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Original Article

Evaluation of choroidal structural changes after silicone oil removal in rhegmatogenous retinal detachment

Sehnaz Ozcaliskan[1], Sevcan Balci[2]

[1]Clinic of Ophthalmology, Beyoglu Eye Training and Research Hospital, Istanbul, Turkey
[2]Clinic of Ophthalmology, Haydarpasa Numune Training and Research Hospital, Istanbul, Turkey

Abstract

Aim: To evaluate the choroidal structural changes after silicone oil (SiO) removal in patients who underwent pars plana vitrectomy (PPV) for macula off rhegmatogenous retinal detachment (RRD).

Material and Methods: In this retrospective study, the charts of patients with macula off RRD who underwent SiO removal between February and June 2019 were reviewed. The subfoveal choroidal thickness (SFCT) was measured before and after SiO removal by enhanced depth imaging optical coherence tomography (EDI OCT). The subfoveal choroidal area was (TCA) segmented into luminal (LA) and interstitial stromal area (SA) by the binarization technique using ImageJ software (Version 1.52i, National Institutes of Health, Bethesda, MD USA). Choroidal vascularity index (CVI) was defined as the ratio of LA to the TCA.

Results: There were 15 (%62.5) male and 9 (%37.5) female patients in the study group. The mean SFCT was 288.71±63.63 µm under SiO in the operated eyes. After SiO removal the mean SFCT significantly decreased to 259.33±51.25 µm at month 3 (p=0.004). The mean CVI was 63.37±3.50% under SiO filled eyes. After SiO removal, the mean CVI significantly decreased to 58.83±3.41% at month 3 (p<0.001). The mean LA was 1.37±0.46 vs. 1.18±0.47 preoperatively and postoperatively in the operated eyes (p=0.028). There was no significant difference in the mean SA and TCA values between preoperative and postoperative measurements (p=0.742, p=0.175, respectively).

Conclusion: Image binarization of EDI OCT scans and CVI analysis enables the assessment of choroidal changes after SiO removal. CVI decreased and the lumens of the choroidal vessels became smaller after SiO removal. CVI may be used as a parameter to monitor the choroidal changes that might be associated with inflammation secondary to SiO.

Keywords: Choroidal thickness; choroidal vascularity index; silicone oil; vitrectomy

INTRODUCTION

Silicone oil (SiO) was first introduced by Cibis for vitreoretinal surgery and was used for intraocular tamponade owing to its buoyant force and high surface tension (1). SiO usage has been associated with higher postoperative success and lower proliferative vitreoretinopathy incidence in rhegmatogenous retinal detachment (RRD) (2). However, complications such as cataract, glaucoma, and corneal decompensation may occur in SiO-filled eyes (3). Histopathological studies have demonstrated the presence of SiO droplets in the iris, retina, trabecular meshwork, and ciliary processes with coexisting inflammation (4). In addition to histopathological evidence, previous optical coherence tomography (OCT) studies have demonstrated that SiO instillation is associated with structural alterations in both the retinal layers and choroid (5-8). Thus, SiO should be removed from the eye as soon as possible after retinal stabilization is achieved.

The choroid layer is formed by blood vessels and stroma. The stroma is the connective tissue that surrounds blood vessels and consists of collagen, elastin, melanocytes, nerves, and extracellular fluid. It is not clear which tissues of the choroid are related to the changes in choroidal thickness (CT). Recently, binarization of enhanced depth imaging optical coherence tomography (EDI OCT) scans and choroidal vascularity index (CVI) have allowed quantitative evaluation of choroidal structures. In contrast to CT, CVI is less variable and less affected by physiological factors (9).

The aim of this study was to assess choroidal structural changes after silicone oil removal in macula-off RRD using the image binarization tool on EDI OCT scans in patients treated with vitrectomy and SiO endotamponade.

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Corresponding Author: Sehnaz Ozcaliskan, Clinic of Ophthalmology, Beyoglu Eye Training and Research Hospital, Istanbul, Turkey
E-mail: drsehnaz@yahoo.com

MATERIAL and METHODS

This retrospective observational study was conducted in accordance with the Declaration of Helsinki and approved by the University of Health Sciences, Hamidiye Ethics Committee. All participants were recruited from Beyoglu Eye Training and Research Hospital. All participants provided written and informed consent before surgery and imaging procedures.

Participants

A review was made of the medical records of patients who had undergone 23 gauge pars plana vitrectomy (PPV) with silicone oil endotamponade for macula off RRD and subsequent uncomplicated silicone oil removal between February and June 2019. Inclusion criteria were patient age of 18 years or older and primary macula off RRD in one eye. Exclusion criteria were as follows: retinal detachment other than RRD, re-detachment within 3 months after SiO removal, a history of glaucoma and ocular hypertension, ocular inflammation, myopia >6 diopters, history of intraocular surgery except for uncomplicated cataract surgery and other retinal pathologies in one or both eyes. Participants underwent a comprehensive ophthalmological evaluation before and at 3 months after silicone oil removal. Examinations included best-corrected visual acuity (BCVA) with Snellen chart, slit-lamp biomicroscopy, intraocular pressure measurement with Goldmann applanation tonometry, dilated fundus examination, and EDI OCT imaging on each visit.

Acquisition and binarization of EDI OCT images

EDI OCT measurements were taken using a Heidelberg Spectralis device (Heidelberg Engineering GmbH, Heidelberg, Germany). OCT were performed between 09:00 and 12:00 a.m. in all study participants at each visit. A preoperative scan of a 6 mm horizontal line passing through the center of the fovea was acquired and set as a reference. The follow-up function was used to align all subsequent scans after SiO removal OCT scans were excluded if the quality score was less than 20.

The subfoveal choroidal thickness (SFCT) was measured with horizontal B-scans on vertical lines running from the outer border of the retinal pigment epithelium towards the choroidal-scleral junction from the center of the subfoveal area manually by two observers (SO, SB) using digital calipers present in the Heidelberg Spectralis OCT software. All the measurements were done after the study protocol was completed. The average of two observers' measurements were taken for the SFCT analysis. The intraobserver and interobserver intraclass correlation coefficient (ICC) was calculated using 30 randomly selected images to determine reliability and reproducibility of the measurements.

The CVI analysis was perfomed semi-automatically by binarization of the horizontal B-scans using ImageJ software (Version 1.52i, National Institutes of Health, Bethesda, MD USA). The fovea was selected, and it was segmented using the protocol described by Agrawal et al. (10). The CVI analysis procedures were repeated three times by the same observer (SB) who was masked to patients' diagnosis and the averaged values of TCA, LA, SA and CVI measurements were used in the analyses. (Figure 1). The differences between the obtained parameters at baseline and 3 months after SiO removal were evaluated.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences for Windows ver. 22.0 software (SPSS Inc., Chicago, IL, USA). Demographic characteristics of the patients were summarized using descriptive statistics. The mean and standard deviation of the parameters were calculated. The Wilcoxon signed-rank test was used for comparisons of SFCT, LA, SA, and CVI between study groups. A value of $p<0.05$ was considered to be statistically significant.

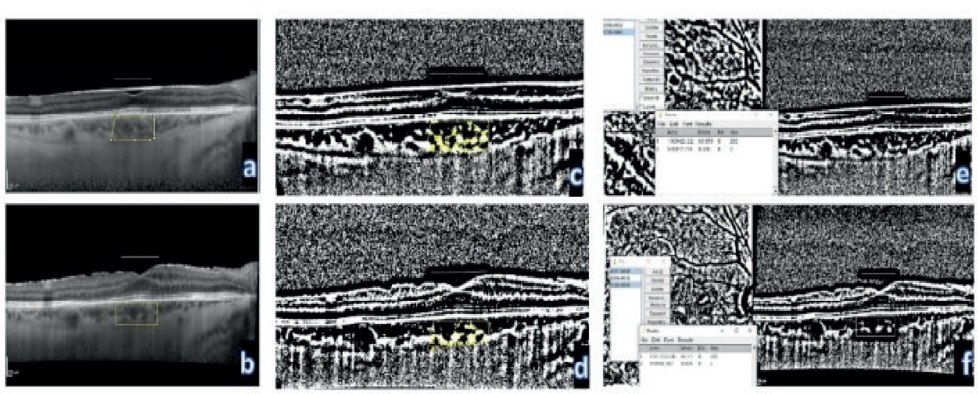

Figure 1. EDI OCT scans of a patient before (a) and after (b) silicone oil removal. (c) and (d) are preoperative and postoperative binarized scans using Niblack's autolocal threshold on ImageJ. The choroidal-scleral junction was selected and segmentation of the subfoveal choroidal area was performed after image binarization. Figures (e) and (f) show the definition of the total subfoveal choroidal area and luminal area within the initially selected polygon in preoperative and postoperative binarized scans

RESULTS

Evaluation was made of 24 eyes of 24 patients comprising 15 (62.5%) males and 9 (37.5%) females with a mean age of 62.21±12.93 years. The mean preoperative and postoperative BCVA were 1.42±0.99 and 0.67±0.48 LogMAR, respectively (p<0.001). The demographic and clinical findings of the study group are presented in Table 1.

Table 1. Demographic and clinical findings of the study group

Gender (male/female)	15/9	
Age (mean±SD, years)	62.21±12.93	
Laterality (right/left)	13/11	
BCVA (mean±SD, logMAR)		
Preoperative	1.42±0.99	p<0.001*
Postoperative	0.67±0.48	
IOP (mean±SD, mmHg)		
Preoperative	19.64±5.06	p=0.076*
Postoperative	17.26±5.74	

BCVA: Best corrected visual acuity, IOP: Intraocular pressure
*Wilcoxon signed rank test; p<0.05 was set as statistically significant

Analysis of EDI OCT images using image binarization

The mean SFCT was 288.71±63.63 µm under SiO in operated eyes. After SiO removal, the mean SFCT significantly decreased to 259.33±51.25 µm at month 3 (p=0.004). Intraexaminer ICC value for SFCT was > 0.9 (95 % confidence interval, 0.996–0.998) and interexaminer ICC was > 0.9 (95 % confidence interval, 0.997–0.998) (Table 2).

The mean CVI was 63.37±3.50% under SiO filled eyes. After SiO removal, the mean CVI significantly decreased to 58.83±3.41% at month 3 (p<0.001). The mean LA was 1.37±0.46 vs. 1.18±0.47 preoperatively and postoperatively in the operated eyes (p=0.028). There was no significant difference between the mean preoperative and postoperative values in SA measurements (p=0.742). There was a decrease in postoperative mean TCA values compared to the preoperative values, but the difference was not statistically significant (p=0.175) (Figure 2).

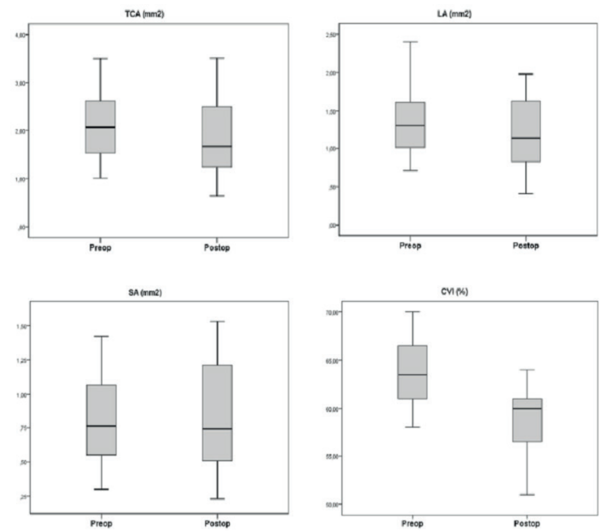

Figure 2. Box plots showing the choroidal parameters before (preop) and after (postop) silicone oil removal of RRD eyes

Table 2. Choroidal thickness and choroidal parameters obtained with the image binarization protocole of macular enhanced depth imaging optical coherence tomography scans before (preoperative) and after SiO removal at month 3 (postoperative)

	Preoperative mean±SD, (range)	Postoperative mean±SD, (range)	p value*
SFCT (µm)	288.71±63.63 (211-422)	259.33±51.25 (180-357)	**0.004**
TCA (mm²)	2.17±0.74 (1.01-3.50)	1.99±0.82 (0.64-3.51)	0.175
LA (mm²)	1.37±0.46 (0.71-2.40)	1.18±0.47 (0.41-1.98)	**0.028**
SA (mm²)	0.80±0.30 (0.3-1.42)	0.83±0.38 (0.23-1.53)	0.742
CVI (%)	63.37±3.50 (58-70)	58.83±3.41 (51-64)	**<0.001**

TCA: Total subfoveal choroidal area, LA: Luminal area, SA: Stromal area, CVI: Choroidal vascularity index
*Wilcoxon signed rank test; p<0.05 was set as statistically significant

DISCUSSION

The results of this study demonstrated that both CT and CVI were significantly decreased in silicone-filled eyes of RRD patients after SiO removal. A significant decrease was also determined in LA measurements after SiO removal. These findings may reflect the inflammatory effects of SiO on intraocular structures.

SiO is the most commonly used vitreous substitute in vitreoretinal surgery. Silicone instillation forces the retina to flatten towards the sclera with the mechanical effect of surface tension. The vitreous absence causes metabolic alterations in adjacent tissues. It has been previously shown that when aqueous is replaced with SiO, potassium ions accumulate in the retina, and subsequently, neurodegeneration and reactive gliosis occur (11). Moreover, the functional interaction between the outer retina, retina pigment epithelium and, choriocapillaris may also alter with impairment of this modulation (12). Previous studies have revealed the adverse effects of SiO on different retinal layers (7,8,13). Odrobina et al. reported that CT was significantly decreased until three months after PPV with silicone oil tamponade (8). Similarly, Karimi et al. showed SiO-associated choroidal thinning in the eyes of RRD patients treated with vitrectomy and SiO endotamponade (14). In that study, at three months after SiO removal, the choroid was still thinner in the operated eyes compared to the fellow eyes. Moreover, Mirza et al. demonstrated that CT decrease continued even after SiO removal in silicone filled RRD eyes (15). In accordance with Mirza et al, the current study also showed a decrease in SFCT after SiO removal. Mirza et al emphasized that SiO removal may not interrupt the intraocular inflammatory process triggered by its instillation. Semeraro et al. showed that heavy SiO is related to increased prostaglandin E2 and interleukin 1 alfa levels in the aqueous and this triggered an inflammatory reaction in a time-dependent manner (16). As a response to these inflammatory and vasoactive mediators, choroidal vasodilatation and vascular congestion may occur in SiO filled eyes.

In the current study, SiO removal was shown to be associated with a decreased CVI in SiO filled RRD eyes. CVI has been proposed as a novel parameter to evaluate choroidal vasculature in various retinal conditions (10,17-19). In a population-based study, CVI was found to be a better, less variable, and relatively more stable marker to monitor the choroid than SFCT (20). Only a few studies have evaluated the effect of intraocular surgery in CVI changes. Chen et al. showed that increased CVI might be related to the choroidal inflammation induced by surgical trauma after phacoemulsification (21). Rizzo et al. showed a CVI decrease after vitreomacular surgery for epiretinal membrane (22). Measurement of CVI includes both vascular and stromal components of the choroid. In addition to CVI, in the current study, a significant decrease was also determined in the luminal vascular component after SiO extraction. It can be assumed that intraocular inflammation secondary to silicone might induce CT changes and vessel engorgement after vitrectomy. Although there is a lack of pre-vitrectomy data, this idea is supported by the significant decrease of both CVI and LA after SiO removal.

There were some limitations to this study, primarily the retrospective design and small sample size. A larger sample-sized study is needed to confirm these findings. The lack of preoperative and postoperative data after PPV is another limiting factor of this study. Further prospective investigations with larger sample size and long-term follow-ups are needed to clarify the effects of SiO on choroidal structures.

CONCLUSION

Image binarization and CVI analysis enabled assessment of the effect of SiO removal on choroidal structures. CVI decreased, and the lumens of the choroidal vessels became smaller after SiO removal. Therefore, CVI could be considered a tool for the monitoring of choroidal changes that may be associated with inflammation secondary to SiO.

Conflict of interest: The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: Ethical approval for this study was obtained from Hamidiye Ethics Committee of the University of Health Sciences.

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