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ORIGINAL ARTICLE

Repercussions of bariatric surgery on bone mineral density: a comparative analysis between Roux-en-Y gastric bypass and sleeve gastrectomy

VISUAL ABSTRACT

Purpose: This manuscript sought to evaluate the effects of **Roux-en-Y Gastric Bypass** and **Sleeve Gastrectomy** on bone mineral density and calcium and vitamin D intake after three years of surgery.

	Sex	Multivitamins	Pre-BMI	Current BMI	Min. Exercise	Lean body mass	EWL
RYGB (n=41)							
Femur z-score	0.403*	0.358*	-0.085	-0.021	0.190	-0.069	-0.190
SG (n=25)							
Femur z-score	-0.146	-0.114	0.178	0.079	0.049	0.181	0.226

Spearman's correlation. *p<0.05. BMI: body mass index; EWL: excess weight loss; RYGB: Roux-en-Y gastric bypass; SG: sleeve gastrectomy.

This study showed a low percentage of patients with bone involvement after RYGB and GS. The type of surgery was not a significant factor in changing BMD. However, it was observed that in all patients with osteopenia and osteoporosis there was a low intake of calcium and vitamin D and almost all did not adhere to the multivitamin treatment.

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ARTICLE HIGHLIGHTS
- Bone impairments are rare following bariatric surgery
- There is no difference regarding bone mineral density between SG and RYGB
- Bariatric patients generally present a low intake of calcium and vitamin D, with poor adherence to supplements and diet recommendations in the long-term

CENTRAL MESSAGE
Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) are currently considered the most used surgical techniques for the treatment of patients with severe obesity. Despite all the benefits, these surgeries seem to interfere with the bone composition of patients. A reduction in serum concentrations of vitamin D and calcium has already been documented during the postoperative follow-up of patients submitted to RYGB, especially in the first 12 months after surgery. In addition, previous studies on bone densitometry have also shown a significant increase in the incidence of osteopenia and osteoporosis in the same context of postoperative RYGB, especially in patients with serum calcium deficit in the preoperative period.

PERSPECTIVES
This study showed a low percentage of patients with bone involvement after RYGB and GS. The type of surgery was not a significant factor in changing bone mineral density. However, it was observed that in all patients with osteopenia and osteoporosis there was a low intake of calcium and vitamin D, and almost all did not adhere to the multivitamin treatment. Despite the findings of the present study, further investigations are essential to establish the real mechanisms and progression of bone impairment after bariatric surgery.

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ORIGINAL ARTICLE

Repercussions of bariatric surgery on bone mineral density: a comparative analysis between Roux-en-Y gastric bypass and sleeve gastrectomy

Repercussões da cirurgia bariátrica na densidade mineral óssea: uma análise comparativa entre o Bypass gástrico em Y de Roux e a gastrectomia vertical

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ABSTRACT

Background: Malabsorption of micronutrients including calcium and vitamin D may lead to pathological bone fractures in the late postoperative period of bariatric surgery. **Aims:** The aim of this study was to evaluate the effects of Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) on bone mineral density (BMD) and calcium and vitamin D intake after 3 years of surgery. **Methods:** Cross-sectional study that included 66 patients in the late postoperative period of bariatric surgery to analyze their BMD. Anthropometric and demographic data were collected, and a 24-hour recall questionnaire was carried out to assess food consumption patterns. BMD was assessed by bone densitometry of the femur and spine, and the values were expressed as z-scores. **Results:** The mean age was 40.1 years, 86.4% were female. RYGB was performed in 60.3% and SG in 39.7%. There was no significant difference between the techniques when comparing anthropometry, body composition, and food consumption patterns. There was a positive correlation, after RYGB, between femoral z-score, calcium and vitamin D intake, and multivitamin supplementation. A total of 12.7% of the sample had compromised bones, and among these, 87.5% underwent RYGB, 100% had inadequate consumption of calcium and vitamin D, and 12.5% were in menopause. **Conclusions:** A small percentage of the sample showed bone loss after RYGB and SG. The type of surgery was not a significant factor in changing BMD. However, all those affected had a low intake of calcium and vitamin D.

Keywords: Bone Density. Bariatric Surgery. Diet. Bone Diseases, Metabolic. Obesity.

RESUMO

Racional: A má absorção de micronutrientes, incluindo cálcio e vitamina D, pode predispor à fraturas patológicas no pós-operatório tardio de cirurgia bariátrica. **Objetivos:** Avaliar os efeitos do *bypass* gástrico em Y de Roux (BGYR) e a gastrectomia vertical (GV) na densidade mineral óssea (DMO) e na ingesta de cálcio e vitamina D após 3 anos da cirurgia. **Métodos:** Estudo transversal que incluiu 66 pacientes no pós-operatório tardio de cirurgia bariátrica para avaliação da DMO. Foram coletados dados antropométricos e demográficos, e um recordatório de 24h foi aplicado para avaliar os padrões de consumo alimentar. DMO foi avaliada através de densitometria óssea do fêmur e coluna lombar e os valores foram expressos através do z-score. **Resultados:** A média de idade foi de 40,1 anos, 86,4% foram do sexo feminino. BGYR foi realizado em 60,3% da amostra, e a GV em 39,7%. Não houve diferença significante entre as técnicas em relação aos dados antropométricos, composição corporal e padrão de consumo alimentar. Houve correlação positiva, no grupo BGYR, entre o z-score do fêmur, ingesta de cálcio e vitamina D e suplementação multivitamínica. 12,7% da amostra apresentaram densidade óssea comprometida e, dentre estes, 87,5% foram submetidos ao BGYR, 100% apresentaram consumo insuficiente de cálcio e vitamina D e 12,5% encontravam-se no climatério. **Conclusões:** Uma pequena porcentagem da amostra apresentou perda de DMO após BGYR e GV. O tipo de cirurgia não foi um fator significante na perda de DMO. Contudo, todos os pacientes afetados apresentavam baixa ingesta de cálcio e vitamina D.

Descritores: Densidade Óssea. Cirurgia Bariátrica. Dieta. Doenças Ósseas Metabólicas. Obesidade.

INTRODUCTION

Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) are currently considered the most used surgical techniques for the treatment of patients with severe obesity[6]. Despite all the benefits, these surgeries seem to interfere with the bone composition of patients. This reality can be explained, in part, by the malabsorption of specific nutrients, such as calcium and vitamin D, which primarily make up the bone mineral matrix. This phenomenon occurs most frequently after RYGB[3,17]. It may occur because in RYGB there is a decrease in food exposure to bile and pancreatic acids, causing impairments to the digestion and absorption of nutrients in a greater proportion when compared to SG[1,12]. A reduction in serum concentrations of vitamin D and calcium has already been documented during the postoperative follow-up of patients submitted to RYGB, especially in the first 12 months after surgery[9]. In addition, previous studies on bone densitometry have also shown a significant increase in the incidence of osteopenia and osteoporosis in the same context of postoperative RYGB, especially in patients with serum calcium deficit in the preoperative period[9].

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Taking into account the facts presented above, there is a need to understand the long-term repercussions of these surgeries (RYGB and SG), not only in relation to bone mineral density (BMD) parameters, but also in relation to micronutrients intake patterns and physical exercise during the postoperative period[11]. There are still a few studies that have evaluated the long-term BMD of patients who underwent bariatric surgery, and the magnitude of bone damage in this population at a later stage is not yet well documented. For this reason, this study aims to evaluate the impact of RYGB and SG on BMD, body composition, and food consumption in patients in the postoperative period (>3 years).

METHODS

Study design

This is a cross-sectional study carried out at our center from April 2019 to November 2020, which analyzed BMD, food consumption patterns, and physical activity of patients in the late postoperative period of bariatric surgery (RYGB or SG). The study included 66 patients undergoing bariatric surgery with a postoperative period of more than 3 years. The research protocol included patients of both genders with ages between 16 and 65 years. Pregnant and lactating patients, patients with metallic implants, patients with permanent pacemakers, and patients with a previous history of pathological fracture surgery were excluded from the analysis. The sample was non-probabilistic, selected through convenience sampling. The study protocol was approved by the Research Ethics Committee of our Institution (CAAE no. 80673217.7.0000.5208). All individuals signed an informed consent.

Anthropometric assessment and body composition

Patients underwent weight and height measurement. Body mass index (BMI) was classified according to age and sex and the World Health Organization (WHO) cutoff points[19]. Body composition was measured by the DEXA (dual X-ray absorptiometry) method using the Lunar Prodigy (GE Health) equipment. Bone mineral content (BMC) (g) and BMD (g/cm^2) of the lumbar region (LR) L2–L4 and femoral head (FH) were evaluated. Patients with a z-score <-1.0 were classified as having bone impairment[19]. The z-score was chosen because its value is based on the mean BMD of patients of the same gender and age group as the patient under study.

Assessment of food consumption and physical exercise

The assessment of the quantitative consumption of calories and macro- and micronutrients was carried out through a 24-hour food recall survey. Data were analyzed by the Diet-box Program following the recommendations of DRI (Dietary Reference Intake)[13,14]. The calculation of food consumption was based on current recommendations for bariatric surgery, with low or adequate intakes defined based on these recommendations[8]. The cutoff values considered for an adequate consumption of calcium and vitamin D were 1200 mg and 3000 UI daily, respectively[14,18]. The study also assessed the supplementation with multivitamins and took into consideration its content to estimate the intake of each nutrient analyzed. Patients used the same formula of multivitamin supplementation (Centrum® adults).

Physical exercise was assessed as a categorical variable. Patients were listed as "yes" for physical exercises when they reported regular practice of at least three times per week for at least 30 minutes of any type of physical activity.

Statistical analyses

Data storage and statistical analysis were performed using SPSS Statistics, version 19.0. Frequencies were described as percentages and analyzed for differences using the χ^2 test or Fisher's exact test, whenever appropriate. The quantitative variables were expressed as mean and standard deviation. When non-normal, they were expressed as medians considering their 25th and 75th percentiles and compared using the non-parametric Mann-Whitney test; when normal, they were analyzed using the Student's t-test. For the analysis of correlations, the Spearman test was used. A $p<0.05$ was considered statistically significant.

RESULTS

The research included 66 patients undergoing surgery, with a mean age of 40.1 years (standard deviation — SD=10.2), 86.4% of whom were female. Regarding the surgical technique, 60.3% (n=41) were submitted to RYGB, while only 39.7% (n=25) were submitted to SG. Table 1 shows the demographic data of the patients studied.

Regarding anthropometric assessment and body composition, there was no statistically significant difference for any of the variables when analyzed according to surgical technique. Similarly, when comparing the food intake of macro- and micronutrients between the groups, there were also no significant differences (Table 2).

The establishment of a correlation between the studied variables and the changes in BMD of the patients showed a statistically significant correlation only with the variables "sex" and "use of multivitamins" in the RYGB group, as Table 3 shows. There was no significant correlation in the SG group.

When evaluating the correlation between variables of BMD and food consumption, there was a positive correlation between the femoral z-score and the consumption of calcium and vitamin D in patients submitted to RYGB. On the other hand, there was no significant correlation in patients who underwent SG (Table 4).

Among the sample, regardless of the type of surgery, 12.7% had bone impairment, which is translated by a z-score <-1.0, and, among these, 87.5% underwent RYGB. In addition, 12.5% were in menopause, and all patients with bone impairment had low dietary intake of calcium and vitamin D, as Table 5 shows.

DISCUSSION

In the current study, there was no significant difference in BMD in relation to the choice of surgical technique. What was observed was a positive correlation of BMD with the use of

Table 1. Demographic data of the studied patients.

Variable	All (n=66)	RYGB (n=41)	SG (n=25)	p-value*
Age (years)	40.1±10.2	41.3±9.3	37.7±11.1	0.164†
Sex				
Male	9 (13.6)	6 (14.6)	3 (12.0)	0.536‡
Female	57 (86.4)	35 (85.4)	22 (88.0)	
Follow-up (years)	5.6±4.1	6.9±4.7	3.44±1.4	0.001†
Physical exercise				
No	36 (54.5)	20 (48.8)	16 (64.0)	0.228*
Yes	30 (45.5)	21 (51.2)	9 (36.0)	
Use of multivitamins				
No	19 (28.8)	12 (29.3)	7 (28.0)	0.912*
Yes	47 (71.2)	29 (70.7)	18 (72.0)	

*χ^2 test; †Student's t-test; ‡Fisher's exact test p<0.05.
RYGB: Roux-en-Y gastric bypass; SG: sleeve gastrectomy.

Table 2. Anthropometric assessment, body composition, and food consumption stratified by surgical technique.

Characteristic	RYGB	SG	p-value*
Anthropometry and body composition			
Current weight (in kg)	83.7±23.2	79.8±21.2	0.489*
Height (meters)	1.6±0.1	1.6±0.7	0.929*
EWL (in kg)	31.42±31.82	32.73±16.38	0.829*
%Fat	41.9±8.0	41.8±7.4	0.921*
Lean body mass (in kg)	46.17±8.88	44.29±10.31	0.463*
Thin/stature	27.9±4.4	27.1±5.2	0.497*
Femur BMD	1.0±0.1	1.1±0.1	0.444*
Spine BMD	1.2±0.2	1.2±0.1	0.726*
Body BMD	1.2±0.1	1.2±0.1	0.457*
Femur BMC	33.0 (28; 36.4)	32.3 (30.1; 37.9)	0.746†
Spine BMC	35.7±7.2	36.1±7.3	0.853*
Body BMC	2.4±0.4	2.5±0.4	0.471*
Femur z-score	-0.1±1.1	0.4±0.8	0.115*
Spine z-score	-0.3 (-1.2; 0.8)	0.2 (-0.4; 0.6)	0.475†
Food consumption			
Calories	1315.1±571.8	1267.4±479.5	0.728*
Proteins	67.6±32.0	62.7±26.6	0.524*
Carbohydrates	149.4±75.0	146.3±60.2	0.863*
Fat	49.1±25.0	47.4±27.7	0.794*
Saturated fat	19.1±12.8	17.2±10.1	0.519*
Monounsaturated fat	15.3±8.3	15.3±9.8	0.968*
Polyunsaturated fat	7.3±5.1	7.6±5.4	0.819*
Trans fat	1.0 (0.5; 2.2)	0.6 (0.2; 1.7)	0.081†
Calcium	698.5±421.7	596.1±360.5	0.317*
Phosphorus	893.7±414.8	803.0±288.1	0.341*
Magnesium	234.5 (151.0; 297.6)	192.4 (151.4; 245.4)	0.387†
Vitamin D	4.2 (1.8; 6.0)	3.9 (1.3; 5.2)	0.606†

*Student's t-test; †Mann-Whitney test, p<0.05.
RYGB: Roux-en-Y gastric bypass; SG: sleeve gastrectomy; EWL: excess weight loss; BMD: bone mineral density; BMC: bone mineral content.

Table 3. Correlation between bone mineral density of the femur by z-score with sex, use of multivitamins, preoperative period, current body mass index, and physical exercise.

	Sex	Multivitamins	Pre-BMI	Current BMI	Min. Exercise	Lean body mass	EWL
RYGB (n=41)							
Femur z-score	0.403*	0.358*	-0.085	-0.021	0.190	-0.069	-0.190
SG (n=25)							
Femur z-score	-0.146	-0.114	0.178	0.079	0.049	0.181	0.226

Spearman's correlation.
*p<0.05.
BMI: body mass index; EWL: excess weight loss; RYGB: Roux-en-Y gastric bypass; SG: sleeve gastrectomy.

Table 4. Correlation between femoral bone mineral density and dietary intake pattern.

	BMC	Z-score	BMD
RYGB (n=41)			
Calories	0.306	-0.137	0.073
Proteins	0.307	0.051	0.110
Carbohydrates	0.241	-0.203	0.093
Lipids	0.386*	0.021	0.161
Calcium	0.253	0.384*	0.284
Phosphorus	0.308	0.161	0.192
Vitamin D	0.046	0.340*	0.230
SG (n=25)			
Calories	0.377	0.221	0.326
Proteins	0.366	0.285	0.296
Carbohydrates	0.197	0.067	0.234
Lipids	0.074	0.001	-0.014
Calcium	0.145	0.132	0.145
Phosphorus	0.316	0.306	0.294
Vitamin D	0.057	0.89	0.034

Spearman's correlation.
*p<0.05.
BMC: bone mineral content; RYGB: Roux-en-Y gastric bypass; SG: sleeve gastrectomy.

multivitamin supplementation and with the dietary intake of calcium and vitamin D; that is, those patients with higher dietary intakes of calcium and vitamin D (through regular diet or multivitamin supplementation) presented higher z-scores for BMD in the femur. Furthermore, it was found that 12.7% of the included patients had bone impairment and, among them, 87.5% had undergone RYGB and had low calcium and vitamin D intakes. In addition, 12.5% were in menopause.

Despite the largely demonstrated benefits of bariatric surgery in the treatment of obesity, evidence suggests the occurrence of associated nutritional disorders and changes in bone metabolism, such as increased bone turnover and low BMD[3]. A cohort that evaluated the bone profile after bariatric surgery presented findings similar to those observed in the present study, showing a greater bone loss after RYGB in comparison with SG[5]. It is noteworthy that, during the first 12 months after surgery, there is a 280% increase in osteoclast activity, indicating an increase in bone resorption despite the use of vitamin D and calcium supplementation. This phenomenon slows down after the first postoperative year, as pointed out by Cadart et al.[5]

A case–control study carried out by Tangalakis et al. with patients undergoing RYGB found a reduction in bone mineral content after 12 months of surgery, with a significant decrease in BMD of the ribs and lumbar spine (p<0.05)[16]. Saad et al. carried out another case-control, involving 44 teenagers and young adults undergoing bariatric surgery, and also found significant reductions in BMD z-scores in the femoral neck, spine, and hip areas within 12 months after surgery[9].

The mechanism for the occurrence of issues in bone metabolism after surgery has not yet been completely identified, but some hypotheses explain its occurrence, as demonstrated by a meta-analysis that gathered 13 studies suggesting reduction of bone mass with weight loss; hormonal changes in leptin, adiponectin, insulin, GLP-1 (glucagon-like peptide-1), ghrelin; changes in the gastrointestinal tract after surgery leading to vitamin D and calcium malabsorption; and possible changes in parathyroid hormone (PTH)[17]. In the kidney, PTH is the main stimulator of vitamin D synthesis, while vitamin D exerts negative feedback on PTH secretion. Both are fundamental elements for maintaining the phosphate/calcium balance. PTH raises calcium levels and suppresses phosphate metabolism, while vitamin D stimulates calcium and phosphate metabolism in order to provide sufficient minerals for bone formation[17]. That meta-analysis concluded that patients treated with RYGB had lower levels of calcium than patients undergoing SG, higher levels of phosphorus, and were more likely to have secondary hyperparathyroidism. There was no difference in BMD when comparing the surgical techniques. This was possibly due to the short follow-up time and the scarcity of studies on this topic[17]. The deleterious effects of bariatric surgery on the bone matrix are not yet fully understood, but it is already known that after 2 years of surgery, the effects become milder[15].

In the present study, when comparing RYGB and SG in relation to body composition, anthropometric assessments, and food consumption of macro- and micronutrients, there were no statistically significant differences. The same situation was reported by Luhrs et al., who studied postmenopausal women in the first year after bariatric surgery[7]. Muschitz et al., who investigated the differences between serum markers of bone turnover, also found no significant differences when correlating BMD with the surgical technique performed[10].

Bredella et al. found no significant differences in weight loss or body composition between the techniques and reported that changes in weight and body composition are mainly associated with bone loss[4]. They explained that mechanical unloading may interfere with the pathophysiology of bone loss after SG. In contrast, they suggested that the bone loss mechanism after RYGB is independent of weight loss. Surgery, by

Table 5. Clinical and nutritional profile of eight patients with bone involvement submitted to Roux-en-Y gastric bypass and sleeve gastrectomy.

Patient	Age (years)	Sex	Surgery time (years)	Surgical technique	Daily exercise time (min)	Supple-mentation	Weight regain	Calcium intake	Vitamin D intake	Meno-pause
1	32	F	3	SG	0	No	No	Low	Low	No
2	28	M	4	RYGB	0	No	No	Low	Low	No
3	54	M	5	RYGB	90	Yes	Yes	Low	Low	No
4	36	F	6	RYGB	45	No	Yes	Low	Low	No
5	56	F	8	RYGB	0	Yes	No	Low	Low	Yes
6	30	F	12	RYGB	0	Yes	No	Low	Low	No
7	35	F	9	RYGB	0	No	No	Low	Low	No
8	33	F	7	RYGB	60	Yes	Yes	Low	Low	No

F: female; M: male; SG: sleeve gastrectomy; RYGB: Roux-en-Y gastric bypass.

isolating the duodenum and proximal jejunum, impairs the absorption of calcium and vitamin D, which are determining factors for bone health. In addition, low hydrochloric acid production after bariatric surgery may further decrease the absorption of these nutrients[4]. Vitamin D deficiency, inadequate calcium intake, and secondary hyperparathyroidism are common in obese individuals, and these metabolic alterations may intensify during the postoperative period[2].

A study carried out by Vasconcelos et al. aimed to assess bone metabolism, BMD, and vertebral fractures in patients with severe obesity, which corroborated our findings[18]. The study reported average calcium and vitamin D intakes below the recommended levels for patients after bariatric surgery. The authors of that study reinforced that the consumption of these micronutrients should not be only through multivitamin supplementation, since the vast majority of them do not contain the daily requirements recommended by guidelines[13,18]. They also reported that, after RYGB, intolerance to foods rich in calcium, such as milk, and low absorption of vitamin D may occur due to poor absorption of fats, and that low calcium absorption, associated with inadequate consumption, may lead to the occurrence of secondary hyperparathyroidism and thus bone impairments[18].

As already mentioned, the prescription of vitamin D and calcium may modify BMD in addition to adequate protein consumption and regular physical exercise, as the study by Muschitz et al. demonstrated[10]. This study differs from ours, as we did not find an association between BMD and physical exercise. It is worth noting that Muschitz's study is an intervention study, methodologically different from ours. The authors also reinforce that oral vitamin D and calcium supplementation in patients undergoing RYGB and SG, compared to people taking no supplementation, leads to higher levels of sclerostin and CTX (C-terminal telopeptide fragment) and normalization of PTH levels[10]. Indirectly, this relationship was observed in the findings of the present study, as evidenced by the higher levels of femur z-score in patients with higher intakes of vitamin D and calcium. However, we could not verify associations with biochemical markers since they were not an objective of the current study.

A randomized clinical trial that examined BMD during weight loss after RYGB found that patients with higher levels of 25(OH) D (vitamin D) >50 nmol/l, in the first postoperative year showed smaller relative decreases in BMD of the lumbar spine, hip, and total body compared to patients with lower levels of vitamin D. They found no association between weight loss and bone loss but observed that lower bone loss was associated with higher concentrations of 25(OH)D during the first postoperative year. Thus, the authors could conclude that high concentrations of 25(OH)D, after high-dose supplementation, in the first post-bariatric year may slow down bone loss[10].

In addition to the factors presented, the strong influence of hormones on bone integrity is known. The protective effect of estrogen on bone tissue is well-demonstrated and known in the literature; however, few data are still available on the decrease in its levels after bariatric surgery[3]. In the current research, we did not measure estrogen levels, but we observed that 12.5% of our sample were in menopause — which is a physiological state marked by hypoestrogenism — and did not present any evidence of bone impairments.

The present study has some issues that must be considered. As limitations, we mention the sample size, the retrospective nature of the analysis, the lack of evaluation of biochemical variables, and the lack of a control group. These factors could complete our findings. As strengths, we highlight the assessment of food consumption, a factor rarely analyzed in the current literature on post-bariatric bone damage.

CONCLUSIONS

This study showed a low percentage of patients with bone involvement after RYGB and GS. The type of surgery was not a significant factor in changing BMD. However, it was observed that in all patients with osteopenia and osteoporosis, there was a low intake of calcium and vitamin D, and almost all did not adhere to the multivitamin treatment. Despite the findings of the present study, further investigations are essential to establish the real mechanisms and progression of bone impairment after bariatric surgery.

AUTHORS' CONTRIBUTIONS

BNSSF: Data analysis, Investigation, Literature review, Writing – original article. ASC: Data analysis. MCA: Conceptualization, Literature review. ATSR: Investigation. FSC: Methodology, Writing – original article. AABF: Conceptualization, Methodology.

DATA AVAILABILITY

The informations regarding the investigation, methodology and data analysis of the article are archived under the responsibility of the authors.

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