

Changes In The Macular Vascular Density after Bariatric Surgery Measured by Optical Coherence Tomography Angiography

Malak I ElShazly

Cairo University

Marwa M Salama

Cairo University

Kareem Elessawy (✉ kemos1984@yahoo.com)

Cairo University <https://orcid.org/0000-0001-6772-7173>

Research Article

Keywords: Bariatric surgery, Optical coherence tomography angiography (OCTA), Macular thickness, Macular vessel density.

Posted Date: March 16th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-303145/v1>

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Abstract

Purpose. To evaluate the effect of the weight loss, 3 months after bariatric surgery on the macular thickness and macular vascular density by optical coherence tomography angiography (OCTA).

Methods. Forty obese patients were included in this prospective study. Body mass index (BMI), macular thickness (whole, fovea, parafovea and perifovea), macular vascular density (VD) in superficial capillary plexus (whole, fovea, parafovea and perifovea), and macular vascular density in deep capillary plexus (whole, fovea, parafovea and perifovea) were measured before and 3 months after bariatric surgery.

Results. The BMI was significantly reduced postoperatively to $43.75 \pm 4.4 \text{ kg/m}^2$ compared to the preoperative results $55.31 \pm 5.1 \text{ kg/m}^2$ ($p < 0.0001$). There was significant increase in the macular thickness in the fovea and parafovea postoperatively ($p < 0.001$), but was not significant in the perifovea. There was significant increase in the macular vascular density in the deep capillary plexus postoperatively ($p < 0.05$), but, there was no significant increase in the macular vascular density in the superficial capillary plexus postoperatively ($p = 0.4$). Significant correlations were detected between the BMI changes and changes in different macular parameters.

Conclusion. Bariatric surgery showed significant effect on certain indices in the macular thickness and macular vascular density especially in the deep capillary plexus. Therefore, OCTA is considered a valuable tool to assess the short term changes in the macular microcirculation following significant weight reduction.

Introduction

Obesity is a major health problem resulting into serious cardiovascular diseases, diabetes mellitus and musculoskeletal disorders [1]. It affects the function of many organ systems, the pathogenesis of which may be mechanical, vascular or oxidative stress [2].

Obesity is a risk factor in different ocular diseases including age related macular degeneration, senile cataract and diabetic retinopathy, with the underlying pathology at the microvasculature level [3].

The weight loss after bariatric surgery was found to have beneficial effect on different diseases associated with obesity, including the eye [4].

Optical coherence tomography angiography (OCTA) is a non-invasive technique which enables detailed morphological visualization, quantitatively assess and detect any abnormalities in the retinal microvasculature, including those in the macular region [5].

The aim of this study was to evaluate the effect of weight loss after bariatric surgery on the macular vessel density (VD) and macular thickness in patients who had undergone bariatric surgery, three months postoperatively, using OCTA.

Patients And Methods

A total of forty obese patients with body mass index (BMI) $>45 \text{ kg/m}^2$ were recruited from Cairo university hospital (Kasr Alaini) and scheduled for bariatric surgery. They were prospectively enrolled from June 2018 to January 2020. Written informed consent was obtained from all patients after the nature of the study had been fully explained. This study was conducted adhering to the tenets of the Declaration of Helsinki.

Patients eligible for bariatric surgery as defined by world health organization were only included in this study. Other inclusion criteria were age >18 years, 6/6 best corrected visual acuity (BCVA) by Snellen chart, spherical equivalent between $+1$ and -4 diopters (D), IOP <21 mmHg and clear refractive media allowing sufficient image quality.

Patients with retinal or systemic vascular disorders, any associated ocular pathology (e.g. macular degeneration, glaucoma or uveitis), prior ophthalmic surgery or trauma were excluded.

Complete physical examination of the patients, history taking and anthropometric measurements including weight and height, fasting blood sugar and blood pressure measurements were done at the bariatric unit of the hospital. Patients with high blood sugar level or high blood pressure measurements were excluded.

All subjects underwent a comprehensive ophthalmological examination, including BCVA, refraction, IOP measurement by Goldmann applanation tonometer. Anterior and posterior segment examinations were performed to rule out any ocular pathology.

OCT and OCTA images of the macular region were done for all patients with the AngioVue system (Optovue RTVue XR Avanti; Optovue, Inc., Fremont, CA, USA). The imaging procedure was done as described previously by Rao et al [6]. The system has an A-scan rate of 70,000 scans per second using light source centered on 840 nm and a bandwidth of 45 nm. The split-spectrum amplitude decorrelation angiography (SSADA) algorithm was used to extract the OCT angiography information. Macular vessel densities were analyzed over a 1.5 mm wide parafoveal, circular annulus centered on the macula as shown in figures 1 & 2.

VD is defined as the percentage area occupied by the large vessels and microvasculature in a certain region. Image quality was assessed for all OCTA and OCT scans and the average of 3 readings obtained was used for the statistical analysis. Poor quality images, as those with a signal strength index (SSI) <45 or images with segmentation errors and motion artifacts were excluded from the analysis. One eye from each patient was imaged and analyzed.

The bariatric surgery performed was gastric bypass surgery in which the stomach was divided into a small upper pouch and a larger lower pouch (remnant), and then the small intestine was connected to both.

The BMI calculated as weight (kg)/height² (m²), OCT and OCTA imaging analysis were performed before and 3 months post-bariatric surgery.

Statistical analysis was done using IBM SPSS v20.0 statistical software (IBM Corporation, New York, USA). Descriptive statistics was calculated and the data was summarized as mean \pm standard deviation (\pm SD), median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables was done using Independent samples student t-test. Comparisons between preoperative data and postoperative data were carried out using paired-samples t-test. Correlation between the changes in different variables was done using Pearson's correlation coefficient. The results were considered statistically significant with a *P*-value \leq 0.05.

Results

A total of 40 eyes of 40 obese patients (19 males, 21 females), seeking bariatric surgery were included in this study. Mean age was 35.7 ± 3.4 years. Three months postoperatively, the mean BMI was significantly reduced to 43.75 ± 4.4 Kg/m² ($p < 0.0001$) compared to the preoperative value (51.31 ± 5.1 Kg/m²). The mean pre- and 3 months post-operative changes in macular thickness with their significance were detailed in table 1.

Significant statistical increase in macular thickness areas of fovea and parafovea (Average, Superior-Hemi and Inferior-Hemi) was detected 3 months after bariatric surgery ($p < 0.05$). However, there was no significant statistical increase in the whole macular thickness area and areas of perifovea (Average, Superior-Hemi and Inferior-Hemi) 3 months after the surgery ($p \geq 0.05$). The decrease in the FAZ area was statistically insignificant too ($p \geq 0.05$).

The mean pre- and 3 months post-operative changes in macular vascular density in superficial and deep plexus with their significance were described in table 2. Significant statistical increase in macular vascular density was detected in the deep capillary plexus 3 months after the bariatric surgery ($p < 0.05$). Meanwhile, the macular vascular density in the superficial capillary plexus showed no significant difference ($p \geq 0.05$).

Statistically significant correlations between the BMI and macular thickness, VD in different areas and the FAZ area were found and shown in table 3.

Discussion

In this study, 40 obese patients were investigated for the effect of bariatric surgery on the macular thickness and macular vascular density in both superficial and deep plexuses. Central macular thickness (CMT) in whole macula in our study preoperatively was 274.55 ± 7.9 μ m with mean BMI of 55.31 ± 5.1 Kg/m².

In 2016, Dogan et al studied a group of 67 patients defined as having morbid or class III obesity with mean BMI of $49.15 \pm 7.65 \text{ kg/m}^2$ and CMT of $240.99 \pm 21.47 \mu\text{m}$, and compared them with 29 age- and sex matched non-obese individuals with mean BMI of $22.99 \pm 1.89 \text{ kg/m}^2$ and CMT of $240.99 \pm 21.47 \mu\text{m}$. No significant statistical difference of CMT was detected ($p= 0.072$). CMT was measured using SD-OCT (Cirrus HD OCT, Carl Zeiss Meditec, Dublin, CA, USA) [7].

The CMT in our study preoperatively was higher than the CMT of the obese group in Dogan's study, although our mean BMI was higher than theirs. This could be explained by the mean age difference between both studies in addition to the ethnic difference [7].

In the current study, significant increase in the macular thickness areas of fovea and parafovea (average, Superior-Hemi and Inferior-Hemi) was detected 3 months after bariatric surgery ($p<0.05$). However, there was no significant increase in the macular thickness area and areas of perifovea (average, Superior-Hemi and Inferior-Hemi) 3 months after the surgery ($p\geq 0.05$).

Our results were similar to Brynskov et al, in which the retinal thickness of 51 patients with type 2 diabetes with no diabetic retinopathy was examined 2 weeks before and 1, 3, 6 and 12 months after bariatric surgery using Spectral domain OCT (Heidelberg Spectralis, Heidelberg Engineering GmbH, Heidelberg, Germany). Their study showed significant increase in the macular thickness (Total macula, Fovea, Parafovea and Perifovea), started at 3rd postoperative month with its peak at the 6th month then dropped back after 12 months [8].

OCTA is an emerging noninvasive tool for imaging and quantifying retinal vasculature at the level both superficial and deep plexuses and areas of non-perfusion such as FAZ. Utilizing standard sectors to measure the vascular density in the macular and the peripapillary regions allows the application of a uniform method to measure the VD in different ophthalmological conditions [9].

In normal subjects, it was found that the macular VD in the deep plexus was higher than the superficial retinal plexuses [9].

The current study also showed that preoperative macular VD in the deep plexus is higher than the superficial plexus in all macular regions. This finding was not far from that of Zhang et al, who studied the VD before intraocular pressure changes [10].

To our knowledge this research was the first to study the effect of weight loss after bariatric surgery on the blood flow of the macular region by measuring the VD in both deep and superficial capillary plexuses in different macular areas by using OCTA AngioVue system (Optovue RTVue XR Avanti; Optovue, Inc., Fremont, CA, USA).

We detected significant statistical increase in macular VD in the deep capillary plexus of all macular areas 3 months after bariatric surgery ($p<0.05$). However, the macular VD in the superficial capillary plexus in all macular areas did not show significant difference ($p\geq 0.05$).

Significant correlations were detected in this study between changes in the BMI, 3 months postoperatively and changes in the macular thickness in certain areas as shown in table 3.

The significant improvement in the macular VD of the deep plexus in our results can be explained by Çekiç et al who showed the effect of bariatric surgery using sleeve gastrectomy on the retrobulbar flow hemodynamic parameters. They found a significant increase in the central retinal artery and the ophthalmic artery blood flow measured by color doppler ultrasound 6 months, after a significant BMI reduction of 12.5 kg/m² [11].

The insignificant improvement of the VD in the superficial plexus in all macular areas in the current study may be attributed to Takuhei Shoji et al, who stated that vascular measurements obtained by OCTA only reflect some aspects of blood flow within the detected vessels, and does not represent an estimate of real blood flow. Specifically, this modality detects vasculature based on amplitude decorrelation, which results from perfused vessels, but does not directly quantify the flow rate within the detected vessels [12].

This study is not free from limitations. In addition to the general limitations related to the OCTA technology itself [13], the short post-operative follow-up period that may prevent detection of other changes or more significant improvements in superficial plexus vascular density indices is an additional downside, hence further studies with longer follow-up are needed. Also, it represented the results of a single center only with relatively homogenous population with certain ethnic origin and it didn't put the gender of the patients into consideration.

In conclusion, bariatric surgery had significant effect on some indices of macular VD measured by OCTA in obese patients 3 months postoperatively. OCTA can therefore be considered a valuable tool to assess the short term changes in the retinal microcirculation following significant weight reduction.

Declarations

- **Author contribution**

The manuscript has been read and approved by all the authors, the requirements for authorship have been met, and each author believes that the manuscript represents honest work.

- **Competing Interests:** Conflict of interest: No conflict of interest to disclose
- **Funding Info:** No source of funding to disclose.
- **Financial disclosure:** The authors have no financial or proprietary interest
- **Data Availability:** All data are available upon request
- **Animal Research:** This study was conducted adhering to the tenets of the Declaration of Helsinki.
- **Consent to Participate:** an informed consent was obtained from every patient before participation in the study
- **Consent to Publish:** an informed consent was obtained to publish their data

Financial disclosure: The authors have no financial or proprietary interest in a product, material or method described here.

Conflict of interest: No conflict of interest to disclose.

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Tables

Table 1
The mean pre- and 3 months post-operative changes in
macular thickness

	Preoperative	Postoperative	P value
Macular thickness			
whole	274.55 ± 7.9	274.60 ± 9.1	0.9
Fovea	231.35 ± 19.2	232.40 ± 19.4	0.002
Parafovea			
Average	311.35 ± 14.9	313.01 ± 16.2	0.0001
Superior Hemi	311.45 ± 14.5	312.90 ± 15.7	0.001
Inferior Hemi	310.95 ± 15.9	313.01 ± 17.0	0.0001
Perifovea:			
Average	271.95 ± 7.8	272.01 ± 8.8	0.9
Superior Hemi	273.10 ± 8.4	273.10 ± 9.3	0.9
Inferior Hemi	270.90 ± 8.2	271.05 ± 9.2	0.8
FAZ area (mm ²)			
	0.32 ± 0.1	0.31 ± 0.1	0.3

Table 2

The mean pre- and 3 months post-operative changes in macular vascular density.

Macular vessel density	Preoperative	Postoperative	P value
Deep VD % :			
whole	53.28 ± 5.2	55.12 ± 3.8	0.008
Fovea	33.61 ± 6.5	36.07 ± 6.3	0.001
Parafovea			
Average	56.19 ± 4.1	59.38 ± 3.2	0.01
Superior Hemi	58.69 ± 3.9	59.87 ± 3.3	0.008
Inferior Hemi	57.73 ± 4.8	59.90 ± 3.3	0.04
Perifovea:			
Average	55.16 ± 5.7	57.17 ± 4.1	0.007
Superior Hemi	54.87 ± 5.5	56.71 ± 4.1	0.01
Inferior Hemi	55.47 ± 6.2	57.64 ± 4.4	0.01
Superficial VD %:			
whole	51.79 ± 2.6	52.05 ± 1.9	0.4
Fovea	18.41 ± 5.5	19.06 ± 5.6	0.3
Parafovea:			
Average	55.09 ± 3.6	55.72 ± 1.9	0.3
Superior Hemi	55.04 ± 3.7	55.79 ± 1.9	0.1
Inferior Hemi	55.03 ± 4.1	55.63 ± 1.9	0.5
Perifovea:			
Average	52.32 ± 2.6	52.58 ± 2.3	0.4
Superior Hemi	52.23 ± 2.4	52.25 ± 2.5	0.6
Inferior Hemi	52.38 ± 3.1	53.02 ± 2.3	0.3

Table 3
Correlation between BMI and changes in OCT and OCTA

Correlations between:			
Changes in BMI and	Changes in	r	P value
	Deep Whole VD	0.289	0.025
	Deep Fovea VD	0.203	0.12
	Deep Parafovea Average VD	0.166	0.205
	Deep Parafovea Superior Hemi VD	0.18	0.168
	Deep Parafovea Inferior Hemi VD	0.281	0.03
	Deep Perifovea Average VD	0.254	0.05
	Deep Perifovea Superior Hemi VD	0.125	0.341
	Deep Perifovea Inferior Hemi VD	0.242	0.06
	Superficial Whole VD	-0.02	0.881
	Superficial Fovea VD	-0.21	0.108
	Superficial Parafovea Average VD	0.024	0.854
	Superficial Parafovea Superior Hemi VD	-0.085	0.519
	Superficial Parafovea Inferior Hemi VD	0.127	0.333
	Superficial Perifovea Average VD	-0.13	0.321
	Superficial Perifovea Superior Hemi VD	-0.21	0.107
	Superficial Perifovea Inferior Hemi VD	-0.23	0.863
	Thickness Whole	-0.251	0.053
	Thickness Fovea	-0.093	0.48
	Thickness Parafovea Average	-0.206	0.114
	Thickness Parafovea Superior Hemi	-0.159	0.226
	Thickness Parafovea Inferior Hemi	-0.383	0.003
	Thickness Perifovea Average	-0.297	0.021
	Thickness Perifovea Superior Hemi	-0.354	0.006
	Thickness Perifovea Inferior Hemi	-0.215	0.099
	FAZ area	0.333	0.009

Figures

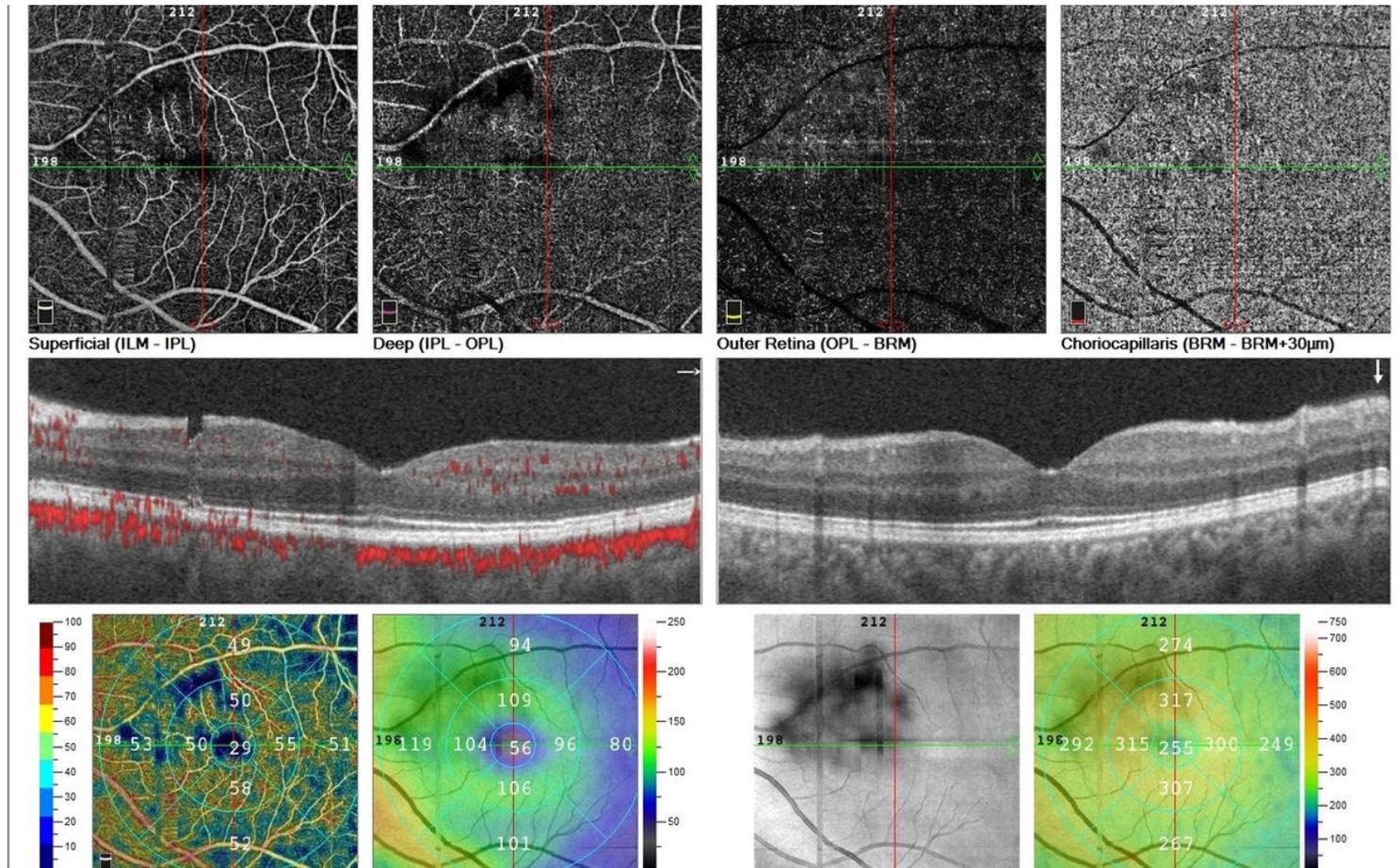


Figure 1

OCTA image of one of the included patients preoperatively showing the superficial and deep capillary plexus

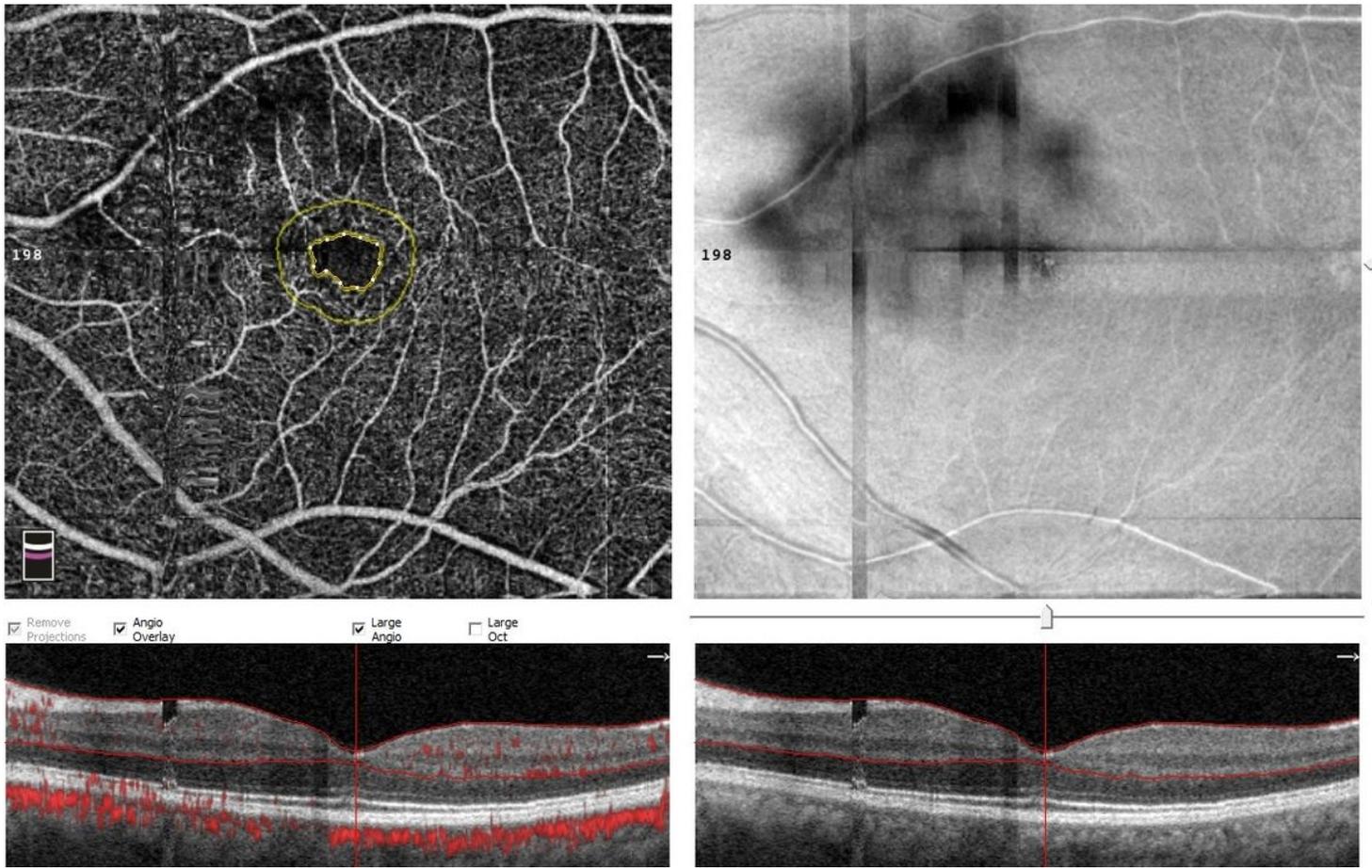


Figure 2

OCTA image of the same patient preoperatively showing FAZ area