



Differences in Calcium Metabolism and Thyroid Physiology After Sleeve Gastrectomy and Roux-En-Y Gastric Bypass

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Abstract

Introduction Bariatric surgery may modulate the hormones and elements which maintain thyroid and calcium homeostasis. These adaptations in hormonal and elemental aspects have previously been determined via some studies with variations in their findings. Thyroid volume and 24-h urinary calcium are two parameters which have not been investigated regarding whether they change during the bariatric postsurgical period. This study planned to examine the changes in calcium metabolism and thyroid gland functioning after sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB).

Materials and Methods Seventy-three morbidly obese patients with planned bariatric surgery were enrolled in the study. Before and 12 months after the operation, parathormone (PTH), 25-OH-vitamin D3(25vitD3), TSH, free triiodothyronine (fT3), free thyroxine (fT4), calcium (Ca), 24-h urinary Ca and ultrasonography-guided thyroid volume were measured.

Results In the beginning, 73 patients were examined and 12 months after surgery out of 25 patients continuing follow-up, 20 (80%) had undergone sleeve gastrectomy (SG) while five (20%) had undergone Roux-en-Y gastric bypass (RYGB). Accompanied by significant BMI decrease, 24-h urinary Ca and thyroid volume did not significantly increase in RYGB, SG, and the whole group after 12 months. The SG group showed a significant drop in TSH (p 0.03) level, while the RYGB group showed significant decreases in fT4 (p 0.00) and fT3 (p 0.00); and significant fT3 decrease (p 0.01) was recorded for the whole group.

Conclusion Bariatric surgery may modify Ca homeostasis and thyroid gland functional status. We documented that these were not statistically significant increases in 24-h urinary Ca level and thyroid volume after 1 year. Further studies are needed to understand the issue, enrolling more patients who underwent the same bariatric procedure and after accounting for the inhibition of supplementary vitamin and mineral effects.

Keywords Bariatric surgery · 24-h urinary calcium · Thyroid volume

Introduction

Bariatric surgery causes great alterations in homeostatic mechanisms including glucose and lipid homeostasis and it alters

the hormonal regulatory system. This hormonal modulation extends along a wide spectrum from the change in levels and also in functions of gastrointestinal peptides to the effect on insulin and on other hormones which regulate nutrient metabolism. The hormones maintaining thyroid and calcium homeostasis are also affected [1–4]. There may be adaptations in thyrotropin (TSH) and thyroid hormone levels and these effects vary among studies. In fact, TSH almost invariably was reported to decrease [5], while free triiodothyronine (fT3) was frequently shown to decrease [5–7] with some variations in modification of free thyroxine (fT4) levels. The thyroid volume also changes following the postsurgical period which has not been explored before. After focusing on calcium level alteration, variations are mentioned, implicated in stable levels [8, 9] or decreased levels even to hypocalcemic values in some patients [4]. Secondary hyperparathyroidism

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due to bariatric surgery is a common clinical presentation associated with decreased absorption of nutrients, minerals, and vitamin D after gastrointestinal luminal loss. Despite routine postsurgical vitamin and mineral replacement, bone architecture in obese individuals is still negatively affected. The other issue is urinary excretion of oxalate, and frequency of kidney stones were constantly reported to increase after bariatric surgery [10, 11] which would evoke another question asking what happens to calcium in urine. Thereafter, we aimed to identify the alterations in calcium metabolism and thyroid function after bariatric surgery, modeling previous articles. The thyroid volume and 24-h urinary calcium (24-h Ca) are two other parameters we investigated which have not been examined in the literature so far.

Materials and methods

This prospective study was designed to examine some parameters related to calcium and thyroid metabolism in 73 morbidly obese patients who had planned bariatric surgery. The study was approved by Ankara Numune Education and Research Hospital Ethical Committee and was performed in accordance with the ethical standards in the Declaration of Helsinki. All participants provided written informed consent. Before the operation, all the subjects' data were recorded including their body weight (kg), body mass index (BMI), insulin, and levothyroxine (LT4) usage status with their dosage. The patients' hormonal [parathormone (PTH), 25-OH-vitamin D (25vitD3), TSH, fT3, fT4] and biochemical tests [calcium (Ca), ionized Ca (iCa), phosphorus (Phos), 24-h(h) urinary Ca] were measured in each patient before and after the study. TSH, fT3, and fT4 were measured by using an electrochemiluminescent immunoassay (ECLIA) with a Beckman Coulter immunoassay analyzer (USA) while Ca and Phos were analyzed photometrically in a Roche P800 autoanalyzer (Roche Diagnostics, Ankara, Turkey). PTH and 25vitD3 values were measured by electroluminescence with a Roche Cobas e-601 (Roche, USA). Twenty-four-hour urinary Ca was measured by an autoanalyzer (Abbott-Architect C4000, Santa Clara, California, USA). Thyroid gland ultrasonography (USG) examination was performed by the same practitioner using a Logic 3 system (GE Medical Systems, Milwaukee, WI) with an 11-MHz transducer and the diameters of each lobe are given as $a \times b \times c$ (cm). The volume of each lobe was calculated with the formula: $a \times b \times c \times 0.524$ (cm³), and total thyroid volume was the sum of right and left lobe volume. In this study, two types of bariatric surgery were performed; Roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (SG). After operation, the patients were free to consume supplementary drugs such as calcium (500 mg/day) and vitamin D (800 IU/day)- if the surgeon

recommended. All the measurements (anthropometric variables, drug consumption data, laboratory tests, and thyroid USG) were repeated 12 months after surgery.

Statistics

Continuous data are presented as mean \pm standard error of the mean (SEM) and categorical data are given as counts and percentages. Statistical analysis was performed using SPSS for Windows [version 21.0; SPSS/IBM, Chicago, IL]. Descriptive statistics and paired samples were used when suitable. The statistical significance level was accepted as a p value of less than 0.05.

Results

Sixty-two patients (85.0%) underwent SG, while eleven patients underwent RYGB (15.0%). The mean age of patients was 41.5 ± 9.6 years. Fifty-nine (80.8%) subjects were female and 14 (18.2%) were male. Twelve months after surgery, out of 25 patients continuing their follow-up examinations, 23 (92%) were female while two patients (8%) were male. Twenty (80%) of these patients underwent SG while five (20%) underwent RYGB.

In the SG group, mean body weight changed from 115.6 ± 3.6 to 83.9 ± 3.3 kg (p 0.00). BMI decreased from 46.1 ± 1.2 to 33.6 ± 1.2 kg/m² (p 0.00). A significant drop in TSH level (from 2.7 ± 0.4 to 1.9 ± 0.3 μ IU/mL) was demonstrated (p 0.03) (Table 1).

However, fT3 and fT4 decreased without significance while 25vitD3, PTH, Ca, 24-h urinary Ca, and thyroid volume increased without significance following the SG procedure ($p > 0.05$).

In the RYGB group, mean body weight changed from 151.2 ± 13.1 to 95.2 ± 12.0 kg (p 0.00), with BMI reducing from 58.9 ± 3.6 to 37.3 ± 4.6 kg/m² (p 0.00) significantly. These were accompanied by significant decreases in fT4 [from 1.1 ± 0.1 to 0.8 ± 0.0 ng/dL (p 0.00)] and fT3 [from 3.2 ± 0.1 to 2.6 ± 0.1 pg/ml (p 0.00)] (Table 1).

TSH, 25vitD3, PTH, 24-h urinary Ca and thyroid volume did not show a significant increase, while Ca level decreased.

After both groups were analyzed together, only fT3 showed a prominent decrease (from 3.1 ± 0.1 to 2.7 ± 0.1 kg, p 0.01) after the operation. TSH and fT4 decreased while 25vitD3, PTH, Ca, Phos, 24-h urinary Ca, and thyroid volume increased without significance (Table 1).

Before the operation, one patient (4%) was hypocalcemic (Ca 8.6 mg/dl), one patient (4%) was hypophosphatemic (Phos 1.9 mg/dl), 22 patients (88%) had vitamin D deficiency (< 20 ng/ml), 24 patients (96%) had reduced vitamin D levels

Table 1 The anthropometric, hormonal and biochemical values before and 12 month after bariatric operation (SG and RYGB)

	SG			RYGB			Both procedures		
	Before the operation	12 months after the operation	<i>p</i> value	Before the operation	12 months after the operation	<i>p</i> value	Before the operation	12 months after the operation	<i>p</i> value
Body weight (kg)	115.6 ± 3.6	83.9 ± 3.3	0.00	151.2 ± 13.0	95.2 ± 12.0	0.00	120.4 ± 4.1	85.5 ± 3.3	0.00
BMI (kg/m ²)	46.1 ± 1.2	33.6 ± 1.2	0.00	58.9 ± 3.6	37.3 ± 4.6	0.00	47.9 ± 1.4	34.1 ± 1.2	0.00
TSH (μIU/mL)	2.7 ± 0.4	1.9 ± 0.3	0.03	2.9 ± 1.3	4.0 ± 2.3	0.40	2.7 ± 0.4	2.2 ± 0.4	0.19
fT4 (ng/dL)	1.2 ± 0.0	1.1 ± 0.1	0.46	1.1 ± 0.1	0.8 ± 0.0	0.00	1.2 ± 0.0	1.1 ± 0.1	0.22
fT3 (pg/mL)	3.1 ± 0.1	2.8 ± 0.1	0.06	3.2 ± 0.1	2.6 ± 0.1	0.00	3.1 ± 0.1	2.7 ± 0.1	0.01
PTH (pg/ml)	52.8 ± 6.1	56.7 ± 6.3	0.42	95.2 ± 10.7	110.7 ± 25.9	0.58	58.9 ± 6.3	64.4 ± 7.5	0.29
25vitD3 (ng/ml)	12.1 ± 1.8	16.3 ± 1.3	0.06	10.3 ± 1.8	16.9 ± 1.7	0.08	14.4 ± 2.2	15.7 ± 1.8	0.57
Ca (mg/dl)	9.2 ± 0.3	9.5 ± 0.6	0.24	9.3 ± 0.3	8.9 ± 0.2	0.39	9.2 ± 0.1	9.4 ± 0.1	0.44
Phos (mg/dl)	3.6 ± 0.1	3.7 ± 0.1	0.37	3.6 ± 0.1	4.0 ± 0.3	0.09	3.6 ± 0.1	3.8 ± 0.1	0.13
24-h urinary Ca (mg)	95.9 ± 21.1	159.4 ± 38.6	0.24	49.6	90.0	0.76	86.8 ± 16.8	146.0 ± 31.2	0.42
Thyroid volume (cm ³)	9.2 ± 1.5	9.5 ± 1.6	0.72	11.2 ± 2.0	11.4 ± 2.2	0.75	9.6 ± 1.4	9.9 ± 1.4	0.69
Levothyroxine dosage (mcg/day)	113.9 ± 37.9	107.2 ± 26.2	0.70	200	150	0.94	120.8 ± 34.5	111.3 ± 38.5	0.83

(< 30 ng/ml), and nine patients (36%) suffered from secondary hyperparathyroidism.

Twelve months after the operation, one patient (4%) had hypocalcemia (Ca 8.5 mg/dl), no patient (0%) had hypophosphatemia, 17 patients (68%) were vitamin D deficient (< 20 ng/ml), 24 patients (96%) had reduced vitamin D levels and ten patients (40%) had secondary hyperparathyroidism.

Levothyroxine was required in nine patients and insulin was required in two patients in the SG group. Mean levothyroxine dosage decreased from 113.9 ± 37.9 to 107.2 ± 26.2 mcg/day (*p* > 0.05), and the insulin requirement reduced from 101.0 ± 15.0 to 18.0 ± 6.0 units in the SG group after operation. For patients who underwent RYGB, there was only one patient who previously used 200 mcg of levothyroxine and used 150 mcg after operation, whereas there was no insulin requirement for any patient in that group.

Discussion

“Bariatric” meaning “dealing with obesity” comprises a huge collection of therapeutic interventions which combat obesity, starting from behavioral managements such as increased physical activity, various dietary programs, and acupuncture and extending to medical treatment and surgery. After comparison of all these treatments, only bariatric surgical approaches have successfully achieved substantial and durable weight loss [12]. Practically, there are two main types of bariatric surgery according to mode of food blockage: restrictive (blocking the transit of food) and malabsorptive (preventing the absorption of food) procedures [12]. SG (sleeve gastrectomy) and RYGB (Roux-en-Y gastric bypass) are the most commonly performed

techniques worldwide. While we discriminate these two procedures according to their type, SG is claimed to be mainly restrictive while RYGB is seen as malabsorptive. However, it is logical to consider these procedures; both have malabsorptive and restrictive effects, although in different proportions, rather than categorizing them as being only one type.

SG involves laparoscopic removal of approximately 75% of the stomach, causing a considerable calorie restriction effect [13] and was first described as a modification of the biliopancreatic diversion-duodenal switch (BPD-DS). The advantages of this approach are summarized as the lack of an intestinal bypass avoiding gastrointestinal anastomoses and internal hernias and provision of a shorter operating time with no implantation of a foreign body [14].

The RYGB procedure involves the creation of a small gastric pouch and bypass of the entire duodenum and the proximal jejunum [15]. It does successfully lead to long-term weight loss over 2 years and maintenance of this condition in 20–30% of patients. Besides, it manages the improvement or remission of multiple comorbidities related with obesity such as hypertension, type 2 diabetes mellitus, obstructive sleep apnea, and musculoskeletal pain [16].

As the very end and most appreciable result, RYGB and LSG both provide a mortality reduction in obese patients [17].

According to the literature, females generally undergo bariatric surgical procedures more frequently [18]. This inequity of gender towards females was a little more prominent in our study than the estimated 80% female proportion reported in the literature. We assume it indicates our male morbidly obese patients are less informed and are more ignorant about the medical and cosmetic problems their obesity may cause. Similarly, it may emphasize our female patients would be

more alert about medical concerns related to obesity and are more aware of their cosmetic needs.

Benefits after surgery occur by different pathophysiological mechanisms sometimes unrelated to weight loss such as increased gastric emptying and intestinal transit and activation of hormonal mechanisms such as increased GLP-1 hormone [19] and decreased ghrelin [20]. Therefore, bariatric surgery does not merely manipulate the weight of the obese patients but also induces significant rehabilitation of the deteriorated glucose and lipid homeostasis in their body. It increases beta cell responsiveness and inhibits insulin resistance in peripheral tissues [21]. Diabetic patients on insulin treatment were consistently shown to experience complete remission after bariatric surgery in high percentages [21, 22]. Besides, a dramatic loss of fatty tissue, bariatric surgery converts the distribution of fat from visceral to the subcutaneous compartment favoring metabolic improvement. The sensitivity to lipolysis which is controlled by insulin and catecholamines is improved [23].

Body weight is positively associated with serum thyrotropin (TSH) concentrations more strongly in obese than in healthy individuals [24]. The development of obesity seems to activate the hypothalamic pituitary thyroid axis in a way which resembles the changes that occur in primary thyroid disease [25], and this could describe the increased TSH in obese populations. Sometimes obese patients are found to have TSH at the high end of the normal range [26], while fT4 and fT3 show variation when decreasing [24] or not. Weight loss might affect thyroid hormonal regulation, result in a decrease of T3 described with the decreased peripheral conversion, or so-called activation of T4 [2]. SG and RYGB, two examples of surgical routes aiming at weight loss, in our study, together decreased TSH insignificantly (p 0.19) and fT3 significantly (p 0.01). After separate examination of bariatric procedures, a significant decrease in TSH (p 0.03) and an insignificant decrease in fT3 (p 0.06) in the SG group were found. While in the RYGB group, TSH increase and significant decrease in fT3 (p 0.00) and fT4 (p 0.00) were determined. TSH increase in the RYGB group can be explained by the decrease in thyroid gland hormones in that group. TSH decrease and insignificant fT3 decrease in the SG group might be explained by the reorganized pituitary thyroid axis after weight loss. fT3 decrease in the whole group would be reactive, and the human body may respond to less body mass by inhibiting the more active component of thyroid hormones. Considering previous studies, miscellaneous examples arrived at a consensus about TSH decrease when the alteration in fT4 and fT3 showed some variation. TSH decrease and stable fT4 levels were determined 6–12 months after SG [1, 27]; fT3 was also found to be steady [27]. One study determined TSH remained unchanged when fT4 significantly increased after RYGB [26]. RYGB was also shown to cause TSH and fT4

decrease in euthyroid obese T2DM patients while duration of diabetes was the factor independently contributing to the decrease in fT4 levels [28]. TSH decrease was redocumented in a meta-analysis comprising 24 articles on the issue of thyroid homeostatic reorganization after bariatric surgery. This decrease was also found valid for fT3 and T3 while fT4 and T4 stayed at sustained levels [29]. TSH again decreased 12 months after RYGB in another article, with decrease associated with excess body weight loss (EBWL), baseline BMI, and baseline fT3. The patients with higher TSH levels and with higher BMI at the start manifested a greater TSH decrease [30]. A TSH decrease after 12 months of SG was not found to be associated with EBWL [27], or the decrease 6 months after SG was found not to be associated with the change in BMI [31]. However, for some authors, this TSH decrease after bariatric surgery (BS) was related with baseline TSH [32].

The TSH decrease following bariatric surgery could be visualized better when all hypothyroid patients undergoing either RYGB and SG [32] or only SG [33] maintained complete or partial resolution of hypothyroid state in 6–12 months after surgery. In another article, subclinical hypothyroidism (SH) completely resolved in 87% of RYGB patients after 1 year of surgery. TSH decrease this time was associated with the decrease in BMI [34]. Resolution and improvement of hypothyroidism after RYGB in about 35% of hypothyroid patients was also documented [35]. The reversal of leptin resistance by surgical intervention was a probable factor in this resolution of hypothyroidism. The patients who remained hypothyroid after the surgery were suspected to possess autoimmune antibodies which are not affected substantially by the procedure [36].

Upon discussion about the condition of hypothyroidism after surgery, the alteration of thyroid hormonal replacement dosage after the surgery should absolutely be under consideration for formerly hypothyroid subjects. There is some debate about this in the literature; however, the decrease of the levothyroxine (LT4) requirements in association with reduction of lean body mass [37] is the most accepted result. LT4 absorption is negatively impacted after bariatric surgery and it does not explain the decrease in LT4 requirement. However, this assumption was investigated, and LT4 absorption was found not to decrease after RYGB but it was delayed significantly [38]. In another study, RYGB was shown to not affect absorption; however, SG was shown to replenish pharmacokinetic parameters of LT4 absorption [39]. In our study, we found almost no difference in LT4 dosage after SG, which was probably associated with both the improved pharmacokinetic parameters and susceptibly decreased absorption of LT4 after SG.

Iodine status clearly has an impact on thyroid hormonal secretion based on the fact that iodine is the essential element

for production of thyroid hormones. The amount of iodine in the body was documented to decline after 10 years following gastric bypass. However, it did not induce a requirement for dietary supplementation with iodine in those patients [40]. Meanwhile, after 6 months of follow-up, gastrointestinal iodine absorption was also stated to remain steady after malabsorptive bariatric surgery including SG, RYGB, and a variant of biliopancreatic diversion [41]. Hence, these studies suggest iodine status does not seem to affect thyroid homeostasis after bariatric procedures.

TSH increases in obese individuals may have an impact on thyroid volume. Women who were mildly obese were found to have higher thyroid volume than non-obese women, and volume was discovered to diminish significantly after even 10% weight loss, accompanied by a TSH decrease in obese women [42]. The finding of larger thyroid size was associated with increased TSH and decreased fT4 levels among the obese population [43], emphasizing the TSH level-thyroid size association. Hence decreased thyroid volume developing after weight loss would be explained by the effect of lowered TSH. However, our study showed an insignificant TSH decrease accompanied by an insignificant increase in thyroid volume in the whole group. In the SG group, there was a significant decrease in TSH and an insignificant increase in thyroid volume. TSH changed negatively compared to thyroid size. The surprising condition of increase in size could be explained by the short period of 1-year follow-up which might not allow the thyroid gland to reorganize its structure according to the decreased body mass and to the decreased TSH. In the following years, a decrease in volume of the gland may be observed due to accustomization to the TSH level decrease.

Although obesity is associated with increased bone mineral density, excess weight due to adiposity is believed to be detrimental to bone health and may elevate fracture risk [44]. Bone quality is affected, which leads to higher—than—expected fracture risk for a given BMD in the obese population. In obese subjects, higher levels of serum parathyroid hormone (PTH) [8, 44] and lower 25 hydroxy vitamin D (25OHD) are documented, both of which have specific actions on bone [8, 44, 45]. Regarding the surgery's other beneficial effects on the human body, conflicting with the prediction of rehabilitative effect of bariatric surgery on bone health, bariatric procedures—especially malabsorptive types—were stated to have detrimental effect on bone metabolism [17]. Nevertheless, these data are not accepted on a general basis, and when the components of bone health are separately investigated, different results were obtained. These were mostly in agreement with the expectation of the reversal of the manifestations of obesity after the surgery.

Nutritional changes after RYGB and SG, including vitamin D and Ca, are dramatic. Twenty-four months after RYGB, 98% of patients need to be prescribed specific supplements such as vitamin B12, iron, and calcium+ vitamin D [46].

While a Ca level decrease would be expected due to the malabsorption of Ca through the gastrointestinal lumen, Ca level alteration after bariatric surgery in fact shows some variation considering articles which reported no change after the operation [8, 9]. For RYGB, the bypassed duodenum and proximal jejunum are usually the predominant sites of active, transcellular, 1,25(OH)₂D-mediated Ca uptake. In fact, Ca absorption occurs throughout the intestine and those who have undergone RYGB might maintain sufficient Ca absorption [15]. However, true fractional calcium absorption (TFCA) decreases after RYGB, and all patients show dramatic increase in markers of bone resorption [47]. In fact, merely caloric restriction reduces Ca absorption efficiency [44]. One of the consequences stemming from this condition is post thyroidectomy hypocalcemia decreasing to extremely low levels for patients who previously underwent RYGB [48]. The prevalence of hypocalcemia was noted to be 1.9% after RYGB, with an unexpectedly higher prevalence of 9.3% for hypocalcemia after SG [4]. Due to our observations, we defined a slight insignificant increase in Ca levels in the SG and whole group with an insignificant decrease in RYGB group. The increase in SG and total group could have been established by the calcium and vitamin D supplements, while despite these, the decrease could not be diminished in the RYGB group which may be associated with its more malabsorptive nature.

Obese individuals are at increased risk for vitamin D deficiency. The reason behind this could be sunbathing less [49] or less out-door exercise among the obese [50]. The other more accepted explanation might be the extra storage of vitD3 in fatty tissues. Weight loss would increase 25OHD due to its release from adipose tissue by losing fatty tissue [44, 51] or it was shown not to change [47, 52] or even decrease [9, 53]. The last mode of change is produced by caloric restriction (CR) which causes decreased intake of vitamins or is produced by malabsorption when weight loss occurs after bariatric surgery [54]. In our observations, 25OHvitD3 did exhibit a small but insignificant increase after the operation. When the procedures were separately examined, 25OHvitD3 increased after SG and RYGB (p 0.06 and p 0.08, respectively). Nevertheless, vitamin D supplementation did not achieve optimal 25OHvitD3 levels but fortunately it attenuated the drop in vitamin D.

It is known that RYGB can cause vitamin D malabsorption, resulting in a high incidence of postoperative vitamin D deficiency and even osteomalacia in the most severe cases [15]. Besides this, vitamin D deficiency is the most common long-term nutritional deficiency following SG [55]. Hence, bariatric osteomalacia is a unique and increasingly common phenomenon in bariatric surgery patients that can have a subtle clinical presentation but potentially devastating consequences [56]. Therefore, high-dose vitD3 supplementation is accepted as vital after bariatric surgery [53]. Meanwhile, it is equally unknown if

improving vitamin D status before and/or after bariatric surgery can affect health-related outcomes in the obese population beyond the traditional roles of vitamin D [45]. As such, in our article, even supplementation with vitamin D does not guarantee an increase in 25OHvitD. In many studies, prevalence of vitamin D deficiency (VDD) (<20 ng/ml) is between 13 and 90% among preoperative patients, and vitamin D insufficiency (VDI) (<30 ng/ml) reaching up to 98% before the operation remained at similar levels postoperatively [57] despite vitamin D consumption. It reflects the insufficient vitamin D supplementation before and after bariatric surgery, with no consensus about proper dosage yet.

Leptin and PTH are believed to act on the pathways between adipose tissue and parathyroid gland causing a bone adaptation to obesity [58] with increased PTH levels. Increased PTH in severely obese subjects declines with dramatic weight loss, sometimes independent of 25OHvitD status. However, persistently elevated PTH levels are commonly described after bariatric surgery [47]. We showed PTH increases after bariatric surgery in the RYGB, SG, and the total group, and it was accompanied by lower Ca and unreplenished vitamin D3 levels in SG and total group, insignificantly. One other observation stated that secondary hyperparathyroidism was reversed by weight loss after RYGB coupled with increase in calcidiol; however, this pre-existing state of secondary hyperparathyroidism and vitamin D deficiency could not be corrected completely [8]. Progressive increases in PTH instead of decreases, as such in our study, were also observed after RYGB, probably depending on accompanying continuation of decrease in 25OH vitamin D [9]. Another explanation for the increased PTH levels is that decreased Ca absorption can be compensated by higher serum PTH levels that develop in response to the decrease in Ca absorption [44]. Low 25OHvitD3 levels which could not be replenished precisely may also cause further elevation of PTH. PTH was reported to increase after bariatric surgery [59, 60] gradually with a prevalence of 17%, 3 years after SG [60] which further increases after 5 years [61, 62] despite most patients being supplemented with Ca and vitamin D [61].

The urinary Ca excretion after bariatric procedures is another topic for consideration which has not been discussed yet. In fact, an increase in kidney stone formation is a well-known outcome of the bariatric surgery [10, 11], and based on this, it is logical to expect higher urinary Ca excretion after bariatric surgery. We found an insignificant rise in 24-h urinary calcium measurements after the surgery in all groups. This rise might be produced by the permitted Ca supplementation and the permanent deficiency of vitamin D in spite of replacement attempts.

There are some limitations of our study. Firstly, the number of patients able to be reached after 1 year was low, and it might have prevented us from collecting sufficient data to generalize our study's findings to all bariatric surgery patients and to reach statistical significance. Patient numbers in RYGB and SG groups were different when they are compared at the start of the study and after the follow-up period, which would be inappropriate for the evaluation of differences between these two surgical techniques. Additionally, the permitted consumption of vitD3 and Ca preparations after the operation might inhibit the interpretation of variations in Ca metabolism following bariatric surgery, properly. However, most studies accept vitamin D supplementation before and/or after the procedure. Moreover, the level of prealbumin (transthyretin), the protein which reflects nutritional status and also is a transporter for thyroid hormones, could be studied to demonstrate if there is a relationship between the nutritional status and thyroid hormone levels or between prealbumin levels and thyroid hormone levels. Lastly, the number of patients who use insulin and/or LT4 was too low to determine the changes in dosages of these drugs after follow-up of bariatric surgery. Hence, we recommend that there should be new studies about bariatric surgery examining thyroid volume, and 24-h urinary Ca, involving larger numbers of patients who underwent the same type of bariatric procedures and, if possible, under no effect from supplements.

Conclusion

Bariatric surgery leads to some differences in Ca and thyroid metabolism which have been previously investigated and conflicting results were reported. This variability may be due to the retrospective design of the studies, comparison of different types of surgical procedures, and differences in vitamin and mineral supplement use among bariatric surgery patients. Despite these differences, the TSH almost invariably decreases with a decrease in fT3 levels in most studies. A decrease in fT4 is also seen in patients who undergo RYGB. In 1 year after the surgery, thyroid volume would increase. Ca and 25OHvitD3 levels would rise most probably depending on their supplementation. However, VitD cannot be optimally replaced after bariatric surgeries which necessitate a satisfactory vitD replacement schedule for those patients who undergo bariatric surgery. Although in the literature, LT4 dosage usually decreases, we could not find a significant decrease in dosage after the operation. The increased 24-h urinary Ca level, although insignificant, could be the result of both Ca supplements and lack of optimal vitD replacement.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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