Changes of bone metabolism markers in obese individuals with laparoscopic sleeve gastrectomy

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Background

Bariatric surgery has proven to be a valuable treatment option for morbid obesity. Laparoscopic sleeve gastrectomy (LSG) has gained popularity as a bariatric procedure owing to its safety, low complication rate, and excellent weight loss results. As calcium requires the action of stomach acid to become solubilized, so by eliminating all HCl-secreting parietal cells and pepsin-secreting chief cells in sleeve gastrectomy, calcium becomes unable to be absorbed. A decrease in whole body bone mineral content was seen at first 2 years after SG. If bone loss continues even at slow rate, these patients may have an increased risk for fractures later in life.

Aim

The aim was to evaluate vitamin D, parathyroid hormone (PTH), and calcium serum after SG and its effect on modulation of postoperative nutritional monitoring and supplementation.

Patients and methods

This prospective study was done on 50 morbidly obese patients (33 females and 17 males), with mean age of 31.8±7.6 years and mean BMI of 41.5±4.6, who underwent LSG operation. Serum calcium, PTH, and vitamin D were measured before and 6 months after LSG.

Results

There was a statistically significant reduction in calcium level from baseline to postoperatively ($P<0.0001$), compared with statistically significant elevation in PTH and vitamin D from baseline to postoperatively ($P<0.0001$). There were negative correlations between vitamin D level and weight and BMI.

Conclusion

LGS is an effective surgery for the management of morbid obesity. An adequate supplementation is important to avoid micronutrient deficiencies, and greater weight loss does not require higher dosage of multivitamins.

Keywords:
BMI, gastrectomy, obesity, parathyroid hormone, vitamin D

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Introduction

Obesity is a major public health issue, as it is associated with increasing health and societal costs. The prevalence of the disease is continuously rising worldwide, especially in low-income and middle-income countries. Improving obesity management in primary care settings is essential to reduce comorbidities and associated costs as well as to increase patients' quality of life [1].

Bariatric surgery has proved to be the most effective treatment for morbid obesity, resulting in excellent weight loss and correcting the associated comorbidities, with a marked survival advantage [2].

Worldwide, the most widely used surgical procedures are the Roux-en-Y gastric bypass and gastric banding. Sleeve gastrectomy has recently been identified as an attractive procedure for the surgical management of obesity [3]. The recent American Society for Metabolic and Bariatric Surgery position statement on the sleeve gastrectomy has also confirmed its use as a sole bariatric operation [3].

Laparoscopic sleeve gastrectomy (LSG) has gained popularity in the surgical armamentarium for treatment of obesity because it does not require gastrointestinal anastomosis or intestinal bypass. Furthermore, there is no dumping because preservation of the pylorus and resection of the stomach minimizes the risk of gastric ulcer and cancer. It also yields, in addition to the restrictive effect, hormonal regulation of appetite, because of reduced levels of ghrelin, a hormone produced by cells in the gastric fundus that stimulates hunger.

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This technique is typically performed laparoscopically, which reduces access morbidity and recovery time [4].

Even before the surgical intervention, many obese patients present abnormal concentrations of bone metabolism parameters. Serum concentrations of vitamin D were found to be frequently insufficient, and parathyroid hormone (PTH) concentrations were reported to be increased in obese patients. Moreover, alkaline phosphatase, a marker for bone formation, was reported to be elevated in obese patients [5].

Aim

The aim of this study was to evaluate vitamin D, parathormone hormone, and calcium serum derangements after sleeve gastrectomy and its effect on modulation of postoperative nutritional monitoring and supplementation.

Patients and methods

This prospective study was done on 50 morbidly obese patients who underwent LSG operation in Department of Surgery, Fayoum University Hospital, and other private hospitals, during the period of October 2017 till April 2019.

The study included patients with a BMI score of at least 40 or a BMI score of 35 with an obesity-related comorbidity such as hypertension, type 2 diabetes, obstructive sleep apnea, polycystic ovarian disease, and joint and back pain.

Those excluded were patients with gastroesophageal reflux disease, psychiatric disorders, known hormonal disorder, previous bariatric procedures, and patients with osteomalacia or hyperparathyroidism.

All patients were subjected to medical and surgical history taking, height and weight obtained on a calibrated scale, careful physical examination, laboratory investigations, and radiological imaging. BMI was calculated by formula BMI=kg/m^2, where kg is person weigh tin kilograms and m^2 height in meters squared. Percentage of excess weight loss (% EWL) was calculated using formula (weight loss/ baseline excess weight)×100, where excess weight=initial weight–ideal weight.

Details of the procedure, its indications, methods, risks, and outcome were explained for every patient. After which, written informed consent was obtained from all patients or their legally authorized representatives. This study was approved by the Institutional Review Board and Ethics Committee of Fayoum University Hospital and was conducted in accordance with International Conference on Harmonization guidelines and other applicable laws and regulations.

Blood tests, including calcium, PTH, and vitamin D measurement, was done.

Specimen collection was performed for all enrolled patients after taking appropriate consent before LSG and after 6 months postoperatively. Overall, 5 ml of venous blood sample was withdrawn from each patient under strict aseptic conditions using wide-bore needle and withdrawn slowly from antecubital vein to avoid hemolysis by careful venipuncture. These samples were added to vacutainer plain tube, allowed to be clotted for 30 min, and then serum was separated by centrifugation at 4000 rpm for 5 min. The serum was stored at −20°C till analysis for total serum calcium level, which was estimated using OCPC kit, catalog No. CALO-0600 (Elitech, Sees, France). The normal level for total calcium is 8.8–10.6 mg/dl. Serum PTH and 25 OH vitamin D were analyzed at Central University Laboratory on Immunoassay Analyzer Access 2 (Beckman Coulter, USA).

The operation was done by laparoscopy with the conventional five-port technique.

Patients were hospitalized and discharged next day with adequate tolerance of oral fluids, no pain, no nausea and normal walking condition and with the following drug regimen: nexium 40 mg/12 h (proton pump inhibitor) for 1 month. Vitamin-mineral and protein supplementation is recommended in the following regimen:

Delta vit B12 (Vitamin B12)/once daily, Centrum [(multi vitamin with trace elements) contains Ca in an active form in a concentration of 162 g]/chewable once daily, Vit D3 50 000 capsule/week, and Neurobion (Vitamin B complex) ampule/2 weeks.

Revaluations with the surgeon and the entire multidisciplinary team are held in the three months till complete first year. After this, an annual consultation is recommended. During follow-up, patients' weight was obtained, and nutritional assessment and counseling was done. Measurement of serum calcium, PTH, and vitamin D was done 6 months after operation. Changes in preoperative comorbidities if present and concomitant medications or procedures were monitored, and any complications were followed up.

The collected data were organized, tabulated, and statistically analyzed using SPSS software statistical computer package version 22 (SPSS Inc., Chicago, Illinois, USA). For quantitative data, the mean and SD were calculated. Paired *t*-test was performed to compare between values of study variables before and after operation. Pearson correlation was run to identify relation of Ca, PTH, and vitamin D levels with anthropometric measurements. Independent *t*-test was used for comparison between the two groups regarding vitamin D status with respect to several anthropometric measurements. Qualitative data were presented as number and percentages.

McNemar's test was used to determine the difference in the proportion of vitamin D inadequacy before and after the operation.

For interpretation of results of tests of significance, significance was adopted at *P* less than 0.05.

Results

In this study, the patient age ranged from 16 to 46 years, with a mean±SD of 31.8±7.6 years. Regarding sex, most of studied patients (66.0%) were females and 34.0% were males.

The weight of the studied patients ranged from 79.9 to 163.2 kg, with mean±SD 120.0±19.0 kg, whereas their height ranged from 148 to 187, with mean±SD 169.8 ±9.8 cm (Table 1).

The BMI of studied patients before LSG ranged from 35.2 to 52.1 with mean±SD of 41.5±4.6, whereas their BMI after operation ranged from 23 to 41.6, with mean±SD of 31.2±4.8, with mean weight loss of 32.1 ±6.2 and 25.1±4.6 kg at 6 and 12 months, respectively (Fig. 1).

The total serum calcium of studied patients before LSG ranged from 7.2 to 10.2 mg/dl, with mean±SD 8.9±0.7 mg/dl, whereas the total calcium postoperatively ranged from 7.1 to 9.6 mg/dl, with mean±SD of 8.4±0.5 mg/dl. There was a statistically significant reduction in calcium level from baseline to postoperatively ($P<0.0001$) (Fig. 2).

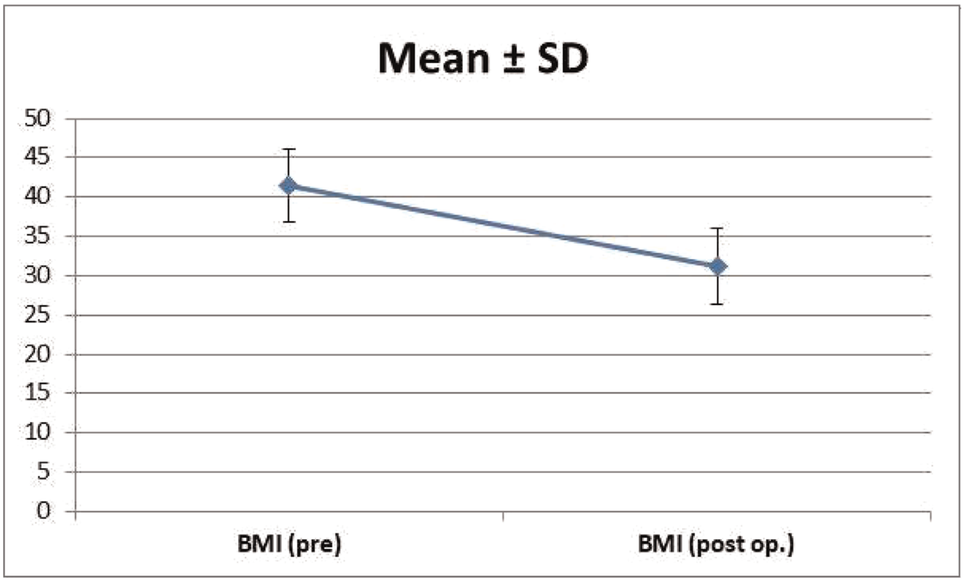
The serum PTH of the studied patients before LSG ranged from 12 to 69 pg/ml, with mean±SD 39.7 ±17.2 pg/ml, whereas PTH postoperatively ranged from 14 to 77, with mean±SD of 43.4±17.2 pg/ml. There was a statistically significant elevation in PTH from baseline to postoperatively ($P<0.0001$) (Fig. 3).

The serum vitamin D of studied patients before LSG ranged from 12 to 55 ng/ml, with mean±SD 14.7

Table 1 Weight and height of studied patients

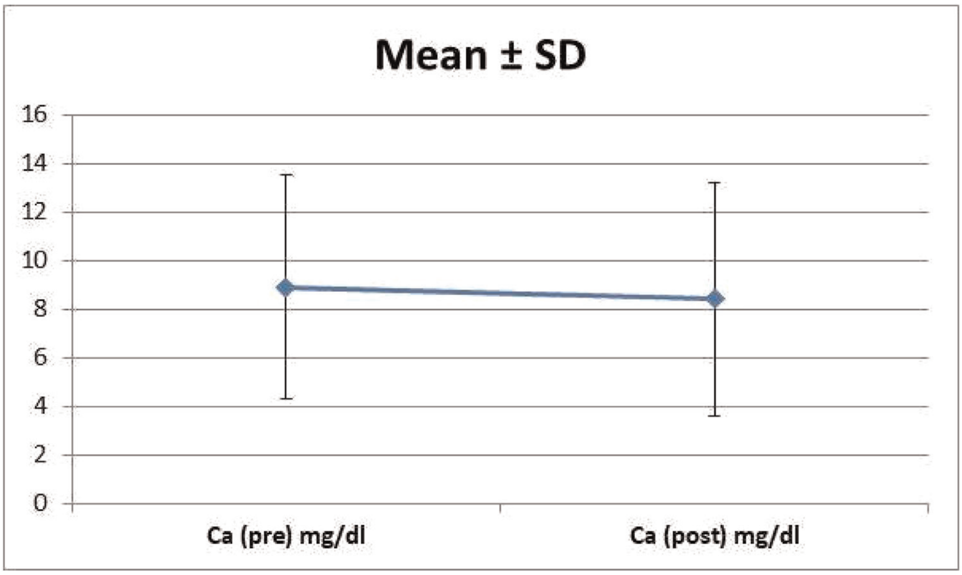
	Mean	SD
Weight (kg)	120.0	19.0
Height (cm)	169.8	9.8

Figure 1



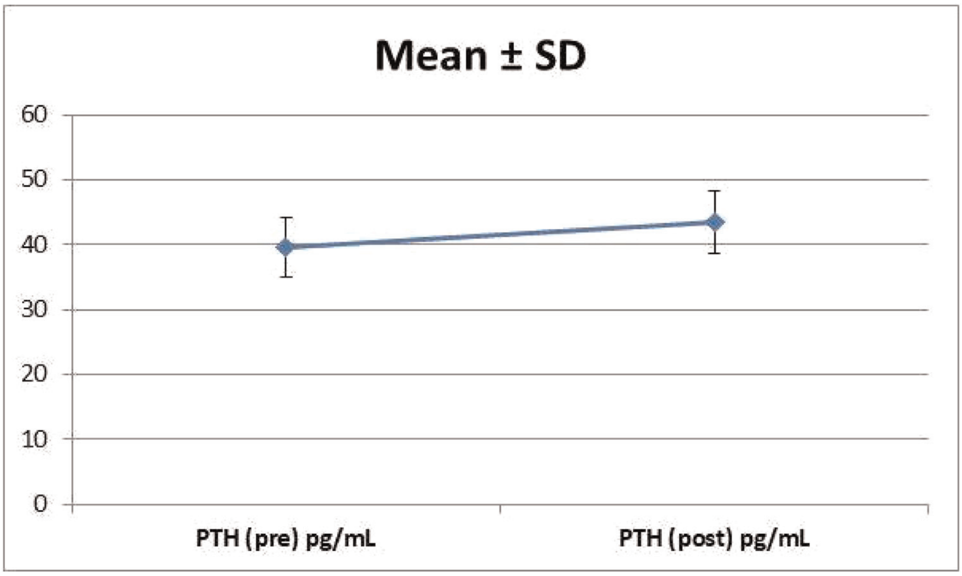
BMI before and after operation.

Figure 2



Ca level before and after operation.

Figure 3



PTH before and after operation.

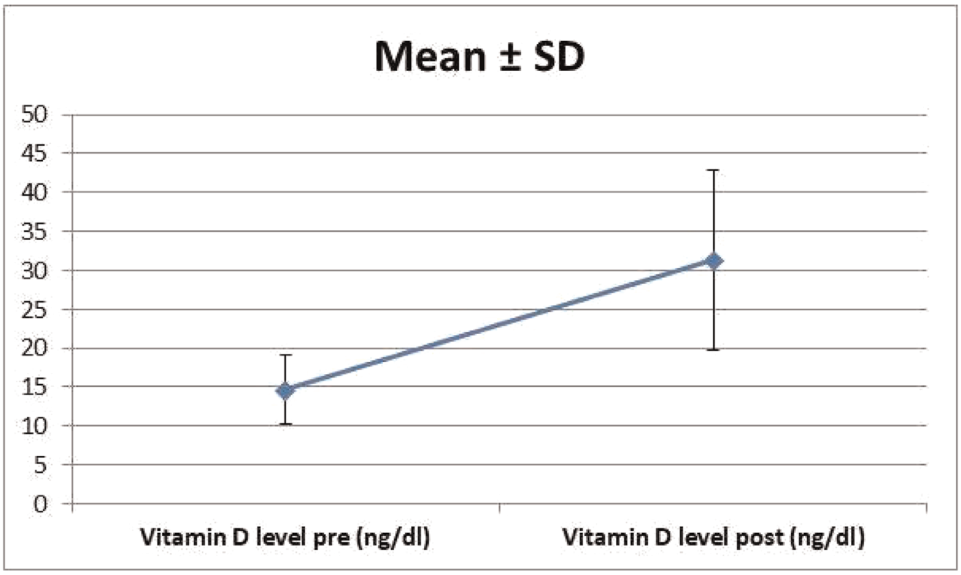
±4.4 ng/ml, whereas vitamin D postoperatively ranged from 18 to 72 ng/ml, with mean±SD of 31.3±11.6 ng/ml. There was a statistically significant elevation in vitamin D from baseline to postoperatively ($P<0.0001$) (Fig. 4).

There was a statistically significant difference in the proportion of patients with inadequate vitamin D level before and after intervention (84 vs 20%) ($P<0.0001$) (Fig. 5).

There was a statistically significant negative correlations between vitamin D level and weight ($r=-0.341$, $P=0.015$), BMI preoperatively ($r=-0.296$, $P=0.037$), and BMI postoperatively ($r=-0.301$, $P=0.034$) (Fig. 6) (Table 2).

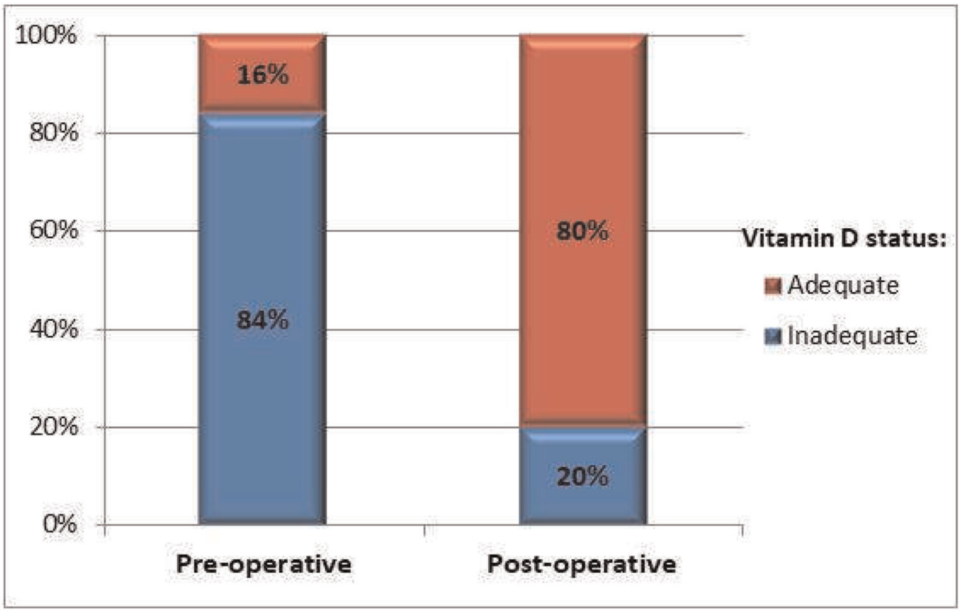
The weight was statistically significantly higher in patients with inadequate postoperative vitamin D level than those with adequate level (130.6±13.6 vs 117.4±19.4 kg, $P=0.050$). Moreover, BMI (post) was higher in patients with inadequate postoperative vitamin D level than those with adequate level (34.0±5.5 vs 30.5±4.4), which was a statistically significant ($P=0.040$) (Table 3) (Figs 7–9).

Figure 4



Vitamin D level (ng/dl) before and after operation.

Figure 5



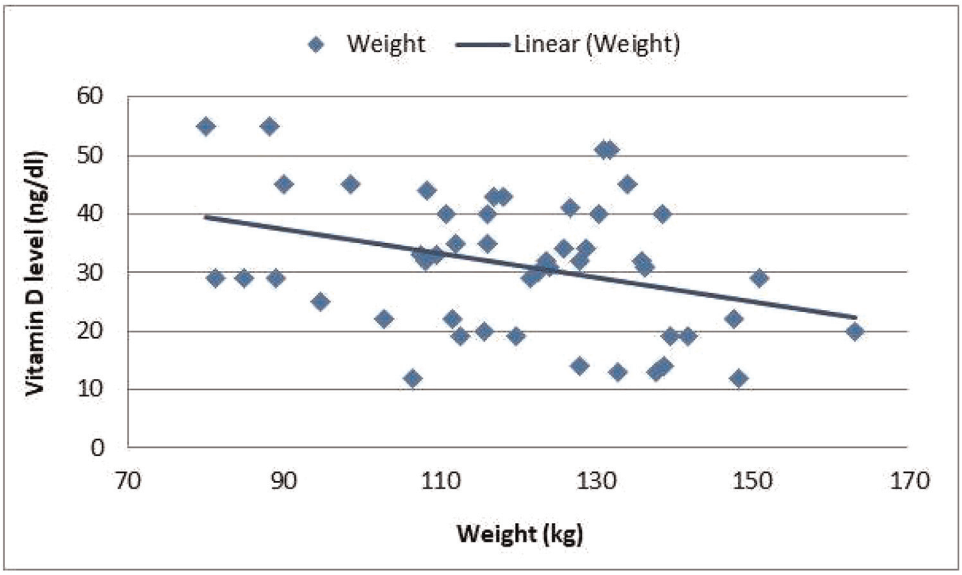
Vitamin D status before and after operation.

Discussion

In general, vitamin D is part of the complex physiology maintaining calcium balance and bone structure, but it also aids in the absorption of calcium from the intestine and reabsorption in the distal renal tubules (in presence of PTH). Deficiencies in vitamin D have effects on the immune system and muscle strength but also can increase the risk of osteoporosis and fracture [6].

Vitamin D deficiencies are common in bariatric surgical practice, and the reported prevalence before surgery varies between 54 and 80% [7]. In patients with obesity, this is often a combination of several problems: limited sun exposure, decreased bioavailability of vitamin D due to sequestration in the excess fatty tissue, and inadequate dietary intake of vitamins and minerals [8]. A secondary hyperparathyroidism can also contribute negatively because it results in increased 25(OH)D hydroxylation, thereby decreasing vitamin D. In addition to hyperparathyroidism, several cases of osteomalacia have been described following bariatric surgery. It needs to be taken into account that these are rare phenomena [9].

Figure 6



Correlation between Vitamin D level and weight.

Table 2 Correlations of Ca, PTH, and vitamin D levels with anthropometric measurements

	Ca (pre) (mg/dl)	Ca (post) (mg/dl)	PTH (pre) (pg/ml)	PTH (post) (pg/ml)	Vitamin D level (ng/ml)
Weight (kg)					
r	–0.253	–0.261	0.234	0.233	**–0.341**
P value	0.076	0.068	0.102	0.104	**0.015***
Weight (kg)					
r	–0.187	–0.258	0.206	0.223	–0.198
P value	0.192	0.070	0.152	0.119	0.167
BMI preoperatively					
r	–0.171	–0.124	0.140	0.124	**–0.296**
P value	0.234	0.392	0.332	0.389	**0.037***
BMI postoperatively					
r	–0.207	–0.164	0.123	0.122	**–0.301**
P value	0.150	0.254	0.397	0.399	**0.034***
BMI reduction					
r	–0.209	–0.169	0.066	0.096	–0.200
P value	0.151	0.173	0.647	0.507	0.164

PTH, parathyroid hormone.

Table 3 Difference in anthropometric measurements in relation to vitamin D adequacy

	Inadequate vitamin D		Adequate vitamin D		*P* value#
	Mean	SD	Mean	SD	
Weight (kg)	130.6	13.6	117.4	19.4	**0.050***
Height (cm)	172.5	3.9	169.1	10.8	0.113
BMI preoperatively	44	5.2	40.9	4.3	0.056
BMI postoperatively	34	5.5	30.5	4.4	**0.040***
Reduction percentage	(–23.1)	4.6	(–25.6)	4.5	0.122

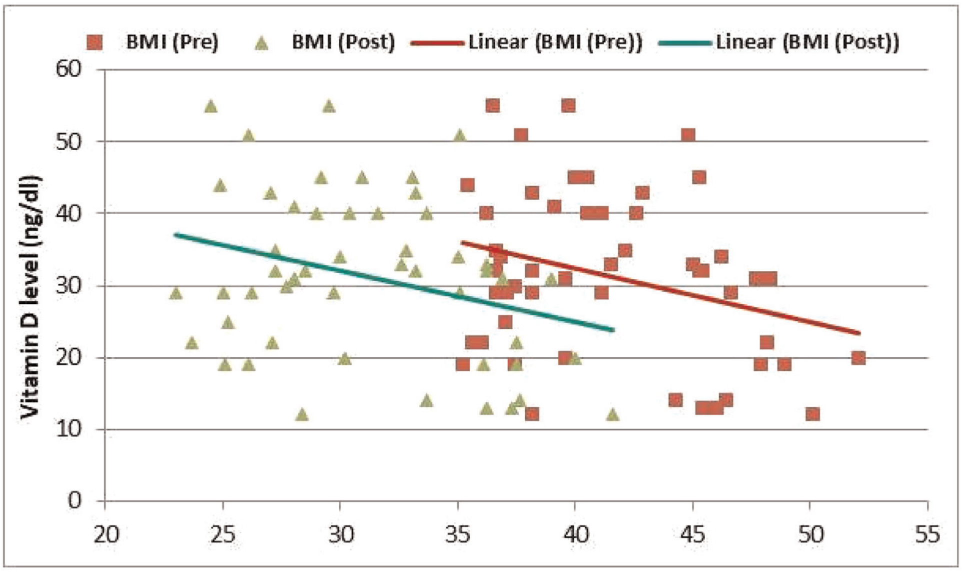
So, the aim of our study was to evaluate vitamin D, PTH, and calcium serum after SG and its effect on modulation of postoperative nutritional monitoring and supplementation.

This prospective study was done on 50 morbidly obese patients (33 females and 17 males) with mean age of 31.8±7.6 years, and mean BMI of 41.5±4.6, who underwent LSG operation in Department of Surgery, Fayoum University Hospital and other private hospitals, during the period of October 2017 till April 2019.

The mean age (31.8±7.6 years) and the male: female ratio (1 : 1.94) for the patients of this study are comparable to the corresponding indicators reported in the long-term results of other studies [10–14].

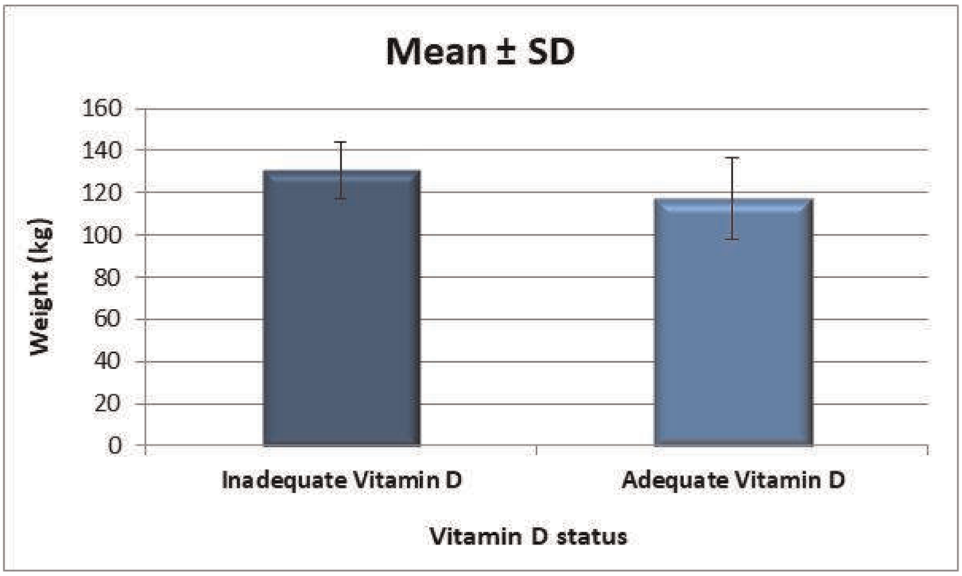
In our study, there was a reduction in BMI from baseline to postoperative (41.5±4.6 vs 31.2±4.8),

Figure 7



Correlation between Vitamin D level and BMI (pre and Post).

Figure 8



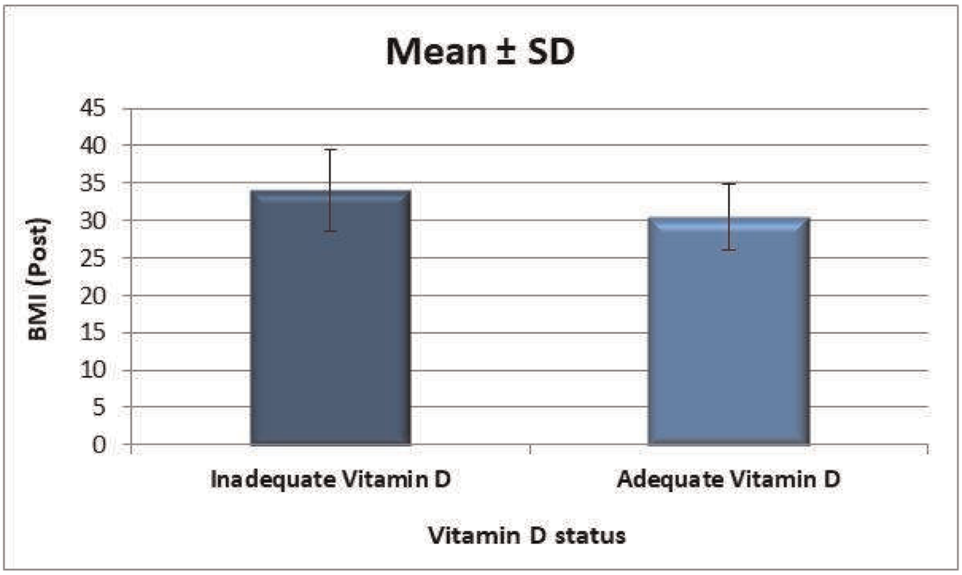
Difference in weight according to vitamin D status.

which was statistically significant ($P<0.0001$), with mean weight loss was 32.1±6.2 kg at 6 months and 25.1±4.6 kg at 12 months.

In agreement with our study, Cengiz and colleagues found that preoperative BMI of patients with an average BMI of 47.7 decreased to 39.3 at the end of the third month, 35.1 at the end of the 6th month, 31.9 at the end of the 12th month, and 31.6 at the end of the 24th month. A statistically significant difference was found between the preoperative BMI and postoperative third ($P<0.001$), sixth ($P<0.001$), 12th ($P<0.001$), and 24th ($P<0.010$) BMI values ($P<0.05$) [15].

We observed a mean weight loss of 32.1±6.2 kg (average excess weight loss of 60% EWL) at 6 months. After 12 months, the average weight loss was 25.1±4.6 kg (45% EWL), which means 15% of the weight regain within one years. This is similar to that reported by Nadler *et al*. [16], who evaluated 33 patients with an average EWL of 40±19% after 12 months.

Figure 9



Difference in BMI (post) according to vitamin D status.

Our data were also like those of Sachdev and his colleagues, who similarly reported a loss of 27% and Lennerz and his colleagues, who observed a loss of 23.1 ±8.2 at 18 months after surgery [17,18].

In the study by Sharma *et al.* [15], the mean weight loss following LSG at 1 week, 3 months, and 6 months was 15.22±4.55, 22.4±9.7, and 30±6.1, respectively, postoperatively and was significant ($P<0.001$). Gluck *et al.* [19] also reported similar results.

On the contrary, our values were lower than those reported by Alqahtani and his colleagues, who studied a group of 108 patients with a mean EWL of 64% at 24 months and Boza and his colleagues, who studied 54 patients and recorded a mean EWL of 96.2% after 12 months [20,21]. However, in the study by Cengiz *et al.* [22], the percentage of postoperative EWL was calculated as 38.7% in 374 patients at third month, 58.3% in 357 patients at sixth month, 72.8% in 307 patients at 12th month, and 74.5% in 171 patients at 24th month. EWL was found to be 72.6% in the calculation based on the latest pounds according to the mean follow-up period of 374 patients.

Recently, Kikkas *et al.* [23] found that the %EWL for the 86 analyzed patients was 44.3±13.0%, 75.8±23.1%, and 61.0%±24.3% at 3 months, 1 year, and 5 years, respectively. A mean maximum %EWL of 85.4±25.6% was usually achieved between the first and second postoperative year.

Differences between previous studies may be owing to various factors that play a role in causing weight loss following LSG, such as decreased gastric capacity, decreased gastric emptying time, and reduced ghrelin levels postoperatively [15,19].

Regarding serum calcium levels among enrolled patients, there was a statistically significant reduction in calcium level from baseline to postoperatively (8.9±0.7 vs 8.4 ±0.5 mg/dl) ($P<0.0001$). This can be explained by the fact that decreased postoperative gastric acid secretion is observed mainly in operations with a malabsorptive component, leading to impaired intestinal calcium absorption [24]. In addition, the extent of fat malabsorption may affect the absorption of fat-soluble vitamins like vitamin D [25]. In addition, patients who underwent bariatric operations report limited intake of dairy products leading to hypocalcemia owing to dietary intolerance after surgery [26].

Against our study, Capoccia *et al.* [27] revealed that plasma calcium levels remained in the normal range in all the patients, regardless of weight loss degree. Plasma levels of vitamin D were low before surgery in all the groups. They remained under normal range after surgery, despite patients were supplemented for all the follow-up period.

In this study, there was a statistically significant elevation in PTH from baseline to postoperatively (39.7±17.2 vs 43.4±17.2 pg/ml) ($P<0.0001$), which is in line with the studies by Keller and Schinke, Mechanick *et al.*, and Alexandrou *et al.* [24,28,29].

According to our findings, mild elevation in serum levels of PTH after SG is mainly determined by levels of circulating vitamin D as well as by the extent of weight loss after surgery. Reduced serum levels of calcium owing to subsequent limited calcium absorption induce the development of increased PTH, whereas increased PTH production results in the mobilization of the skeletal calcium, aiming to preserve normocalcemia [26,30].

Regarding vitamin D levels among our studied cases, there was statistically significant elevation in vitamin D level from baseline to postoperatively (14.7±4.4 vs 31.3 ±11.6 ng/ml) ($P<0.0001$). Preoperatively, obese individuals seem to be more vulnerable regarding the development of vitamin D deficiency, mainly owing to sunlight avoidance, relative inactivity, reduced bioavailability of the fat-soluble vitamin, and inhibited hepatic vitamin activation [26,30,31].

In current study, the incidence of vitamin D deficiency declined from 84.0 to 20.0%, after LSG. The mid-term effect of SG on calcium and vitamin D metabolism was investigated by Ruiz-Tovar *et al*. [32] on 30 females, and the incidence of vitamin D deficiency declined from 96.7% preoperatively to 13.3% at 1-year postoperative follow-up, which is closer of our findings.

Against our study, Aarts *et al*. [8] emphasized that patients after SG are at serious risk of developing nutrient deficiency because of inadequate intake and uptake of micronutrients and nutrients. Among 60 patients, 39% experienced vitamin D deficiency, 26% developed anemia, 15% had folic acid deficiency, 15% developed hypoalbuminemia, and 9% had vitamin B12 deficiency.

Damms-Machado *et al*. [33] compared pre and postoperative nutritional status after SG. At 1 year postoperatively, the incidence of vitamin D and iron deficiency declined from 83.0 to 70.4% and from 29.0 to 4.3%, respectively. Although none of the patients had calcium deficiency preoperatively, 4.3% of patients had low serum calcium levels postoperatively.

Van Rutte *et al*. [34] also assessed nutrient deficiency before and 1 year after SG, and noted that calcium deficiency increased from 0.5 to 2.0%, and magnesium deficiency from 2.0 to 3.0%. The incidence of vitamin D deficiency decreased from 81.0 to 36.1%, whereas vitamin B1 increased from 5.5 to 9.0%.

Conversely, Ben-Porat *et al*. [35] found the effect of SG on nutrient deficiency at 1 year postoperatively to be modest. The incidence of iron deficiency decreased from 40.4 to 27.7%, folate deficiency from 40.5 to 21.4%, and vitamin D deficiency from 97.9 to 93.6%. The study concluded that proper recognition of preoperative nutrient deficiency alongside tailoring a specific supplemental program for each individual should prevent postoperative ND.

Belfiore *et al*. [36] used bioelectrical impedance analysis to assess changes in body composition after SG. Iron deficiency decreased from 14.9 to 8.8%, and vitamin D deficiency from 31.9 to 11.8%.

Al-Mulhim [37] described vitamin and nutrient deficiency after SG as a common phenomenon. The incidence of anemia declined from 24.0 to 6.25%, iron deficiency from 11.6 to 7.1%, vitamin D deficiency from 60.0 to 8.9%, and magnesium from 6.2 to 2.7%.

According to recent evidence, rates of hypovitaminosis D in patients who had undergone bariatric procedures range from 13 up to 30.0%, which is in agreement with our results [26].

A plausible explanation for discrepancies of these results was that our study was conducted in Egypt, which has a higher sunlight exposure than other countries where the previous studies were undertaken. Furthermore, our patients were encouraged to practice outdoor activities to enhance physical performance that helped increase exposure to sunlight as well as their daily supplementation with 5000 IU of vitamin D3/week.

Compared with our findings, several studies administering a low dose of vitamin D, 200 to 800 IU/day, showed no change or a decrease in vitamin D level. In vitamin D-deficient patients, a significant increase in vitamin D level, of 9–13 ng/ml, was shown only in studies that used loading doses of vitamin D (1100–7100 IU/day) followed by a maintenance dose (400–2000 IU/day) [9]. However, these increments in vitamin D level remained lower than increments observed with similar doses in the general non-obese population [38].

Moore and Sherman [39] suggested that vitamin D deficiency after bariatric surgery, including SG, is caused by reduced food intake. The authors advocated a daily supplementation with 2000 IU of vitamin D3 and 1500 mg calcium citrate; they found this protocol successful in reducing the incidence of vitamin D deficiency from 54.5% preoperatively to 27.4% 3 months after SG.

Lanzarini *et al.* [40] advocated that 'patients undergoing bariatric surgery should receive high-dose vitamin D supplementation independently of the surgical technique'. Patients who underwent SG or Roux-en-Y gastric bypass were administered 400 IU/day of vitamin D with additional supplementation of 16 000 IU of vitamin D3 every 2 weeks if vitamin D serum levels were less than 30 ng/ml. Normal vitamin D levels were recorded in 69% of patients who received high-dose vitamin D supplementation, compared with 48.3% in the group that received the regular dose of the vitamin. This recommendation was supported by the conclusion of a randomized trial that a supplementation of 80 μg/day of oily vitamin D3 effectively prevents vitamin D deficiency as well as to treat pre-existing deficiencies after SG [41].

Another systematic review and meta-analysis of prospective studies in patients undergoing gastric bypass, of at least 6 months' duration, revealed no significant change in serum vitamin D level with vitamin D doses less than or equal to 1200 IU/day [42].

These indirect comparisons suggest that higher doses of vitamin D are needed to correct vitamin D deficiency in obese patients undergoing bariatric surgery.

In current study, there was a statistically significant elevation in vitamin D level from baseline to (14.7 ±4.4 ng/ml) to postoperatively (31.3±11.6 ng/ml) ($P<0.0001$) even with external vitamin D supplementations.

The few studies that did not include any supplementation following laparoscopic SG showed a significant improvement in serum vitamin D level at early (6 months) [40] and late (1–2 years) follow-up [32,43]. In one study, vitamin D level increased from 23.6 to 32.2 ng/ml, at 6 months postoperatively [36]. In two studies, vitamin D levels at baseline were 13.5 and 17.4 ng/ml, and increased to 26.3 and 42.1, at 1 year after surgery, respectively, and 1 of them reported a vitamin D level of 49.4 at 2 years [32,43].

Against our findings, Chakhtoura *et al.* [9] in a systematic review of observational studies revealed that only 13% of the included studies reported a mean postreplacement vitamin D level greater than 30 ng/ml, measured 3 months to 10 years postoperatively.

In this study, there was a statistically significant negative correlations between vitamin D level and weight (r=−0.341, P=0.015), BMI preoperatively (r=−0.296, P=0.037), and BMI postoperatively (r=−0.301, P=0.034). Weight was statistically significantly higher in patients with inadequate postoperative vitamin D level than those with adequate level (130.6±13.6 vs 117.4±19.4 kg, P=0.050). Moreover, BMI (post) was higher in patients with inadequate postoperative vitamin D level than those with adequate level (34.0±5.5 vs 30.5±4.4), which was statistically significant (P=0.040).

The majority of data support an inverse association between BMI and levels of vitamin D [36], in agreement with our results. Interestingly, a recent study evaluated a large sample of 293 cases that had undergone SG surgery with a median follow-up of 11 ±2.8 years, aiming to identify predictors of vitamin D deficiency. This study reported significant correlations between serum levels of BMI and circulating vitamin D ($P<0.001$) [44].

Interestingly, Lin *et al.* [45] observed significant correlations between adipose tissue mass and plasma levels of vitamin D, further supporting our findings. This study suggested an increased storage of vitamin D in patients with excessive adipose tissue, with a concomitant release during the stage of initial weight loss.

Lastly, bone metabolism can change during the first year after LGS. Part of this change is explained by the weight loss itself owing to the loss of pressure on the weightbearing bones, thus losing a potent stimulant for bone preservation. Furthermore, normal levels of vitamin D are essential for an adequate intestinal calcium uptake. A shortage in vitamin D eventually leads to a negative calcium balance and causes a compensatory rise in PTH to promote bone resorption [27]. Aarts *et al.* [8] reported normal calcium levels 1 year after LGS, but suboptimal levels of vitamin D, all throughout daily multivitamin supplementation.

Conclusion

Vitamin D deficiency is highly prevalent among patients with obesity referred for bariatric surgery.

Preoperative assessment of vitamin D status and active treatment would be beneficial rather than routine postoperative supplementation as absorption may not be very predictable.

Calcium metabolism should be closely monitored in bariatric patients after surgery and any deficits should be vigorously treated.

An adequate supplementation is important to avoid micronutrient deficiencies, and greater weight loss does not require higher dosage of multivitamins.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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