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Evaluation of changes in posterior segment parameters and cardiovascular risk score following laparoscopic sleeve gastrectomy in obese patients

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ABSTRACT

Introduction: To investigate the effects of laparoscopic sleeve gastrectomy (LSG) on body mass index (BMI), visceral adipose index (VAI), waist circumference (WC), cardiovascular risk score, and retinal microvascular and neurogenic changes in obese patients.

Materials and Methods: This retrospective study included 30 obese patients and 40 age- and sex-matched control subjects. Comprehensive systemic and ophthalmic examinations, including posterior segment parameters preoperatively and at six months postoperatively, were obtained for all participants. Data on BMI, VAI, and WC were collected from patient records. The Framingham Risk Score (FRS) was calculated both preoperatively and six months postoperatively.

Results: The study indicated a significant reduction in BMI, VAI, WC, and FRS post-surgery (p=0.015, p=0.001, p=0.035, p<0.001, respectively). Retinal assessments revealed thinner temporal quadrant central macular thickness (CMT) and nasal quadrant peripapillary retinal nerve fiber layer (RNFL), as well as reduced vascular densities in all quadrants of the superficial capillary plexus (SCP), except for the fovea, and in the superior, temporal, and nasal quadrants of the deep capillary plexus (DCP) in obese patients compared to the control group preoperatively, with improvements noted in temporal quadrant RNFL and nasal quadrant SCP post-LSG surgery. Significant negative correlations were observed between VAI and subfoveal choroidal thickness (SCT), between WC and both superior quadrant MT and SCT, and between FRS and both temporal quadrant RNFL and nasal choriocapillaris vascular density.

Conclusion: These findings suggest that LSG not only facilitates weight loss but also positively impacts retinal neurogenic and microvascular health, Furthermore, changes in retinal parameters may indicate potential predictive markers for future cardiometabolic risks in obese patients.

Keywords: Body mass index (BMI), laparoscopic sleeve gastrectomy, optic coherence tomography, optic coherence tomography angiography, the framingham risk score (FRS), visceral adipose index (VAI), waist circumference (WC).

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Introduction

Obesity is a significant public health challenge, currently affecting approximately 650 million adults worldwide, with its prevalence on the rise.[1] Obesity is associated with numerous chronic conditions, including diabetes, hypertension, and various cancers, and is responsible for high levels of morbidity and mortality.[2,3] Moreover, obesity plays a direct and indirect role in the development of cardiovascular diseases (CVD), including atherosclerotic and vasospastic coronary heart disease, arrhythmias, cardiomyopathy, and congestive heart failure, by causing endothelial dysfunction, changes in the microvascular structure, and cardiomyocyte toxicity.[4] It has been shown that approximately 29–40% of patients with heart failure are overweight (body mass index [BMI] 25.0–29.9 kg/m²), and 30–49% are obese (BMI ≥ 30 kg/m²).[5] Although BMI has long been considered the gold standard for defining obesity and evaluating associated cardiovascular risk, recent studies indicate that risk may differ across various obesity phenotypes. As a result, visceral adipose tissue (VAT) is increasingly acknowledged as a critical indicator of obesity, complementing the information provided by BMI.[5,6] The visceral adipose index (VAI), which is calculated using BMI, waist circumference (WC), triglycerides (TG), and high-density lipoprotein (HDL), is a straightforward, cost-effective, and practical method for assessing VAT compared to magnetic resonance imaging (MRI) and computed tomography (CT).[7]

Laparoscopic sleeve gastrectomy (LSG) is an increasingly utilized and effective treatment option for obesity that significantly reduces the prevalence of obesity-related morbidity and mortality.[8] In their review, Kwok et al.[9] found that among 29,208 patients who underwent bariatric surgery, there was a 50% reduction in cardiovascular risk compared to a control group of 166,200 patients who did not undergo surgery. It is believed that bariatric surgery reduces cardiovascular risk by improving certain vascular biomarkers associated with weight loss.[10,11] Habib et al.[12] demonstrated a reduction in carotid intima-media thickness and an increase in flow-mediated brachial artery dilation in 50 obese patients following bariatric surgery. Meanwhile, Backdahl et al.[13] reported significant improvements in aortic elasticity and left ventricular diastolic function during a 36-month postoperative follow-up in 60 obese patients.

Weight loss resulting from bariatric surgery can induce changes in various tissues, including the eye. Studies have demonstrated alterations in retinal and choroidal thickness, as well as retinal microvascular perfusion, in obese patients undergoing bariatric surgery.[14,15] Microvascular dysfunction is an early indicator of CVD, and there is a well-established significant association between retinal microvascular changes and the risk of CVD.[16,17]

Optical coherence tomography angiography (OCTA) is a non-invasive and practical technique that provides detailed morphological imaging and allows for the quantitative assessment of changes in the microvascular structure of the macula and choroid.[18]

This study aimed to evaluate the changes in BMI, WC, and VAI in obese patients who underwent LSG, along with alterations in neurogenic and vascular parameters in the posterior segment, in relation to changes in CVD risk.

Materials and Methods

This retrospective study comprised obese patients who were monitored at the Obesity Unit and referred for laparoscopic bariatric surgery indications in collaboration with the General Surgery Clinic between January 2022 and January 2024. Additionally, control subjects were recruited from the Ophthalmology Clinic, presenting with minor symptoms, such as refractive disorders, and without any concomitant systemic diseases. The study was conducted following the principles of the Helsinki Declaration, and ethical approval was obtained from the local ethics committee of our hospital (Protocol No: 010.99/12). Given the retrospective nature of the research, obtaining informed consent from patients was not required. However, all patients who underwent LSG received comprehensive information and signed consent forms before the procedure.

The study included patients aged 30 to 60 years with a BMI of ≥40, as well as those with a BMI of ≥35 who had obesity-related comorbidities (such as hypertension, diabetes mellitus, or severe musculoskeletal disorders), all of whom underwent LSG. Patients with endogenous obesity diagnoses, such as Cushing's syndrome, as well as those suffering from retinal and choroidal diseases—including diabetic retinopathy, hypertensive retinopathy, central serous chorioretinopathy, and macular degeneration—were excluded from the study. Additionally, individuals with uveitis, optic nerve disorders, glaucoma, a history of ocular trauma, or refractive errors of +6 or -6 D (high hyperopia and myopia) were not included. Furthermore, patients with media opacities due to cataracts, corneal disorders, or vitritis, as well as those unable to cooperate with optical coherence tomography (OCT) and optical coherence tomography angiography (OCTA) imaging, were also excluded from the study.

Patient data, including age, sex, presence of systemic diseases, medications used, smoking status, height, weight, BMI, WC, systolic and diastolic blood pressure, hemoglobin A1c (HbA1c), total cholesterol, low-density lipoprotein (LDL), and HDL levels, were collected. Additionally, best-corrected visual acuity (BCVA) measured using the Snellen chart, intraocular pressure (IOP) assessed with a non-contact tonometer, pachymetry measurements, anterior and posterior segment examinations performed using slit-lamp biomicroscopy, central macular thickness (CMT), peripapillary retinal nerve fiber layer (RNFL), subfoveal choroidal thickness (SCT) evaluated by OCT, and superficial and deep macular vascular densities, foveal avascular zones, and choriocapillaris vascular densities assessed with OCTA, were recorded from patient files.

The preoperative examination findings of patients who underwent LSG were compared with the findings obtained during the postoperative assessment at six months. Based on the collected data, BMI was calculated as weight (kg) divided by height^2 (m^2), and the Framingham cardiovascular risk scores (FRS) and VAI scores were determined. The VAI serves as a clinical index that combines anthropometric and metabolic parameters to provide a better assessment of visceral fat. In men, the visceral adiposity index (VAI) is calculated using the formula:

VAI (Men) = [WC (cm)/39.68 + (1.88 × BMI)] × (TG (mmol/L)/1.03) × (1.31/HDL (mmol/L))

In women, VAI is calculated as:

VAI (Women) = [WC (cm)/36.58 + (1.89 × BMI)] × (TG (mmol/L)/0.81) × (1.52/HDL (mmol/L)) [19]

Data from one randomly selected eye of each participant were included in both the obese patient group and the control group.

All patients diagnosed with obesity underwent LSG. This surgical procedure entailed the vertical resection of the stomach, initiated 4 cm from the pylorus and 2 cm from the esophagogastric junction. A tri-stapler was utilized as a stabilizing device, and the site was subsequently reinforced with omentopexy.[20]

The Framingham Risk Score (FRS)

The Framingham Risk Score (FRS) is a widely used cardiovascular risk assessment tool developed by the Framingham Heart Study, which calculates the 10-year risk of cardiovascular events based on sex-specific factors.[21] In this study, the FRS for each participant was calculated using data such as age, sex, total cholesterol, HDL, systolic blood pressure, hypertension status, and smoking habits. For patients who underwent LSG, FRS scores were computed based on preoperative data and results obtained at the six-month postoperative follow-up. In the control group, individuals were included if their medical records contained the necessary blood parameters within the last three months.

Optical Coherence Tomography and Optical Coherence Tomography Angiography

The CMT and peripapillary RNFL parameters measured with the Swept Source Optical Coherence Tomography (SS-OCT) device (Topcon, Japan), were recorded for all participants. In the measurement of CMT in accordance with the ETDRS study, macular thickness was evaluated at central (1 mm, foveal) and parafoveal (3 mm) areas. For assessing RNFL thickness, average measurements were calculated within a 3.45 mm diameter scanning circle surrounding the optic disc, at 90-degree intervals across the four quadrants (superior, inferior, temporal, and nasal) (Fig. 1). Only those imaging results with a signal strength of ±7 were included in the study. Furthermore, SCT was assessed by manually measuring the distance from the retinal pigment epithelium to the choroid-sclera junction in the foveal area using cross-sectional OCT scans. En face OCTA images were obtained from a 3×3 mm^2 central macular area using OCTA (DRI OCT Triton Plus, Topcon, Japan). The superficial capillary plexus (SCP), deep capillary plexus (DCP), and choriocapillary vascular plexus were measured using the IMAGEnet software developed by Topcon. The area of the foveal avascular zone (FAZ) was manually delineated and measured by two different researchers (UK, ÖFB), and the average was calculated. All measurements were conducted between 10:00 and 12:00 to minimize the effects of diurnal variation. Vessel density was defined as the percentage of the area occupied by large and microvessels. Images with a signal strength index (SSI)<45 or those exhibiting segmentation errors and motion artifacts were excluded from the analysis.

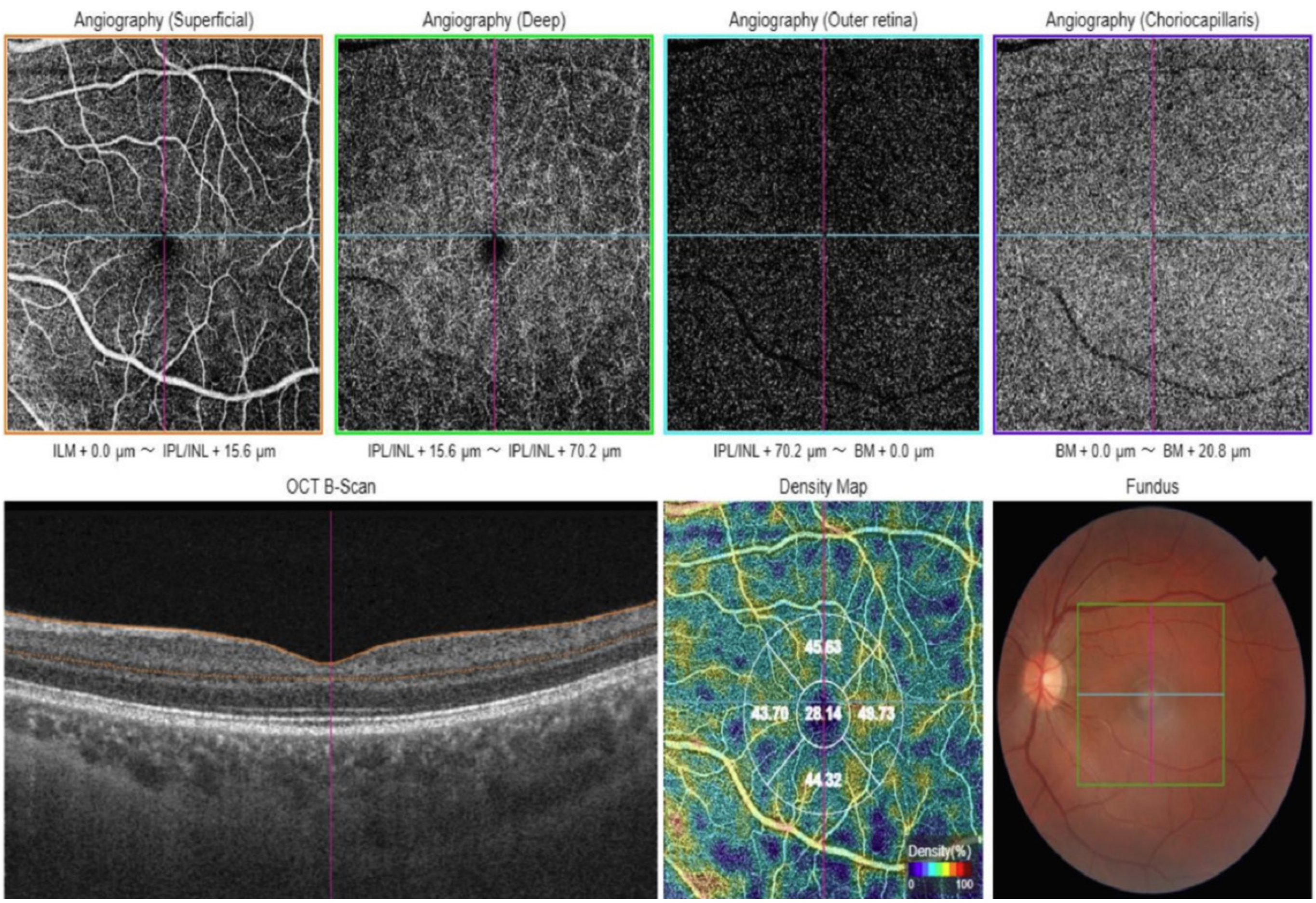

Figure 1. Optical coherence tomography angiography images of the macula.

Statistics

Statistical analyses were conducted using IBM SPSS Statistics (version 26). Descriptive statistics included percentages and frequencies for grouped data, while continuous data were summarized using mean, standard deviation, median, and interquartile ranges (25^{th} to 75^{th} percentiles). The Shapiro-Wilk test indicated that continuous data did not meet the criteria for normal distribution. For comparisons between independent groups, the Mann-Whitney U test and Student's t-test were employed, while paired groups were analyzed using the paired t-test and Wilcoxon signed-rank test. The Spearman rank correlation coefficient was utilized to assess relationships between continuous variables. The Chi-square test was applied to compare the distributions of grouped data. A significance level of $p<0.05$ was established.

Results

The study included 30 obese patients who underwent LSG and 40 healthy controls. The mean age of the obese patients was 37.30±7.75 years, while the control group had a mean age of 40.33±9.97 years (p=0.079). Table 1 presents the clinical and demographic characteristics of all participants.

In obese patients, the preoperative BMI was 45.57±4.85 kg/m^2, whereas the control group had a BMI of 21.78±1.76 kg/m^2, indicating a statistically significant difference between the two groups (p<0.001). In the analysis of posterior segment parameters, SCT and CMT were found to be reduced in the obese patients compared to the control group; however, these differences did not reach statistical significance (p=0.164 and p=0.200, respectively). Furthermore, while macular thickness was consistently thinner in all four quadrants among obese patients relative to controls, a statistically significant difference was identified specifically in the temporal quadrant (p=0.011). Analysis of RNFL values revealed that the average RNFL measurements, along with those assessed in each of the four quadrants, were significantly reduced in obese patients. Notably, the decrease in RNFL in the nasal quadrant was statistically significant (p=0.004).

In the evaluation of the macular vascular plexus, it was observed that vascular densities in the SCP were signif-

Table 1. Demographic and clinic features of all study participants

	Patients with Obesity (n=30)	Control Group (n=40)	p
Age, (Mean±SD)	37.30±7.75	40.33±9.97	0.079
Gender, Female, n (%)	24 (80%)	30 (75%)	0.622
IOP (mm Hg), (Mean±SD)	15.1±3.3	15.4±3.1	0.294
Corneal Pachymetry, (μm) (Mean±SD)	556±55	550±48	0.135
DM, n (%)	17 (56.7%)	9 (22.5)	0.035
HT, n (%)	7 (23.3%)	6 (15%)	0.124
BMI (kg/m^2)	45.57±4.85	21.78±1.76	<0.001

IOP: Intraocular pressure; DM: Diabetes Mellitus; HT: Hypertension; BMI: Body Mass Index.

icantly reduced in obese patients across all quadrants outside the fovea (p=0.004, p=0.07, p=0.001, p=0.005 for the superior, inferior, temporal, and nasal quadrants, respectively). In the DCP, notable reductions in vascular densities were detected in the superior, temporal, and nasal quadrants of the obese cohort (p=0.007, p<0.001, p=0.008 for the superior, temporal, and nasal quadrants, respectively). However, no statistically significant differences were identified between the two groups concerning the superior and deep FAZ areas (p=0.136 and p=0.196, respectively).

In the choriocapillaris, vascular densities in the foveal and superior quadrants were significantly lower in obese patients, whereas no significant reductions were observed in the other quadrants (p<0.001 and p=0.004 for the fovea and superior quadrant, respectively). Furthermore, the FRS was found to be significantly higher in the obese patients compared to the control group (p=0.049) (Table 2).

In obese patients, the BMI decreased significantly from a preoperative value of 45.57±4.85 kg/m² to 29.65±6.01 kg/m² at six months postoperatively (p=0.015). The VAI also showed a statistically significant reduction, changing from 2.52±1.28 preoperatively to 1.52±1.14 at the six-month follow-up (p=0.001). Additionally, WC decreased significantly from 133.0±11.31 cm preoperatively to 103.63±13.09 cm at six months post-surgery (p=0.035).

Upon analyzing the posterior segment parameters, it was observed that there was an increase in SCT, CMT, and macular thickness across all four quadrants in the postoperative period compared to the preoperative period; however, this increase was not statistically significant (p>0.005 for all measures). In the peripapillary RNFL, only the increase in the temporal quadrant was found to be statistically significant (p=0.020).

In the evaluation of macular vascular densities, a statistically significant increase was observed in the nasal quadrant of the SCP (p<0.001). Conversely, in the DCP, there was a statistically significant increase in both the foveal and temporal quadrants in the postoperative period compared to the preoperative period (p=0.044 and p=0.046, respectively). However, the differences in the superficial and deep FAZ area values were not statistically significant (p>0.005 for all). In the assessment of vascular densities within the choriocapillaris, no statistically significant changes were observed across all quadrants during the postoperative period when compared to the preoperative period (p>0.005).

In the obese patients, the preoperative FRS risk score was recorded at 6.21±5.28, while the postoperative score exhibited a marked reduction to 2.51±1.28, reflecting a statistically significant decrease in FRS (p<0.001) (Table 3).

In examining the correlations between changes in posterior segment parameters postoperatively and variables such as BMI, VAI, WC, and FRS values in obese patients, a significant negative correlation was found between VAI and SCT (rho=-0.446, p=0.009). Additionally, a significant negative correlation was noted between WC and both superior quadrant MT and SCT (rho=-0.497, p=0.005; rho=-0.363, p=0.048). Furthermore, a significant negative correlation was observed between FRS and both temporal quadrant RNFL and nasal choriocapillaris vascular density (rho=-0.456, p=0.011; rho=-0.356, p=0.044) (Table 4).

Table 2. Comparison of posterior segment parameters and cardiovascular risk scores between patients with obesity and the control group

	Patients with Obesity	Control Group	p
Central MT (µm)	242.57±28.52	251.07±26.20	0.200
Superior quadrant MT (µm)	303.95±21.15	308.43±13.45	0.313
Inferior quadrant MT (µm)	296.53±18.60	303.15±21.68	0.184
Nasal quadrant MT (µm)	301.47±14.95	307.87±13.99	0.073
Temporal quadrant MT (µm)	292.47±16.37	302.68±15.84	0.011
SCT (µm)	307.93±59.17	326.63±51.63	0.164
Average RNFL (µm)	107.05±11.02	108.20±9.70	0.651
Superior quadrant RNFL (µm)	134.00±17.31	138.85±15.94	0.599
Inferior quadrant RNFL (µm)	135.00±20.65	136.03±13.35	0.801
Nasal quadrant RNFL (µm)	80.80±11.99	91.46±18.25	0.004
Temporal quadrant RNFL (µm)	72.17±8.79	74.03±13.50	0.489
SCP (%)			
Foveal	17.86±3.55	18.37±4.38	0.601
Superior	40.49±4.18	43.53±4.39	0.004
Inferior	38.71±4.49	41.78±4.67	0.007
Temporal	41.22±4.09	44.20±3.03	0.001
Nasal	39.73±4.33	42.66±3.98	0.005
DCP (%)			
Foveal	16.54±3.84	16.71±4.57	0.875
Superior	44.09±4.41	46.29±5.19	0.007
Inferior	44.43±5.26	50.86±6.42	0.586
Temporal	42.39±4.25	48.34±3.38	<0.001
Nasal	42.37±4.77	45.49±4.65	0.008
FAZ (µm^2)			
Superficial	332.75±409.24	313.242±362.114	0.136
Deep	375.585±426.443	325.722±411.502	0.196
Choriocapillaris (%)			
Foveal	49.28±5.08	52.80±2.38	<0.001
Superior	49.39±2.71	51.49±3.12	0.004
Inferior	50.23±3.81	50.85±2.09	0.424
Temporal	52.16±3.07	52.89±2.23	0.269
Nasal	52.55±1.81	52.59±2.15	0.938
FRS	6.21±5.28	1.5±4.40	<0.001

Mean±standard deviation values are shown. MT: Macular Thickness; SCT: Subfoveal Choroidal Thickness; RNFL: Retinal Nerve Fiber Layer; SCP: Superficial Capillary Plexus; DCP: Deep Capillary Plexus; FAZ: Foveal Avascular Zone; FRS: Framingham Risk Score.

Discussion

Obesity is a multifactorial disease characterized by the abnormal increase and distribution of adipose tissue.[22] In addition to inducing various hormonal, inflammatory, and metabolic changes in the body, obesity can lead to significant microvascular alterations in multiple organs.[23] Obesity is also an independent risk factor for CVD, particularly in relation to coronary heart disease and stroke. It is also associated with other CVD risk factors, including systemic hypertension, metabolic dyslipidemia, inflammation, and thrombosis.[24,25] It is well established that central obesity plays a significant role in the risk of developing CVD.[26] To the best of our knowledge, this study is the first to comparatively assess the changes in BMI, VAI,

Table 3. Comparison of posterior segment parameters and cardiovascular risk scores in obese patients who underwent LSG in the preoperative period and in the 6th month postoperatively.

	Preoperative period	Postoperative period	p
Central MT (μm)	242.57±28.52	243.03±27.19	0.915
Superior quadrant MT (μm)	303.95±21.15	306.90±21.78	0.635
Inferior quadrant MT (μm)	296.53±18.60	299.33±18.20	0.292
Nasal quadrant MT (μm)	301.47±14.95	303.17±15.44	0.545
Temporal quadrant MT (μm)	292.47±16.37	293.10±17.60	0.347
SCT (μm)	307.93±59.17	310.93±59.50	0.590
Average RNFL (μm)	107.05±11.02	107.87±8.31	0.775
Superior quadrant RNFL (μm)	134.00±17.31	139.50±16.14	0.100
Inferior quadrant RNFL (μm)	135.00±20.65	139.17±12.32	0.222
Nasal quadrant RNFL (μm)	80.80±11.99	91.46±18.25	0.004
Temporal quadrant RNFL (μm)	72.17±8.79	78.13±10.44	0.020
SCP (%)			
Foveal	17.86±3.55	18.01±5.63	0.539
Superior	40.49±4.18	41.42±6.54	0.096
Inferior	38.71±4.49	39.69±5.92	0.110
Temporal	41.22±4.09	43.13±6.65	0.104
Nasal	39.73±4.33	44.49±4.65	<0.001
DCP (%)			
Foveal	16.54±3.84	19.92±8.21	0.044
Superior	44.09±4.41	47.30±4.19	0.052
Inferior	44.43±5.26	46.74±6.95	0.239
Temporal	42.39±4.25	45.63±7.57	0.046
Nasal	42.37±4.77	43.03± 7.44	0.797
FAZ (μm^2)			
Superficial	332.75±409.24	342.20 ±395.552	0.509
Deep	375.585±426.443	327.50±419.432	0.070
Choriocapillaris (%)			
Foveal	52.21±5.03	52.80±2.39	0.540
Superior	51.41±4.14	51.49±3.12	0.896
Inferior	50.85±2.09	50.93±3.72	0.912
Temporal	52.89±2.23	53.16±3.89	0.651
Nasal	51.49±3.37	52.56±1.81	0.069
BMI (kg/m^2)	45.57±4.85	29.65±6.01	0.015
VAI	2.52±1.28	1.52±1.14	0.001
Waist Circumference (cm)	133.0±11.31	103.63±13.09	0.035
FRS	6.21±5.28	2.51±1.28	0.017

Mean±standard deviation values are shown. MT: Macular Thickness; SCT: Subfoveal Choroidal Thickness; RNFL: Retinal Nerve Fiber Layer; SCP. Superficial Capillary Plexus; DCP. Deep Capillary Plexus; FAZ: Foveal Avascular Zone; FRS: Framingham Risk Score; BMI: Body Mass Index; VAI: Visseral Adipose Index.

and WC due to obesity following LSG, in relation to the alterations in cardiovascular risk as reflected in retinal vascular and neurogenic structures.

Morbid obesity affects various tissues through multiple pathophysiological processes and also leads to several changes in the eye. Studies have reported that conditions

Table 4. Correlations between the differences in posterior segment parameters and BMI, VAI, waist circumference and cardiovascular risk score before and after LGS surgery in obese patients

	BMI (kg/m²)		VAI		Waist circumference (cm)		FRS	
	Spearman's rho	p	Spearman's rho	p	Spearman's rho	p	Spearman's rho	p
Central MT (µm)	-0.113	0.552	-0.071	0.707	-0.068	0.618	0.282	0.131
Superior quadrant MT (µm)	-0.211	0.263	-0.021	0.913	-0.497**	0.005	-0.278	0.136
Inferior quadrant MT (µm)	-0.107	0.575	-0.051	0.790	-0.229	0.224	-0.095	0.616
Nasal quadrant MT (µm)	-0.199	0.293	-0.212	0.262	-0.138	0.468	-0.003	0.985
Temporal quadrant MT (µm)	-0.014	0.940	-0.202	0.284	0.146	0.442	-0.153	0.421
SCT (µm)	-0.026	0.890	-0.446**	0.009	-0.363*	0.048	-0.215	0.253
Average RNFL (µm)	-0.008	0.967	0.059	0.757	-0.147	0.437	-0.149	0.432
Superior quadrant RNFL (µm)	-0.237	0.206	-0.197	0.297	0.052	0.785	-0.135	0.478
Inferior quadrant RNFL (µm)	-0.177	0.350	-0.078	0.681	-0.089	0.639	-0.301	0.106
Nasal quadrant RNFL (µm)	-0.092	0.629	-0.096	0.613	0-.108	0.570	-0.338	0.068
Temporal quadrant RNFL (µm)	-0.225	0.232	-0.239	0.204	-0.246	0.190	-0.456*	0.011
SCP (%)								
Foveal	-0.256	0.173	-0.198	0.295	-0.004	0.981	-0.140	0.461
Superior	-0.021	0.912	-0.115	0.545	-0.297	0.111	-0.094	0.622
Inferior	-0.238	0.206	-0.084	0.658	-0.022	0.873	-0.092	0.629
Temporal	-0.245	0.192	-0.074	0.698	-0.216	0.252	-0.088	0.642
Nasal	-0.217	0.249	-0.240	0.202	-0.087	0.647	-0.101	0.594
DCP (%)								
Foveal	-0.107	0.575	-0.133	0.483	-0.112	0.557	-0.004	0.982
Superior	-0.106	0.578	-0.024	0.902	-0.224	0.234	-0.171	0.365
Inferior	0-.216	0.252	-0.056	0.769	-0.021	0.912	0.096	0.615
Temporal	-0.066	0.729	-0.059	0.756	-0.096	0.615	-0.017	0.930
Nasal	-0.360	0.051	-0.170	0.370	-0.130	0.494	-0.053	0.781
FAZ (µm²)								
Superficial	-0.209	0.268	-0.092	0.627	0.100	0.597	-0.247	0.188
Deep	-0.135	0.477	-0.140	0.460	0.036	0.851	-0.086	0.653
Choriocapillaris (%)								
Foveal	-0.115	0.547	-0.047	0.805	-0.268	0.152	-0.113	0.551
Superior	-0.208	0.269	-0.009	0.963	-0.012	0.949	0.203	0.282
Inferior	-0.302	0.105	0.080	0.674	-0.149	0.433	-0.131	0.489
Temporal	-0.095	0.618	0.170	0.368	0.116	0.540	-0.157	0.406
Nasal	-0.038	0.843	-0.115	0.545	-0.022	0.907	-0.356*	0.044

MT: Macular Thickness; SCT: Subfoveal Choroidal Thickness; RNFL: Retinal Nerve Fiber Layer; SCP. Superficial Capillary Plexus; DCP. Deep Capillary Plexus; FAZ: Foveal Avascular Zone; FRS: Framingham Risk Score; BMI: Body Mass Index; VAI: Visseral Adipose Index.

such as age-related macular degeneration, optic neuritis, glaucoma, diabetic retinopathy, and hypertensive retinopathy occur more frequently in obese patients.[27-29] Throughout this process, it is believed that both vascular and mechanical etiologies associated with morbid obesity play a significant role.[30] Doğan et al.[31] conducted a study involving 67 patients with morbid obesity, which revealed a thinning of the CMT that did not reach statistical significance. However, they found that the RNFL, retinal ganglion cell layer, and SCT were significantly thinner in comparison to the control group. Teberik et al.[32] observed that in patients with morbid obesity, the nasal and temporal CMT, temporal RNFL, and SCT were statistically significantly lower compared to the control group. In their study comparing retinal and optic disc vascular densities between 27 obese patients and a control group, Doğan et al.[33] found that both the SCP and DCP were statistically significantly thinner in all quadrants among the obese patients. They also observed a significant negative correlation between these vascular densities and BMI. Roland et al.[34] observed that in obese patients, both the central macular density and perfusion density were significantly lower compared to the control group. The neurogenic and vascular changes observed in the posterior segment of obese patients have been linked to the hyperinflammation and vasoconstrictive molecules associated with obesity.[31,32,34]

Weight gain and obesity contribute to the formation of visceral adipose tissue, which is characterized by immune cell infiltration and the presence of inflammatory, dysfunctional adipocytes. These adipocytes release both local and systemic pro-inflammatory cytokines. Additionally, the increased levels of leptin and the decreased levels of the anti-inflammatory hormone ghrelin further intensify this inflammatory process.[35,36] Furthermore, it has been observed that in obese patients, levels of nitric oxide (NO) are decreased, while vasoconstrictive molecules such as endothelin-1 and angiotensin-II are found to be elevated in association with higher BMI.[37] In our study, consistent with previous research, we found that in obese patients, the SCT, CMT, and RNFL were thinner compared to the control group. Notably, the CMT in the temporal quadrant and the RNFL in the nasal quadrant were statistically significantly lower. Additionally, we observed that vascular densities in all quadrants of the SCP, except for the fovea, as well as in the superior, temporal, and nasal quadrants of the DCP, were significantly reduced in the obesity group. We attribute these changes to the inflammatory process induced by the increase in adipose tissue and the elevated levels of vasoconstrictive molecules in obese patients.

LSG is a commonly preferred bariatric surgical procedure for obese patients, demonstrating successful outcomes in weight loss.[38] Additionally, it is believed to have beneficial effects on microvascular circulation.[39] Toptan et al.[40] demonstrated a significant increase in vascular density across all retinal layers, particularly in the DCP, in obese patients following bariatric surgery. They attributed this improvement to the enhanced retinal perfusion observed after the surgery. ElShazly et al.[41] observed a significant increase in CMT and DCP during the three-month follow-up after bariatric surgery. They attributed these changes to improvements in retrobulbar hemodynamic parameters. In our study, we observed a significant reduction in BMI, VAI, and WC in patients following LSG. Additionally, there was an increase in CMT, SCT, and RNFL, with the increase in temporal RNFL reaching statistical significance. We found a statistically significant increase in the nasal quadrant of the SCP and in the foveal and temporal quadrants of the DCP in the postoperative period compared to preoperative values. Furthermore, we identified significant negative correlations between VAI and SCT, as well as between WC and both superior quadrant macular thickness and SCT. This suggests that VAT has a notable impact on microvascular structures, indicating that the reduction of VAT after LSG may lead to decreased inflammation and a reduction in vasoconstrictive molecules, ultimately improving retinal perfusion.

In the Look AHEAD study, 5,145 obese patients with type 2 DM were randomized into an intensive lifestyle intervention (ILI) group and a routine care group, followed for an average of 9.6 years. The ILI group experienced a weight loss of 6.0%, while the routine care group lost 3.5%. Although improvements in CVD risk factors were observed, there were no significant changes in CVD risk or mortality between the two groups.[42] In contrast, the Swedish Obese Subjects (SOS) study demonstrated that weight loss following bariatric surgery is associated with a reduction in CVD risk.[43] In our study, we found a significant reduction in the FRS score following LSG. Additionally, a significant negative correlation was identified between the FRS score and both the temporal quadrant RNFL and nasal choriocapillaris vascular density. vascular density. This finding suggests that as the risk of CVD increases, thinning of retinal neuronal structures and a reduction in vascular densities may occur in patients. We hypothesize that changes in retinal parameters could serve as potential indicators of CVD risk.

This study had several limitations. The retrospective design, along with a relatively small sample size and limited follow-up duration, contributed to these constraints. Additionally, the obese patients in our study were not stratified or evaluated into groups based on the presence or absence of metabolic syndrome, which may have affected the results. Lastly, the potential confounding effects of diet, exercise, or other lifestyle factors alongside LSG were not accounted for in our analysis.

In conclusion, obesity-related alterations in retinal neurogenic and microvascular structures have been observed. Following LSG, improvements were noted in parameters such as BMI, VAI, and WC, alongside improvements in retinal parameters. This study suggests that VAT may play a particularly significant role in these improvements. Furthermore, the reduction in cardiovascular risk scores post-surgery, alongside associated microvascular and neurogenic changes in the retina, supports the hypothesis that retinal microvascular alterations could serve as predictive markers for future cardiometabolic diseases. Overall, these findings indicate that LSG may be a safe and effective method for weight loss in obese patients.

Disclosures

Ethichs Committee Approval: The study was conducted following the ethical approval obtained from the local ethics committee of Kartal Dr. Lütfi Kırdar City Hospital (No: 010.99/12, Date: 28/02/2024).

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