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Microstructural macular changes after pars plana vitrectomy for primary rhegmatogenous retinal detachment.

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ABSTRACT

Purpose. To describe the foveal microstructural changes after pars-plana vitrectomy (PPV) with air tamponade for reghmatogenous retinal detachment (RRD).

Methods. External limiting membrane (ELM) and ellipsoid zone (EZ) integrity, cystoid macular edema (CME) and subretinal fluid blebs (SBs) presence were analyzed with optical coherence tomography (OCT) in 59 eyes undergone surgery for RRD, divided between macula-on (n=30) and macula-off (n=29) and followed up 6 months. The association between ELM and EZ recovery and best-corrected visual acuity (BCVA) was investigated. Predictive factors for ELM and EZ recovery were also identified.

Results. The nterval between symptoms and surgery didn't significantly differ between the groups. Macula-on patients showed ELM and EZ integrity. In macula-off patients, ELM and EZ were namely restored in 89.7% and in 86.2% of cases. Final BCVA was higher when ELM and EZ were restored. Significant associations were found at several time points between ELM/EZ recovery and macular preoperative involvement and EMC development, and between BCVA and preoperative BCVA and EZ recovery. EMC and SBs development were equally distributed between the groups.

Conclusion. Prompt surgery for macula-off RRD usually allows a progressive recovery of outer retinal layers. Thus, a high visual gain can be achieved, regardless of macular involvement.

INTRODUCTION

Retinal detachment (RD) is defined as the separation of neurosensory retina from underlying retinal pigment epithelium (RPE). Retinal apposition to the RPE is essential for supporting vision, and RD involving the foveal center can lead to significant visual loss. Rhegmatogenous RD (RRD) is the most frequent form of RD, where a retinal break allows the fluid passage from the vitreous chamber into the subretinal space, resulting in retinal separation. RRD can occur at any age, with a peak prevalence of 13 cases per 100000 amongst individuals aged 60 to 70 years. Pars plana vitrectomy (PPV) has been increasingly adopted for the treatment of RRD, with recent advances in its techniques having improved its outcomes. Several factors, such as RD duration, macular involvement, proliferative vitreoretinopathy (PVR), epiretinal membrane (ERM) development, cystoid macular edema (CME) occurrence, retinal fold formation and pigment migration, seem to affect postoperative functional outcomes [1, 2]. Regardless of these macroscopic features, poor visual recovery can also occur in retinas of normal appearance, suggesting the existence of microstructural alterations not detectable upon fundus examination. The advent of high-resolution spectral-domain optical coherence tomography (SD-OCT) has allowed macular microstructural abnormalities detection and a better understanding of the discrepancies between anatomical and functional surgical outcomes.

In our center, PPV with air tamponade represents the technique of choice in case of uncomplicated primary RRD. Gas or silicon oil are usually used in case of a supposed risk of RD recurrence (giant retinal tears, PVR stage higher than B). The aims of this study are to investigate microstructural changes after primary uncomplicated RRD repair and to identify both preoperative and postoperative factors that could affect healing processes and functional outcomes.

METHODS

PATIENT SELECTION

This is a retrospective study based on a review of consecutive patients' medical records who were affected by uncomplicated primary RRD and underwent PPV with air tamponade at IRCCS Sacro Cuore-Don Calabria Hospital in Verona (Italy) between 2017 and 2019. Patients having undergone baseline as well as 1, 3 and 6-month follow-up postoperative visits were included. Exclusion criteria were: axial length > than 26 mm; previous retinal surgery; inadequate imaging due to low quality; any ocular condition that could influence best-corrected visual acuity (BCVA), with the exception of lens opacity; and the absence of a complete 6-month follow-up. All procedures adhered to the tenets of the Declaration of Helsinki. This study was approved by the Institutional Review Board Committee of IRCCS Sacro Cuore-Don Calabria Hospital and by the Ethical Committee of Verona and Rovigo (reference number: Prot. Negrar-2020 K).

Patients were divided into two groups (macula-on and macula-off) according to macular involvement in the RRD. At baseline and at each follow-up visit, a complete ophthalmic examination was performed, including BCVA measurement, slit-lamp biomicroscopy, intraocular pressure (IOP) evaluation, dilated fundus examination with a 90 diopters indirect lens and SD-OCT evaluation (Spectralis HRA-OCT, Heidelberg Engineering GmbH, Heidelberg, Germany). At baseline, axial length was also measured in phakic eyes (IOLMaster; Carl Zeiss Meditec, Jena, Germany). A Snellen Chart was used for the assessment of BCVA and converted into the logarithm of minimum angle of resolution (LogMAR) for statistical analysis purposes. The semi-quantitative scale "counting fingers" was transposed into logMAR 2 and "hand motion" into logMAR 3 (Holladay 2004).

RRD duration was also considered and was defined as the length of time between the onset of central or peripheral vision loss, and surgery as opposed to the length of time between clinical evaluation and surgery. Macular microstructural changes were evaluated by OCT. The hyperreflective outer retinal bands (external limiting membrane (ELM) and ellipsoid zone (EZ)) were defined according to the International Nomenclature for OCT panel classification. The ELM was defined as a discrete hyperreflective band at the outermost border of the outer nuclear layer, located above the inner segment/outer segment (IS/OS) junction. The EZ line was defined as the second hyperreflective band above the RPE. The following OCT features were recorded at each visit: (1) external limiting membrane (ELM) integrity, (2) ellipsoid zone (EZ) integrity, (3) the presence of cystoid macular edema (CME), (4) the presence of an epiretinal membrane (ERM), and (5) the presence of subretinal fluid blebs (SBs). The integrity of the foveal ELM and EZ was assessed as follows: line not visible or disrupted in at least one scan (band defect) and continuous line in both the horizontal and vertical scans (intact band). The same analysis was always performed also in fellow eyes to minimize potential bias arising from artefacts. The eye-tracking dual-beam technology (TruTrack$_{TM}$ Active Eye Tracking Software, Heidelberg Engineering, Heidelberg, Germany) mitigated eye movement artefacts and ensured point-to-point correlations between the OCT scan and fundus images. The “automatic real-time” (ART) function provided by the software was used to reduce noise and increase image quality. With ART activated, multiple frames (B-scans) of the same scanning location being performed during the scanning process, and only scans with elevated ART (range 90–100) being considered. Follow-up visits were scheduled at 1, 3 and 6 months after the operation.

SURGICAL TECHNIQUE

All patients underwent the same surgical technique. General or local anesthesia was chosen according to both the patient preference and the anesthesiologist’s indication. Local anesthesia was induced by retrobulbar nerve block. A 23-gauge PPV was performed using EVA (Dutch Ophthalmic Research Centre, DORC, The Netherlands) or Constellation (Alcon, USA) platform. Cataract surgery was also performed during the same procedure, on a case-by-case basis as required. Patients underwent complete vitrectomy and peripheral vitreous shaving. A posterior hyaloid separation from the retina was obtained if needed. Perfluorocarbon liquid (PFCL) was used to reattach the retina. Subretinal fluid was drained through retinal breaks during fluid-air exchange. The procedure was completed using 360° endolaser photocoagulation around retinal breaks and on the peripheral retina. Postoperative positioning was determined according to the retinal breaks position.

STATISTICAL ANALYSIS

Demographic and clinical data were summarized using descriptive statistics, variability and precision measures and plots. Statistical tests were used based on the type of variables, test assumptions and sample dimension. All parameters were reported with 95% confidence intervals. Statistical models were adjusted for covariates if necessary.

T-test and Wilcoxon rank-sum test were used to compare continuous variables in independent groups whereas one-way analysis of variance was adopted to compare continuous variables stratified in more than two groups. The Chi-square test and the Fisher test were used to compare categorical variables.

Multivariate linear regression models and multivariate logistic models were used to model continuous and binary dependent variables respectively.

A p-value of less than 5% was considered as statistically significant. Data were analyzed by STATA vers. 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC.).

RESULTS

Fifty-nine patients met the inclusion criteria. Macula-on group included 30 patients, while macula-off group comprised 29 patients. Demographic and the baseline characteristics of patients are summarized in Table 1. The two groups were homogeneous with no statistically significant differences at baseline other than BCVA. Phacoemulsification was performed together with PPV in 13 cases (22%) from within the entire cohort. The median interval between symptoms being reported and surgery was 4 days for both groups and so was not significantly different ($p = 0.85$).

In the macula-on group, the mean BCVA was 0.24 (SD 0.18) logMAR (20/35) at baseline, and 0.14 (SD 0.16) logMAR (20/28), 0.13 (SD 0.21) logMAR (20/27) and 0.14 (SD 0.25) logMAR (20/28) at 1, 3 and 6 months after surgery, respectively. In the macula-off group, BCVA was 1.33 (SD 0.18) logMAR (20/400) at baseline, and 0.36 (SD 0.40) logMAR (20/45), 0.31 (SD 0.42) logMAR (20/40) and 0.20 (SD 0.25) logMAR (20/32) at 1, 3 and 6 months after surgery, respectively. The difference in BCVA between the macula-on and macula-off groups was statistically significant at baseline ($p < 0.01$), and at 1 month ($p = 0.01$) and 3 months ($p = 0.05$) after surgery, while there was no significant difference in BCVA between groups at 6 months after surgery ($p = 0.33$) (fig. 1).

In the macula-on group, no ELM or EZ defects were detected at any time point. In the macula-off group, the number of eyes showing complete recovery of both the ELM and EZ at 1, 3 and 6 months after surgery is shown in figure 3. ELM and EZ foveal defects both decreased progressively up to 6 months after surgery. At the end of follow-up, the ELM was restored in 89.7% of the patients studied, while EZ reached completion in 86.2% of cases (fig. 2). Figure 3 also provides examples of macula-on and macula-off cases, in which the progressive recovery of the ELM and EZ was observed during follow-up.

The analysis of the relationship between visual outcomes and outer retinal layers revealed a higher mean BCVA when the ELM and EZ were restored. No significant relationship was found between BCVA and ELM or EZ status 1 month after surgery ($p = 0.33$), and although a clinical difference was reported 3 months after surgery, it was not statistically significant ($p = 0.07$). However, a statistically significant difference was found 6 months after surgery ($p = 0.04$) (fig. 4).

After surgery, 6 macula-off patients (20.7%) and 5 macula-on patients (16.7%) developed CME, with no statistically significant difference between groups ($p = 0.69$). CME was observed in 3 of 13 patients (23.1%) who underwent phacoemulsification and PPV, and in 6 of 46 cases (13.1%) in which PPV alone was performed. CME occurrence was significantly more frequent when phacoemulsification and PPV were both performed ($p = 0.04$). In the majority of cases, CME reabsorption was achieved within 3 months of topical 1% prednisolone acetate tapering administration. In three cases, CME was still present at the end of follow-up.

Three macula-off patients (10.3%) and 4 macula-on patients (13.3%) presented with SBs, with no significant difference between groups ($p = 0.72$). ERM formation was not detected in either group.

Of the patients that did not undergo phacoemulsification, clinically relevant cataract onset was observed in 1 macula-off (3.5%) and in 2 macula-on patients (6.7%).

Only 1 case of RRD recurrence was observed in the macula-off group, which was due to PVR development.

Multivariate logistic regression models revealed the following significant associations. 1 month after surgery, ELM restoration was directly associated with preoperative macular non-involvement (odds ratio, OR = 45.13, $p = 0.05$), while it was inversely associated with age (OR = 0.83, $p = 0.02$) and EMC development (OR = 0.3, $p = 0.04$). At 3 months, ELM restoration was directly associated with preoperative macular non-involvement (OR = 17.27, $p = 0.03$), while it was inversely associated with EMC development (OR = 0.03, $p = 0.02$). The model could not reach statistical convergence for the 6-month follow up data, due to the extremely low number of ELM disruption cases. As expected, 1 month after surgery, EZ restoration was strongly associated with preoperative macular non-involvement (OR = 71.23, $p = 0.01$). At 3 months, EZ restoration was strongly associated with preoperative macular non-involvement (OR = 27.11, $p = 0.01$), while it was inversely associated with EMC development (OR = 0.05, p = 0.03). A marginal inverse association with age was also found (OR = 0.88, p = 0.07). As for ELM, the model could not reach statistical convergence for the data regarding EZ recovery at 6 months. 1 month after surgery, BCVA was directly associated with baseline BCVA (beta coefficient, β = 0.10; p = 0.05) and inversely associated with EMC development (β = 0.28; p = 0.03). At 3 months, BCVA was directly associated with baseline BCVA (β= 0.13; p = 0.03) and with EZ recovery (β = -0.35; p = 0.03). BCVA at 6 months was directly associated with EZ recovery only (β = -0.30; p = 0.04). No significant associations were found with SBs, RRD duration and RRD recurrence. Preoperative macular involvement was not significantly associated with final BCVA (β = 0.01; p = 0.98), confirming the results of the direct comparison between macula-on and macula-off BCVA at 6 months. No statistically significant association was found between preoperative macular involvement and RRD duration (OR = 1.00, p = 0.84).

DISCUSSION

Despite successful retinal reattachment, functional results can vary greatly among eyes treated for RRD. With the SD-OCT introduction, several studies have demonstrated that outer retinal layer defects correlate with low visual gain after surgery in patients with macular involvement [3-8].

Wakabayashi was amongst the first to study SD-OCT foveal changes after RRD surgery. They found that the postoperative recovery of the ELM may serve as a predictive factor for the subsequent restoration of the photoreceptor layer [4]. Shimoda observed a gradual IS/OS line recovery after PPV with sulfur-hexafluoride (SF_6) tamponade. Six months after surgery, a disrupted IS/OS line was observed in 3 eyes (17%), a foveal detachment in 6 eyes (33%), and a continuous IS/OS line in 9 eyes (50%), with a significant association between BCVA and IS/OS line restoration [5]. Other studies reported similar postoperative ELM and EZ recovery rates [3, 6]. Although we have reported a higher outer retinal band recovery rate, our data suggest an association between outer retinal layer recovery and BCVA improvement after surgery. However, limitations of sample size have resulted in relatively few EZ recovery cases in our study, especially at 6 months, which has affected the statistical robustness of our findings (fig. 2, 4).

Park identified the detachment extent, macula-off duration, and ELM integrity as being preoperative prognostic factors potentially influencing functional RRD surgery outcomes. Postoperative EZ recovery was also found to impact the final visual outcome. The mean macula-off duration was 18.44 ± 60.54 days. The final BCVA in patients with a macula-off duration lasting less than a day, was significantly higher than in patients with a macula-off duration lasting more than 7 days. However, there were no statistically significant differences when compared with cases of macula-off duration lasting between 1 and 7 days [8]. Malosse reported EZ and ELM defects in 100 (47.2%) and 64 (30.2%) eyes respectively, 1 month after surgery and in 44 (17.4%) and 18 (7.1%) eyes respectively, 6 months after surgery. The median macula-off duration was 5.0 days (range 1–90) and a multivariate analysis showed that the duration of macular detachment was the only factor associated with ELM and EZ damage at 6-months. [7]. While mean RRD durations, and ELM and EZ recovery rates that are similar to our findings, other studies demonstrated that shorter delays in surgery correlate with better ELM and EZ recovery and BCVA improvement [9-11]. In addition, Narala have demonstrated a significant positive association between photoreceptor volume, BCVA and short surgery wait time [12].

Studies on animal models show that cell apoptosis occurs within hours of RD induction, peaking at 2 to 3 days, and dropping at 7 days [13, 14]. Diederen found that visual acuity rapidly worsened when the macular detachment lasted longer than 6 days, concluding that surgical repair can be undertaken within 7 days of macular detachment without negatively affecting visual outcomes [15]. However, Frings reported a narrower time frame, observing worse final visual outcomes from 3 days of macula-off RRD [16]. Taken together, these data support the importance of a prompt RRD surgical repair. Interestingly, we have not observed any significant difference in the final BCVA between macula-on and macula-off patients. This might suggest that the short interval between diagnosis and surgery allowed us to minimize functional impairment even in cases of macula-off RRD. This is an intriguing point that could prompt a revision of current practices where macula-on RRD patients are prioritized for surgery over macula-off cases. As such, surgery timing should carefully consider RRD duration.

Regarding complications, CME development occurred in about 6.5% of patients in our study, with a similar prevalence the 2 groups. According to our regression models, it seemed to affect ELM and EZ healing processes and, at least in the first part of the follow-up, BCVA recovery. In the majority of cases, topical steroids were able to resolve this complication by the follow-up. Our data suggest that CME could slow and critically compromise both microstructural and functional recovery. In our series, patients who had undergone combined surgery, showed a significantly higher CME prevalence during follow-up. Conversely, other studies have not found any significant difference in CME prevalence between combined surgery and PPV alone [17]. Some publications have speculated that the breakdown of the blood–aqueous–barrier due to cataract surgery and of the blood–retinal barrier due to vitrectomy together could cause stronger ocular inflammatory responses in RRD eyes, leading to a higher reoperation rate following combined surgery than after PPV alone [18]. However, this hypothesis is not widely confirmed by the literature. Other authors have hypothesized that 360° retinopexy could increase CME risk [19]. In our surgical practice, 360° retinopexy is performed in both combined surgery and in PPV alone. Further studies are required, on larger series, to confirm the higher EMC prevalence in cases of combined surgery that were observed in our study. Moreover, cases of EMC that persist for more than 6 months after surgery should be monitored for any resolution at a later time point. Preoperative and intraoperative factors should also be examined to better predict the postoperative EMC risk in patients treated for RRD.

SBs are relatively common after scleral buckling procedures having been described since the 1980s [20]. They are confirmed by OCT in about 9% of buckling procedures [21]. Their mechanism of formation has not yet been clarified, but they usually disappear spontaneously within a year. Some authors have speculated that they could originate from vascular changes resulting from cryotherapy used during scleral buckling procedures [21], but it has been recently demonstrated that they can also occur after PPV [22, 23]. However, in our study, no significant difference in SBs prevalence was demonstrated between macula-on and macula-off RRDs [4]. Another study has found that subfoveal located blebs may slow visual recovery, although the final BCVA outcome is not affected [3]. In our study, BCVA recovery was not affected by SBs at any time point.

CONCLUSIONS

The main limitations of this study arise from its retrospective nature. However, taken together, our data suggest that prompt surgery for macula-off RRD allows the recovery of outer retinal layers in the majority of cases. As a consequence, a high degree of visual gain can be achieved after surgery for RRD, regardless of macular involvement.

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REFERENCES

1. Cleary PE and Leaver PK. Macular abnormalities in the reattached retina. Br J Ophthalmol 1978; 62:595-603.
2. Ross WH and Kozy DW. Visual recovery in macula-off rhegmatogenous retinal detachments. Ophthalmology 1998; 105:2149-2153.
3. Gharbiya M et al. Correlation between spectral-domain optical coherence tomography findings and visual outcome after primary rhegmatogenous retinal detachment repair. Retina 2012; 32:43-53.
4. Wakabayashi T et al. Foveal microstructure and visual acuity after retinal detachment repair: imaging analysis by Fourier-domain optical coherence tomography. Ophthalmology 2009; 116:519-528.
5. Shimoda Y et al. Restoration of photoreceptor outer segment after vitrectomy for retinal detachment. Am J Ophthalmol 2010; 149:284-290.
6. Lai WW et al. Simultaneous spectral domain OCT and fundus autofluorescence imaging of the macula and microperimetric correspondence after successful repair of rhegmatogenous retinal detachment. Br J Ophthalmol 2010; 94:311-318.
7. Malosse L et al. Prevalence and risk factors for outer retinal layer damage after macula-off retinal detachment. Br J Ophthalmol 2020; 104:660-665.
8. Park DH et al. Factors Associated with Visual Outcome after Macula-Off Rhegmatogenous Retinal Detachment Surgery. Retina 2018; 38:137-147.
9. Joe SG et al. Structural recovery of the detached macula after retinal detachment repair as assessed by optical coherence tomography. Korean J Ophthalmol 2013; 27:178-185.
10. Kim JD et al. Effect of symptom duration on outcomes following vitrectomy repair of primary macula-off retinal detachments. Retina 2013; 33:1931-1937.
11. Burton TC. Recovery of visual acuity after retinal detachment involving the macula. Trans Am Ophthalmol Soc 1982; 80:475-497.
12. Narala R et al. Longitudinal Quantitative Evaluation of Photoreceptor Volume Following Repair of Macula-Off Retinal Detachment. Retina 2016; 36:1432-1438.
13. Lewis GP et al. Animal models of retinal detachment and reattachment: identifying cellular events that may affect visual recovery. Eye (Lond) 2002; 16:375-387.
14. Cook B et al. Apoptotic photoreceptor degeneration in experimental retinal detachment. Invest Ophthalmol Vis Sci 1995; 36:990-996.
15. Diederen RM et al. Scleral buckling surgery after macula-off retinal detachment: worse visual outcome after more than 6 days. Ophthalmology 2007; 114:705-709.
16. Frings A et al. Visual recovery after retinal detachment with macula-off: is surgery within the first 72 h better than after? Br J Ophthalmol 2016; 100:1466-1469.
17. Savastano A et al. Combining cataract surgery with 25-gauge high-speed pars plana vitrectomy: A prospective study. Eur J Ophthalmol 2020:1120672120902030.
18. Loukovaara S and Haukka J. Repair of primary RRD - comparing pars plana vitrectomy procedure with combined phacovitrectomy with standard foldable intraocular lens implantation. Clin Ophthalmol 2018; 12:1449-1457.
19. Wang JC et al. Factors Associated with the Use of 360-Degree Laser Retinopexy during Primary Vitrectomy with or without Scleral Buckle for Rhegmatogenous Retinal Detachment and Impact on Surgical Outcomes (Pro Study Report Number 4). Retina 2019.

20. Avins LR and Hilton GF. Lesions simulating serous detachment of the pigment epithelium. Occurrence after retinal detachment surgery. Arch Ophthalmol 1980; 98:1427-1429.

21. Kang SW et al. Subretinal fluid bleb after successful scleral buckling and cryotherapy for retinal detachment. Am J Ophthalmol 2008; 146:205-210.

22. Otsuka Y et al. Multiple subretinal fluid blebs after pars plana vitrectomy for rhegmatogenous retinal detachment repair. Graefes Arch Clin Exp Ophthalmol 2019; 257:921-929.

23. Coppola M et al. Macular optical coherence tomography findings after vitreoretinal surgery for rhegmatogenous retinal detachment. Eur J Ophthalmol 2020:1120672120911334.

FIGURE CAPTIONS

Fig.1. Best corrected visual acuity (BCVA) changes during the follow-up in macula-on and macula-off patients. BCVA is expressed as a logarithm of minimum angle of resolution (LogMAR). The difference between macula-on and macula-off patients was significant at baseline, and 1 and 3 months after surgery, whereas no significant difference was observed 6 months after surgery. Asterisks indicate a statistically significant difference between the two groups ($p < 0.05$).

Fig. 2. External limiting membrane (ELM) and ellipsoid zone (EZ) recovery rate during the follow-up in macula-off patients.

Fig. 3. Follow-up in a case of macula-on (A-D) and another of macula-off (E-H) rhegmatogenous retinal detachment (RRD). Both the ELM and EZ in the preoperatively detached retina progressively recovered during the follow-up. Preoperative (A, E). 1 month after surgery (B, F). 3 months after surgery (C, G). 6 months after surgery (D, H).

Fig. 4. The relationship between best corrected visual acuity (BCVA) and external limiting membrane (ELM) and ellipsoid zone (EZ) recovery during the follow-up in macula-off patients. No significant relationship was found at 1 month ($p=0.33$); however, a clinical difference that was not statistically significant was found at 3 months ($p=0.07$), and a statistically significant difference was found at 6 months after surgery ($p = 0.04$). ELM− EZ− = neither ELM nor EZ recovery; ELM+ EZ− = ELM recovery; ELM+ EZ+ = ELM and EZ recovery. Asterisks indicate a statistically significant difference between the two contiguous points ($p < 0.05$).