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Evaluation of macular vessel density with OCTA in patients undergoing inferior oblique muscle surgery

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ABSTRACT

Aims: To evaluate pre-and postoperative macular vascular density changes in patients undergoing inferior oblique muscle surgery using optical coherence tomography angiography (OCTA).

Methods: 28 eyes of 16 patients who underwent inferior oblique muscle surgery were included in the study. Measurements were taken preoperatively (T0) and one day (PO1), 15 days (PO15) and 6 weeks (PO6w) after surgery. The vessel densities of the superficial capillary plexus (SCP), deep capillary plexus (DCP) and choriocapillaris (CCL) were measured by OCTA.

Results: This study included 28 eyes of 16 patients. The mean age of the patients was 8.07±5.5 years (4-23 years). SCP and DCP mean vascular densities decreased significantly at PO1 and PO15 compared to T0, but increased at PO6w, reaching their initial levels. Mean CCL levels were lower at PO1 compared to all other measurements and reached their preop values at PO6w.

Conclusion: The inferior oblique muscle insertion is known to be close to the macula and surgical interventions for this muscle may cause changes in macular vascular density. In our study, macular vascular density decreased in all parameters at PO1 compared to T0, but almost reached its preop levels at PO6w.

Keywords: Inferior oblique muscle, vessel density, OCTA

INTRODUCTION

Inferior oblique muscle hyperfunction (IOHF) is a common motility disorder associated with many types of strabismus.[1] In case of IOHF, elevation is observed in the adducting eye. If it is caused by paresis or paralysis of the superior oblique or superior recti muscles, it is called secondary IOHF, and if the etiology is unclear, it is called primary IOHF.[2,3] Surgical treatment of strabismus due to IOHF mainly aims to weaken the muscle. The most preferred methods are myectomy and anterior transposition.[4] According to Parks, anterior transposition is the most effective and longest lasting of the weakening procedures.[5]

The inferior oblique muscle insertion is located very close to the macula, one of the most critical regions of the eye. In addition, the inferior oblique muscle is the shortest of the ocular muscles, making it very difficult to manipulate during surgery. Excessive traction and globe compression causes compression of the short posterior arteries and this traction can also affect the macula due to its close proximity. The fusion of the muscle with the sclera varies between individuals and in 50% of cases it fuses in 2-6 separate layers.[6] Some studies have reported that the inferior oblique muscle is more hypertrophic in men than in women.[7,8] Possible changes in the choroidal and retinal circulation after inferior oblique muscle surgery are thought to be related to surgically induced inflammation.[9,10]

Although many studies have been performed using fundus photography, color Doppler ultrasound, fluorescein angiography, indocyanine green angiography, there is no general consensus on hemodynamic changes after strabismus surgery.[11-13] Optical coherence tomography angiography (OCTA) is noninvasive and visualizes microvascular structures of the retina and optic nerve head without pupil dilation. In addition to saving time, it does not require dye injection and shows both thickness and vascular density of certain layers of the retina at the same time compared to fluorescein angiography.[14] When we look at the literature, the effect of surgery on vascular density is not yet clear in OCTA measurements obtained with OCTA in patients undergoing inferior oblique surgery.[10,15] The aim of our study is to show possible macular vascular density changes after inferior oblique surgery in patients with IOFH with OCTA.

METHODS

Twenty-eight eyes of 16 patients who were followed up in the strabismus unit of Fırat University Medical Faculty Hospital and planned to undergo inferior oblique muscle surgery were included. The study was performed with the approval of Fırat University Non-interventional Researches Ethics Committee (Date: 13.02.2024, Decision No: 2024/03-48). Informed consent was obtained from all subjects or their legal representatives and the study was conducted in accordance with the principles of the Declaration of Helsinki. Each patient underwent a complete ophthalmologic examination including visual acuity measurement with Snellen chart with and without correction, cycloplegic refraction, anterior segment examination, dilated fundus examination, detailed strabismus examination (cardinal gaze positions, covering test, prism, Krimsky and head position tests). IOHF grading was performed by the same ophthalmologist specializing in strabismus. IOHF was determined by grading from +1 to +4.[1]

Only IOHF patients with +2 and above were included in surgery. Patients with sensory and restrictive strabismus, history of ocular surgery and corneal opacity, medical history involving retinal and choroidal tissues such as glaucoma, uveitis, maculopathy and amblyopia were excluded. Patients with systemic diseases affecting the vascular tissues such as hypertension and diabetes mellitus, systemic drug use in the last one month affecting the surgery, and patients who could not adapt to OCTA were excluded. Finally, patients with significant growth retardation and neurologic abnormalities were also excluded.

Surgical Method

All surgical procedures were performed under general anesthesia by the same experienced strabismus surgeon. In inferio oblique muscle retraction surgery, the eye was retracted towards the superonasal quadrant after placement of a traction suture superotemporal to the cornealimbus border. An incision was made in the inferotemporal conjunctiva 8 mm from the limbus. Blunt dissection was continued until the sclera was exposed. The inferior oblique muscle was then dissected from the surrounding tissues using two strabismus hooks. The muscle was first clamped with clamped 6/0 vicryl sutures Vicryl near the entry site and then cut. The inferior oblique muscle was sutured with 6/0 Vicryl sutures 2 mm temporal and 2 mm posterior to the insertion site of the inferior rectus muscle in patients without DVD pattern and at the inferior rectus level in patients with DVD pattern. Tenon capsule and conjunctiva were sutured with 8/0 Vicryl and the operation was completed.

Optical Coherence Tomography Angiography

Quantitative measurements were obtained with OCTA (Solix, Visionix/Optovue, USA) preoperatively (T0) and one day (PO1), 15 days (PO15) and 6 weeks (PO6w) after surgery. An eye-tracking system was used during angiographic scans. Pupil dilatation was not performed. Scans were concentrated in the center of the fovea and covered a 3×3 mm area of the macula. Retinal vasculature was assessed in three horizontal segmentations: superficial capillary plexus (SCP), deep capillary plexus (DCP) and choriocapillaris (CCL). According to default settings, the SCP layer was considered to be the ganglion cell layer and the inner plexiform layer (60 µm layer thickness from the inner limiting membrane), the segmentation of the inner plexiform layer and outer plexiform layer for the DCP (30 µm thick layer from the inner plexiform layer), and the CCL segmentation with the outer margin of Bruch's membrane as the upper boundary (30 µm thick layer from the outer edge of Bruch's membrane).[15-17] OCTA examinations were repeated if a decentralized condition was detected. Images showing segmentation errors and/or artifacts were excluded from the analysis.

Statistical Analysis

The study data were computerized and evaluated using "SPSS (Statistical Package for Social Sciences) for Windows 25.0 (SPSS Inc., Chicago, IL)". The conformity of continuous numerical variables to normal distribution was evaluated by Shapiro Wilk test. Paired Samples T test was used to compare the data between the times of measurements. Bonferroni correction was used in pairwise comparisons to determine the significant group. 95% confidence interval was used. Data were summarized as mean±standard deviation values. P<0.05 was accepted as statistically significant for all analyses.

RESULTS

The study included 28 eyes of 16 patients. Ten of the patients were female and six were male. The mean age of the patients was 8.07±5.5 years (4-23 years). There was no significant difference in best corrected visual acuity before and after surgery (p>0.05). There were no complications during and after surgery. Inferior oblique muscle function improved significantly in all patients.

Table shows the vascular density values in the SCP, DCP and CCL in the macular region before and after surgery. Accordingly, SCP and DCP mean vascular densities decreased significantly at PO1 and PO15 compared to T0, but increased at PO6 weeks and reached their initial levels (p<0.05, p<0.05, p<0.05, p<0.05, respectively). Mean CCL levels were lower at PO1 compared to all other measurements and reached their preop values at PO6 weeks (p<0.05).

Table. Vascular density in the macula by OCTA before and after inferior oblique muscle surgery

OCT and OCTA measurements	T0	PO1	PO15	PO6w
SCP	48.464±1.426[a]	45.721±1.278	47.386±1.910[a, b]	48.550±1.702[a, c]
DCP	50.986±2.243[a]	48.443±2.279	49.286±2.574[b]	51.043±2.138[a, c]
CCL	55.357±2.822[a]	52.779±2.520	54.150±2.630[a]	56.500±2.308[a, c]

CCL, choriocapillaris layer; DCP, deep capillary plexus; SCP, superficial capillary plexus. Results are given as mean±standard deviation. [a]p<0.05 compared with PO1, [b]p<0.05 compared with T0, [c]p<0.05 compared with PO15

DISCUSSION

In this study, we evaluated the vascular densities in the capillary plexuses (SCP, DCP, CCL) in the macular region before and after inferior oblique muscle surgery with OCTA in patients with IOHF who underwent surgery. Although vascular density decreased in the early postoperative period (postoperative day 1 and day 15), it reached the preoperative values at postoperative week 6.

OCTA can objectively measure the retinal microvasculature in a noninvasive and reproducible manner.[18] It provides a three-dimensional representation of the retinal vascular circulation in the macula in different layers: SCP, DCP and CCL. Numerous studies using OCTA have demonstrated vascular changes in the posterior pole in different diseases.[16,19] Strabismus surgery is especially performed in the pediatric population. Therefore, the fact that OCTA has an eye tracking system and provides high quality photography without pupil dilatation provides an advantage in the field compared to many other examinations.[18] Studies using OCTA in patients undergoing strabismus surgery are available in the literatüre.[10,15,17] However, there is no clear consensus on the effect of surgery on retinal vascular circulation.

In our study in which we performed inferior oblique muscle surgery in 28 eyes of 16 patients and examined the vascular density in the macula with OCTA one day, 15 days and 6 weeks after preop surgery; SCP and DCP mean vascular densities decreased at PO1 and PO15 compared to T0 and increased at PO6w and reached their values at T0, CCL mean levels were lower at PO1 compared to all other measurements and reached their preop values at PO6w. In the retrospective OCTA study by Çelik et al.,[10] which was similar to our study and was conducted with a relatively larger number of patients and eyes, the vascular density in the SCP, DCP, CCL and foveal avascular zone (FAZ) were examined preop, at 1, 7 and 30 days after surgery. In this study, there was no difference in SCP, DCP and FAZ after surgery, and although there was an increase in CCL after one week, it reached its initial levels after one month.

When we look at other strabismus studies performed with OCTA, the study of Vage et al.[15] and the study of Inal et al.[17] are found in the literature. Vage et al.included 92 eyes of 56 patients and performed surgery mostly on the medial retctus and lateral rectus muscles. In this study, DCP and CCL measurements obtained by OCTA increased significantly on the first postoperative day compared to the preoperative values, but again reached the preoperative values on the 30th postoperative day. Inal et al. performed surgery unilaterally on two horizontal muscles in their OCTA study involving 32 eyes of 16 patients. In this study, they found a significant increase in SCP and DCP and a decrease in the foveal avascular area 3 months after surgery. The medial rectus and lateral rectus muscles are also supplied by the anterior ciliary artery.[20] The inferior oblique muscle is supplied by branches from the ophthalmic artery and infraorbital artery.[21] The vascular supply between the horizontal muscles and the inferior oblique muscle may explain the differences between the studies. Previous studies have also shown that retinal blood supply increases in the first days in some studies, but the general opinion is in favor of returning to baseline levels by day 7.[11,20,22]

Atalay et al.[23] in their study including 41 patients in whom they underwent rectus muscle surgery and inferior oblique muscle surgery, they found a greater increase in choroid thickness in patients in whom they underwent rectus surgery than in inferior oblique muscle surgery. They attributed this result to less inflammation in inferior oblique muscle surgery because they made a fornix incision and did not use sutures. They also argued that inferior oblique hyperfunction may have created a traction effect in the macular region and that this traction was reduced by surgery. Celik et al.[10] they found an increase in CCP only in the first postoperative week after inferior oblique muscle surgery. And they attributed this result to inflammation and the possibility that compensatory mechanisms may have developed to prevent anterior segment ischemia. Again, in a recent study involving 18 patients, they concluded that inferior oblique myectomy surgery may increase choroidal hemodynamics in the early period and that this effect is temporary.[25]

There are 3 phases of wound healing: The hypodynamic phase (1), characterized by limited blood loss; the hyperdynamic phase (2), characterized by increased blood flow; and the healing phase (3), which lasts for months and attempts to return the human body to its pre-injury state.24 In our study, our finding of low avacular density in all layers in the early postoperative period can be explained by hypodynamia in the early phase of wound healing. In the 6th week, it returned to its previous levels, which can be explained by the completion of wound healing. When we look at the literature, the effect of surgery on vascular density in OCTA measurements taken in patients undergoing inferior oblique surgery is not yet clear. Differences in study results may be attributed to differences in individual healing response.

Limitations

The small number of cases included in our study is our biggest limitation. Further studies with a larger patient population are needed.

CONCLUSION

Our results demonstrate that transient hemodynamic changes may occur in the SCP, DCP, and CCL following inferior oblique muscle anterior transposition surgery and emphasize the utility of OCTA in assessing vascular changes after strabismus surgery.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was performed with the approval of Fırat University Non-interventional Researches Ethics Committee (Date: 13.02.2024, Decision No: 2024/03-48).

Informed Consent

Written consent was obtained from the patient participating in this study.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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