

PAPER

Gastric banding induces negative bone remodelling in the absence of secondary hyperparathyroidism: potential role of serum C telopeptides for follow-up

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OBJECTIVE: Data about the consequences of laparoscopic adjustable gastric banding (LAGB) on phospho-calcic and bone metabolism remain scarce.

SUBJECTS: We studied a group of 37 obese premenopausal women (age: 24–52 y; mean BMI = 43.7 kg/m²) who underwent LAGB.

METHODS: Serum calcium, phosphate, alkaline phosphatase, parathormone (PTH), vitamin D₃, serum C-telopeptides, IGFBP-3 and IGF-1 were measured at baseline, 6, 12, 18 and 24 months after surgery. Body composition, bone mineral content (BMC) and density (BMD) were measured using dual-X-ray absorptiometry (DXA) at baseline, 6, 12 and 24 months after surgery.

RESULTS: There was no clinically significant decrease of calcemia; PTH remained stable. Serum telopeptides increased by 100% ($P < 0.001$) and serum IGFBP-3 decreased by 16% ($P < 0.001$) during the first 6 months, and then stabilized, whereas IGF-1 remained stable over the 2 y. BMC and BMD decreased, especially at the femoral neck; this decrease was significantly correlated with the decrease of waist and hip circumference.

CONCLUSIONS: We concluded that there was no evidence of secondary hyperparathyroidism 24 months after LAGB. The observed bone resorption could be linked to the decrease of IGFBP-3, although this decrease could be attributable to other confounding factors. Serum telopeptides seem to be a reliable marker of bone metabolism after gastric banding. DXA must be interpreted cautiously during major weight loss, because of the artefacts caused by the important variation of fat tissue after LAGB.

International Journal of Obesity (2005) 29, 1429–1435. doi:10.1038/sj.ijo.0803040; published online 2 August 2005

Keywords: gastric banding; osteoporosis; bone metabolism; bone markers; weight loss

Introduction

As it is now recognized that conservative therapy for morbid obesity is associated with an 85–95% failure rate,¹ the role of bariatric surgery is becoming more important in the treatment of morbid obesity. In Switzerland, the number of obese patients treated by surgery has doubled between 1997 and 2001.² Gastric banding and Roux-en-Y bypass (RYGB) are actually the most commonly performed surgical procedures and gastric banding is currently the most popular purely restrictive bariatric operation in Europe and many other countries.

Laparoscopic adjustable gastric banding (LAGB) causes a significant reduction of food intake, and thereby a signifi-

cant weight reduction, especially during the first post-operative year.^{3,4} Data related to bone metabolism after LAGB still remain scarce, while RYGB has already been shown to cause secondary hyperparathyroidism^{5,6} because of its partially malabsorptive nature. We recently reported that there was no evidence of secondary hyperparathyroidism 1 y after LAGB in obese premenopausal women. However, a significant rise in biochemical bone markers (serum C-telopeptides) suggested a negative bone remodelling balance, characterized by an increase of bone resorption.⁷ We present herewith the results of the second year of follow-up, in a larger cohort of patients.

Our first aim was to confirm the hypothesis that no secondary hyperparathyroidism occurs 2 y after LAGB, as that LAGB causes no malabsorption. Secondly, we examined the question if the markers of bone remodelling still suggest a negative bone balance during the second postoperative year. Thirdly, we evaluated the persistence of the correlation

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Received 18 January 2005; revised 24 April 2005; accepted 29 May 2005; published online 2 August 2005

between the changes of anthropometric parameters and changes in BMD and BMC.

Methods

Patients

Our patients were evaluated by a multidisciplinary team, including an endocrinologist, a psychiatrist, a dietician, an anesthesiologist, a pneumologist and a bariatric surgeon. Provided there was a history of obesity for at least several years, and attempts of unsuccessful treatments with diet for at least 2y, patients were considered for bariatric surgery if their body mass index (BMI) exceeded 40 kg/m² (morbid obesity), or if it exceeded 35 kg/m² with at least one comorbidity. Contraindications were essentially of a psychiatric nature (psychosis, drug or alcohol dependence). In order to have a homogeneous group, and because most of our patients are females, only premenopausal women were included in the study. During the whole study period, all patients received dietary advice according to their needs; however, dietary intake was not controlled. Five patients took a self-medication with commercial multivitamin pills, and one patient took a vitamin D3 supplementation during 3 months (months 4–6). Nevertheless, these treatments were quickly stopped and the assessment of serum biological values of iron, folic acid, vitamin B12 and vitamin D3 documented no changes of evaluated parameters. Exclusion criteria were pre-existing hepatic, renal, metabolic or bone diseases, or the use of drugs that could influence bone metabolism, such as oral contraceptives. All patients provided informed consent, and the study was approved by the institutional review board.

Surgical procedures

All the patients received one dose of prophylactic perioperative antibiotics, and were given peri- and postoperative low-molecular-weight heparin. LAGB was performed through five operative ports according to a technique that has been described in details elsewhere.⁸ An adjustable gastric band (Lap-Band[®], Bioenterics, Carpinteria, CA, USA) or a Swedish adjustable gastric band (SAGB[®], Obtech Medical, Zug, Switzerland) was used. The band was left deflated at the end of the operation, and was first adjusted after 1 month. Further adjustments were performed according to weight loss and food tolerance.

Anthropometric measures

Body weight and height were measured with a Detecto scale and stadiometer, and the BMI was calculated as weight (kg) divided by the square of height (m²). Percentage excess body weight (EBW) was calculated as percentage excess of ideal body weight.⁹ All body circumferences were taken in a standing position using a TEC anthropometric tape (Rollfix, Hoechst. Mass, Germany). Waist and hip circumferences

were measured at the smallest standing horizontal circumference between the ribs and the iliac crest and the largest standing horizontal circumference of the buttocks, respectively.¹⁰ Three measurements were taken at each site with the criterion that the difference between the measurements had to be less than 2 cm; if the difference exceeded 2 cm, a fourth measure was made, and the most outlying value was considered to be erroneous. Additional measurements were taken when needed until this criterion was fulfilled.

The anthropometric parameters were measured at baseline, and after 6, 12, 18 and 24 months. Furthermore, the total body composition, that is, fat body mass and fat-free mass, was assessed at baseline and after 6, 12 and 24 months using dual-energy X-ray absorptiometry (DXA; Hologic QDR 2000; software 11.2.1.1).^{11,12} The weight limit of the Hologic densitometer is 140 kg, allowing all our patients to fit within the scan field.

Biochemical parameters

Blood samples for measurement of bone markers were collected in the morning after an overnight fast. Serum corrected calcium (total calcium/(total proteins/160) + 0.55) (Ca), phosphate (P), alkaline phosphatase (AP), γ -glutamyl-transferase (γ -GT), bilirubin, urea, creatinine, uric acid and total proteins were measured by the SSCC (Société Suisse de Chimie Clinique) 37°C method, using an automatic Hitachi 917 Roche, with Roche and BioMérieux kits. Intraassay precision error (CV) for these measurements was 1.2–3.9%. Vitamin D₃ was assessed by radioimmunoassay (RIA) with the 125-I-RIA Kit from DiaSorin, which measures 25-hydroxyvitamin D₃, 25-hydroxyvitamin D₂ and metabolites (CV: 8.6–12.5%). The intact parathyroid hormone (PTH) was assessed by immunometric dosage (CIA, Chemiluminescens Immuno Assay; Nichols Institute Diagnostics) (CV: 5.7–6.2%). The urinary telopeptide was measured by CrossLaps[™] Elisa assay (Osteometer Biotech A/S, Herlev, Denmark). The serum telopeptide was measured by β -CrossLaps/serum Elecsys test (Roche) (CV:3.7%). Insulin-like growth factor 1 (IGF-1) and insulin-like growth factor-binding protein 3 (IGFBP-3) were measured by RIA kits with extraction (Nichols Institute Diagnostic) (CV: 3.4–8.0%). Those three latter parameters were measured in a subgroup of 21 patients. All parameters were assessed before and 6, 12, 18 and 24 months postoperatively. All biochemical analyses were carried out by certified laboratories (ISO/CEI 17025); they were run in duplicate or triplicate samples, after having been previously tested in a healthy population.

Bone mineral density and bone mineral content

DXA was performed before, and 6, 12 and 24 months after surgery. The bone mineral density (BMD) and bone mineral content (BMC) were evaluated at the lumbar spine (L₂–L₄) and the trochanter levels (mainly trabecular bone), and at the femoral neck (mainly cortical bone). Short-term DXA

Table 1 Baseline characteristics of the 37 obese premenopausal women

	Mean	Range	s.d.
Age (y)	35.7	24–52	6.6
Weight (kg)	117.1	93.7–141.5	11.7
BMI (kg/m ²)	43.7	36.0–51.7	4.1
Excess body weight (%)	100.5	65.3–138.4	18.7
Waist (cm)	113.9	93–132	9.8
Hip (cm)	137.9	119–157	9.9
Fat mass (kg)	63.3	48.2–82.0	9.0
Fat free mass (kg)	50.0	37.7–60.7	5.3

precision error (where precision is meant as the variation between two measures in a same subject, with repositioning between two scans) of the lumbar spine and femoral neck is about 0.9 and 1.4%, respectively, in normal subjects.^{13,14} A change of BMD exceeding 3% at any site for individual subjects was considered significant in accordance to the CV of the Hologic machine used in this study.¹⁵ The machine was calibrated before each densitometry.

Statistical analysis

Means and standard deviation (s.d.) were calculated for age, anthropometric measurements, biological parameters and bone mineral results (all results are shown as means ± s.d.). Comparison of data before and after gastroplasty was performed by analysis of variance and paired Student's *t*-test for all variables. Spearman's correlation was used to assess multivariate relationships between anthropometric and biological parameters and bone mineral measurements. Differences were interpreted as statistically significant at *P* < 0.05. Statistics were performed using the Statview package (SAS Institute Inc. ©).

Results

In all, 37 obese premenopausal women, referred consecutively over a period of 12 months, were included in the study. Median age was 35 y (range 24–52, s.d. 6.6). Pre-operative characteristics are summarized in Table 1.

Anthropometric parameters

We observed a significant mean weight loss of 39.1 ± 15.5 kg (*P* < 0.0001), respectively, of 33.4% of the initial body weight over 2 y. BMI decreased from 43.7 ± 4.1 kg/m² at baseline to 29.0 ± 4.4 kg/m². Fat body mass decreased by 32.1 kg (–50.7%; *P* < 0.0001) at 24 months; 76% of this fat loss occurred during the first postoperative year. Baseline and follow-up body composition data are illustrated in Figure 1. Waist and hip circumferences decreased significantly by 29.1 cm (–25%; *P* < 0.0001) and 29.7 cm (–22%; *P* < 0.0001), respectively; 73 and 74% of the decrease of waist and hip, respectively, occurred during the first year after LAGB (see

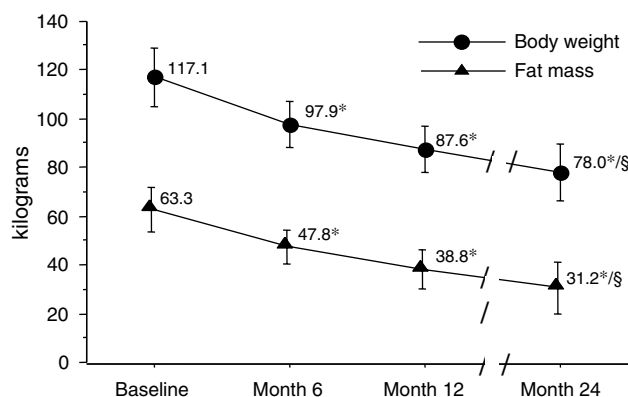


Figure 1 Evolution of body weight and fat mass over 24 months; data are given mean values ± s.d. (**P* < 0.0001 when compared to baseline; §*P* < 0.0001 when compared to month 12).

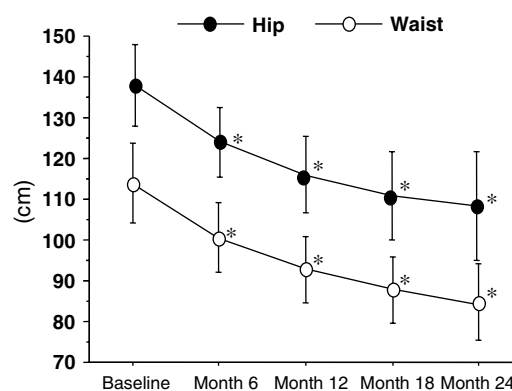


Figure 2 Decrease of waist and hip circumferences during follow-up; data are as mean values ± s.d. (**P* < 0.001 when compared to baseline).

Figure 2). The percentage of excess body weight decreased by 66% after 24 months (*P* < 0.0001).

Biochemical parameters

Evolution of biological parameters is summarized in Table 2. Phosphate remained stable, whereas calcium decreased significantly at month 24. However, only three patients (8.1%) developed a true, but very light hypocalcemia, with calcium between 2.05 and 2.1 mmol/l. Vitamin D₃ increased slightly and significantly, but remained within normal ranges; this increase occurred as well in those patients who took a multivitamin supplementation as in those who took no supplementation. Alkaline phosphatase decreased very significantly from month 18. PTH remained stable during these first 24 postoperative months. There was a 100% increase in serum telopeptides during the first 6 months, followed by a stabilization. In opposition, IGFBP-3 decreased significantly by 16% (*P* < 0.001) during the first semester,

Table 2 Modifications of biological parameters during 24 months after gastric banding. Data are given as mean \pm s.d.

	Baseline	Month 6	Month 12	Month 18	Month 24
Vitamin D3 ($\mu\text{g/l}$) (8.4–52.3)	18.5 \pm 7.2	19.3 \pm 8.9	22.1 \pm 9.5**	19.8 \pm 8.8	22.7 \pm 11.6**
PTH (ng/l) (10–70)	52.8 \pm 17.2	46.8 \pm 14.3	44.4 \pm 14.2**	45.1 \pm 16.3*	47.4 \pm 18.2
Phosphate (mmol/l) (0.8–1.4)	1.04 \pm 0.15	1.06 \pm 0.13	1.10 \pm 0.17	1.12 \pm 0.17*	1.09 \pm 0.17
Calcium (mmol/l) (2.1–2.55)	2.32 \pm 0.08	2.36 \pm 0.08*	2.32 \pm 0.08	2.30 \pm 0.10	2.25 \pm 0.08***/§§§
Alkaline phosphatase (U/l) (36–110)	74.6 \pm 23.8	69.1 \pm 18.9*	70.1 \pm 26	62.1 \pm 16.2***/§	59.8 \pm 16.7***/§§
γ -GT U/l (11–62)	27.8 \pm 22.3	15.8 \pm 7.7***	13.7 \pm 7.0***	12.1 \pm 4.8***/§	12.2 \pm 4.9***
Serum telopeptides (ng/l) (0.14–0.57)	0.16 \pm 0.10	0.32 \pm 0.14***	0.35 \pm 0.12***	0.34 \pm 0.12***	0.37 \pm 0.14***
Urinary telopeptides/urinary creatinine ($\mu\text{l/l}$) (<500)	132.2 \pm 84.1	184.6 \pm 102.5*	212.7 \pm 108.1***	182.0 \pm 82.6*	193.0 \pm 128.9*
IGFBP3 (mg/l) (1.47–4.80)	4.58 \pm 0.95	3.83 \pm 0.72***	3.85 \pm 0.71***	3.93 \pm 0.74**	3.98 \pm 0.72**
IGF-1 ($\mu\text{g/l}$) (46–459)	149 \pm 39	159 \pm 40	155 \pm 38	159 \pm 37	155 \pm 51

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ when compared to baseline. § $P < 0.05$; §§ $P < 0.01$; §§§ $P < 0.001$ when compared to month 12. Serum and urinary telopeptides as well as IGFBP-3 were measured in a subgroup of 21 patients.

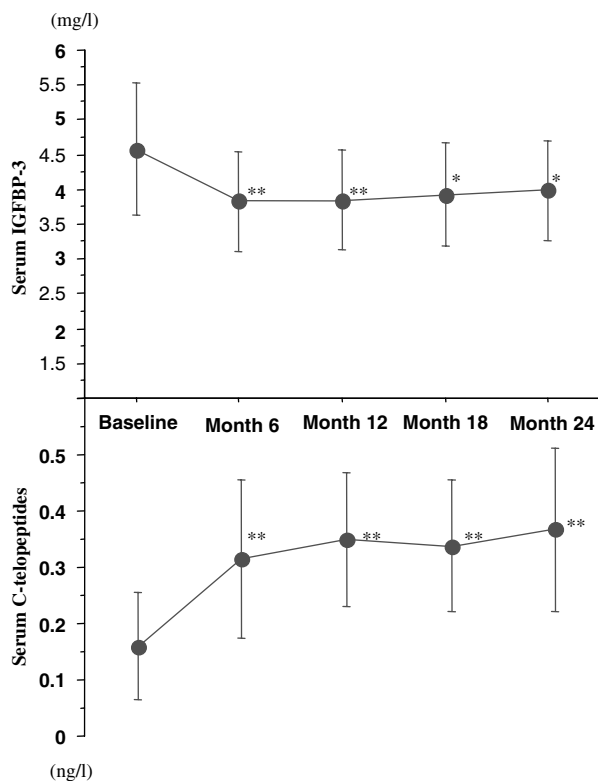


Figure 3 Modifications of serum IGFBP-3 and serum C-telopeptides during 24 months after gastric banding; data are given as mean values \pm s.d. (* $P < 0.01$ and ** $P < 0.001$ when compared to baseline).

and then stabilized too (Figure 3), whereas IGF-1 remained unchanged over the 2y.

Bone mineral density and bone mineral content

Changes in bone mineral content and bone mineral density are summarized in Table 3.

Total BMC decreased exceeding the threshold of the significant change (3%) in 23 patients (62%) after 24 months

($P < 0.001$). However, total BMD remained unchanged. Interestingly, the decrease of total BMC was correlated with the rise of serum telopeptides as well as with the changes in body composition. Thus, the increase in serum telopeptides was higher in those patients who lost the most total BMC ($P = 0.0001$; $r = -0.74$). A significant and positive correlation was also found between the decrease of total BMC and the decrease of fat mass ($P = 0.002$; $r = 0.71$): the higher the loss of fat mass, the higher was the observed loss of total BMC. At the femoral neck, we observed a decrease of BMC and BMD, which were both correlated with the decrease of waist circumference ($P = 0.002$; $r = 0.50$ and $P < 0.0001$; $r = 0.61$, respectively). Furthermore, the decrease of BMD at the femoral neck was also significantly correlated with decrease of hip circumference ($P < 0.001$; $r = 0.55$) (see Figure 4). The same observation was made for the decrease of BMD at the level of trochanter, which was also significantly correlated with the changes in waist ($P = 0.0001$; $r = 0.52$) and hip ($P < 0.0001$; $r = 0.52$) circumference. The decrease of fat-free mass correlated positively with the decrease of BMD at the trochanter ($P = 0.03$; $r = 0.35$), but not with the changings at other sites.

Thus, patients with the biggest decrease in waist and hip circumference also had the biggest decrease in BMC and BMD at the femoral neck and in BMD at the trochanter.

Discussion

The aims of this study were: (1) to demonstrate the absence of secondary hyperparathyroidism 2y after LAGB; (2) to evaluate bone metabolism by the follow-up of its biological markers; (3) to observe the evolution of BMC and BMD by DXA-absorptiometry.

Our results allow us to draw four main conclusions. First, there was no evidence of secondary hyperparathyroidism 2y after LAGB. Second, starting from month 12, we observed a stabilization of bone markers. Third, the bone remodelling occurring in our patients could be correlated with a decrease of IGFBP-3. Finally, serum telopeptides seem to be the most

Table 3 Bone mineral content (BMC) and bone mineral density (BMD) measured at 6, 12 and 24 months after gastric banding

	Total BMC (g)	Total bone area (cm ²)	Total BMD (g/cm ²)	L ₂ -L ₄ BMC (g)	L ₂ -L ₄ bone area (cm ²)	L ₂ -L ₄ BMD (g/cm ²)	Trochanter BMC (g)	Trochanter bone area (cm ²)	Trochanter BMD (g/cm ²)	Femoral neck BMC (g)	Femoral neck area (cm ²)	Femoral neck BMD (g/cm ²)
Baseline	2693	2280	1.18	15.97	14.4	1.1	9.52	11.2	0.85	5.29	5.5	0.97
Range	2230–3570	2091–2642	1.03–1.35	12.06–24.99	12.4–17.5	0.84–1.41	7.16–14.44	8.9–15.2	0.69–1.04	4.14–6.31	4.7–6.1	0.81–1.14
Month 6	2698	2250	1.2***	17.04***	15.1	1.13*	9.96***	11.8	0.84	5.25	5.5	0.95*
Range	2260–3580	1985–2672	1.02–1.39	12.46–27.6	12.8–18.1	0.89–1.52	7.61–15.07	9.5–15.8	0.69–1.01	3.95–6.25	4.8–6.2	0.82–1.10
Change (%)	0.19		1.44	6.67		2.36	4.6		-0.59	-0.76		-1.55
Month 12	2661**	2229	1.19	17.39***	15.3	1.14**	9.9**	11.9	0.83**	5.25	5.6	0.95***
Range	2230–3510	1944–2562	1.04–1.37	13.02–27.58	12.7–18.5	0.90–1.66	7.18–13.84	10.1–14.9	0.67–1.02	4.14–6.37	5.0–6.1	0.82–1.11
Change (%)	-1.19		0.93	8.84		3.54	4		-2.12	-0.76		-2.28
Month 24	2599***	2177	1.19	17.25***	15.4	1.12	9.65	12.1	0.79***	5.04***	5.5	0.91***
Range	2110–3400	1949–2556	1.00–1.36	13.1–27.77	12.9–18.5	0.9–1.5	7.21–14.25	10.1–16.5	0.61–0.99	3.88–6.26	4.8–6.3	0.77–1.11
Change (%)	-3.49		0.93	7.99		1.91	1.38		-6.48	-4.8		-5.79

L₂-L₄ BMC = (BMC of L₂+BMC of L₃+BMC of L₄)/3; L₂-L₄ bone area = (area of L₂+area of L₃+area of L₄)/3. L₂-L₄ BMD = (BMD of L₂+BMD of L₃+BMD of L₄)/3. Data are given as mean value, and percentage change from baseline. *P<0.05; **P<0.01; ***P<0.001.

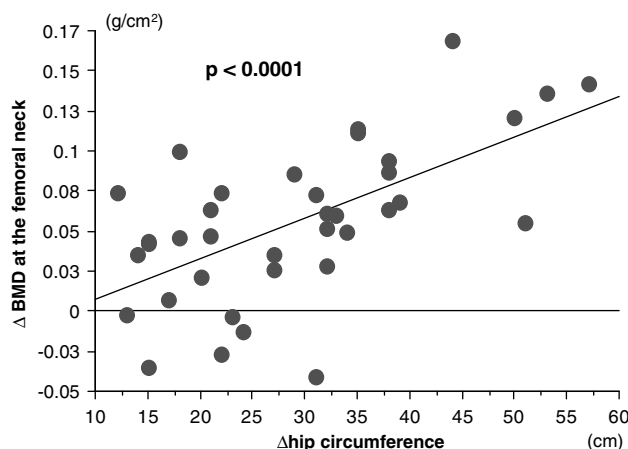


Figure 4 Correlation between modification of hip circumference and decrease of BMD at the femoral neck; data are given as the difference (absolute value) between mean value at month 24 and mean value at baseline.

accurate parameter to evaluate bone remodelling during major weight loss in obese women.

LAGB caused very significant changes in body weight and composition in our patients, as they lost 33% of their initial body weight. These changes were especially dramatic during the first year, but were still observed after 2 y. The weight loss after 2 y largely exceeded the weight loss achieved by the patients of Cundy *et al*¹⁶ who studied the effects of vertical banded gastroplasty (VBG)—which is also a purely restrictive procedure—on bone metabolism in a group of 18 obese patients (14 premenopausal women, two postmenopausal and two men). In fact, their patients lost only 21% of their initial body weight.

Our hypothesis, which was that no secondary hyperparathyroidism would occur during the second year of follow-up, was confirmed by the stability of PTH supported by the absence of a significant decrease of serum calcium. To our knowledge, this is the first study documenting these trends after LAGB. It is in accordance with that of Cundy *et al*¹⁶ who observed the same evolution of calcium and PTH 2 y after VBG. In a more recent study, Coates *et al*¹⁷ also showed decreased bone mass and increased turnover without secondary hyperparathyroidism 9 months after laparoscopic gastric bypass surgery, suggesting that the rise of PTH which has been observed in older studies may be due to a prolonged inadequate intake in calcium and vitamin D₃ after surgery or to their malabsorption.

There was a slight, but statistically significant, rise of vitamin D₃ over the 24 months, despite the absence of oral vitamin supplementation. This rise cannot be explained by the seasonal variability of vitamin D₃ levels, as the measures at baseline, month 12 and 24 were always carried during the same season for each patient. Thus, we propose three other hypotheses which could explain this increase in vitamin D₃. First, Wortsman *et al*¹⁸ suggested that the lower levels of

circulating vitamin D₃ levels in the obese, in comparison to its lean counterpart, may be attributable to its excessive storage in the subcutaneous fat, which is more abundant in the obese. Thus, once an important weight loss occurs, vitamin D₃ may become more available in the blood because of the decrease of fat mass. Second, the major weight loss experienced by our patients may have encouraged them to increase their outdoor activities, and consequently their exposure to sun, with a consequent increase in vitamin D₃ production. Third, an increased dietary intake in vitamin D₃ cannot be excluded.

Interesting conclusions can also be drawn from the evolution of several markers of bone metabolism. Alkaline phosphatase remained stable during the first year, but decreased significantly thereafter, whereas γ -GT decreased mainly during the first year. The evolution of these two parameters probably represents, at least partially, the reversal of hepatic steatosis, which has been observed after major weight losses in obese subjects.¹⁹ However, the fact that alkaline phosphatase, which is also a marker of bone formation, decreased later than and independently from gamma-GT may also indicate a late decrease of bone formation, even if alkaline phosphatase is not a specific marker of bone formation. The very significant rise of serum telopeptides shows an increased bone resorption during the first year, followed by a stabilization. Thus, the decrease of alkaline phosphatase and the rise of serum telopeptides suggest a negative bone remodelling balance over the 2y.

In the absence of secondary hyperparathyroidism, the possible diminution of bone formation could be explained by the significant decrease of IGFBP-3, which we observed during the first year. However, these results must be interpreted with some caution, as the hyposomatotropinism of obesity appears to be associated with normal or high IGFBP-3 serum concentrations:²⁰ thus, the important weight loss occurring after LAGB may contribute by itself to the decrease of IGFBP-3. Moreover, IGF-1, which is a more sensitive marker of bone turnover than IGFBP-3, did not change over the 2y. Systemic osteotropic hormones (IGF-1, IGFBP-3, platelet-derived growth factor, transforming growth factors) play a critical role in the control of bone remodelling, especially in the cortical bone. The insulin-like growth factors affect the synthesis of bone-specific proteins and the proliferation and differentiation of osteoblast precursors.^{21,22} Serum levels of the growth-hormone-dependent growth factors IGFBP-3 and IGF-1 are reduced but positively correlated to BMD in men with idiopathic osteoporosis.²³⁻²⁶ Now, the distribution of cortical bone varies in the skeleton. In the lumbar spine, cortical bone comprises only about a third of the total bone content, whereas the trochanteric area contains about 50% and the femoral neck 75% of cortical bone, the remainder being cancellous bone.²⁷ Thus, the apparently selective decrease in bone density at these two latter sites could partially be explained by these differences. However, the increased bone

resorption, which seems to be predominant in our subjects, still lacks an explanation.

Another factor potentially involved in bone remodelling is the reduced level of sex steroids usually observed during weight loss and fat mass reduction. As the menstrual cycle is irregular for several months after surgery, because of the effect of anesthesia and the rapid weight loss, sex hormones cannot be reliably measured in these patients with no definite cycle. This is illustrated by the preliminary results of serum oestradiol, assessed in the first 10 patients of our study, which showed a large intraindividual variability. Therefore, we could not evaluate the sex steroids and their possible correlations with changes in bone turnover.

Finally, the reduction in bone density at weight-bearing sites like femoral neck and trochanter, could be the consequence of the changing load on these sites. In fact, as Edelstein and Barrett-Connor²⁸ suggested, the relationships between body weight and bone density are strongest at weight-bearing sites, at least in older white adults.

Although the results provided by dual-energy X-ray absorptiometry suggest a decrease of bone mineral density at the trochanter and the femoral neck over the 2y of follow-up, they must be interpreted with caution. In fact, we noted a significant positive correlation between the decrease of hip circumference and the decrease of BMD at the femoral neck and at the trochanter. This seems to confirm the hypothesis that the DXA method has a limited accuracy in evaluating the BMD in obese patients and during weight loss. In 1998, Van Loan *et al*²⁹ observed that the variability of BMD is low for depths of 5–20 cm, but increases significantly when depths exceed 25 cm, as this is the case in severe obesity. Pietrobelli *et al*³⁰ found a fat estimation error due to variation in soft tissue hydration. Tohill *et al*³¹ but also Spector *et al*³² agree in reporting problems with the method used, which could result from the use of a fat distribution model that is not adequate. The lean and fat components can only be determined in areas that contain no bone. Fat around bone increases falsely BMD, as it was shown by Madsen *et al*³³ by placing porcine lard on the body of women before measuring BMD with DXA. Thus, the effective decrease of BMD at the trochanter and the femoral neck, and consequently also the discrepancy between this decrease and the gain in lumbar BMD in our patients are probably lower than suggested by DXA.

In conclusion, our study confirms the absence of secondary hyperparathyroidism 2y after LAGB in premenopausal obese women, despite major weight loss. It shows however a negative bone remodelling balance during the first post-operative year, which could at least partially be explained by the decrease of IGFBP-3. This could be an indication for a calcium and vitamin D supplementation, especially during the first postoperative year. Moreover, the association between modifications of anthropometric parameters, like hip circumference, and changes in BMD at the femoral neck and the trochanter, suggest that DXA may not be an accurate method to evaluate BMD during major weight loss in obese

subjects. Serum C-telopeptides appear as the most accurate parameter for the follow-up of bone metabolism during important weight loss.

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