Original Article

# Analysis of Retinal Layers' Thickness and Vascular Density after Successful Scleral Buckle Surgery

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## Abstract

**Purpose:** To investigate retinal layers' thickness and vascular density after successful scleral buckle surgery using the optical coherence tomography angiography (OCTA) method.

**Methods:** In this prospective interventional case-control study, 24 patients with macular-off rhegmatogenous retinal detachment (RRD) were included after performing successful reattachment by scleral buckling. Retinal layers' thickness and vascular density were assessed in the patients using the OCTA method compared to normal fellow eyes as controls 10 months postoperation.

**Results:** Inner retinal layers showed no significant difference, but there was a significant reduction in outer central 1-mm retinal layers' thickness. Outer plexiform-Bruch's membrane (153.1 ± 24.3 µm vs. 166.2 ± 15.1 µm, $P = 0.003$) and ellipsoid zone to Bruch's membrane (51.25 ± 9.3 µm vs. 57.35 ± 3.8 µm, $P = 0.009$) were thinner in the operated eyes compared to fellow eyes. Vascular density within a 300 µm wide region around the foveal avascular zone (FAZ) (foveal density-300) was significantly lower in the detached eyes (46.28% ± 7.12% vs. 51.01% ± 4.73%, $P = 0.016$), however, there was no difference in superficial and deep vascular density at 1-mm central circle. Superficial parafoveal vascular density was lower in the operated eyes (46.24% ± 5.30% vs. 49.52% ± 5.93%, $P = 0.026$) with no significant difference in deep parafoveal vascular density (49.93 ± 4.29% vs. 51.88% ± 4.79%, $P = 0.137$). There was no difference in FAZ area and perimeter between the two groups.

**Conclusions:** Complete recovery of retinal thickness and vascular density did not achieve in the patients with RRD even after 10 months of reattachment by scleral buckling surgery. Superficial capillary vascular density was more affected than deep vascular density almost in the parafoveal area.

**Keywords:** Buckling, Deep, Encircling band, Foveal avascular zone, Foveal density-300, Retinal detachment, Superficial, Vascular density, Visual recovery

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## Introduction

Retinal rhegmatogenous detachment is one of the most common and sight-threatening diseases in ophthalmology practices. The reattachment rate is high in scleral buckling or pars plana vitrectomy (PPV).[1-3] In most patients, functional improvement does not match with excellent anatomic results after surgery and visual function is not completely recovered.[3]

Christensen *et al*. showed that foveal macular thickness was significantly increased after scleral buckle surgery within 2 years on average postoperation, and poor visual recovery was correlated with the increased foveal thickness. They found no significant increase in retinal thickness in the para and perifoveal region.[4]

The optical coherence tomography angiography (OCTA) method is applied for quantitative evaluation of retinal

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layers' thickness and perfusion.[5,6] Very limited studies have investigated changes in retinal thickness and vasculature after buckling surgery. For example, Tsen *et al*. applied the OCTA method after complete resolution of postoperative inflammation, about 3.6 ± 2.4 months after surgery. Mean vessel density and parafoveal vessel density were significantly lower in the detached eyes compared to fellow eyes in superficial and deep capillary plexus. However, only five patients were studied.[7] Therefore, the current study was done to investigate subtle anatomical changes in retinal layers' thickness and vascular density in the absence of gross anatomical abnormalities in postoperative optical coherence tomography (OCT) after successful reattachment with buckling surgery.

## Methods

In this prospective interventional case-control study, 24 patients with macular-off rhegmatogenous retinal detachment (RRD) treated by 360° encircling scleral buckling surgery in the Nikookari Eye Hospital (Tabriz City, East Azerbaijan Province, Iran) from September 2017 to April 2019 were enrolled. This study was conducted according to the principles in the Declaration of Helsinki. The study protocol was supervised and approved by the Ethics Committee of Tabriz University of Medical Sciences (Ethics code: IR.TBZMED.REC.1398.241). An informed written consent was obtained from all the patients to participate in this study and to publish resulting data. All the operations were performed by one expert retina specialist (M. N.) and all the patients were treated within 3 days of referral depending on hospital working days and surgeons' time schedule. Segmental scleral buckles (silicone band 240 and tire 276) were secured to the sclera using 5-0 Mersilene partial-thickness suture passes. Buckle height was adjusted intraoperatively to achieve appropriate scleral indentation as judged by the surgeon. Cryotherapy and/or laser were not applied during the surgery. Likewise, expansile gas (such as C3F8, SF6, or air) was not used to refill the eye volume during surgery. For each patient, refractive error and best corrected visual acuity (BCVA) were recorded in the operated and normal fellow eyes in follow-up visits. BCVA was recorded according to the Snellen visual acuity chart and then, the values were converted into logMAR. For better investigating pure changes in the retinal layer, strict inclusion and exclusion criteria were considered. Inclusion criteria were diagnosis of macular-off RRD not more than 7 days after patients' visual field defect or visual loss with successful attachment after the first scleral buckling surgery. All the patients had foveal detachment detected by slit-lamp ophthalmoscopy. Preoperative OCT was not performed for the patients. Exclusion criteria were any prior intraocular surgery, traumatic RRD, significant cataract, proliferative vitreoretinopathy, glaucoma, diabetes, uncontrolled hypertension, any macular pathology in the fellow eye, high virtuous opacity in rendering image quality in each eye, history of asymmetric visual acuity or asymmetric refractive error before RRD, and gross postoperative OCT abnormalities including remnant sub-macular fluid 1 month after surgery, epiretinal membrane, cystoid macular edema, and disruption and undulation in retinal layers on OCT. Patients were followed up 10 months after the operation to provide them with enough time regarding resolving inflammation and retinal remodeling.[7] Patients with BCVA more than 0.5 logMAR were excluded from the study.

Retinal layers' thickness and vascular density were studied by OCTA device (Optovue, RTVue XR 2018.1.0.43, CA, USA) and normal fellow eyes were served as controls. Image quality <0.5 was excluded. OCTA images focused on 3-mm central macula were studied.

Different retinal layers' thicknesses were studied in 1-mm central circle of OCTA device output. Segmentation of retinal layers was automatically done by OCTA Optovue software (Optovue, RTVue XR 2018.1.0.43, CA, USA) within 1-mm central circle. Before analysis, all images were checked for good segmentation and centration. However, for para and perifoveal regions, only full retinal thickness was available. Parafoveal region was defined as the area in 3-mm circle out of 1-mm central foveal circle and the remaining tissue in 6-mm circle was considered as perifoveal region. Vascular density was defined as the percentage of area containing blood vessels. The superficial capillary plexus was segmented 3 μm below the inner limiting membrane (ILM) and 15 μm below the inner plexiform layer (IPL). The deep capillary plexus was segmented 15 μm below the IPL and 70 μm below the IPL.

Foveal avascular zone (FAZ) was calculated automatically by device software using nonflow measurement in the foveal area [Figure 1]. The boundary of FAZ was presented as perimeter. Foveal density-300 (FD-300) was defined as vascular density within a 300 μm wide region around the FAZ, and acircularity

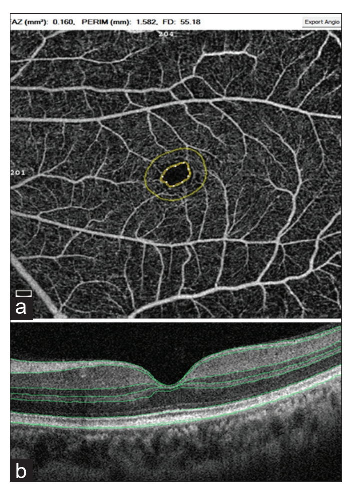


**Figure 1:** Automatic segmentation provided by optical coherence tomography angiography (Optovue, CA, USA). Foveal avascular zone (FAZ), boundary of FAZ presented as perimeter (PERIM), and foveal density-300 defined as vascular density within a 300 μm wide region around the FAZ are shown in (a) and retinal layers' segmentation is shown in (b)

index (AI) of FAZ was calculated by the Optovue system as well.[3-5] AI was measured as a ratio of FAZ perimeter to the perimeter of a circle equal to FAZ area. These parameters showing changes in vascular density were compared between the two groups. Flow density was measured based on the proportion of pixels formed by capillaries with blood flow compared to each total area.

Statistical analyses were performed using SPSS software (IBM SPSS Statistics for Windows, Version 22.0., Armonk, NY, USA: IBM Corporation). Descriptive statistics were used to evaluate the distribution of data. Continuous data with normal distribution were presented as mean ± standard deviation. Herein, both eyes of subjects were included therefore, generalized estimating equations approach was used to compare means and percentages between two groups using the STATA software version 14.0 (Stata Corp, College Station, TX, USA). A P of 0.05 or less was considered statistically significant.

## Results

Totally, 48 eyes of 24 patients with macular-off RRD were studied. Among them, 15 eyes had retinal detachment in 2 quadrants, 6 eyes in 3 quadrants, and 3 eyes in 4 quadrants. Fifteen (62%) patients were male and 9 patients were (38%) female. The mean age of patients was equal to 42.1 ± 14.1 years old (age range of 15–62 years old). All the patients were phakic. Preoperative visual acuity was equal to 1.33 ± 0.28 logMAR. The mean time between the onset of visual loss and surgery was equal to 5 ± 2 days. Mean postoperative spherical equivalent refractive error was equal to -3.97 ± 3.85 (−0.5 – −11.88) diopters (D) and −2.02 ± 2.01 (0.0 – −11.25) D in RRD and control groups, respectively ($P$ = 0.004). There was no complication during surgery or in the postoperative period interfering with the results, such as choroidal hemorrhage reaching the macula or choroidal detachment.

Ten months postoperation, BCVA of the patients was obtained as 0.31 ± 0.18 logMAR and 0.01 ± 0.02 logMAR in RRD and control groups, respectively ($P < 0.001$). Preoperative visual acuity was significantly improved 10 months postoperation ($P$ = 0.000) in the RRD group.

Full retinal thickness (ILM to retinal pigment epithelium [RPE] layer) in 1-mm central macula was measured as 252.23 ± 39.97 µm and 257.19 ± 24.59 µm in RRD and control groups, respectively ($P$ = 0.329). Inner retinal thickness (ILM to IPL) was equal to 61.8 ± 15.6 µm and 59.1 ± 13.9 µm in RRD in control groups, respectively ($P$ = 0.498). Outer retinal thickness (IPL to Bruch's membrane) was obtained as 201.95 ± 35.32 µm and 209.90 ± 14.65 µm in RRD and control groups, respectively ($P$ = 0.269).

Outer plexiform to Bruch's membrane thickness (OPL-BrM) was significantly reduced in the RRD group (153.09 ± 24.3 µm vs. 166.24 ± 15.19 µm, $P$ = 0.003). Inner segment/outer segment to BrM was significantly reduced in the RRD group ($P$ = 0.009), [Table 1].

Parafoveal (313.66 ± 18.25 µm vs. 320.19 ± 18.30 µm) and perifoveal (275.85 ± 16.66 µm vs. 281.0 ± 15.04 µm) full retinal thickness was lower in the RRD group compared to the control group but it was not statistically significant ($P$ = 0.289 and 0.283, respectively), [Table 1].

Difference in superficial 1-mm central foveal (23.34% ±8.77% vs. 20.72% ± 6.44%) and deep 1-mm central foveal (38.81% ± 8.94% vs. 37.52% ± 8.25%) vascular density was not statistically significant between two groups ($P$ = 0.082 and 0.436, respectively).

Superficial parafoveal vascular density (46.24% ± 5.30% vs. 49.52% ± 5.93%, $P$ = 0.026) and deep parafoveal vascular density (49.93% ± 4.29% vs. 51.88% ± 4.79%, $P$ = 0.137) were lower in RRD group and only superficial layer was statistically significant P, [Table 2 and Figure 2].

FAZ and its perimeter were higher in the RRD group, but they were not statistically significant ($P$ = 0.321 and 0.328, respectively). FD-300 was significantly reduced in RRD group (46.28% ± 7.12% vs. 51.88% ± 4.79%) ($P$ = 0.016). Mean outer retina flow in central 3.14 $mm^2$ (1-mm circle) area was equal to 0.96 ± 0.58 $mm^2$ in RRD group and it was equal to 0.83 ± 0.51 $mm^2$ in control group ($P$ = 0.246). There was no difference in AI between the groups ($P$ = 1.00).

## Discussion

The results of this study showed some changes in retinal layers' thickness and perfusion after successful retinal reattachment by scleral buckling surgery for the patients with macular-off RRD explaining incomplete visual recovery. A decrease was observed in retinal thickness in the deep retina beyond OPL [Table 1]. Atrophy of the deep retina can be explained by ischemic injury after detachment from the underlying resourceful choroid layer. Even after 10 months, complete recovery of retinal layers was not achieved. This atrophy was not noticed in inner retinal layers due to different and probably more intact circulation of superficial retinal layers. Menke *et al*.,[8] similarly reported a decrease in retinal layers' thickness after retinal reattachment in OCT outcomes of the patients. Outer nuclear layer and ellipsoid zone to RPE thickness were lower in the RRD group in comparison with the control group. They found that retinal thickness was increased significantly in the outer retina until follow-up. However, even after restoration, retinal thickness was lower than the control group.

In the present study, there were also some abnormalities in the vascular flow of the retina after retinal reattachment. Parafoveal superficial vascular density was lower in the RRD group and this may imply that even superficial vascular tissue can be affected to some extent after detachment.

FD-300 was significantly reduced in the RRD group proving that vascular changes happen after RRD leading to incomplete visual recovery. In this study, there was no significant change in superficial and deep 1-mm central foveal vascular density in contrast to FD-300. This can be due to the presence of FAZ

**Table 1: Thickness parameters in operated and normal fellow eyes**

| Parameter | Group, mean±SD | | $P^{§}$ |
|---|---|---|---|
| | Operated eye | Fellow eye | |
| BCVA (logMAR) | 0.31±0.18 | 0.01±0.02 | <0.001 |
| Full retinal thickness in central 1 mm (µm) | 252.23±39.97 | 257.19±24.59 | 0.329 |
| Inner retinal thickness in central 1 mm (µm) | 61.8±15.6 | 59.1±13.9 | 0.498 |
| Outer retinal thickness in central 1 mm (µm) | 201.95±35.32 | 209.90±14.65 | 0.269 |
| OPL-BrM (µm) | 153.09±24.3 | 166.24±15.19 | 0.003 |
| IS/OS-BrM (µm) | 51.25±9.3 | 57.35±3.8 | 0.009 |
| Parafoveal full retinal thickness (µm) | 313.66±18.25 | 320.19±18.20 | 0.289 |
| Perifoveal full retinal thickness (µm) | 275.85±16.66 | 281.0±15.04 | 0.283 |

§*P*: *P* for comparison of parameters in the operated eye versus fellow eye based on GEE analysis. GEE: Generalized estimating equations, BCVA: Best corrected visual acuity OPL-BrM: Outer plexiform layer to Bruch's membrane thickness, IS/OS-BrM: Inner segment/outer segment to Bruch's membrane thickness, SD: Standard deviation

**Table 2: Vascular density parameters in operated and normal fellow eyes**

| Parameter | Group, mean±SD | | $P^{§}$ |
|---|---|---|---|
| | Operated eye | Fellow eye | |
| Superficial 1 mm central foveal vascular density (%) | 20.72±6.44 | 23.34±8.77 | 0.082 |
| Deep 1 mm central foveal vascular density (%) | 37.52±8.25 | 38.81±8.94 | 0.436 |
| Superficial parafoveal vascular density (%) | 46.24±5.30 | 49.52±5.93 | 0.026 |
| Deep parafoveal vascular density (%) | 49.93±4.29 | 51.88±4.79 | 0.137 |
| FAZ (mm) | 0.28±0.2 | 0.24±0.1 | 0.321 |
| FD-300 (%) | 46.28±7.12 | 51.88±4.79 | 0.016 |
| FAZ perimeter (mm) | 2.02±0.6 | 1.91±0.4 | 0.328 |
| Acircularity index | 1.10±0.04 | 1.10±0.03 | 1.00 |
| Mean outer retina flow in 1 mm central region ($mm^2$) | 0.96±0.58 | 0.83±0.51 | 0.246 |

§*P*: *P* for comparison of parameters in the operated eye versus fellow eye based on GEE analysis. GEE: Generalized estimating equations, FAZ: Foveal avascular zone, FD-300: Foveal density-300: SD: Standard deviation

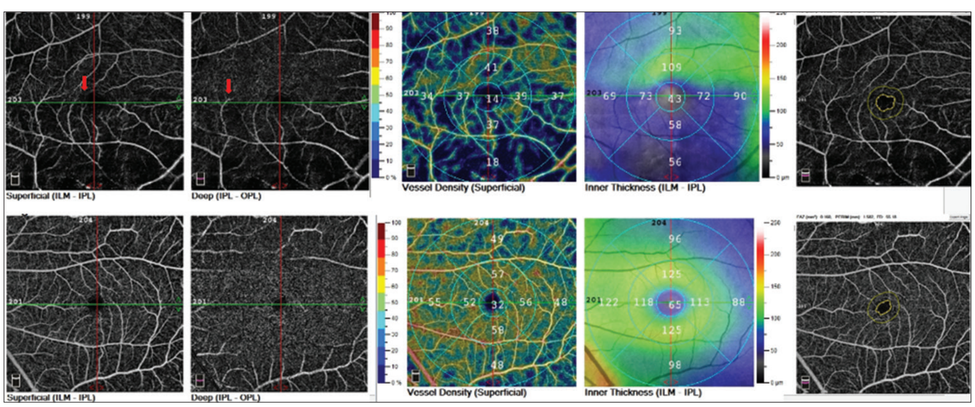


**Figure 2:** Optical coherence tomography angiography of a representative patient. Upper row shows his right eye (the diseased eye that received encircling band) and lower row shows his left eye (the normal control eye) images. Note that even 10 months after performing reattachment procedure; previous inferior retinal detachment border is evident in superficial and deep capillary plexus maps (red arrows). In this patient, the increased foveal avascular zone area and the decreased foveal density-300 can be seen in the diseased eye

nonvascular area in the central 1-mm zone that can mask considerable change in vascular density of the remaining area to be detected. However, this confounding area is excluded within FD-300. Tsen and *et al*.[7] studied microvascular changes after primary repair of 28 patients with RRD. Mean foveal and parafoveal vascular density were lower in the RRD group in comparison with controls both in superficial and deep plexus. In their study, 5 eyes (18%) underwent scleral buckling surgery, 11 eyes (39%) underwent PPV, and 12 eyes (43%) underwent the combined surgery. Comparing different procedures, the scleral buckling group had higher subfoveal choroidal thickness; the PPV group had higher choriocapillaris vascular density, and the combined surgery group showed significantly lower vascular density in superficial capillary plexus and deep capillary plexus.

Recently, Wang *et al*.,[9] investigated macular perfusion after PPV surgery for patients with RRD. They reported a significant reduction in superficial and deep parafoveal capillary plexus flow density and choriocapillary plexus flow density (CCPFD) postoperatively compared to normal fellow eyes that was resolved after 8 weeks. In other words, parafoveal flow density was increased to normal level in this period. However, in our study, this difference remained in superficial parafoveal vascular density and FD-300 in the RRD group even after 10 months of follow-up. In their study, CCPFD was higher in the patients with better visual recovery. Like our study, there was no significant difference in parafoveal retinal thickness between the operated and normal fellow eyes.[9]

In another study, the patients with RRD were evaluated after PPV surgery by swept-source OCTA. Central retinal thickness was lower in macula-off RRD-affected eyes compared to fellow eyes. It was concluded that defects in choriocapillary vascular density can lessen outer retinal restoration and can be used as a prognostic factor for recovery of visual acuity.[10]

Woo *et al*.[11] showed that superficial and deep FAZ were wider in RRD-affected eyes than fellow eyes postoperatively. FAZ was larger in the patients with macular-off RRD than controls after PPV surgery. They concluded that this may be due to ischemic damage in the foveal area. However, in our study, the difference in FAZ was insignificant between groups and this may be due to exclusion of patients with logMAR > 0.5 in our study. Francisconi *et al*.[12] investigated FAZ changes after pneumatic retinopexy in 19 macular-off RRD-affected eyes. Superficial and deep FAZ areas were not significantly different from fellow eyes, which was in contrast to the eyes that had undergone PPV surgery with larger FAZ area postoperatively. They concluded that ischemic attack is less in pneumatic retinopexy than PPV. This can be explained better by the preoperative status of the eyes undergoing pneumatic retinopexy compared to those needing PPV surgery.

There are studies confirming retinal remodeling capability.[13,14] There are some reports about visual improvement after low-level laser therapy in the macular area in some retinal pathologies like retinitis pigmentosa, age-related macular degeneration, and amblyopia. The laser activates retina self-remodeling and leads to restoration of cell function in nonfunctional cells and improves vision.[15] Nonfunctional cells can be the case in patients with RRD having incomplete visual recovery and excellent anatomical results after reattachment. Such treatments may be helpful in patients with RRD to activate retinal restoration and cellular function. Although, further studies are suggested in this regard.

In the present study, the patients with disruption in the outer retina and other anatomical abnormalities like epiretinal membrane formation were excluded. On the other hand, it was tried to include patients with higher postoperative visual acuity (BCVA <0.5 logMAR) with the least possible confounding factors to purely determine the effect of subtle retinal layers' thickness and vascular change on visual acuity. A noninvasive imaging-OCTA method was applied to explain different postoperative visual outcomes in the patients with macular-off RRD having near-normal structural OCT outcomes. FD-300 can be an important parameter for assessing recovery of retinal vascular density in patients with RRD; though it is suggested to more focus on FD-300 in future studies. The most important limitation of this study was low number of patients. Furthermore, the trend of changes in vascular density and retinal layers' thickness was not investigated over time.

In conclusion, outer retinal thickness and retinal vascular density did not recover completely after reattachment in the patients with macular-off RRD treated by scleral buckling surgery.

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### Conflicts of interest

There are no conflicts of interest.

## References

1. Schwartz SG, Flynn HW Jr., Mieler WF. Update on retinal detachment surgery. Curr Opin Ophthalmol 2013;24:255-61.
2. Ebrahimiadib N, Hassanpoor N, Niyousha M, Modjtahedi BS. The effect of scleral buckling on accommodative amplitude. Int J Retina Vitreous 2020;6:14.
3. Oshima Y, Yamanishi S, Sawa M, Motokura M, Harino S, Emi K. Two-year follow-up study comparing primary vitrectomy with scleral buckling for macula-off rhegmatogenous retinal detachment. Jpn J Ophthalmol 2000;44:538-49.
4. Christensen U, Sander B, Villumsen J. Retinal thickening after successful surgery for macula-off retinal detachment. Curr Eye Res 2007;32:65-9.
5. Sugahara M, Miyata M, Ishihara K, Gotoh N, Morooka S, Ogino K, *et al.* Optical coherence tomographyangiography to estimate retinal blood flow in eyes with retinitis pigmentosa. Sci Rep 2017;7:46396.
6. Liu L, Gao J, Bao W, Hu C, Xu Y, Zhao B, *et al.* Analysis of foveal microvascular abnormalities in diabetic retinopathy using optical coherence tomography angiography with projection artifact removal. J Ophthalmol 2018;2018:3926745.
7. Tsen CL, Sheu SJ, Chen SC, Wu TT. Imaging analysis with optical coherence tomography angiography after primary repair of macula-off rhegmatogenous retinal detachment. Graefes Arch Clin Exp Ophthalmol 2019;257:1847-55.
8. Menke MN, Kowal JH, Dufour P, Wolf-Schnurrbusch UE, Ceklic L, Framme C, *et al.* Retinal layer measurements after successful macula-off retinal detachment repair using optical coherence tomography. Invest Ophthalmol Vis Sci 2014;55:6575-9.
9. Wang H, Xu X, Sun X, Ma Y, Sun T. Macular perfusion changes assessed with optical coherence tomography angiography after vitrectomy for rhegmatogenous retinal detachment. Graefes Arch Clin Exp Ophthalmol 2019;257:733-40.
10. Hong EH, Cho H, Kim DR, Kang MH, Shin YU, Seong M. Changes in retinal vessel and retinal layer thickness after vitrectomy in retinal detachment via swept-source OCT angiography. Invest Ophthalmol Vis Sci 2020;61:35.
11. Woo JM, Yoon YS, Woo JE, Min JK. Foveal avascular zone area changes analyzed using OCT angiography after successful rhegmatogenous retinal detachment repair. Curr Eye Res 2018;43:674-8.
12. Francisconi CL, Kim DT, Juncal V, Qian J, Brosh K, Wong DT, *et al.* Foveal avascular zone area analysis using OCT angiography after pneumatic retinopexy for macula-off rhegmatogenous retinal detachment repair. J Vitreo Retin Dis 2019;3:297-303.
13. Shimoda Y, Sano M, Hashimoto H, Yokota Y, Kishi S. Restoration of

photoreceptor outer segment after vitrectomy for retinal detachment. Am J Ophthalmol 2010;149:284-90.
14. Ozdek S, Lonneville Y, Onol M, Gurelik G, Hasanreisoglu B. Assessment of retinal nerve fiber layer thickness with NFA-GDx following successful scleral buckling surgery. Eur J Ophthalmol 2003;13:697-701.
15. Ivandic BT, Ivandic T. Low-level laser therapy improves vision in a patient with retinitis pigmentosa. Photomed Laser Surg 2014;32:181-4.