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Original article

Changes in bone metabolism and densitometry after metabolic/bariatric surgery: a comparison of pre- and postoperative results in a prospective long-term study

Daniel M. Felsenreich, P.D., M.D, Ph.D.[a,*], Natalie Vock, M.D.[a,*], Lea Pedarnig, M.D.[a], Benjamin Fiedler, Cand. Med.[a], Iris M. Nöbauer-Huhmann, P.D., M.D.[b], Julia Jedamzig, P.D., M.D.[a], Lisa Gensthaler, M.D.[a], Larissa Nixdorf, M.D.[a], Paula Richwien, M.D.[a], Rebeka Jörg, M.D.[a], Christoph Bichler, M.D.[a], Magdalena Mairinger, P.D., M.D., Ph.D.[a], Felix B. Langer, P.D., M.D.[a], Gerhard Prager, P.D., M.D.[a,*]

[a]*Division of Visceral Surgery, Department of General Surgery, Medical University of Vienna, Vienna, Austria*
[b]*Division of Neuroradiology and Musculoskeletal Radiology, Department of Biomedical Imaging and Image Guided Therapy, Medical University of Vienna, Vienna, Austria*

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Abstract

Background: Metabolic and bariatric surgery (MBS) is associated with sustained weight loss and metabolic improvement. However, the understanding of its long-term effects on skeletal health remains incomplete, particularly with respect to different surgical procedures.

Objectives: This study aimed to evaluate long-term changes in bone metabolism, bone mineral density (BMD), and fracture risk after sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB), and one-anastomosis gastric bypass (OAGB).

Setting: University hospital.

Methods: In this retrospective cohort with prospective long-term follow-up, 60 patients (20 RYGB, 20 OAGB, and 20 SG) underwent primary MBS. Dual-energy X-ray absorptiometry–derived bone densitometry and bone metabolism markers were assessed preoperatively and after a mean follow-up of 10.1± 2.5 years. Measurements included BMD, T-score, and z score at lumbar spine and femoral neck. Ten-year fracture probability was estimated using the FRAX (Fracture Risk Assessment tool) score.

Results: Bone metabolism markers largely remained within reference ranges throughout follow-up. Serum vitamin D levels increased significantly after all procedures reflecting postoperative supplementation. In contrast, significant reductions in femoral BMD was observed after all three procedures (SG: .99 ± .14 to .49 ± .17 g/cm^2, $P = .03$; RYGB: 1.09 ± .80 to .59 ± .17 g/cm^2, $P = .02$; OAGB: 1.11 ± .18 to .53 ± .13 g/cm^2, $P = .01$), whereas lumbar spine BMD showed no significant change. FRAX-estimated 10-year risk for major osteoporosis and hip fractures was elevated at long-term follow-up.

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Ethical approval: The local ethical committee of the Medical University of Vienna has approved this follow-up study (reference number: 1034/2021).

Informed consent: Informed consent was obtained from all participating patients.

*Daniel M. Felsenreich and Natalie Vock co-first authors and contributed equally to this study.

*Correspondence: Gerhard Prager, Department of General Surgery, Medical University of Vienna, Waehringer Guertel 18-20, Vienna 1090, Austria.

E-mail address: gerhard.prager@meduniwien.ac.at (G. Prager).

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Conclusions: Despite largely preserved biochemical bone markers, substantial long-term structural bone loss and increased fracture risk were observed after MBS. These findings support the consideration of routine postoperative bone health surveillance following MBS to allow early therapeutic intervention when indicated. (Surg Obes Relat Dis 2026;■:1–8.) © 2026 American Society for Metabolic and Bariatric Surgery. Published by Elsevier Inc. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

Keywords: Densitometry; Bone density; Bone metabolism; One-anastomosis gastric bypass; Sleeve gastrectomy; Roux-en-Y gastric bypass; Fracture risk

Obesity and its associated medical complications have been increasing worldwide. Beside lifestyle changes and dietary support, different types of obesity management medications, endoscopic, and surgical treatments are available. Metabolic and bariatric surgery (MBS) is currently the therapy with the best long-term outcomes in terms of weight loss and remission/improvement of obesity-related medical complications. Sleeve gastrectomy (SG), Roux-en-Y gastric bypass (RYGB), and one-anastomosis gastric bypass (OAGB) are currently the most frequently performed procedures worldwide [1]. While the metabolic effects of MBS are well established, its long-term effects on skeletal health remain a subject of ongoing investigation.

Bone loss and increased fracture risk have been reported after MBS [2], particularly following hypoabsorptive procedures, but most available data are limited to short-term or midterm follow-up. Furthermore, comparative long-term data between different metabolic/bariatric procedures are scarce [3]. Bone health is affected by multiple factors following MBS, including rapid weight loss, reduced mechanical loading, altered gut hormone signaling, changes in calcium and vitamin-D absorption, and factors related to aging and hormonal changes, such as menopause. Understanding long-term skeletal alterations is clinically relevant, as reduced bone density is associated with fractures, functional impairment, and increased healthcare utilization. Currently, follow-up densitometry scans after MBS are not included in metabolic and bariatric guidelines.

The aim of this study was to assess long-term changes in bone metabolism markers, dual-energy X-ray absorptiometry (DXA)–derived bone mineral density (BMD), and fracture risk over a mean follow-up of more than 10 years after SG, RYGB, and OAGB.

Methods

Study design and population

This study was designed as a retrospective cohort analysis with prospective long-term follow-up examinations. A total of 60 patients who underwent primary MBS at the Medical University of Vienna before December 31st 2021 were included.

Twenty patients each underwent SG, RYGB, or OAGB. Patients with previous bariatric procedures, revisional surgery, or major postoperative complications were excluded. Participants were recruited from a larger institutional cohort based on availability of preoperative DXA data and willingness to participate in long-term follow-up assessments. All patients provided written informed consent.

Outcome parameters

Baseline and follow-up data included sex, age, body weight, body mass index (BMI), excess weight loss (EWL), and total weight loss (TWL).

Bone metabolism markers

Serum parameters assessed preoperatively and at follow-up included calcium, phosphate, vitamin D, parathyroid hormone (PTH), alkaline phosphatase (AP), bone-specific AP (BAP), C-terminal telopeptide (CTX), osteocalcin, and procollagen type-1 N-terminal propeptide (P1NP). Whereas basic bone metabolism parameters are gathered postoperatively once a year in all patients, these parameters were analyzed for this study.

Whereas serum calcium reflects the mineral availability for bones and is tightly regulated by hormones, phosphate is required for bone mineralization and hydroxyapatite formation. Vitamin D is essential for calcium absorption and normal bone mineralization. PTH regulates calcium homeostasis by stimulating bone resorption and AP indicates overall osteoblastic activity but lacks bone specificity. However, BAP is a specific marker of osteoblastic bone formation. CTX reflects osteoclast-mediated bone resorption and osteocalcin is a marker of bone formation and turnover. Finally, P1NP reflects type I collagen synthesis and bone formation.

Densitometry

According to the International Society for Clinical Densitometry, densitometry is a diagnostic imaging technique using DXA to measure BMD and assess fracture risk [4]. For this study, preoperative densitometry as well as

KEY POINTS

- Bone mineral density shows significant decreases in long-term follow-up after metabolic and bariatric surgery (MBS).
- Bone metabolism markers remain largely unchanged over mean follow-up of 10.1 ± 2.5 years after MBS.
- Long-term follow-up after MBS is associated with a high 10-year fracture risk as assessed by the Fracture Risk Assessment tool score.

densitometry at the time of the follow-up included measurements at the lumbar spine as well as at the femoral neck. The first variable is BMD, which is the absolute mineral content of bone, expressed in g/cm^2 and in % difference compared to a healthy young adult population. Further, the T-score compares BMD to that of a healthy young adult reference population, and the *z* score compares BMD to an age- and sex-matched reference population. Both scores report the standard deviation (SD) in comparison to the reference population [4]. Whereas the *z* score is mainly used for male patients below 50 years of age and premenopausal women, the T-score focuses on male patients above 50 and postmenopausal women [4].

Further variables (only of the postoperative densitometry) are the overall 10-year major osteoporotic fracture risk and the hip fracture risk calculated by FRAX (Fracture Risk Assessment tool). FRAX calculation includes BMD of the femoral neck, age, sex, BMI, previous fractures, smoking, glucocorticoid use, rheumatoid arthritis, secondary osteoporosis, and alcohol consumption [5].

BMD in % and FRAX analysis were only available in the follow-up density scan as these values were not documented/measured in earlier years.

Surgical techniques and vitamin supplementation

Detailed descriptions of surgical techniques of the three procedures, SG [6], RYGB [7], OAGB [8], as performed at the Medical University of Vienna have been published previously.

Patients received specific multivitamin pills for bariatric patients, meant for lifelong intake, on a daily basis. Vitamin dosages in the multivitamin pills differ between the three procedures and were checked annually. Further, calcium citrate (including vitamin D) was also taken on a daily basis.

Statistical analysis

Due to the lack of data in the literature, this study was set up as a pilot study with a small number of patients in each group. Therefore, no power analysis was performed. The descriptive data in this study were presented as percentage or mean with SD. Comparisons of blood values and densitometry data before and after surgery were performed using a paired *t* test for normally distributed variables and a confidence interval of 95%. A *P* value of $<.05$ was considered as significant. Ten-year fracture risk was calculated using the FRAX tool. Statistical calculations were performed using SPSS® v28 for Windows (IBM Corporation).

Results

Sixty patients (20 SG, 20 RYGB, and 20 OAGB) were enrolled in this study with a minimal follow-up of 5 years and a mean follow-up of 10.1 ± 2.5 years. Follow-up (SG was 9.4 ± 3.3 years, for RYGB 10.7 ± 2.0 years and for OAGB 10.1 ± 1.6 years) was not significantly different between the groups ($P = .11$). Follow-up of more than 10 years was reached in 8/20 SG patients, 15/20 RYGB patients, and 11/20 OAGB patients. Complete follow-up was available in all patients selected for this study.

Baseline characteristics and history of weight

Forty out of 60 patients (66.7%) were female with a mean weight and BMI at surgery of 125.1 ± 15.8 kg and 43.6 ± 5.0 kg/m^2 (Table 1). Eight male patients were aged below 50 and 21 female patients were premenopausal at the initial densitometry. Twelve male patients were above 50 years of age and 19 female patients postmenopausal at this time. For the follow-up densitometry after a mean 10.1 ± 2.5 years later, only eleven male patients were above 50 and 10 female patients were premenopausal (9 male patients above 50 and 20 female patients postmenopausal). There were no statistical differences between the groups in terms of sex, age, weight, and BMI between the three groups.

At the time of collecting follow-up data for this study, weight and BMI had decreased to 86.8 ± 18.4 kg and 30.2 ± 5.8 kg/m^2, with an EWL of 74.7 ± 29.4% and TWL of 30.5 ± 11.2%. TWL and EWL were slightly higher after OAGB than after RYGB and SG, nevertheless, due to the small sample size, these differences were not statistically significant (Table 1). The mean age at the time of the primary procedure was 42.4 ± 11.6 and 52.5 ± 11.5 years at the time of the study (Table 1).

Bone metabolism markers

All measured blood markers of calcium, phosphate, AP were within a normal range preoperatively and at long-term follow-up (after a mean of 10.1 ± 2.5 years) and have not changed significantly. Preoperative serum vitamin D levels were below the normal range in all patient groups. Serum Vitamin D levels increased significantly after all three procedure types: from 55.1 ± 40.3 to 85.7 ± 47.6 nmol/l after SG ($P = .02$), from 34.5 ± 19.3 to

Table 1
Baseline characteristics and history of weight

	All patients (n = 60)	SG (n = 20)	RYGB (n = 20)	OAGB (n = 20)>	*P* value
Sex (female) (%)	66.7	60.0	75.0	65.0	.24
Age at MBS (years)	42.4 ± 11.6	40.4 ± 12.9	41.8 ± 11.3	44.5 ± 10.1	.25
Age at follow-up (years)	52.5 ± 11.5	49.8 ± 12.2	52.5 ± 11.6	54.6 ± 9.8	.17
Previous MBS (%)	.0	.0	.0	.0	N/A
Weight at MBS					
Weight (kg)	125.1 ± 15.8	123.4 ± 19.6	127.9 ± 13.5	124.1 ± 14.0	.60
BMI (kg/m^2)	43.6 ± 5.0	42.3 ± 4.4	45.7 ± 5.3	42.7 ± 4.9	.42
Weight at follow-up					
Weight (kg)	86.8 ± 18.4	91.4 ± 23.8	87.9 ± 13.4	80.6 ± 14.5	.19
BMI (kg/m^2)	30.2 ± 5.8	31.2 ± 7.2	31.4 ± 5.0	27.8 ± 4.1	.11
Change BMI	12.7 ± 6.2	11.1 ± 6.8	14.3 ± 6.0	19.9 ± 5.8	.08
TWL (%)	30.5 ± 11.2	26.3 ± 12.8	31.5 ± 10.5	34.7 ± 8.3	.07
EWL (%)	74.7 ± 29.4	68.4 ± 36.6	70.4 ± 21.5	86.5 ± 24.	.13
Follow-up					
Mean follow-up (years)	10.1 ± 2.5	9.4 ± 3.3	10.7 ± 2.0	10.1 ± 2.0	.11

SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; OAGB = one-anastomosis gastric bypass; MBS = metabolic and bariatric surgery; BMI = body mass index; EWL = excess weight loss; TWL = total weight loss; N/A = not available.
Bold indicates statistical significance ($P < .05$).

66.4 ± 26.1 nmol/l after RYGB ($P = .01$), and from 33.6 ± 13.9 to 66.5 ± 30.5 nmol/l after OAGB ($P = .01$), reflecting postoperative supplementation. Mean PTH levels were within the normal range before and after all three operations with levels between 45.7 ± 18.3 pg/ml (before OAGB) and 60.5 ± 27.8 pg/ml (after OAGB).

Other bone metabolism markers including BAP, CTX, osteocalcin, and P1NP showed numerical increases consistent with increased bone turnover, although these changes did not reach statistical significance (Table 2).

Densitometry

BMD in g/m^2, T-score, and *z* score were available for all three operations before and after a mean follow-up of 10.1 ± 2.5 years after the surgery (reviewer 3#8). BMD

Table 2
Blood panel values preoperatively and at the end of the mean follow-up (10.1 ± 2.5 yr)

	SG pre-OP n = 20	SG post-OP n = 20	*P* value	RYGB pre-OP n = 20	RYGB post-OP n = 20	*P* value	OAGB pre-OP n = 20	OAGB post-OP n = 20	*P* value
Calcium in mmol/l (2.15–2.50)*	2.3 ± 0.1	2.3 ± 0.1	.26	2.4 ± 0.1	2.3 ± 0.1	.84	2.4 ± 0.1	2.3 ± 0.1	.53
Phosphate in mmol/l (.81–1.45)*	1.0 ± 0.3	1.1 ± 0.2	.15	1.1 ± 0.2	1.2 ± 0.2	.92	1.0 ± 0.2	1.1 ± 0.2	.18
Vitamin D in nmol/l (75–250)*	55.1 ± 40.3	85.7 ± 47.6	**.02**	34.5 ± 19.3	66.4 ± 26.1	**.01**	33.6 ± 13.9	66.5 ± 30.5	**.01**
PTH in pg/ml (15–65)*	52.1 ± 25.1	57.4 ± 34.4	.30	55.1 ± 21.7	53.9 ± 24.6	.40	45.7 ± 18.3	60.5 ± 27.8	.55
BAP in ng/ml (4.9–26.6)† (5.2–24.4)‡	10.8 ± 4.7	12.3 ± 6.9	.10	15.8 ± 3.8	15.6 ± 5.9	.33	12.1 ± 4.8	18.2 ± 8.5	.06
AP in U/l (35–105)*	92.5 ± 43.5	73.9 ± 30.0	.40	87.2 ± 27.4	82.3 ± 18.8	.10	76.3 ± 22.5	96.5 ± 36.7	.06
CTX in ng/ml (.03–.37)† (.09–.44)‡	.37 ± 0.2	.37 ± 0.2	.27	.37 ± 0.2	.42 ± 0.3	.33	.36 ± 0.1	.46 ± 0.4	.25
Osteocalcin in ng/ml (11–36)† (14–46)‡	20.6 ± 11.4	24.4 ± 15.6	.26	18.0 ± 7.6	27.3 ± 11.3	.32	14.9 ± 4.6	34.2 ± 16.3	.70
P1NP in ng/ml (20–75)† (28–92)‡	48.2 ± 20.6	50.8 ± 21.2	.07	70.0 ± 41.1	62.3 ± 25.3	.15	48.3 ± 15.4	73.1 ± 45.4	.43

SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; OAGB = one-anastomosis gastric bypass; BAP = bone-specific alkaline phosphatase; AP = alkaline phosphatase; PTH = parathyroid hormone; CTX = C-terminal telopeptide; P1NP = procollagen type-1 N-terminal propeptide; OP = operation.
Bold indicates statistical significance ($P < .05$).
* Normal values.
† Normal values for men and premenopausal women.
‡ Normal values for postmenopausal women.

change in % in comparison to a healthy young adult population and fracture risk were only available postoperatively. Lumbar spine BMD did not change significantly over time. In contrast, femoral neck BMD declined significantly after SG (from .99 g/m^2 ±.14 to .49 g/m^2 ±.17 [P = .03]), RYGB (from 1.09 g/m^2 ±.80 to .59 g/m^2 ±.17 [P = .02]), and OAGB (from 1.11 g/m^2 ±.18 to .53 g/m^2 ±.13 [P = .01]).

Looking at BMD change in % as compared to a healthy young adult population, decreased levels were found in the follow-up examinations after all three operations for both regions (lumbar spine and femoral neck), whereas the lowest levels were observed after SG and RYGB at the femoral neck (−5.7% ± 14.7 and −4.6% ± 16.3). Except the z score of the lumbar spine after SG, all other T-scores and z scores of the lumbar spine and the femoral neck decreased significantly after a mean follow-up of 10.1 ± 2.5 years after the operations when comparing pre- and postoperative results (see Table 3 and Fig. 1).

The 10-year risk for a typical osteoporotic fracture based on the FRAX score was 13.6% ± 10.4 in the SG group, 12.7% ± 10.8 in the RYGB group, and 9.9% ± 8.7 in the OAGB group. For a hip fracture, the 10-year risk was also highly increased with 5.3% ± 6.6 after SG, 4.7% ± 6.8 after RYGB, and 3.7% ± 6.1 after OAGB (Table 3).

Discussion

This study provides long-term comparative data on skeletal health after SG, RYGB, and OAGB. Despite largely preserved biochemical bone markers, significant long-term structural bone loss was observed over time, particularly at the femoral neck, accompanied by increased fracture risk. These findings highlight a possible dissociation between biochemical bone markers and structural skeletal changes in a long-term follow-up after MBS.

Bone metabolism after MBS

For a comprehensive evaluation of bone metabolism and structure, the assessment of bone-specific blood parameters is essential. In the present study, most preoperatively measured bone-related laboratory parameters were within the normal range in patients with obesity, except for vitamin D levels. At the long-term postoperative follow-up of mean 10.1 ± 2.5 years, these parameters remained within the reference range, and no significant changes were observed.

Comparable findings have been reported in previous studies: Almeida et al. [9] compared bone metabolism biomarkers between patients 2–5 years after RYGB and a control group, and observed significant differences in phosphate, vitamin D, PTH, CTX, and P1NP levels between

Table 3
Densitometry preoperatively and at the end of the mean follow-up (10.1 ± 2.5 yr)

	SG pre-OP n = 20	SG post-OP n = 20	P value	RYGB pre-OP n = 20	RYGB post-OP n = 20	P value	OAGB pre-OP n = 20	OAGB post-OP n = 20	P value
BMD lumbar spine in (g/m^2) (.9–1.3)*	1.03 ± .13	.96 ± .12	.45	1.05 ± .14	.96 ± .16	.33	1.44 ± 1.33	.95 ± .18	.21
BMD lumbar spine in (%)†	NA	−2.6 ± 10.3	NA	NA	−.9 ± 16.2	NA	NA	−2.2 ± 12.8	NA
T-score lumbar spine in (SD) (>−1.0)*	−.50 ± 1.03	−.94 ± .83	.29	−.04 ± 1.14	−.76 ± 1.42	**.01**	−.67 ± 1.34	−1.29 ± 1.36	**.01**
z score lumbar spine in (SD) (>−2.0)*	−.31 ± 1.01	−.11 ± .88	.33	−.41 ± 1.18	−.72 ± 1.34	**.04**	−.36 ± 1.33	−.54 ± 1.36	**.04**
BMD femoral neck in (g/m^2) (.75–1.05)*	.99 ± .14	.49 ± .17	**.03**	1.09 ± .80	.59 ± .17	**.02**	1.11 ± .18	.53 ± .13	**.01**
BMD femoral neck in (%)†	NA	−5.7 ± 14.7	NA	NA	−4.6 ± 16.3	NA	NA	−3.9 ± 20.5	NA
T-score femoral neck in (SD) (>−1.0)*	.26 ± 1.11	−1.15 ± 1.17	**.01**	1.17 ± 1.07	−1.00 ± 1.22	**.01**	.68 ± 1.59	−1.48 ± 1.14	**.01**
z score femoral neck in (SD) (>−2.0)*	.44 ± 1.28	−.33 ± 1.05	**.00**	1.51 ± .92	−.26 ± .99	**.04**	1.41 ± 1.50	−.46 ± 1.11	**.02**
Fracture risk osteoporosis in (%)‡ (<10%)*	NA	13.6 ± 10.4	NA	NA	12.7 ± 10.8	NA	NA	9.9 ± 8.7	NA
Fracture risk hip in (%)‡ (<1%)*	NA	5.3 ± 6.6	NA	NA	4.7 ± 6.8	NA	NA	3.7 ± 6.1	NA

SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; OAGB = one-anastomosis gastric bypass; BMD = bone mineral density; SD = standard deviation; OP = operation; NA = not available.

Bold indicates statistical significance (P < .05).

* Normal values.

† In % as a reference value of a healthy young adult population.

‡ Ten-year fracture risk based on the FRAX score including BMD and clinical risk factors.

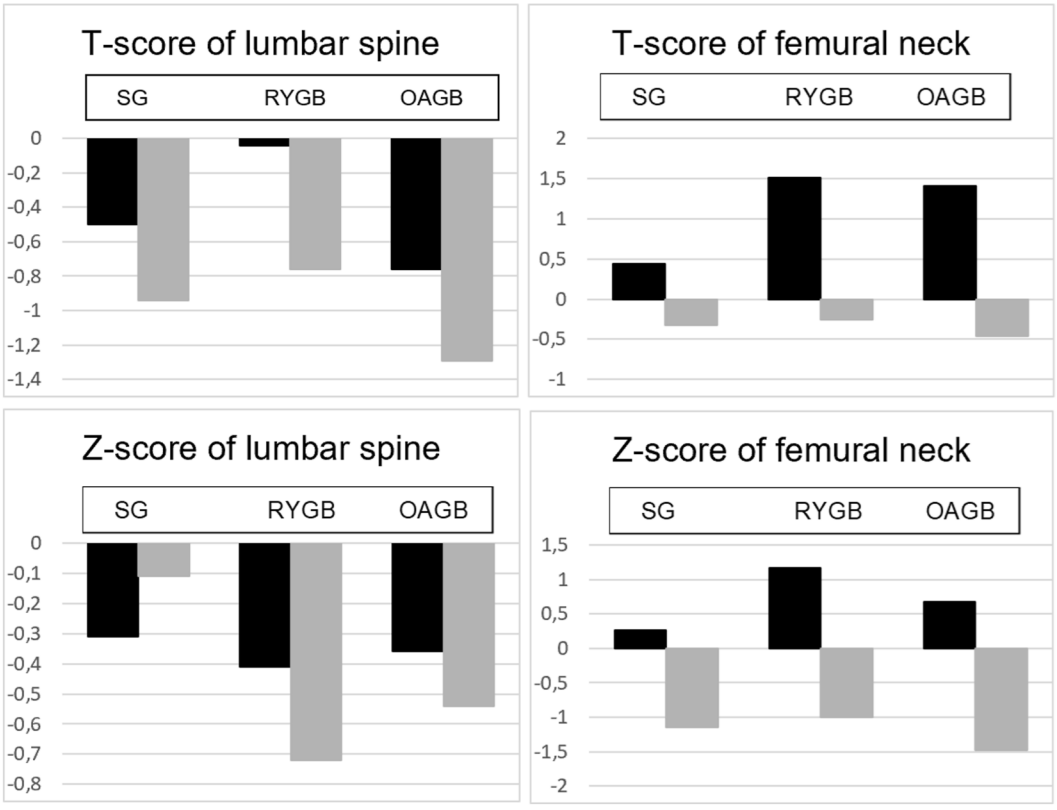

Fig. 1. Pre- and postoperative T-scores and *z* scores of the lumbar spine and the femoral neck. Preoperative results are in black, and postoperative results are in gray. SG = sleeve gastrectomy; RYGB = Roux-en-Y gastric bypass; OAGB = one-anastomosis gastric bypass.

the two groups. Similarly, Lindemann et al. reported decreased CTX and P1NP levels over 10 years after RYGB compared to a control group, while PTH and calcium remained within normal ranges. This effect was not observed after gastric banding in their study [10]. However, both studies lacked preoperative baseline measurements in the surgical cohorts, limiting direct comparison with the present findings. Nevertheless, despite differences compared with control populations, bone metabolism parameters remained within reference ranges in both studies, which is consistent with the results of the current analysis. Thus, it is still unclear if the well-preserved biochemical parameters in the setting of bone density loss after MBS represent a compensatory mechanism of the bone homeostasis in the setting of reduced axial load after weight loss or if the parameters are just not sensitive enough for testing this issue.

Further, reactive hyperparathyroidism is well known in the literature after MBS [11]. In this study, the mean PTH was within the normal range after all three procedures. Nevertheless, especially in the postoperative OAGB group, the PTH levels were relatively high—patients in this group had levels above 65 pg/ml, that is, a mild reactive hyperparathyroidism.

Vitamin D represented the only parameter that showed a clear postoperative improvement. Patients in the SG group were able to achieve normal vitamin D levels at mean 10.1 ± 2.5-year follow-up, whereas patients who underwent bypass procedures still had slightly lower levels. A study by Luger et al. [12], which measured vitamin D levels before OAGB and 12 months after surgery, reported similar findings, with increasing vitamin D levels postoperatively.

The increase in vitamin D levels after MBS is an expected effect due to postoperative vitamin supplementation and mainly reflects patient compliance. Nevertheless, patient compliance for postoperative vitamin supplementation was not measured in this study but is generally poor in bariatric/metabolic patients as described in the literature [13]. Furthermore, achieving normal vitamin D levels appears to be easier after SG than after hypoabsorptive procedures, where a significant intestinal bypass may impair vitamin absorption.

Bone densitometry after MBS

Although routine densitometric assessment before and after MBS is currently not recommended in most guidelines, bone density represents an important aspect of long-term

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metabolic health that should not be neglected. In general, bone density may show a positive correlation with lumbar BMD and BMI, as demonstrated in a study by Su et al. [14] including 3708 patients, suggesting protective mechanical effects in higher BMI categories. Consequently, substantial weight loss following MBS may reduce skeletal loading and contribute to bone loss.

Previous studies have consistently demonstrated early declines in bone density after MBS: Yuan et al. [2] reported reductions in BMD of −3.19% at the lumbar spine and −8.35% at the femoral neck within the first year after MBS. Another study comparing pre- and postoperative bone density after MBS reported similar findings, with decreasing BMD levels of −3.49% at the lumbar spine and −5.25% at the femoral neck [15]. Both studies demonstrated that bone loss begins early after MBS, even starting within the first postoperative year. Further, decreasing BMD levels in the literature and in this study as well seem to be more frequent at the femoral neck than in the lumbar spine region. A hypothesis for this effect could be the mechanical unloading in the femoral hip region compared to the lumbar spine, which leads to more bone loss. Further the cancellous (spongy) bone, which is highly metabolically active, is more present in the lumbar spine region and therefore seems to have a protective effect on the bone [16].

In the current study, mean BMD values and T-scores were below the normal range in nearly all postoperative measurements after a mean follow-up of 10.1 ± 2.5 years. A T-score below −1, which was observed postoperatively (after mean 10.1 ± 2.5 years) across all three surgical procedures—particularly at the femoral neck—corresponds to low bone mass and is associated with an increased fracture risk. However, a relatively large SD of BMD values suggests considerable interindividual variability. While some patients developed substantial bone loss, others maintained BMD within the normal range. A randomized controlled study by Diniz-Sousa et al. [17] found that exercise programs are an effective strategy to ameliorate bone health in patients after MBS. These findings support the potential role of postoperative screening strategies to identify patients with low bone density and to initiate early therapeutic interventions in order to prevent fractures [18].

Due to the lack of existing data in this field, this study was conducted as a pilot study without power analysis and with only a small number of patients. Therefore, the significant findings of this study should be interpreted with caution. Further studies with larger cohorts could focus on the identification of patients at risk.

Importantly, the present data indicate that bone density reduction after MBS is not merely a transient phenomenon but may persist during long-term follow-up. Particular attention should therefore be paid to women who reach menopausal status during the MBS follow-up period, as these two factors contributing to bone loss may have an additive effect.

Risk of fractures after MBS

Reduced bone density is a well-established risk factor for fractures. The FRAX score incorporates clinical risk factors and previous fracture history to estimate an individual (age- and sex-adjusted) 10-year fracture risk.

Studies based on large populations have reported an increased fracture risk after MBS: A Danish nationwide cohort study including 16,121 RYGB patients and 1509 SG patients, matched to 408,580 controls, demonstrated a significantly increased risk of any fracture, including major osteoporotic fractures, after both procedures. The overall fracture risk increased by 56% after RYGB and 38% after SG [19].

Similarly, a propensity score-matched study by Hadi et al., including 26,431 patients in both RYGB and SG groups, reported a higher incidence of osteoporotic fractures after MBS during a 3-year follow-up. RYGB was associated with a higher fracture risk compared to SG, leading the authors to conclude that SG may be the preferred procedure in patients with an elevated baseline risk of osteoporosis [20].

In the present study, an increased risk of osteoporotic fractures, as assessed by the FRAX score, was observed after a mean of 10.1 ± 2.5 years after all three surgical procedures. In particular, the risk of hip fractures was several times higher than expected in an age-matched, general population. As fractures are often associated with prolonged recovery periods and may require orthopedic surgery, this complication should be prevented whenever possible and prophylactic treatment initiated if indicated [18]. However, the SD was also high, indicating substantial variability, and not all patients exhibited an increased fracture risk. Therefore, studies with larger sample sizes are necessary to further evaluate potential differences between surgical procedures.

Furthermore, bone density is of particular clinical relevance as some patients undergo MBS specifically to become eligible for joint replacement. Any deterioration in skeletal quality may adversely affect the outcome of any following orthopedic operations.

Limitations

In order to minimize potential confounders that could influence the study outcome, only patients without previous or subsequent bariatric procedures were included. Nevertheless, a potential limitation of this study is that only 20 selected patients per group who were willing to participate were included, which may have resulted in selection bias. In addition, patients who underwent preoperative densitometry were older at the time of follow-up, which could lead to an overestimation of bone density loss, as increasing age itself is associated with declining bone density. However, most densitometry parameters are adjusted for age and sex and are therefore comparable to the preoperative measurements. Patients' pre- and postoperative hormonal status was not available, which would be interesting to look into

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in a future study, especially in women in the postoperative period.

Furthermore, due to the pilot study design, only a small sample size was included to detect potential differences between the groups. As a result, smaller differences between the three surgical procedures may have remained undetected. Potential confounding factors (sex, age, BMI, menopausal status, etc.) within the treatment groups may differ in this study. Therefore, further studies with larger sample sizes and appropriate power analyses and propensity score matching are required.

Conclusion

This pilot study demonstrates a significant age- and sex-adjusted decrease in BMD after MBS, with no significant differences observed between the procedures SG, RYGB, and OAGB.

Furthermore, a relatively high risk for femoral neck fractures was identified across all three surgical procedures. Bone-related blood parameters were not significantly affected during long-term follow-up after MBS. Patients undergoing MBS may benefit from postoperative densitometry during follow-up to enable early therapeutic intervention when indicated.

Disclosures

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