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Investigation of the effects of laparoscopic sleeve gastrectomy and laparoscopic one anastomosis gastric bypass on metabolic syndrome components

Vahit Mutlu[1*], Mahmut Arif Yüksek[2], Bülent Koca[3] and Gökhan Selçuk Özbalcı[4]

Abstract

Background Obesity and accompanying comorbidities are serious diseases that impair the quality of life and even threaten human life. Today, the most effective method for providing sustainable weight loss in the treatment of obesity is Bariatric and Metabolic Surgery procedures. In our study, we aimed to compare the therapeutic effects of Laparoscopic Sleeve Gastrectomy (LSG) and One Anastomosis Gastric Bypass (OAGB) on metabolic syndrome components. We also planned to investigate the complications after bariatric and metabolic surgery, whether the patients had recurrent weight gain, and the short, medium and long-term effects.

Methods Patients who underwent bariatric and metabolic surgery with the diagnosis of obesity between December 2012-January 2020 were retrospectively analyzed. 561 patients who were followed up at 3, 6 months, 1, 2 and 3 years after the operation were included in the study. The effects of bariatric and metabolic surgery on metabolic syndrome components were evaluated as partial and complete remission according to the status at the last follow-up. Statistical analysis were performed by SPSS 18. Results were reported as mean ± standard deviation. $P < 0.05$ was accepted as statistical significance.

Results In 516 patients who underwent LSG and 45 patients who underwent OAGB, a decrease in BMI and an increase in EWL(%) values were observed at the 3rd month, 6th month, 1st year and 2nd year controls. In the 3rd year controls of patients who underwent LSG, recurrent weight gain was observed, therefore there was an increase in BMI and a decrease in EWL(%) values compared to the 2nd year. In patients who underwent OAGB, a decrease in BMI continued at the 3rd year, while an increase in EWL(%) values was observed. Thanks to both LSG and OAGB; a remission was achieved at the rates of DM, HT, HL/DL, OSAS, hypothyroidism in the early period. As the follow-up period extended, the rate of patients showing complete recovery decreased for DM($p = 0.0001$). No change was observed during the follow-up period for other parameters.

*Correspondence:
Vahit Mutlu
dr.vahitmutlu@gmail.com
Full list of author information is available at the end of the article

Conclusıon Therapeutic effects of LSG and OAGB on metabolic syndrome components have been demonstrated in our study. However, when DM remission and sustainable weight loss are evaluated, OAGB is more effective in the long term.

Keywords Bariatric/metabolic surgery, Obesity, Metabolic syndrome

Introduction

Each year in the United States, approximately 400,000 obesity-related deaths were reported. Obesity is a problem that threatens public health and, if left untreated, can lead to many fatal diseases related with metabolic syndrome (MS) [1, 2]. Abdominal obesity, nuclear peroxisome proliferator-activated modulation, insulin resistance with or without glucose intolerance, atherogenic dyslipidemia, high blood pressure, and proinflammatory states are included in the core components of the MS [3, 4, 5]. The prevalence of MS criteria is type 2 diabetes mellitus (DM) 15%, hypertension 41.4%, obesity 44.1%, abdominal obesity 56.8%, low HDL-cholesterol 34.1%, hypertriglyceridemia 35.9%, and high LDL-cholesterol 27.4% [6]. Conservative approaches to weight loss, consisting of diet, exercise, and medication, generally do not result in more than a 5–10% loss in body weight, and recurrent weight gain reaches 90% within 5 years after such weight loss [7, 8, 9, 10].

Laparoscopic Sleeve Gastrectomy (LSG) has been preferred more in obesity surgery in recent years with successful short- and medium-term results [11]. LGS also provides significant improvement in diseases accompanying obesity such as type 2 DM, hypertension, hyperlipidemia, obesity-related asthma, OSAS, subclinical hypothyroidism/hypothyroidism and metabolic syndrome [12]. Another method, One anastomosis gastric bypass (OAGB) is an easy technique as it involves fewer anastomoses and the anastomosis is performed distally in the long gastric pouch. OAGB provides better weight loss and more effective improvement in comorbid diseases compared to volume-restrictive techniques [13].

Our aim in this study was to evaluate the therapeutic effects of bariatric/metabolic surgery methods such as LSG and OAGB on metabolic syndrome components (obesity, DM, HT, HL, OSAS and hypothyroidism), and additionally to investigate whether recurrent weight gain, their complications and their short, medium and long-term effects.

Patients and methods

This study was conducted based on the ethics committee approval received from OMÜ KAEK (Ondokuz Mayıs University Clinical Researches Ethics Committee) (with the decision numbered 2020/163 dated 22/04/2020) for the specialization thesis titled “Bariyatrik/Metabolik Cerrahinin Metabolik Sendrom Bileşenleri Üzerine Etkilerinin Araştırılması” (Investigation of the Effects of Bariatric/Metabolic Surgery on Metabolic Syndrome Components) at the Ondokuz Mayıs University, Faculty of Medicine, General Surgery Department. Between December 2012 and January 2020, patients who underwent bariatric/metabolic surgery with the diagnosis of obesity and who had completed at least 3 months after surgery were retrospectively scanned through the examination of the hospital information system and patient files, and those with missing information were contacted to complete the requested information. ASMBS (American Society for Metabolic and Bariatric Surgery)/International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) 2022 guidelines for bariatric surgery indications which supports surgery for Lower BMI thresholds was followed. The ASMBS/IFSO Guidelines recommend metabolic and bariatric surgery for individuals with a BMI of 35 or more regardless of the presence, absence, or severity of obesity-related conditions and that it be considered for people with a BMI of 30-34.9 and metabolic disease [14]. Informed consent was obtained from all participants. 561 patients with no missing preoperative and postoperative 3rd month, 6th month, 1st year, 2nd year and 3rd year information were included in the study. OAGB was performed on 48 patients and LSG was performed on 524 patients. It was observed that 89 out of 561 patients completed the 5th year and their information was available, and this patient group was also evaluated according to our mid- and long-term results. In our study, we evaluated 561 patients who had no missing preoperative and postoperative 3rd month, 6th month, 1st year, 2nd year and 3rd year information. Within 5 year follow up, only 45 AOGB patients were eligible. Although sample size is limited, it has a reliable sample over 30 statistical units as normality consumptions.

Since our study was retrospective, the guideline compliance levels were determined by the guidelines for that period. ASMBS/IFSO 2022, which was released in 2022, recommends bariatric surgery for lower BMI values. Since bariatric surgery was recommended for higher BMI in previous guidelines and surgical indication was in the higher range in the past, all cases are also compatible with ASMBS/IFSO 2022.

In our study, out of 561 patients we examined, we were able to reach only 89 patients who signed the patient consent form with the exclusion and inclusion criteria. Patient selection criteria as inclusion and exclusion were as follows:

Inclusion criteria:

- underwent bariatric/metabolic surgery.
- who had completed at least 3 months after surgery.
- patient files having resarch parameters retrospectively.

Exclusion criteria:

- Having chronical diseases may affect weight regime.
- Having complications which may affect research results.
- Files having lack of research parameters.

In state hospitals, deficiencies in file data, patients going to different health institutions, patients who are out of follow-up, and those who change addresses are quite common. During the period covered by the study, there was a high patient transfer between public and private health institutions in Türkiye. For this reason, there was a serious loss of follow-up in patient follow-up. In each time interval, percentage of follow up dropped due to lost to follow up, changes of health institutions and other reasons. In total, 561 operations including 516 LSG (92,0%) and 45 OAGB (8,0%) were performed within 5-year time interval included in the research.

Operations were performed under accordance of common guidelines and ASMBS/IFSO Guidelines with hospital opportunities. Since the research is patterned in retrospective manner, operation techniques were limited with common public hospital applications.

The effects of bariatric/metabolic surgery on MS components were evaluated according to the status at the last follow-up, as partial and complete remission. Partial recovery criterias were determined for each disease. Quitting the medication being used because of the disease was considered as complete remission, and reducing the dose of the medication was considered as partial remission.

Bariatric applications in obesity surgery are basically determined by the patient's condition, surgeon's preference and ASMBS/IFSO Guidelines. LSG and OAGB are the most frequently preferred methods, which are considered most appropriate for the general conditions of the patients according to the guidelines and surgeons. Therefore, since LSG and OAGB were the two most preferred methods in the five-year follow-up, these two methods were compared.

Patients history, the treatment protocols and medications used by those with Comorbidities, anamnesis-physical examination information has included preoperative height, weight and BMI values, as well as additional diseases and medications used were reported. All patients were questioned preoperatively about whether they had tried to lose weight for at least 6 months by diet, exercise, behavior and lifestyle changes and medical treatment methods. Patients who did not receive support before bariatric/metabolic surgery were asked to apply to dietetics and endocrinology outpatient clinics. For those who could not lose weight despite receiving professional support for at least 6 months, bariatric/metabolic surgery methods were preferred patient-centered according to the indications determined by the National Institutes of Health (NIH). Reference criteria for remission and improvement were selected according to The ASMBS/IFSO Guidelines.

Patient follow-up

Our patients were called for a check-up at 1 month, 3 months, 6 months and 1 year, after this period one time in each year following the operation. It is also recommended that they contact us immediately in case they have any complaints, and if they apply to another center, that center should contact us or these patients can apply to our clinic directly. When they are present for a check-up or if they cannot attend to the check-up in that day, they are contacted by phone and their weight values are recorded. Patients with comorbidities accompanying obesity before the operation, were referred to the departments dealing with comorbidities at each check-up and changes in the treatment of comorbidities were noted. In each follow-up of these patients, complete blood count, biochemistry (lipid panel, liver function tests, kidney function tests and electrolytes), thyroid function tests, HbA1c, vitamin B, vitamin D and folic acid levels were analyzed regularly. Weight values, laboratory values, MS components (Type 2 diabetes, HT, HL, OSAS, CAH, Osteoporosis, Polycystic ovary syndrome, hypothyroidism etc.) of all our patients who completed at least 3 months after bariatric/metabolic surgery, post-surgical remissions of these comorbidities and developing complications were determined. Patients with complications that prevented comparison of the two methods were excluded from the study.

Statistics

SPSS 18 program was used for statistical analysis of data. Results were reported as mean ± standard deviation values and n (%). Normality of data distribution was checked by using Kolmogorov-Smirnov test. Chi-square test or Fischer's Exact test was used when appropriate for evaluation of categorical data. Independent Sample t test was used for the difference between two groups showing normal distribution and Mann-Whitney U test was used for those not showing normal distribution. $P < 0.05$ was considered to be significant.

Table 1 General characteristics and comorbiditieas of the patients

Variable	LSG	OAGB	*p*
Mean age (year) ± SD, (min.-max.)	36,80 ± 11,14 (18–64)	51,58 ± 8,75 (29–68)	0,000[a]
Mean BMI (kg/m2) ± SD, (min.-max.)	45,64 ± 7,24 (34,4–79,6)	46,43 ± 7,67 (35,8–62,2)	0,569[a]
Operation duration (dk) ± SD, (min.-max.)	106,86 ± 40,58 (20–240)	107,13 ± 34,10 (60–180)	0,829[a]
Hospitalization duration (day) ± SD, (min.-max.)	4,71 ± 1,92 (3–36)	6,38 ± 3,32 (3–20)	0,000[a]
Gender, **n (%)**			0,220[b]
Female	379 (73,4)	36 (80,0)	
Male	137 (26,6)	9 (20,0)	
Follow-up Duration(Mounth) n(%)			0,005[b]
Early Period (0–24)	209 (40,5)	17 (37,8)	
Middle Period (25–60)	223 (43,2)	28 (62,2)	
Late Period (61+)	84 (16,3)	-	
ASA Scores n(%)			0,000[b]
ASA-1	467 (90,5)	30 (66,7)	
ASA-2	41 (7,9)	14 (31,1)	
ASA-3	8 (1,6)	1 (2,2)	
Diseases n(%)			
DM	166 (32,2)	38 (84,4)	0,000[b]
HT	130 (25,2)	25 (55,6)	0,000[b]
HL/DL	107 (20,8)	17 (37,8)	0,010[b]
OSAS	42 (8,1)	10 (22,2)	0,005[b]
Hypothyroidism	78 (15,1)	9 (20,0)	0,251[b]

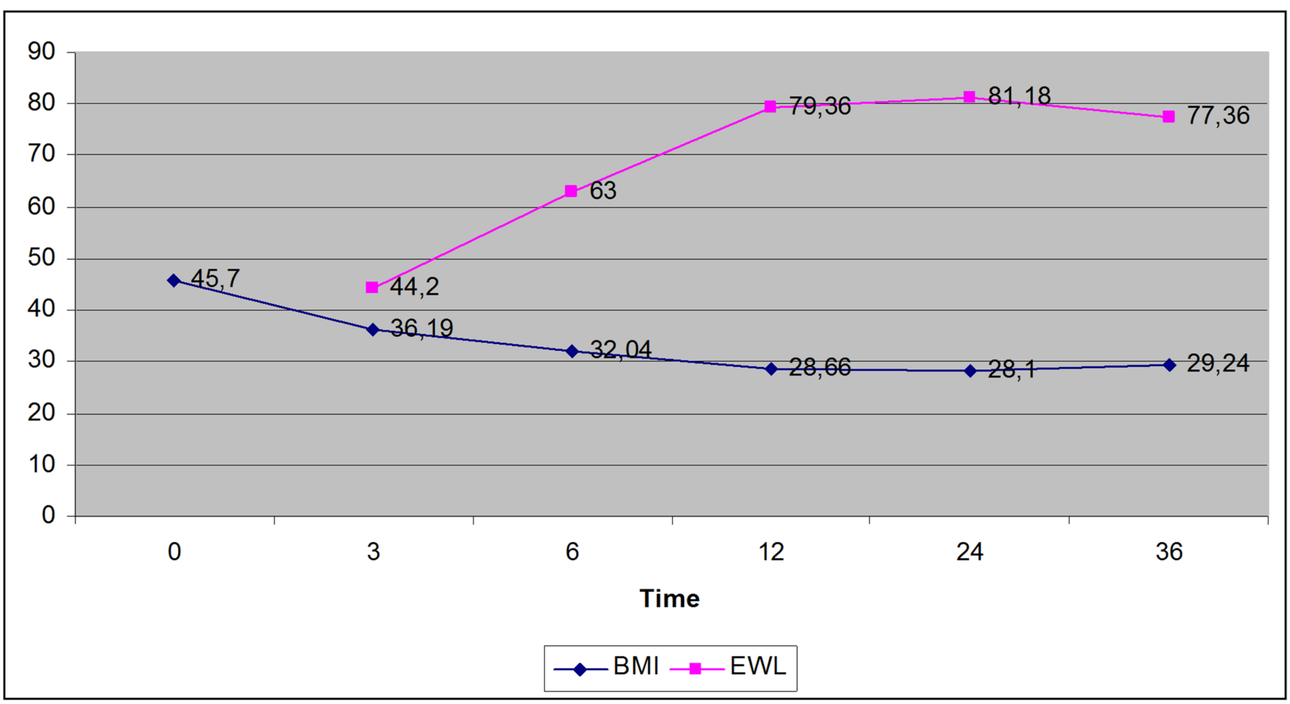

Fig. 1 Changes in BMI and EWL(%) values of 561 patients before and after the operation at 3 months, 6 months, 1 year, 2 years and 3 years

Results

Our study included 561 patients, 415 female and 146 male, with an average age of 38. The general characteristics and comorbidity status of the study group are shown in Table 1. In the patient group who underwent LSG, there were 516 patients, 379 female and 137 male, with an avarage age of 44. In the statistical comparison, there was no significant difference between the two groups in terms of age ($p = 0.81$), gender ($p = 0.541$) and BMI ($p = 0.673$). The mean BMI value was observed in decreasing trend, whereas the mean EWL(%) was increasing trend as expected (Fig. 1).

Mean age ad hospitalization duration means were significantly higher in OAGB group ($p < 0,05$). Follow up was significantly higher in LSG group, whereas ASA score was significantly higher in OAGB group. DM, HT, HL/DL and OSAS were significantly more common in OAGB group ($p < 0,05$) (Table 1).

(a) Mann Whitney U Test, (b) Chi-Square Test, SD: Standard Deviation.

When the mean BMI values of the patients who underwent LSG were compared with the mean pre-operative BMI values, it was determined that there was a significant weight loss in the first two years, but the mean BMI increased at the end of second year, therefore recurrent weight gain was observed (Table 2). The pre-operative BMI values of OAGB treatment were compared with the BMI values of the 3rd month, 6th month, 1st year, 2nd year and 3rd year. OAGB provided a statistically significant decrease in BMI values according to the measurements made on the same individuals after the 3rd month, 6th month, 1st year, 2nd year and 3rd year.

The mean EWL(%) values calculated 3 months after the operation were 44.4 for LSG and 41.75 for OAGB and no significant difference was found between the two means ($p = 0.106$). The mean EWL(%) values calculated 6 months after the operation were 64.48 for LSG and 55.58 for OAGB and were significant in favor of LSG ($p = 0.001$). The mean EWL(%) values calculated 1 year after the operation were 80.13 for LSG and 69.20 for OAGB and the difference between the two means was significant ($p = 0.002$). The mean EWL(%) values calculated 2 years after the operation were 82.05 for LSG and 70.38 for OAGB and the difference between the two means was significant in favor of LSG ($p = 0.012$). The average of EWL(%) values calculated 3 years after the operation was 77.42 for LSG and 75.15 for OAGB, and the difference between the two average values was not significant ($p = 0.252$), (Fig. 2). A 3-month period is not sufficient to reveal the effect of LSG and OAGB on EWL(%), and although the difference becomes quite apparent at the end of 2 years, EWL(%) values tend to approach each other in the 3rd year. (Fig. 3) LSG was performed on 168 patients with IR/DM diagnosis, and partial recovery was 8.93% in 15 patients, and complete recovery was 83.93% in 141 patients. OAGB was performed on 38 patients with DM diagnosis, and partial recovery was 15.79% in 6 patients, and complete recovery was 84.21% in 32 patients.

LSG was performed on 130 patients diagnosed with HT, and partial recovery was 15.38% in 20 patients, and complete recovery was 73.85% in 96 patients. OAGB was performed on 25 patients diagnosed with HT, and partial recovery was 12% in 3 patients, and complete recovery was 76% in 19 patients.

LSG was performed on 107 patients diagnosed with HL/DL, and partial recovery was 14.95% in 16 patients and complete recovery was 60.75% in 65 patients. OAGB was performed on 17 patients diagnosed with HL/DL, and partial recovery was 17.65% in 3 patients and complete recovery was 64.71% in 11 patients.

LSG was performed on 42 patients diagnosed with OSAS, and partial recovery was 2.38% in 20 patients, and complete recovery was 95.24% in 40 patients. OAGB performed on 10 patients diagnosed with OSAS, and partial recovery was 20% in 2 patients, and complete recovery was 70% in 7 patients.

LSG was performed on 78 patients diagnosed with hypothyroidism, and partial recovery was 23% in 18 patients and complete recovery was 50% in 39 patients. OAGB was performed on 9 patients diagnosed with hypothyroidism, and partial recovery was 66.6% in 6 patients and complete recovery was not achieved in any patient (Table 3).

In the evaluation made on DM recovery rates, no significant difference was found between surgical methods ($p = 0.125$). However, 100% of our patients who underwent OAGB have shown complete or partial recovery from DM. It was not found to be significant due to the small number of our patients who underwent OAGB. Despite this, it is understood that OAGB is more effective on DM when looking at the patient group who did not recover (Table 5).

Table 2 The comparison of preoperative mean BMI value and mean BMI value of after LSG operation

Variable	*n*	Median	Min-Max	Z	*p*
Preoperative	516	44	34,4–79,6	-19,548	,000
3 Months Later	516	34,7	25,7–62,5		
Preoperative	461	44	34,4–79,6	-18,605	,000
6 Months Later	461	30,8	22–56,9		
Preoperative	375	44,3	35–79,6	-16,782	,000
1 Year Later	375	27,3	18,4–52		
Preoperative	274	45	35–79,6	-14,348	,000
2 Year Later	274	26,95	19–49,6		
Preoperative	190	45,1	35–79,6	-11,922	,000
3 Year Later	190	28,15	18,6–52,4		

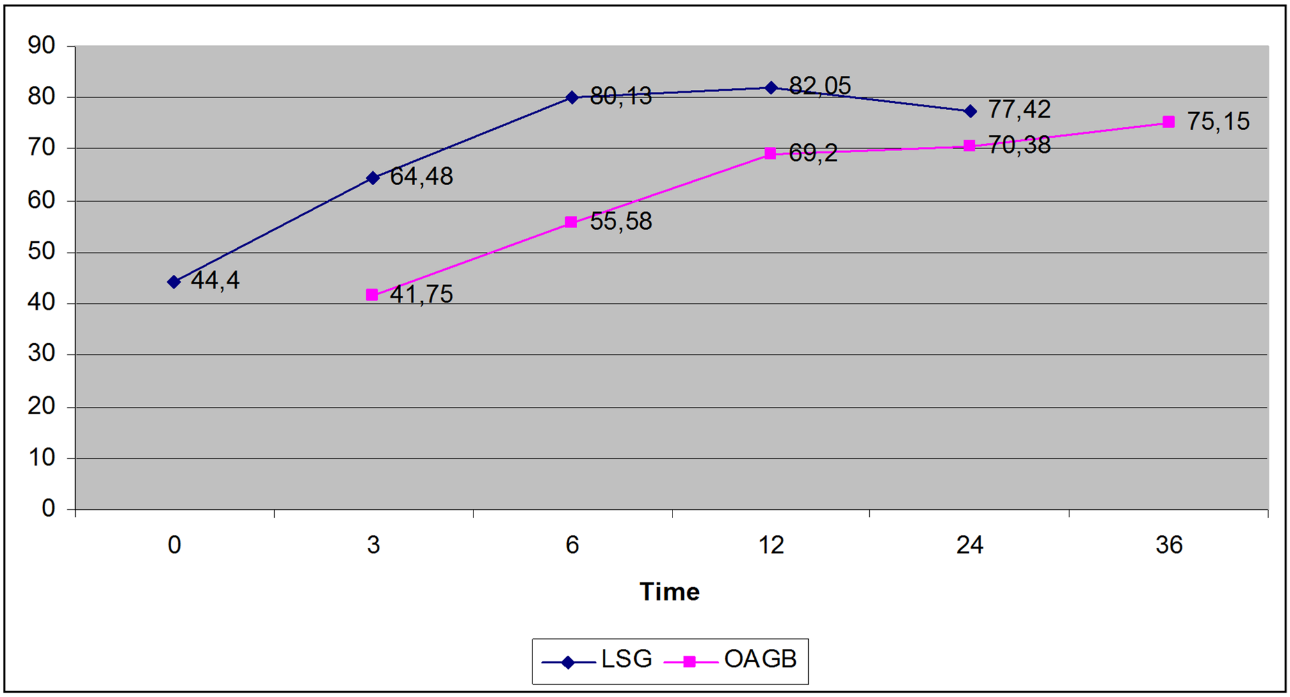

Fig. 2 EWL(%) changes of LSG and OAGB methods in the periods

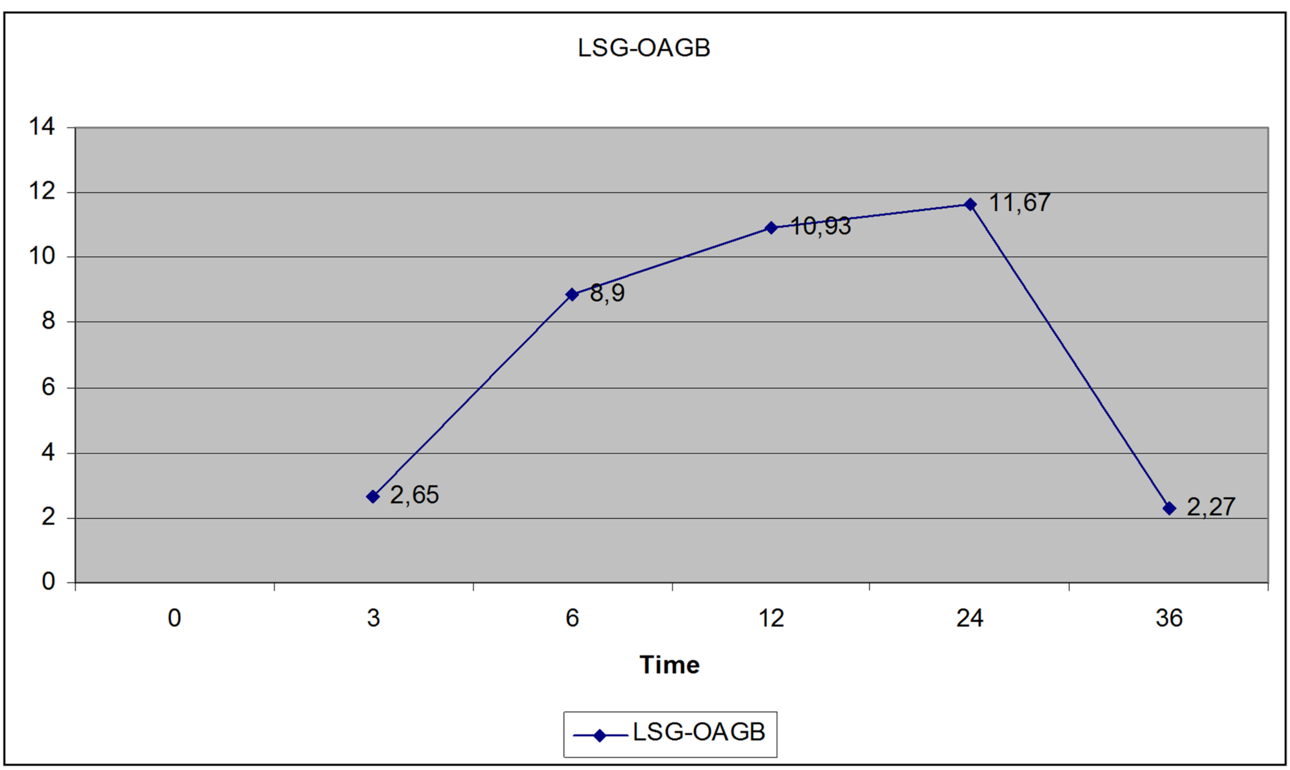

Fig. 3 Periodic changes in EWL(%) differences of LSG and OAGB methods

It was observed that the 25 patients in the study group were MS patients with abdominal obesity, IR/DM, HT and HL/DL comorbidities before the operation. Since waist circumference measurements were not present for the abdominal obesity recovery status of this group of patients, the mean and standard deviation values of BMI before and after the operation were calculated respectively. It was observed that the mean BMI was

Table 3 Recovery values for components of MS according to bariatric surgery methods

LSG						OAGB					
				Recovery status						Recovery status	
Disease	**Status**	**n**	**%**	**n**	**%**	**Disease**	**Status**	**n**	**%**	**n**	**%**
IR/DM	No recovery	12	7,14%	-	-	**IR/DM**	No recovery	0	0,00%	-	-
	Partial recovery	15	8,93%	15	9,62%		Partial recovery	6	15,79%	6	15,79%
	Full recovery	141	83,93%	141	90,38%		Full recovery	32	84,21%	32	84,21%
	Total	168	100,00%	156	100,00%		Total	38	100,00%	38	100,00%
HT	No recovery	14	10,77%	-	-	**HT**	No recovery	3	12,00%	-	-
	Partial recovery	20	15,38%	20	17,24%		Partial recovery	3	12,00%	3	13,64%
	Full recovery	96	73,85%	96	82,76%		Full recovery	19	76,00%	19	86,36%
	Total	130	100,00%	116	100,00%		Total	25	100,00%	22	100,00%
HL/DL	No recovery	26	24,30%	-	-	**HL/DL**	No recovery	3	17,65%	-	-
	Partial recovery	16	14,95%	16	19,75%		Partial recovery	3	17,65%	3	21,43%
	Full recovery	65	60,75%	65	80,25%		Full recovery	11	64,71%	11	78,57%
	Total	107	100,00%	81	100,00%		Total	17	100,00%	14	100,00%
OSAS	No recovery	1	2,38%	-	-	**OSAS**	No recovery	1	10,00%	-	-
	Partial recovery	1	2,38%	1	2,44%		Partial recovery	2	20,00%	2	22,22%
	Full recovery	40	95,24%	40	97,56%		Full recovery	7	70,00%	7	77,78%
	Total	42	100,00%	41	100,00%		Total	10	100,00%	9	100,00%
Hypothyroidism	No recovery	21	26,92%	-	-	**Hypothyroidism**	No recovery	3	33,33%	-	-
	Partial recovery	18	23,08%	18	31,58%		Partial recovery	6	66,67%	6	100,00%
	Full recovery	39	50,00%	39	68,42%		Full recovery	0	0,00%	0	0,00%
	Total	78	100,00%	57	100,00%		Total	9	100,00%	6	100,00%

A detailed comparison was made on the recovery status of individuals with MS components DM, HT and HL/DL according to the follow-up periods. Those who did not recover in case of DM, 2.6% were in the early period, 4.8% in the mid-term and 25.9% in the late period follow-up period. An increase was observed in the rate of patients who did not recover according to the follow-up period. The patients who showed partial recovery, 5.1% were in the early period, 9.5% in the mid-term and 18.5% in the late period follow-up period. Those who showed complete recovery, 92.3% were in the early period, 85.7% in the mid-term and 55.6% in the late period follow-up period. As the follow-up period increased, the rate of patients who showed complete recovery decreased ($p = 0.0001$) (Table 4).

Table 4 Recovery status of MS components in the follow-up times

Disease	Recovery Status	Follow up period				
		Early (3.-24.months)	Middle (24–60.months)	Late (+60 months	Total	p*
		%	%	%	%	
DM	No recovery	2,6	4,8	**25,9**	7,1	**0,0001**
	Partial recovery	5,1	9,5	18,5	8,9	
	Full recovery	92,3	85,7	**55,6**	83,9	
	Total	100,0	100,0	100,0	100,0	
HT	No recovery	7,3	12,0	16,0	10,8	0,4754
	Partial recovery	10,9	18,0	20,0	15,4	
	Full recovery	81,8	70,0	64,0	73,8	
	Total	100,0	100,0	100,0	100,0	
HL/DL	No recovery	29,0	18,4	29,6	24,3	0,5576
	Partial recovery	16,1	18,4	7,4	15,0	
	Full recovery	54,8	63,3	63,0	60,7	
	Total	100,0	100,0	100,0	100,0	

Table 5 Recovery status of DM patients according to surgery method

Recovery Status	Surgery Method			
	LSG	OAGB	Total	p
	%	%	%	
No recovery	7,1	0,0	5,8	0,1258
Partial recovery	8,9	15,8	10,2	
Full recovery	83,9	84,2	84,0	
Total	100,0	100,0	100,0	

Table 6 Recovery status and data of the patient with MS in the study group

Variable	Group	*n*	%
Surgery Method	LSG	17	68,0
	OAGB	8	32,0
	Total	25	100,0
Gender	Erkek	8	32,0
	Kadın	17	68,0
	Total	25	100,0
Age	17–45	11	44,0
	45+	14	56,0
	Total	25	100,0
IR/DM-Postoperative	No recovery	3	12,0
	Partial recovery	5	20,0
	Full recovery	17	68,0
	Total	25	100,0
HT-Postoperative	No recovery	1	4,0
	Partial recovery	4	16,0
	Full recovery	20	80,0
	Total	25	100,0
HL/DL-Postoperative	No recovery	7	28,0
	Partial recovery	7	28,0
	Full recovery	11	44,0
	Total	25	100,0

Table 7 Complications according to bariatric/metabolic surgery methods

Complication	**Surgery Method**					
	LSG		**OAGB**		**Total**	
	n	**%**	***n***	**%**	***n***	**%**
No	495	95,9%	42	93,4%	537	95,8%
Leakage	1	0,2%	0	0,0%	1	0,2%
Bleeding	9	1,7%	2	4,4%	11	2,0%
Neuropathy	5	1,0%	0	0,0%	5	0,9%
Twist	2	0,4%	1	2,2%	3	0,5%
Portomesenteric Thrombosis	2	0,4%	0	0,0%	2	0,4%
Trocar Site Infection	2	0,4%	0	0,0%	2	0,4%
Total	516	100,0%	45	100,0%	561	100,0%

44.86 ± 8.01 before the operation and 31.08 ± 6.07 after the operation. The BMI value decreased by 30.71% compared to the pre-operation BMI value.

We see in the data that patients with MS are older in age, OAGB is preferred at a higher rate in this patient group, and their additional comorbidities recover in a lower scale (Table 6).

Out of 561 patients in the study group, 516 underwent LSG and 45 underwent OAGB. When both patient groups were examined, the major complication (leak) rate was 0.2% for LSG and 0.0% for OAGB. Minor complication rates were similar. No significant difference was found between the groups in terms of the frequency of complications (Table 7).

Discussion

Obesity is the most common metabolic disease in the world today. Obesity is a condition that needs to be combated as it causes psychosocial problems and high cost of treating the comorbidities. Sustainable weight loss is achieved with bariatric surgery, the metabolic effects of obesity are reduced, many comorbidities are improved, and survival increased [11]. Surgery is a part of the multidisciplinary approach in the treatment of morbid obesity. The results of surgical treatment are better in patients who are well-motivated, educated in multidisciplinary evaluations, and who have failed medical treatment [15].

Among bariatric/metabolic surgical techniques, LSG is the most frequently performed one worldwide and is rapidly gaining popularity [16, 17]. Although LSG was initially considered a purely restrictive procedure, we know in our time that it promotes weight loss by inducing anorexia through the removal of most ghrelin-producing cells in the gastric fundus [18]. In general, LSG results in weight loss and remission of most obesity-related comorbidities. LSG has less morbidity than other bariatric operations due to its technical simplicity and limited alteration of normal anatomy [19].

OAGB has made a significant contribution to the strengthening and diversification of bariatric/metabolic surgery. OAGB is a low-risk surgical method with sustainable weight loss with high patient satisfaction. With a short learning curve, new surgeons can minimize complications. In addition, OAGB is easy to reverse or correct [20]. When comparing OAGB and RYGB, OAGB provides advantages with higher first year and second year EWL(%) rates, better type 2 DM remission, and shorter case duration, while other effects are similar [21].

The short-term achievement of postoperative DM remission has not been clearly explained. Decreased energy intake and loss of adiposity play an important role in improving metabolism [22]. Recovery rates are lower than expected in those with a long-standing DM diagnosis and those receiving insulin therapy [23, 24]. In patients whose DM improves during postoperative follow-up, glucose intolerance and insulin resistance develop along with recurrent weight gain in the long term, while 25% of cases are re-diagnosed with DM [25]. Remission rates of 60–70% can be achieved after HT and HL/DL bariatric/metabolic surgery [26].

The SLEEVEPASS study showed that gastric bypass caused more weight loss than LSG [27]. The SM-BOSS study reported that the percentage of BMI loss associated with gastric bypass and LSG was 68% and 61%, respectively [28]. For EWL(%); increasing studies show the effectiveness of LSG. Himpens et al. reported EWL(%) as 77.5% and 57.3% at third year and sixth year, respectively [29]. Long-term LSG patients showed partial or complete remission of diabetes in 77% at sixth year and eighth year [30]. Improvement in lipid profile after LSG, especially HDL and TG levels, total cholesterol/HDL and TG/HDL ratios, was reported without decrease in total cholesterol and LDL levels at 1-year follow-up. Zhang et al. reported that all lipid profiles of patients who underwent LSG improved and that bariatric surgery was effective in the treatment of hyperlipidemia [31].

The development of cardiovascular and cerebrovascular diseases increases in proportion to the duration and degree of hypertension. Therefore, effective normalization of blood pressure is thought to significantly reduce morbidity and mortality [32]. Each 20 mm-Hg increase in blood pressure doubles the risk of death from cardiovascular causes [33]. A meta-analysis found that mean systolic blood pressure decreased by 4.4 mm-Hg and diastolic blood pressure decreased by 3.6 mm-Hg with a mean weight loss of 5.1 kg [34]. There is a direct relationship between EWL(%) and MS improvement. The LSG group had similar morbidity rates even with weight gain during follow-up. The physiological and molecular mechanisms underlying glycemic improvement after metabolic surgery are not yet fully understood, but the effects of hormonal factors are unknown [35, 36].

OAGB is a technically feasible, effective, and safe procedure with a low complication rate in the treatment of obesity and obesity-associated HT, type 2 DM, and hyperlipidemia/dyslipidemia [37]. All studies reviewing OAGB reported that it is effective and significantly improves the treatment of type 2 DM [38, 39]. Two years after OAGB, the remission or cure rate of type 2 DM has been reported to increase from 67% to [38, 40, 41]. Quan et al. reported better remission rates in four significant studies for type 2 DM after OAGB compared with LSG in their meta-analysis [42]. In addition, Kular et al. reported that the 5-year type 2 DM remission rate was significantly better after OAGB [43].

According to the studies of Buchwald et al., the remission rates of MS components after bariatric/metabolic surgery were reported as; 76.8% for type 2 DM complete remission and 85.4% for recovery; 61.7% for HT complete remission and 78.5% for recovery; 70% for HL/DL complete remission and 96.9% for recovery besides 83.6% for OSAS complete remission and 85.7% for recovery (114). After bariatric/metabolic surgery, the quality of life of patients increases by 95%, and the 10-year mortality rate decreases by 30–40% [43].

When the data of 561 patients included in our study were examined, the preoperative BMI average of the general group was 45.7, while the lowest BMI average was 28.1 in the 2nd year and the BMI average was 29.2 in the 3rd year. EWL (%) values were calculated as 44.2% in the 3rd month, 63.8% in the 6th month, 79.36 in the 1st year, 81.18% in the 2nd year and 77.36 in the 3rd year. According to these data, recurrent weight gain occurs after bariatric surgery and this recurrent weight gain begins at the end of the early follow-up period and at the transition to the mid-follow-up period.

According to our results, LSG provides more effective excess weight loss in a shorter period of time, but after the second year, this situation changes in favor of OAGB and OAGB can be considered more effective in long-term sustainable weight loss. Both types of surgery are successful when evaluated with EWL(%).

LSG was performed on 168 patients diagnosed with IR/DM, one of the first and most important components of MS, and partial remission (hbA1c < 7 mmol/l, reduction in drug dose or switching from insulin treatment to oral antidiabetic) was detected in 15 patients at 8.93%, and complete remission (hbA1c < 6 mmol/l and quittance of drug) was detected in 141 patients at 83.93%. OAGB was performed on 38 patients diagnosed with DM, and partial remission was detected in 6 patients at 15.79%, and complete remission was detected in 32 patients at 84.21%. These results are consistent with the literature. However, most studies did not classify remission as partial or complete, therefore changes in response during the follow-up period were not clearly evaluated. When we examine the change according to the follow-up period of DM disease; 2.6% of those without remission were in the early period (before 24 months), 4.8% in the middle period (24 months – 60 months), and 25.9% in the late period (after 60 months) follow-up period. According to the follow-up period, an increase was observed in the rate of patients who did not recover. As of the patients who showed partial remission, 5.1% were in the early period, 9.5% in the mid-term, and 18.5% in the late period. For those who showed complete remission, 92.3% were in the early period, 85.7% in the mid-term, and 55.6% in the late period. As the follow-up period increased, the rate of patients who showed complete remission decreased. In the literature, it has been reported that DM remission decreased by 25% due to weight gain, glucose intolerance, and insulin resistance in the long term [44]. However, in our study, DM remission decreased by 23.3% in the long term, while DM complete remission decreased by 36.7%. Therefore, the decrease in complete remission should be investigated in longer follow-up periods and through more comprehensive studies, because we think that it will be effective in determining the type of surgery for patients with preoperative DM and for ensuring postoperative success. When we examined DM remission according to the type of surgery, no significant difference was found between these surgical methods. However, all our patients who underwent OAGB had complete or partial remission from DM. Due to the small number of patients who underwent OAGB, statistical significance was not found. Despite, it is understood that OAGB is more effective on DM when we look at the patient group who did not recover.

Our results on HT remission are consistent with the literature. HT remission is not significantly affected by variables such as surgery type, follow-up period, age and gender.

Our remission results regarding HL/DL are consistent with the literature. We think that the postoperative effects, remissions and relationships of our patients with preoperative HL/DL and those with fatty liver detected as a result of preoperative USG should be evaluated.

OSAS/obesity-related asthma remission rates in our study are relatively high compared to the literature. We also think that OSAS/obesity-related asthma is one of the MS components that improves most rapidly with the decrease in BMI and increase in EWL(%).

LSG was performed on 78 patients diagnosed with hypothyroidism/subclinical hypothyroidism, and partial remission was 23.08% in 18 patients, and complete remission was 50.0% in 39 patients. OAGB was performed on 9 patients diagnosed with OSAS, and partial remission was 66.67% in 6 patients, and complete remission was not achieved in any patient. The relationship and correlation of hypothyroidism with obesity has been reported in the literature, but there is no clear study on remission after bariatric/metabolic surgery. Therefore, we think that our hypothyroidism remission results are significant, but more detailed studies are needed together with preoperative and postoperative endocrinology.

When we examined the MS patient group, we found that these patients were older in age and that we preferred OAGB more compared to the general group. We saw that the remission rates of their comorbidities were similar to the general group, but the complete remission rate was lower for DM and HL/DL. It should be considered that this is due to the fact that these patients are more resistant in terms of lipotoxicity, glucose intolerance, insulin resistance and drug use. In addition, the postoperative BMI value of this group of patients decreased by 30.71% compared to the preoperative BMI value. As a result, the quality of life of MS patients increases significantly.

Low complication rates are reported for bariatric/metabolic surgery, such as 1.1% leakage, 1.8% bleeding, and 0.9% stenosis [45]. When the two patient groups were examined in our series, the major complication rate was 0.2% for LSG and 0.0% for OAGB. Minor complication rates are similar. Our complication rates are lower compared to the ones in literature.

Although EWL values were high in the LSG group from the 6th month to the 2nd year, the difference decreased from the 3rd year onwards. There may be many reasons for this, but according to the available data, it indicates that weight loss is more effective in short-term surgical operations performed with LSG. In addition, other patient parameters and LSG selection criteria may also have an effect on this result. Further prospective studies are needed on this subject.

Although it is understandable that the relationship between hypothyroidism and bariatric surgery is difficult to analyze due to limited literature it may be argued that thyroid function may affect weight loss by obesity mechanism. In their research, Reinehr and Andler [46] reported that weight loss decrease peripheral thyroid hormones in long term. Because leptin levels affect the release of TSH, leptin appears to be a promising link between obesity and changes in thyroid hormones [47].

Conclusion

Patients who undergo LSG lose weight in the early period but recurrent weight gain later. In patients who undergo OAGB, there is no recurrent weight gain in the long term compared to LSG and it can be said that it is more effective in terms of sustainable weight loss Our results support that LSG is a reliable method with low morbidity and mortality rates; is quite effective on comorbidities like MS components. Nevertheless, considering its effectiveness in DM remission, long-term results and sustainable weight loss, we think that OAGB should be preferred as patient-oriented.

Abbreviations

ASMBS	American Society for Metabolic and Bariatric Surgery
BMI	Body mass index
CAH	Congenital adrenal hyperplasia
DL	Dislipidemia
DM	Diabetes mellitus
EWL	Excess weight loss
HDL	High-density lipoprotein
HL	Hyperlipidemia
HT	Hypertension
IFSO	International Federation for the Surgery of Obesity and Metabolic Disorders
IR	Insulin resistance
Kg/m^2	$Kilogram/meter^2$
LDL	Low-density lipoprotein
LSG	Laparascopic sleeve gastrectomy
MS	Metabolic syndrome
OAGB	One anastomosis gastric bypass
NIH	National Institutes of Health
OMUTF	Ondokuz Mayıs University Faculty of Medicine
OSAS	Obstructive sleep apnea syndrome
RYGB	Roux-en-Y gastric bypass
TG	Triglyceride
USG	Ultrasonography

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Author contributions
V.M. collected data and wrote manuscriptM.A.Y. helped to analysing and wrote manuscriptB.K. helped to design the study, wrote manuscript and helped to analysing dataG.S.Ö. drafted the work, helped to analysing and wrote manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study is conducted based on the ethics committee approval received from OMÜ KAEK (Ondokuz Mayıs University Clinical Researches Ethics Committee) (with the decision numbered 2020/163 dated 22/04/2020) for the specialization thesis titled "Bariyatrik/Metabolik Cerrahinin Metabolik Sendrom Bileşenleri Üzerine Etkilerinin Araştırılması" (Investigation of the Effects of Bariatric/Metabolic Surgery on Metabolic Syndrome Components) at the Ondokuz Mayıs University, Faculty of Medicine. The research was designed and prepared in compliance with the Helsinki Declaration. Informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of General Surgery, Uskudar University, İstanbul, Turkey
[2]Faculty of Medicine, General Surgery Department, Hitit University, Çorum, Turkey
[3]Faculty of Medicine, General Surgery Department, Tokat Gaziosmanpaşa University, Tokat, Turkey
[4]Faculty of Medicine, General Surgery Department, Ondokuz Mayıs University, Samsun, Turkey

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