aggressive supplementation of calcium and vitamin D has been recommended around the time of the operation to combat these adverse effects.[28] We supplemented our patients with the recommended doses of vitamin D and Ca.

Thiamine and **Pyridoxine** concentrations did not change significantly among both study groups at the end of all follow up visits. Again, there were no significant changes in **vitamin A** and **C** between the 2 surgical procedures at the end of the study period. We only reported one case of vitamin A deficiency at 3 months follow up visit due to noncompliance with the recommended vitamin supplementation.

CONCLUSION

Currently, only few randomized controlled trials have compared VSG and MGBP and their effect on macro- and micro- nutrient deficiencies following such surgeries leading to serious consequences. Reduced bioavailability, malabsorption, poor dietary intake and compliance with micronutrient supplementation following surgery may result in such deficiencies. Adherence to micronutrient and multivitamin supplementation and routine monitoring blood tests are of primary significance in all cases of bariatric surgery. Moreover, many patients do not undergo routine monitoring for deficiencies and thus the effectiveness of prophylactic supplementation is not clear.

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