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ORIGINAL CONTRIBUTIONS

Does Central Fat Distribution Reduction After Bariatric Surgery Induce Ocular Refraction Change Independent of Body Mass Index?

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Abstract

Purpose The effect of body mass index (BMI) and central fat distribution (CFD) reduction after bariatric surgery on ocular refraction is not well established. We assessed association between anthropometric parameters and refraction errors with other ocular and metabolic parameters 1 year after the surgery.

Materials and Methods This was a retrospective study with patients underwent bariatric surgery and had at least 1 year follow-up. Data were extracted from the bariatric and ophthalmology outpatient clinic records of the participants. Measurements of metabolic, anthropometric, and ocular parameters including BMI, CFD, refraction status, visual acuity, intraocular pressure (IOP), optic coherence tomography (OCT), and biometry test of the eyes were evaluated.

Results Seventy-four eyes of 37 patients had a mean follow-up of 14.4 ± 1.7 months after the surgery. Mean BMI and percentage of CFD decreased from 47.5 ± 6.7 to 33.1 ± 5.2 kg/m^2 ($p < 0.01$) and 28.5 ± 5.74 to 17.8 ± 4.64 ($p < 0.001$) after 1 year, respectively. Mean refractive errors of the right and left eyes changed from − 0.62 ± 1.23 D to − 0.17 ± 1.36 D and from − 0.79 ± 1.39 to − 0.34 ± 1.56 after 1 year of the surgery ($p < 0.001$). Mean IOP was significantly reduced ($p < 0.001$). Unlike BMI, reduction in CFD was significantly correlated with refraction change in both eyes (right eyes; $r = 0.783$, left eyes; $r = 0.791$, $p < 0.001$) after 1 year. No significant differences were found in the other parameters.

Conclusion Bariatric surgery induced significant refractive change in eyes, which is significantly associated with CFD reduction after 1 year. Bariatric surgery should be considered as a risk factor in patients with unexpected refractive error changes.

Keywords Obesity · Bariatric surgery · Refractive error · Hyperopic shift · Central fat · Laparoscopic sleeve gastrectomy

Key Points

- Laparoscopic sleeve gastrectomy can lead to hyperopic shift in human eyes.
- Central fat distribution, rather than BMI, is associated with refractive error changes.
- Bariatric surgery may affect various ocular parameters by different mechanisms.
- Ophthalmic exam should be considered in patients undergoing bariatric surgery.

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Introduction

Obesity is progressively recognized as a serious, worldwide public health condition, and may result with serious health complications [1]. Along with metabolic and cardiovascular complications, obesity may also deteriorates life quality in terms of mechanical and psychosocial effects [2]. Previous studies revealed that obesity can also be related to a number of ocular diseases, such as age-related macular degeneration, glaucoma, diabetic retinopathy, and cataract [3, 4].

It was well documented that weight loss following bariatric surgery has considerable improvements regarding obesity-associated medical problems including hypertension (HTN), diabetes mellitus (DM), and dyslipidemia [5–7]. Recent developments have also indicated the beneficial effects of bariatric surgery on intraocular pressure and retinal microvascular perfusion [8–10], whereas most investigations discussed the impact of bariatric surgery on the changes of ocular features with little attention to refractive

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changes of the eyes. Previous studies addressed the transient refractive changes associated with various physiological and hormonal changes in human body, including glycemic fluctuations of patients with DM and in the clinical setting of a pregnancy [11–16]. On the other hand, we believe that investigating the change in refraction and its association with other ocular parameters following bariatric surgery is also of great importance regarding the properly evaluation of these group of patients during post-operative period.

Herein, our aim is to report the follow-up results of bariatric surgery on refractive status changes in eyes and its possible associations in patients with severe obesity.

Methods

Study Design and Patient Recruitment

This retrospective and single-center study was conducted at a tertiary referral hospital for obesity treatment. The study protocol was approved by the institutional ethical committee and was conducted according to the tenets of the Declaration of Helsinki.

Between June 2018 and April 2020, the patients with severe obesity, who met the eligibility criteria defined by the WHO and operated for bariatric surgery along with the previous history of detailed ophthalmic examination were recruited in this study. We only included patients aged 18 to 65 and with only a body mass index (BMI) $\geq$ 40 kg/m^2. Except of dyslipidemia, patients having a BMI > 35 kg/m^2 with obesity-associated medical problems including DM, HTN, dementia, Alzheimer's disease, or a history of current use of systemic steroids were excluded to avoid confounding factor since these factors can alter the investigated ophthalmologic parameters. The ophthalmic exclusion criteria were determined as patients with ocular pathologies including cataract, glaucoma or ocular hypertension, uveitis, any type of retinopathy, prior ophthalmic surgery or trauma, refractive errors with a spherical equivalent < −8 diopters or > +5 diopters. Among the preliminary selected participants, who met the primary inclusion criteria, a subsequent exclusion was performed according to the presence or the absence of any comprehensive ophthalmic examination records, such as lack of OCT or biometry test parameters. Selection of the participants regarding their eligibility according to inclusion/exclusion criteria was illustrated with a flowchart (Fig. 1).

Clinical, Laboratory, and Ophthalmic Assessment

Anthropometric data (weight, height) were converted to the BMI for analysis with the formula of weight (kg)/height^2 (m^2) at each visit. The data of abdominal fat percentage and total body fat amount change in kilogram for all patients with severe obesity were recorded from their comprehensive anthropometric measurements. Regarding laboratory test evaluation, fasting serum samples were run for serum glucose (g/dL), glycosylated hemoglobin (HbA1c, %),

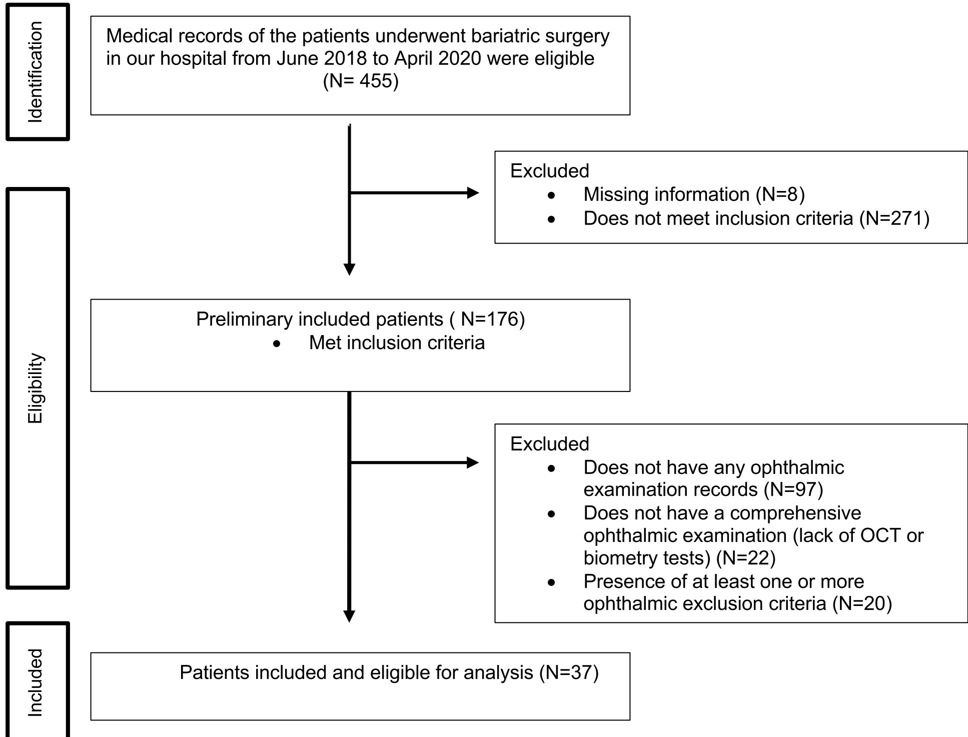


Fig. 1 Flowchart of patients who met the inclusion/exclusion criteria for the study

creatinine (mg/dL), thyroid-stimualting hormone (TSH, mlU/L), parathyroid hormone (PTH, pg/mL), cortisol (mcg/dL), folate (µg/L), vitamin B12 (pg/mL), total cholesterol (mg/dL), tryglyceride (mg/dL), high-density lipoprotein (HDL, mg/dL), and low-density lipoprotein (LDL, mg/dL) both before and at least 12 months after the surgery.

Complete physical examination of the participants, detailed history taking, anthropometric calculations, and blood pressure measurements were performed at the bariatric unit of the hospital. Fat percentage distribution calculations were automatically done by the electrical bioimpedance machine for all participants. The medical records of all patients with severe obesity having an available comprehensive ophthalmic examination notes prior to the surgery and after at least 12 months of the bariatric surgery were reviewed and analyzed by a different ophthalmologist, who was unaware of the study protocol to prevent an observer bias. As the primary outcomes the data of uncorrected and best-corrected visual acuity (UCVA and BCVA, Snellen equivalent), refractive errors (spherical equivalent) were recorded for both right eye (RE) and left eye (LE) of every participant at each visit. As the secondary outcomes, intraocular pressure (IOP) measurement by Goldmann applanation tonometer, central corneal thickness (CCT), and the other anterior segment parameters were recorded for both right eye (RE) and left eye (LE) of every participant at each visit. All posterior segment examinations were performed after loading a topical eye drop to obtain a clear visualization with pupil dilation. In addition, ultrasound biometry (Sonomed®, PACSCAN 300A, USA) to measure anterior chamber depth (ACD) and axial length (AL) for all patients. The mean nerve fiber layer thickness value on 4 sectors (inferior, superior, nasal, temporal) of optic disc (RNFL), the mean central macular thickness (CMT), and sub-foveal choroidal thickness (SFCT) values were obtained using optic coherence tomography (RS-3000, NIDEK, Gamagori, Japan).

All patients were tested to calculate their refractive errors using an auto-refractometer (KR-800 Auto-kerato-refractometer; Topcon Inc. Japan), then underwent for visual acuity measurement with a standart 6 m Snellen chart by a trained ophthalmologist. If any patient had spectacles, the number of lenses was measured by a lensmeter (CL200 Digital Lensmeter; Topcon Inc., Japan) prior to the ocular examination. A refractive change in either RE or LE was considered as hyperopic shift if $> +0.25$ D, as myopic shift if < -0.25 D, and as emetropic if between -0.25 D and $+0.25$ D.

The bariatric surgery for each patient was performed as laparoscopic sleeve gastrectomy (LSG) involved the construction of a vertical gastric sleeve over a 40 French orogastric tube starting 4–6 cm from pylorus and ending approximately 1 cm lateral to the angle of His using staplers.

Statistical Analysis

SPSS Statistics 21 (IBM Corporation, Armonk, NY, USA) was used to carry out statistical analysis. The Shapiro–Wilk test was used to assess normality of data. Parametric data were expressed as mean ± SD; non-parametric data were expressed as median and interquartile range (IQR). Categorical variables were presented as number (*n*) and percentage (%). In comparison of pre-operative and post-operative data, paired *t* tests were used for normally distributed variables, the Wilcoxon signed-rank pairs test was used for non-parametric variables, and McNemar's test was used for categorical variables. Correlations were carried out using Pearson's test for parametric data and using Spearman's test for non-parametric data. A p value of < 0.05 was considered as statistically significant. The estimated sample size required to detect an effect size of 0.5 in refraction parameters (the main outcome of interest) was 32 patients to achieve an alpha level of 0.05 and a power of 80% [17].

Results

The medical records of 455 consecutive patients underwent LSG were eligible to be evaluated for the primary inclusion criteria. Subsequently, 74 eyes of 37 (11 men, 26 women) out of 176 patients who met the primary inclusion criteria were finally included in this study and were eligible for analysis. Mean follow-up of the patients were 14.4 ± 1.7 months. Mean age was 37.9 ± 10.5 years. All patients underwent their primary bariatric surgery (LSG). Pre-operative clinical and demographic characteristics of the participants are presented in Table 1.

Over 12 months post-operatively, the mean BMI was significantly reduced from 47.5 ± 6.7 to 33.1 ± 5.2 kg/m^2

Table 1 Pre-operative clinical and demographic characteristics of the participants

Parameters	Baseline results
Female gender, *n* (%)	26 (70.2%)
Age (years), mean ± SD	37.9 ± 10.5
Height (cm), mean ± SD	162 ± 8.7
Weight (kg), mean ± SD	125.2 ± 20
BMI (kg/m^2), mean ± SD	47.7 ± 6.3
Central fat distribution (%), mean ± SD	28.5 ± 5.74
Systolic BP (mmHg), mean ± SD	132.78 ± 9.72
Diastolic BP (mmHg), mean ± SD	80.91 ± 9.11
Glucose (mg/dL), median (IQR)	99.4 (19)
HbA1c (%, mmol/mol), median (IQR)	6.14 (0.2)

BMI, body mass index; *SD*, standard deviation; *IQR*, interquartile range; *BP*, blood pressure; *HbA1c*, hemoglobin A1c

Table 2 Changes in clinical, anthropometric, and biochemical parameters following bariatric surgery (laparoscopic sleeve gastrectomy) 1 year later

Parameters	Baseline results	After surgery (mean follow-up: 14.4 ± 1.7 months)	p
Weight (kg), mean ± SD	125.2 ± 20	89.4 ± 13.8	< 0.001*
BMI (kg/m^2), mean ± SD	47.7 ± 6.3	34 ± 5.14	< 0.01*
Central fat distribution (%), mean ± SD	28.5 ± 5.74	17.8 ± 4.64	< 0.001*
Systolic BP (mmHg), mean ± SD	132.78 ± 9.72	127.51 ± 9.1	< 0.01*
Diastolic BP (mmHg), mean ± SD	80.91 ± 9.11	77.7 ± 6.9	< 0.01*
FBG (mg/dL), median (IQR)	99.4 (19)	91 (12.4)	0.002*
HbA1c (%, mmol/mol), median (IQR)	6.14 (0.2)	5.4 (0.6)	0.027*
Total cholesterol (mg/dL), mean ± SD	164.96 ± 30.3	176.82 ± 23.91	0.19
Triglyceride (mg/dL), mean ± SD	146.55 ± 45.1	102.95 ± 27.1	0.023*
HDL-C (mg/dL), mean ± SD	45.46 ± 11.51	49.81 ± 10.2	0.28
LDL-C (mg/dL), mean ± SD	92.3 ± 23.4	96.2 ± 16.5	0.46
TSH (mlU/L), mean ± SD	2.65 ± 1.49	2.09 ± 0.67	0.08
Folate (µg/L), mean ± SD	6.9 ± 3.11	6.57 ± 3.95	0.62
Vitamin B12 (pg/mL), mean ± SD	340.5 ± 142.74	300.37 ± 129.05	0.13
PTH (pg/mL), mean ± SD	68.16 ± 37.42	61.27 ± 34.19	0.27
Cortisol (mcg/dL), mean ± SD	11.15 ± 4.74	10.11 ± 3.15	0.36
Creatinine (mg/dL), mean ± SD	0.64 ± 0.11	0.67 ± 0.12	0.19

BMI, body mass index; *FPG,* fasting blood glucose; *BP*, blood pressure; *HbA1c,* glycosylated hemoglobin; *HDL-C*, high-density lipoprotein cholesterol; *LDL-C*, low-density lipoprotein cholesterol; *TSH*, thyroid stimulating hormone; *PTH*, parathyroid hormone

Data are presented as mean ± standard deviation for continuous variables with normal distribution, as median (interquartile range) for continuous variables with non-normal distribution. Paired-*t* test and Wilcoxon signed-rank test were used for the comparison of continuous variables regarding normally distributed and non-normally distributed, respectively

*$p < 0.05$

($p < 0.01$). The mean percentage of central fat distribution significantly decreased from 28.5 ± 5.74 to 17.8 ± 4.64 ($p < 0.001$). There were also significant reductions in SBP ($p < 0.01$) and DBP ($p < 0.01$). Pre-operative the mean serum fasting glucose ($p = 0.002$), HbA1c ($p = 0.027$), and triglyceride ($p = 0.023$) levels significantly decreased over 12 months after the surgery. No significant differences were detected the mean levels of serum creatinine, cortisol, PTH, folate, total cholesterol, TSH, HDL, LDL, and vitamin-B12 between the pre-operative and at least post-operative 12-month visits. Table 2 highlights the comparison of clinical and laboratory parameters of all the participants 1 year after the surgery.

The mean refractive error of the right eyes changed from − 0.62 ± 1.23 D to − 0.17 ± 1.36 D and that of the left eyes changed from − 0.79 ± 1.39 to − 0.34 ± 1.56 after 1 year of the surgery ($p < 0.001$, $p < 0.001$, respectively). Twenty of 37 patients (54%) had hyperopic shift either in their RE or LE or both eyes (8 of 20 on the RE, 4 of 20 on the LE, 4 of 20 on both eyes). Twelve of 37 patients (32.4%) were emetropic and 5 of 37 patients (13.6%) had myopic shift. The mean UCVA significantly increased from 20/25 ± 20/100 to 20/20 ± 20/80 ($p < 0.01$) in the right eyes and from 20/25 ± 20/200 to 20/20 ± 20/160 in the left eyes. There was no significant difference between the mean BCVA of both eyes of the patients before and 1 year after the surgery. The mean IOP of the RE and LE significantly reduced from 16.95 ± 2.87 to 15.54 ± 2.54 ($p < 0.001$) and from 17.1 ± 2.57 to 15.77 ± 2.1 ($p < 0.001$), respectively at the final visit. No significant differences were found between the mean of CCT, ACD, AL, CFT, SFCT, and RNFL values at the pre-operative visit and at least post-operative 1-year visit in both eyes. The comparisons of ocular parameters before and 1 year after the surgery are shown in Table 3.

The reduction rate of central fat distribution was significantly correlated with the mean refractive error change in both eyes (RE; $r = 0.783$, $p < 0.001$, LE; $r = 0.791$, $p < 0.001$) (Fig. 2). The mean change in BMI was not associated with the mean refractive error change in both eyes. In addition, the absolute decrease in IOP was significantly associated with the decrease in BMI in both eyes (RE; $r = 0.661$, $p = 0.001$, LE; $r = 0.801$, $p < 0.001$). No correlations were found between the refractive error changes and the RNFL thickness, SFCT, CMT, CCT, ACD, AL, fasting blood glucose level, SBP, or DBP changes. There was also no significant association between IOP and any ocular parameter, fasting blood glucose level, SBP, DBP, or the rate of central fat distribution.

Table 3 Comparison ocular parameters of the participants before and after bariatric surgery (laparoscopic sleeve gastrectomy)

Parameters	Before surgery		After surgery (mean follow-up: 14.4 ± 1.7 months)		*p*
	OD	OS	OD	OS	OD/OS
UCVA (Snellen chart), mean ± SD	20/25 ± 20/100	20/25 ± 20/200	20/20 ± 20/80	20/20 ± 20/160	< 0.01/0.03*
BCVA (Snellen chart), mean ± SD	20/20 ± 20/160	20/20 ± 20/100	20/20 ± 20/100	20/20 ± 20/80	0.13/0.29
Refraction error (D), mean ± SD	− 0.62 ± 1.23	− 0.79 ± 1.39	− 0.17 ± 1.36	− 0.34 ± 1.56	< 0.001/ < 0.001*
IOP (mmHg), mean ± SD	16.95 ± 2.87	17.1 ± 2.57	15.54 ± 2.54	15.77 ± 2.1	< 0.001/ < 0.001*
CCT (μm), mean ± SD	548 ± 35.97	547.3 ± 37.4	540.66 ± 35.1	537.5 ± 39.43	0.07/0.18
ACD (mm), mean ± SD	3.45 ± 0.3	3.49 ± 0.25	3.52 ± 0.28	3.49 ± 0.24	0.19/0.26
AL (mm), mean ± SD	23.38 ± 0.9	23.37 ± 0.92	23.48 ± 1.05	23.59 ± 1.06	0.33/0.59
CFT (μm), mean ± SD	228. 73 ± 21.23	220.54 ± 17.69	227.66 ± 24.39	226.13 ± 21.38	0.41/0.25
SFCT (μm), mean ± SD	291.34 ± 44.6	283.53 ± 37.14	294.46 ± 45.28	289.34 ± 40.69	0.37/0.16
RNFL (μm), mean ± SD	105 ± 14.1	114.8 ± 17.2	101 ± 11.3	112.43 ± 9.7	0.08/0.12

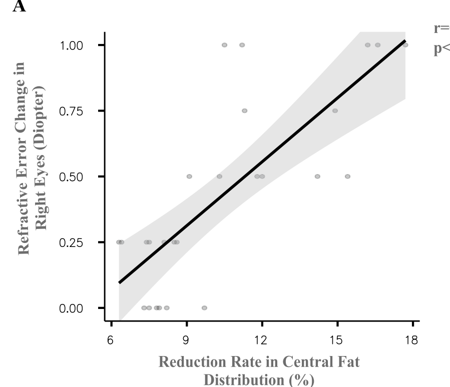
UCVA, uncorrected visual acuity; *BCVA*, best-corrected visual acuity; *IOP*, intraocular pressure; *CCT*, central corneal thickness; *ACD*, anterior chamber depth; *AL*, axial length; *CFT*, central foveal thickness; *SFCT*, sub-foveal choroidal thickness; *RNFL*, retinal nerve fiber layer; *SD*, standard deviation; *μm*, micrometer; *mm*, millimeter; *D*, diopter; *OD*, right eye; *OS*, left eye

*$p < 0.05$

Discussion

In this study, the patients with severe obesity were investigated predominantly for the impact of bariatric surgery on the refractive changes in eyes and its associations with the metabolic, systemic, and ocular parameters. There was a marked and statistically significant hyperopic shift in the eyes of our cohort one year after the surgery. Moreover, we found a considerable correlation between the refraction changes and central fat distribution. This is the first study to explore the effect of bariatric surgery regarding refractive changes and its correlations in human eyes with over 1 year of follow-up.

Recently, it has been proposed that the hypothesis of hormonal change effect can be the attributable factor for the possible underlying mechanism of obesity-related ocular diseases [8, 9]. A previous research report showed that ghrelin hormone, which is known to have anti-inflammatory and anti-oxidant effect, has an important role in anterior and posterior segment of an eye [18]. In support of that, Katsanos et al. reported that the patients with glaucoma had significantly lower level of ghrelin in the anterior segment of the eyes than those without glaucoma [19]. Therefore, investigators have speculated that reducion in excess fat secondary to the hormonal changes, such as ghrelin and leptin following bariatric surgery, can lead to an improvement in the ocular effects of obesity. A previous study conducted by Chaichian et al. reported a hyperopic shift in the eyes of patients with severe obesity following bariatric surgery in a short term period [17]. In the current study, we found a significant association between the refractive status and the change in the amount of central fat distribution of the patients. The observed correlation with the present findings might be explained the hypothesis of hormonal factors regarding the impact of bariatric surgery on refraction status changes.



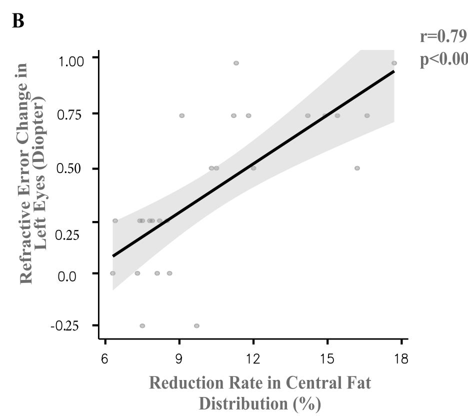


Fig. 2 Relationship between the mean refractive error change and central fat distribution following bariatric surgery over 1 year. Relationship between the mean refractive error change of the right eyes and central fat distribution in (**A**). Relationship between the mean refractive error change of the left eyes and central fat distribution in (**B**)

No significant correlation was demonstrated between the refractive status and BMI changes in spite of remarkable reduction in BMI. Instead, we have shown a significant association between central fat distribution and refractive status of the patients. This contradiction of the influence of BMI and central fat distribution on refraction error changes can be attributed to that BMI is a measurement, which is not able to distinguish fat and muscle from each other. In favor of that, recent studies have indicated that fat mass index and percentage body fat can be the better screening tools in the prediction of the presence of metabolic syndrome than BMI in men and women [20, 21].

As a rule, refractive errors, hyperopia, or myopia occurs in case of the mismatch of the axial length of the eye with the focal plane in human eyes. Furthermore, enviromental, anatomical, and physiological factors, such as body stature, near-work activities, and hyperglycemia, can lead to transient changes in refraction status [22–25]. Several authors speculated that these refraction changes may occur due to the change of osmotic pressure and accumulations in crystalline lens of an eye secondary to increased or blood glucose level [26, 27]. The patients in our cohort had a significant reduction in blood glucose and HbA1c levels at the final visit after the surgery; nevertheless, refractive error changes had no correlation with neither the blood glucose level nor HbA1c changes.

Over the last years, several studies have argued the impact of bariatric surgery on ocular surface and tear film stability, which has a crucial role on the refractive properties of cornea [28, 29]. It is well known that tear film instability on cornea is one of the most important driving factors in refractive status of a patient. Relevantly, Fahmy et al. reported that there was a significant correlation between the degree of dry eye syndrome and hyperopia [30]. Hyperopic shift in our cohort may be explained by possible the lipid tear layer instability, which leads to dry eye syndrome, in the effect of suspected hormonal alterations secondary to central fat distribution change following bariatric surgery. However, tear film parameters were not evaluated and measured in our study.

As the secondary outcome, we detected a remarkable reduction in the mean IOP of the patients and its 1 year after the surgery. Despite our sample's mean IOP change was statistically significant, the mean IOPs were within normal limit (≤ 21 mmHg) both at pre-and post-operative visits. Nevertheless, it is important to highlight the fact that previous studies reported that reduced body weight after bariatric surgery resulted in clinically significant normalization of IOP in patients with ocular hypertension and glaucoma [8, 31]. In addition, there was a significant correlation between IOP and BMI measurements. These findings are consistent with those of other studies, which showed that the mean IOP was significantly reduced in patients with severe obesity who underwent bariatric surgery [9, 31]. Inspite of the correlation between IOP and BMI, there was no correlation between the refractive status and BMI in our patients. This inconsistency may be due to different mechanisms of the effect of bariatric surgery on IOP and refraction status of an eye.

Regarding clinical importance of refractive status changes after bariatric surgery, a patient with hyperopic error pre-operatively may present with the complaints of visual disturbance or decreased vision due to deterioration of hyperopia post-operatively. Therefore, given the evidence discussed above, an ophthalmology consultation may be suggested for pre-operative and post-operative follow-up visits with a baseline ophthalmic evaluation including refractive error measurement, visual acuity and IOP check, and at least non-mydriatic fundoscopic examination. Although a routine ophthalmology screening for the patients with severe obesity might not be cost-effective, in the context of bariatric surgery, it may be more reasonable.

Several limitations to the current study need to be acknowledged. First, the numbers of the patients were relatively small and there was lack of a age-matched control healthy group. Second, the relevant hormonal status of the patients was not assessed. The tear film quality and stability as a risk factor for refraction status were also not evaluated. Finally, our patient cohort was recuited from a single-center only with a relatively homogenous population.

In conclusion, we demonstrated for the first time that bariatric surgery can potentially change the refractive status of the patients with severe obesity, thereby leading to visual complaints and spectacle dissatisfaction after post-operative period. We also reported an important association between the central fat distribution change and refraction status of the patients with severe obesity. Further studies with the new technological ophthalmic imaging devices and regarding the role of bariatric surgery on ocular surface, tear film, refraction status, and anterior segment parameters would increase our understanding the underlying mechanisms of these effects.

Declarations

Ethics Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare no competing interests.

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