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Posterior ocular parameters following extraocular muscle surgery: an optical coherence tomography study

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Abstract

Background/Aim: Muscle trauma, vascular injury, and compensatory vasoconstriction during strabismus surgery may cause changes in the choroidal circulation in the early postoperative period. This study aims to evaluate the effect of extraocular muscle surgery on posterior ocular parameters, including central subfield thickness (CST), average retinal thickness (ART), choroidal thickness (CT), and macular volume (MV).

Methods: This prospective cohort study included 26 eyes of 26 strabismic patients who underwent single medial or lateral rectus recession surgery using a fornix-based conjunctival incision. All participants underwent detailed ophthalmologic evaluation, including axial length (AL) and spherical equivalent (SE), uncorrected (UCVA), and best-corrected visual acuity (BCVA). Retinal and choroidal images were obtained using spectral-domain optical coherence tomography (OCT). All measurements were performed preoperatively and repeated 1 week and 1 month after surgery.

Results: All patients received satisfactory results in terms of deviation. None of the patients showed changes in AL, SE, UCVA, and BCVA. No significant differences were noted in CST and MV values (P=0.472 and P=0.182, respectively). Although subfoveal CT and ART showed statistically significant decreases 1 week after surgery (P=0.012 and P=0.046, respectively), no significant differences in these values were observed 1 month after surgery (P>0.05). No significant differences exist in the measurements between the preoperative, postoperative first week, and first month in nasal and temporal CT (P>0.05).

Conclusion: Extraocular muscle surgery performed with the fornix-based conjunctival incision is a safe procedure for posterior ocular parameters, including CST, ART, CT, and MV.

Keywords: Choroidal thickness, EDI-OCT, Retinal thickness, Recession surgery, Strabismus

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Ethics Committee Approval
The study was approved by the Ordu University Ethics Review Committee (approval date/no: 2020/41).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Introduction

Strabismus surgery aims to achieve a proper ocular alignment, prevent or treat amblyopia and improve binocular visual function in children [1-3]. Strabismus is one of the most common surgical indications in ophthalmologic practice [4]. Extraocular muscle disinsertion and reinsertion during surgery may affect other ocular tissues. The effect of strabismus surgery on anterior segment circulation is well-known. Muscle trauma, vascular injury, and compensatory vasoconstriction during strabismus surgery may cause changes in the choroidal circulation in the early postoperative period. However, the effect on the posterior segment is still unclear.

The choroid functions in outer retinal supplementation, thermoregulation, secretion of growth factors, and thus scleral growth, refractive focus, and emmetropisation [5]. Age, gender, refractive errors, and even diurnal rhythm affect choroidal thickness (CT) [5-7]. Changes in CT may result in retinal and retinal pigment epithelial diseases [8,9]. Thus, several studies are being conducted on retinochoroidal analysis at an increasing rate to understand the pathophysiology of many disorders. Optical coherence tomography (OCT) is an important tool for the diagnosis and treatment of chorioretinal diseases [10]. The enhanced depth imaging-OCT (EDI-OCT) provides comprehensive choroidal imaging and helps understand the pathophysiology of ocular disorders.

Limited studies evaluating the effect of different strabismus surgeries on CT or macular changes are available in the literature [11-13]. Thus, this study aims to evaluate the effect of extraocular muscle surgery on posterior ocular parameters, including central subfield thickness (CST), average retinal thickness (ART), CT, and macular volume (MV).

Materials and methods

This prospective study was conducted following the Helsinki Declaration and was approved by the Ordu University Ethics Review Committee (approval date/no: 2020/41). Written informed consent was obtained from all participants or their parents.

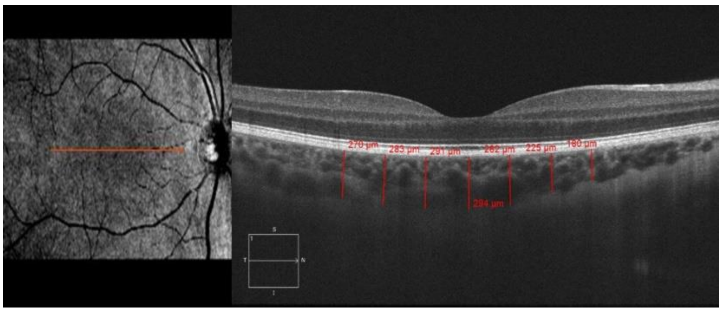
This study included 26 eyes of 26 patients diagnosed with horizontal strabismus and underwent single medial rectus (MR) or lateral rectus (LR) recession surgery between April 2020 and December 2020. Patients with a history of prematurity, chronic systemic diseases, vascular abnormalities, craniofacial anomalies, nystagmus, sensory or restrictive strabismus, retinal or macular pathologies, glaucoma, orbital pathology, ocular trauma, previous ocular or extraocular muscle surgery were excluded. Similarly, patients who underwent vertical rectus or oblique muscle surgery, horizontal muscle resection surgery, and who could not cooperate for the OCT imaging were also excluded.

All participants underwent detailed ophthalmologic evaluation, including uncorrected (UCVA) and best-corrected visual acuity (BCVA) using the Snellen chart, cycloplegic refraction, slit-lamp biomicroscopy, and dilated fundus examination. The angles of near and distance deviations were measured using an alternate prism cover test and recorded in terms of prism dioptres (PD). Abnormal head position, extraocular muscle overaction, and eye movements in nine cardinal positions were also noted. Axial length (AL) was measured using ultrasonic biometry (Pac-Scan 300p, Sonomed Escalon, New Hyde Park, NY, USA). Retinal and choroidal images were obtained using the spectral-domain OCT (SD-OCT; Cirrus HD-OCT 4000, Carl Zeiss Meditec Inc., Dublin, CA, USA) before pupillary dilation. Cycloplegic refraction was measured using an autorefractometer (Tonoref III, NIDEK Co., Ltd., Tokyo, Japan) 30 min after instillation of 1% cyclopentolate hydrochloride (Sikloplejin®, Abdi Ibrahim Pharmaceuticals, Istanbul, Turkey) twice at an interval of 5 min. All measurements were taken between 09.00 and 12.00 a.m. to exclude diurnal variation.

All patients were operated on using the same technique under general anesthesia by a single surgeon (AU). A fornix-based conjunctival incision was used to reach extraocular muscles. Single muscle recession surgery (MR recession for esodeviation and LR recession for exodeviation) was performed in all patients. The muscles were inserted into the sclera using absorbable double-armed 6-0 vicryl (polyglactin 910) suture, and the conjunctiva was closed with absorbable 8-0 vicryl (polyglactin 910) suture. Topical moxifloxacin (0.5%)–dexamethasone (0.1%) combination (Moxidexa®, Abdi Ibrahim Pharmaceuticals) was prescribed four times daily for two weeks, postoperatively.

SD-OCT images were obtained by a single experienced technician. Those scans with a signal strength of ≥7/10 were taken. CST (the average thickness of macula in the central 1-mm diameter circle) and ART scans were performed using a macular cube 512 × 128 scan protocol (128 consecutive line scans). This protocol has a scan area of 6 × 6 mm of the retina, and macular thickness is calculated in microns in an area corresponding to the Early Treatment Diabetic Retinopathy Study grid. CT was obtained using SD-OCT with EDI modality. The CT was measured from the outer part of the hyperreflective line corresponding to the retinal pigment epithelium, perpendicular to the inner surface of the sclera (Figure 1). CT was measured in 7 points: at the foveal center (one point) and within the horizontal temporal (three points) and nasal (three points) positions at 500-μm intervals to a distance of 1,500 μm from the foveal center. Furthermore, CT measurements were manually evaluated by two experienced masked ophthalmologists (AU and AKS) via the Cirrus HD-OCT software caliper, and the measurements were averaged for analysis.

Figure 1: Enhanced depth optical coherence tomography image of choroidal thickness in a patient



Detailed ophthalmologic evaluation, angle of deviation, AL, and retinal and choroidal measurements were performed preoperatively and then repeated at 1 week and 1 month after surgery. All participants completed the study.

Statistical Analysis

All data were analyzed using the SPSS statistical software package, version 21.0 (SPSS Inc., Chicago, IL, USA). The sample size is based on the literature of the difference observed in CT after strabismus surgery. A power of 80% and a confidence level of 95% yielded the sample size. The Shapiro–Wilk test was used to determine whether variables are normally distributed. Data are given as mean and standard deviation or median (minimum-maximum) for continuous variables according to the normality of distribution and as frequency (percentage) for categorical variables. The normally distributed repeated measurements were analyzed with the paired t-test or repeated-measures analysis of variance (ANOVA), depending on the count of measurements. With the Wilcoxon signed-rank test or Friedman's ANOVA by ranks, non-normally distributed repeated-measurements were analyzed. $P<0.05$ was accepted as a statistically significant level.

Results

The mean age of the 26 patients in the study was 18.85 (11.12) years. The demographic and clinical characteristics of the participants in the study groups are presented in Table 1. Fifteen (57.69%) and eleven (42.31%) patients with esodeviation and exodeviation underwent MR and LR recessions, respectively. Slit-lamp and fundus examination were normal in all eyes. None of the patients had an abnormal head position or extraocular muscle overaction. Eye movements in nine cardinal positions showed no limitation in all participants.

Table 1: Demographic and clinical characteristics of the patients

Parameter	n=26
Age (years)	15 (7–45)
Gender	
Male	10 (38.46%)
Female	16 (61.54%)
Diagnosis	
Esotropia	15 (57.69%)
Exotropia	11 (42.31%)
Preoperative angle of deviation (PD)	40.5 (30–50)
Amount of recession (mm)	6 (5–9)

PD: prism dioptres

No major complications (e.g., scleral perforation, ocular hemorrhage, or fat prolapse) were observed in any patients during or after surgery. All patients received satisfactory results in terms of deviation, and all of them were within 10 PD of deviation in the first month. None of the patients showed any major changes in cycloplegic refraction. No significant difference was noted in postoperative SE (P=0.845). Compared to preoperative values, no change in postoperative UCVA and BCVA was also noted.

The OCT scans were qualitatively and quantitatively assessed. Moreover, postoperative morphological abnormalities were not detected in OCT scans. No significant differences in CST and MV values were observed 1 week and 1 month after surgery (P=0.472 and P=0.182, respectively; Table 2). Similarly, no significant difference was noted in postoperative AL (P=0.637).

In the preoperative and postoperative comparison, subfoveal CT and ART showed a statistically significant decrease 1 week after surgery (P=0.012 and P=0.046, respectively). No significant differences in measurement exist between the preoperative, postoperative first week and first month in terms of nasal (P=0.494, P=0.590 and P=0.446, respectively) and temporal (P=0.815, P=0.868 and P=0.506, respectively) CT values (Table 1).

Table 2: Summary of preoperative and postoperative measurements of the patients

Parameter	Preoperative	Postoperative 1st week	Postoperative 1st month	*P*-value	*P*-value Preoperative vs. 1st week	*P*-value Preoperative vs. 1st month
AL (mm)	22.33 (20.36-24.83)	22.34 (20.45–24.80)	22.46 (20.36–24.76)	0.637[a]	0.354[c]	0.588[c]
SE (diopter)	2.13 (−0.63–6.38)	1.94 (−0.63–7.63)	2.00 (−0.75–6.38)	0.845[a]	0.943[c]	0.552[c]
CST (µm)	243.85 (19.79)	243.92 (20.15)	245.50 (20.08)	0.472[b]	0.964[d]	0.261[d]
ART (µm)	279.12 (19.91)	277.08 (20.04)	279.19 (19.59)	0.098[b]	**0.046[d]**	0.953[d]
MV (mm^3)	10.05 (0.72)	9.99 (0.72)	10.6 (0.72)	0.182[b]	0.083[d]	0.807[d]
Subfoveal CT	354 (274-529)	352 (273-520)	354.50 (287-509)	0.062[a]	**0.012[c]**	0.264[c]
Nasal CT						
500 µm	332.96 (53.42)	329.27 (48.32)	328.50 (49.05)	0.494[b]	0.341[d]	0.315[d]
1000 µm	319 (242-448)	319.50 (240-448)	311.50 (227-480)	0.590[a]	0.577[c]	0.899[c]
1500 µm	283.50 (205-420)	282 (227-420)	281 (215-438)	0.446[a]	0.289[c]	0.199[c]
Temporal CT						
500 µm	340 (267-546)	338.50 (265-546)	329.50 (253-515)	0.815[a]	0.331[c]	0.576[c]
1000 µm	333 (237-519)	335 (260-519)	335 (256-508)	0.868[a]	0.764[c]	0.830[c]
1500 µm	320 (217-511)	307 (242-511)	315 (229-485)	0.506[a]	0.721[c]	0.360[c]

AL: axial length, SE: spherical equivalent, CST: central subfield thickness, ART: average retinal thickness, MV: macular volume, CT: choroidal thickness, [a] Friedman's analysis of variance by ranks, [b] Repeated measures analysis of variance, [c] Wilcoxon Test, [d] Paired-Samples T Test

Discussion

Advances in OCT technology, allow detailed analysis of the retinal and choroidal structures and understanding of the pathophysiology of many diseases. In the literature, the relationship between retinal/CT and strabismus, anisometropic amblyopia, and strabismic amblyopia were investigated [14-17]. Studies investigating the retinal structures and choroidal thickness in patients who underwent strabismus surgery are limited. In this study, the morphological effects of extraocular muscle surgery on posterior segment structures were evaluated.

Yetkin and Simsek [11] evaluated CT at seven points and found a significant decrease at all points in the first week and the first month after double horizontal muscle surgery. Consequently, it returned to normal in the third postoperative month. In contrast, no significant differences were noted in our study between the preoperative, postoperative first week, and first month measurements in the nasal and temporal CT. A possible explanation for this discrepancy is that our study included only patients with single muscle recession. Furthermore, Inan and Niyaz [13] showed a significant decrease in CT in all areas in the first postoperative day and 2 weeks after single muscle surgery. Similarly, a significant decrease was noted in only the subfoveal CT in the first month but returned to preoperative values at the end of the third month. The subfoveal CT in our study showed a significant decrease in the first week, but returned to preoperative values 1 month after surgery. Contrary to these results, Atalay et al [18] reported a temporary increase in subfoveal CT in the first postoperative day following single muscle surgery, but a return to preoperative values in the first postoperative week. The disruption of anterior ciliary arteries and anterior ciliary circulation, venous drainage obstruction (due to recession/resection of rectus muscle), and periocular inflammation may be responsible for the temporary increase in subfoveal CT [18].

Inan and Niyaz [13] also examined the effect of different strabismus surgeries on CT at five points and found that a decrease in CT was lower in multiple muscle surgeries compared with single muscle surgery. They suggested that multiple muscle surgeries may cause choroidal vasoconstriction, ischemia, and inflammation resulting in increased choroidal blood flow. Studies investigating CT in inflammatory diseases showed choroidal thickening in the active phases of diseases related to the corresponding vascular involvement [19]. In the present study, nasal and temporal CT may not have changed due to single muscle recession surgery resulting in less choroidal microcirculatory dysfunction, less mechanical traction, and less surgical trauma. Although inflammation following strabismus surgery is an expected condition, vasoconstriction in the dense vascular structures of the choroid may cause a decrease in CT [13]. Postoperative steroid therapy may also affect the extent of the inflammation and thus choroidal thickness. In studies evaluating the effect of strabismus surgeries on CT, there was no significant difference between the postoperative steroid treatment regimen [11,13]. In our study, postoperative steroid treatment was applied similarly to previous studies.

All surgeries were performed with a limbal conjunctival incision in previous studies evaluating the effect of different strabismus surgeries on CT or macular changes. In this study, the fornix-based conjunctival incision was used in all patients. Atalay et al [18] commented that using a limbal incision instead of a fornix-based incision and applying more mechanical traction to muscles during surgery may cause greater inflammation. Consequently, the American Association for Pediatric Ophthalmology and Strabismus members thought that fornix-based incisions result in less postoperative inflammation and faster soft-tissue healing [20]. Furthermore, no significant decreases were observed in nasal and temporal CT values in this study, although subfoveal CT and ART showed statistically significant decreases in only the first postoperative week. In addition, any significant differences in CST and MV values and morphological abnormalities in OCT scans could not be found. The use of fornix-based conjunctival incision resulting in less inflammation in the patients of the current study may cause unchanged CT, CST, ART, and MV values at month 1. Moreover, retinal thickness could be expected to not be different because CT did not change. Subfoveal CT is the highest in this study, followed by temporal CT. Moreover, nasal CT is the thinnest. The results of this study are consistent with previous studies suggesting a radial distribution of choroidal vessels from the peripapillary region and progressive increase of choriocapillaris vessel size, increased density of vascular structures in the foveal area due to increased metabolic activity, and finally optic nerve passage through the lamina cribrosa [21, 22].

Zhou et al [23] demonstrated an increase in central retinal arteriolar equivalent and central retinal venular equivalent on the first day following strabismus surgery and reported that both double and single muscle surgeries may increase retinal blood flow in the early postoperative period but will return to normal later. Additionally, they detected retinal hemodynamic changes in the eyes undergoing only MR muscle surgery and argued that the main cause of these changes compared to inflammation was the number of transected ACAs, and at least two ACAs injuries were required to change retinal blood flow. Unfortunately, the correlation between retinal/CT and retinal blood flow was not evaluated in that study.

In addition to unchanging AL, retinal, and CT, none of the patients in this study developed a significant change in SE, UCVA, and BCVA. Visual function was reported to remain unaffected, even if changes were detected in CT following strabismus surgery [11]. No change in visual function can be expected because a significant difference in CT was not determined.

Limitations

The small number of cases and the relatively short-term follow-up were the limitations of this study. All examinations including posterior ocular parameters were evaluated 1 week and 1 month after surgery. However, AL, retinal and choroidal thickness could not be measured on the first postoperative day due to the patients’ discomfort. This is also a limitation. Despite these limitations, the current study will contribute to the literature because it is the first to evaluate the posterior ocular parameters including CST, ART, CT, MV, and also AL and SE following single horizontal rectus muscle recession surgery performed with the fornix-based conjunctival incision.

Conclusion

Extraocular muscle surgery performed with the fornix-based conjunctival incision is a safe procedure in terms of posterior ocular parameters including CST, ART, CT, and MV. Thus, further studies comparing the effect of recession and resection surgeries performed with a limbal or fornix-based conjunctival incision on posterior ocular parameters with a larger number of subjects are needed.

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