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# Optical Coherence Tomography Analysis of the Macula after Macula-off Rhegmatogenous Retinal Detachment Surgery

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**Background:** To define the incidence, duration, and clinical associations of persistent foveal retinal detachment and central foveal thickness after macula-off rhegmatogenous retinal detachment (RRD) surgery, using optical coherence tomography (OCT). **Methods:** Prospective study. Thirty-nine patients with macula-off RRD after successful RD repair, from January 2006 to Februrary 2007. Using OCT, we prospectively examined cross-sectional retinal images of 39 eyes of 39 consecutive patients who underwent surgery for the treatment of RRD. The patients were divided into two groups and it was non randomized. Primary scleral buckling (SB) was performed on 18 eyes of 18 patients, and 21 eyes of 21 patients were treated with pars plana vitrectomy (PPV) and SF6 tamponade with or without SB. All eyes underwent clinical examination and OCT postoperatively at two weeks, and one, three, and six months. Postoperative OCT findings and best-corrected visual acuity (BCVA) were analyzed statistically. **Results:** The patients' ages ranged from 17 to 63 years (mean, 46.5±15 years). The time from the onset of subjective symptoms to retinal surgery ranged from 4 to 56 days (mean, 15±16 days). BCVA in logMAR units ranged from 0.3 to 1.47 before retinal surgery (mean, 0.96±0.15). OCT showed residual foveal detachment in 11 eyes (28.2%) and in adjacent areas one month after surgery. The remaining 28 retinas (71.8%) were attached when examined tomographically. In six of the 11 eyes (54%) with residual foveal detachment due to subretinal fluid (SRF) on OCT, the retinas reattached spontaneously within six months after surgery. Postoperative BCVA improved over three months in both groups. There was a decrease in the absolute difference value between the central foveal thickness of the lesion eye and that of the contralateral eye in each patient. But the correlation coefficient was not statistically significant ($P$ = 0.113). **Conclusion:** Increased macular thickness due to SRF after retinal detachment surgery may persist for several months, and tends to cause delayed visual recovery.

Key words: optical coherence tomography, rhegmatogenous retinal detachment, pars plana vitrectomy, scleral Buckling

## INTRODUCTION

Postoperative visual complaints may occur despite anatomically successful repair of rhegmatogenous retinal detachment (RRD). The duration of the preoperative macula detachment, preoperative visual acuity, and postoperative pathologies, including epiretinal membranes, pigment migration, cystoid macular edema, and retinal folds, are thought to be important factors.[1,2,3]

The advent of optical coherence tomography (OCT) has permitted detailed visualization of the retinal anatomy and anatomic responses to medical or surgical interventions. OCT noninvasively obtains cross-sectional retinal images in vivo, with 10-20 μm resolution.[4] As an objective and reliable test, it is useful for studying the retina[5,6]. According to our clinical observations, OCT images after retinal detachment (RD) surgery show markedly increased central macular thicknesses which may be due to the subretinal fluid (SRF).

This study was undertaken to investigate the persistent foveal RD resulted from the SRF after ophthalmoscopically successful scleral buckling (SB) or pars plana vitrectomy (PPV) surgery for macula-off RRD. We also evaluated the statistical relationship between the OCT findings and visual acuity levels.

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## METHODS

This investigation was an interventional consecutive case series. Demographic data, including RD characteristics, surgical details, and previous ocular histories, were collected from the patients' case notes.

Patients undergoing SB or PPV surgery for uncomplicated primary macula-off RRD were enrolled in the study. All surgery was performed by a single surgeon (Dr. J. T. Chen). These patients ($n$ = 39) were divided into two groups according to the surgical technique used and it was non-ramdomized. Primary SB was performed on 18 eyes of 18 patients, and 21 eyes of 21 patients were treated with PPV and SF6 tamponade with or without SB.

Patients with a history of previous ocular trauma, surgery, maculoretinopathy, or dense media opacity (any type of cataracts) that made the fundus invisible and were likely to influence imaging and visual outcomes were excluded from the study. In addition, patients with postoperative cystoid macular edema, epiretinal membrane instead of subretunal fluid were also excluded from the study.

All patients underwent outpatient follow-up at two weeks, one month, three months, and six months after surgery. The examinations included best-corrected visual acuity (BCVA) assessment, anterior segment and retinal examinations with indirect and slit-lamp biomicroscopy, and OCT scan of the central macula.

BCVA was measured as a Snellen equivalent. We transformed Snellen acuity into a logarithm of the minimum angle of resolution (logMAR) equivalent to create a linear scale of BCVA (logMAR value = log (1/ Snellen equivalent). Visual acuity at the level of counting fingers was correlated with a Snellen equivalent as (the counting fingers distance)/200. A logMAR value of 3.0 was assigned to visual acuity of hand motion. The final postoperative visual acuity (FPVA) was defined as the BCVA at six months after surgery. The postoperative improvement in BCVA was defined as the difference between the preoperative BCVA and BCVA six months after surgery.

We performed OCT (OCT Stratus Model 3000, Carl Zeiss Meditec Inc. Dublin, CA, USA) at two weeks, and one, three, and six months after surgery. These involved 6×6 mm radial line scans through the fovea. The fovea was identified as the patient's fixation point or with the fundus monitor in the OCT device. The cross-sectional images were normalized and smoothed using OCT plug-in software. The appearance of the SRF was recorded at every OCT examination. The pattern of SRF was defined according to those noted in a previous investigation by Benson et al.[7,8] (Fig1). The absolute difference value between the central foveal thicknesses of both eyes (ΔFT, μm) in each patient was obtained at every examination.

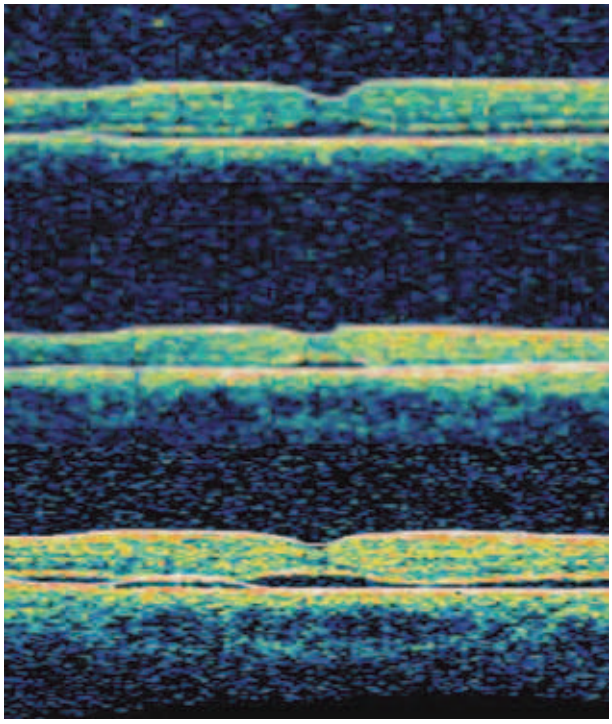

Fig. 1 The pattern of subretinal fluid. Upper. confluent type. Middle. single bleb type. Buttom. multiple bleb type.

Descriptive statistics are presented for the demographic and ocular characteristics and OCT findings. Analysis of variance methods were used to study the differences in visual acuity outcomes between the two groups. Visual acuity was treated as a continuous variable after a logMAR transformation was applied for the analysis of variance (ANOVA). $P \leqq 0.05$ was considered statistically significant.

We analyzed the incidence, duration, pattern, and clinical associations of persistent SRF. The relationship between ΔFT calculated two weeks postoperatively and FPVA was also assessed with Pearson's test. The relationship between postoperative ΔFT and visual acuity at two weeks, and one, three, and six months was analyzed statistically by linear regression. All statistical analyses were performed with SPSS version 11 (SPSS, Chicago, IL).

Table 1 Demographic data on 39 patients

| | |
|---|---|
| Age (yrs) | Mean, 46.5; range, 17-63 |
| Sex | Male, 28; female, 11 |
| Eye | Right, 17; Left, 22 |
| Preoperative BCVA Log MAR* | Mean, 0.96; range, 0.3 to 1.47 |
| Preoperative IOP (mmHg) | Mean 10.8; range 5 to 22 |
| Number of retinal breaks | 60 |
| Clock hours detachment | |
| 1-3 | 18 |
| 4-6 | 10 |
| 7-9 | 11 |
| 10-12 | 17 |
| Intraoperative PPV | 21 |
| Intraoperative scleral buckling | 18 |

*BCVA LogMAR = best-corrected visual acuity as tested on the Snellen chart and transformed into the LogMAR unit

Table 2 Outcomes of 39 patients at 1 month after the RRD surgery

| | |
|---|---|
| Follow up (mos) | Mean, 4.6; range, 1-8 |
| BCVA Log MAR* at 1 mo | Mean, 0.94; range, 0.4 to 3 |
| Subretinal fluid at 1 mo | 11 |
| Pattern of subretinal fluid (SRF) | |
| Confluent | 7 (7/11=64%) |
| Single Bleb | 3 (3/11=27%) |
| Multiple Blebs | 1 (1/11=9%) |

*BCVA LogMAR = best-corrected visual acuity as tested on the Snellen chart and transformed into the LogMAR unit

## RESULTS

Thirty-nine patients were enrolled in the study. Demographic data are presented in Table 1. The patients' ages ranged from 17 to 63 years (mean, 46.5±15 years). The time from the onset of subjective symptoms to retinal surgery ranged from 4 to 56 days (mean, 15±16 days). The value of preoperative IOP ranged from 5 to 22 mmHg (mean 10.8 mmHg). On preoperative fundus examination, the mean quadrant of the detached retina was 1.4 (range, 1-4). Visual acuity was measured with the Snellen chart. BCVA in logMAR units ranged from 0.3 to 1.47 before retinal surgery (mean, 0.96±0.15).

The characteristics of the SRF one month after surgery were documented (Table 2). Eleven patients (28.2%) had persistent SRF demonstrable by OCT. In the group of PPV patients, the incidence of SRF was obviously reduced after three months (19% at three months, 4.7% at six months). However, the group of SB patients revealed relatively persistent SRF after three months (33% at three months, 22% at six months). At six months after surgery, five patients (13%) had residual SRF. Of these five patients, four patients (80%) were treated with SB. The patterns of SRF in the SB and PPV groups at each follow-up were also documented (Table 3). The presence of SRF was not associated with other variables, including age, sex, number of breaks, preoperative BCVA, or laterality ($P > 0.05$), but was associated with the surgical technique used ($P = 0.047$).

On postoperative OCT findings, ΔFT was significantly different between the 3 rd-month and 6$^{th}$ month follow-up times after surgery for all 39 patients ($P = 0.0173$). It was also significantly different between the SB & PPV groups one month after surgery ($P = 0.04$). We analyzed the correlation between ΔFT and visual acuity at every examination (Fig2). The correlation coefficient was calculated by Pearson's test, but it was not statistically significant ($P = 0.113$).

BCVA in all 39 eyes was significantly improved six months after surgery ($P = 0.01$). For the 21 eyes of the PPV group, the preoperative mean BCVA was 0.97 and the mean FPVA was 0.19. For the 18 eyes of the SB group, the preoperative mean BCVA was 0.89 and the FPVA was 0.27. There was no significant difference in the preoperative BCVA of the two groups ($P = 0.08$). However, there was a significant difference in the visual improvement of the PPV and SB groups during the period three to six months after surgery ($P = 0.029$). We defined the visual improvement at every follow-up as the postoperative BCVA minus the preoperative BCVA. The mean visual improvement of all patuents was 0.02 at two weeks, -0.10 at one month, -0.26 at three months, and -0.32 at six months after surgery. The correlation between ΔFT at two weeks and visual improvement at six months after surgery was weak ($r = 0.127$, $P = 0.047$). The median visual acuity in patients with SRF was 1.04, whereas that in patients with no SRF was 0.88.

## DISCUSSION

Incomplete visual recovery after successful surgery

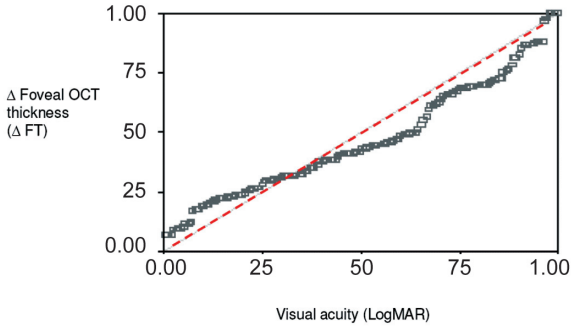


Fig. 2 A linear regression plot of visual acuity (LogMAR) with differences in the central foveal thickness (ΔFT, μm) of both eyes.

Table 3 Pattern of subretinal fluid after the RD surgery

| SRF* | 2 weeks | 1 month | 3 months | 6 months |
|---|---|---|---|---|
| Confluent | | | | |
| SB※ | 5 | 5 (71%) | 5 | 3 |
| VT# | 2 | 2 | 2 | 1 |
| Single | | | | |
| SB | 1 | 1 | 1 | 0 |
| VT | 2 | 2 (50%) | 2 | 0 |
| Multiple | | | | |
| SB | 1 | 1 | 1 | 1 |
| VT | 0 | 0 | 0 | 0 |

*SRF: Subretinal fluid; ※SB: Scleral buckle; #VT: Pars plana vitrectomy

for macula-off RD results from many factors, including cystic degeneration of the detached macula, the duration of the detachment, preoperative visual acuity, and some kinds of postoperative pathologies, including epiretinal membranes, pigment migration, cystoid macular edema, and retinal folds.[9,10,11] Persistent SRF is considered to be another factor. OCT can detect SRF that is not apparent on clinical examination in patients who have undergone surgery for RD.

SRF is promptly absorbed once retinal breaks are closed by SB or PPV surgery. Both the oncotic pressure of the protein-rich choroid and metabolic transport across the retinal pigment epithelium (RPE) contribute to this rapid absorption.[12] Experimental studies have also shown that hyperosmotic solutions, such as serum, are absorbed up to 10 times more slowly than isosmotic solutions. In acute RRD, the SRF is liquid vitreous, which has passed through the retinal break. The protein concentration of the SRF is considerably lower than that of the plasma and it contain hyaluronic acid, which is a component of the vitreous but not of the plasma.[13] With increasing duration of the RD, the composition of the SRF becomes more and more like that of plasma. The total protein content increases and the osmolality of the SRF increases. The fluid drained from a detachment of recent onset is watery, whereas the fluid found in a long-standing RD is viscous. Even when all the retinal holes are completely sealed, it may take months for the viscous fluid to be absorbed.

In several reports, residual SRF has persisted for six or more months after surgery, and foveal reattachment seemed to occur faster after PPV than after SB.[14,15] In our postoperative OCT investigations, the incidence of SRF was 13%-28%, and its incidence was higher after SB than after PPV (33% vs 23%, respectively, at one month after surgery). Some factors have been postulated to influence SRF after RD surgery.

The surgical technique may play an important role in persistent SRF. The RPE and choriocapillary can be badly damaged by cryopexy, laser photocoagulation, epiretinal membrane peeling, and scleral buckling during surgery, which characteristically indicates the breakdown of the blood-retinal barrier.[16,17,18] This possibly causes choroidal vascular insufficiency, subretinal precipitates, and elevated protein content or viscosity of the SRF, which therefore reduces the efficiency of SRF clearance.

It has previously been observed that complete vitrectomy, air-fluid exchange, and gas tamponade help to reattach the detached retina, and a postoperative prone position may decrease the potential space for SRF.[12] SRF may also result from incomplete vitrectomy, and the residual vitreous gel may play a role in foveal detachment. Alternatively, the SRF might be displaced by intraocular gas entering the macular region, resulting in a period of foveal detachment and consequent retinal changes, such as epiretinal membrane and retinal fold, which may exacerbate this phenomenon.[7,8]

Encircling scleral buckles have been demonstrated to reduce choroidal blood perfusion and may result in serous RD.[19] However, segmental SB does not seem to reduce choroidal perfusion.[20] In our patients, only some patients in the SB group (15%) or the PPV group (9%) were treated with encircling buckles. It is difficult to correlate the scleral buckles with persistent SRF. But it seems that any choroidal vascular insufficiency by scleral buckling procedures might influce the SRF absorption.

We analyzed the patterns of persistent SRF, according

to the study of Benson et al.[7,8] The incidence of confluent SRF at one month was 71% in patients treated with SB, and single-bleb SRF occurred at one month in 50% of patients treated with PPV.

In RRD, cells proliferate on both surfaces of the retina and on the vitreous base, known as proliferative vitreoretinopathy. With PPV, we can seal all peripheral retinal breaks and remove the vitreous content and the preretinal membrane completely. This may reduce the abnormal traction and retinal wrinkling, which may explain the higher incidence of single blebs in the PPV patients than in the SB patients. However, this may be related to different RD and patient characteristics, as well as to the surgical technique used.

Wolfensberger reported that foveal reattachment after macula-off RD occurs without delay after vitrectomy and SRF may persist for months in patients after buckle surgery.[13] Although our findings are compatible with the proposition that foveal reattachment is faster in PPV patients than in SB patients, persistent SRF can occur in PPV patients even six months after surgery. Many pre- or postoperative factors must also be considered. It is hard to compare the absorption time points with those of similar studies. However, the phenomenon of faster foveal reattachment in PPV patients than in SB patients is generally confirmed.

The thickness of the detached retina, as described in a previous study, did not correlate with FPVA.[21] The structure of the detached retina, as described by Hagimura et al.[22] using OCT, was moderately associated with the final visual result ($r = 0.48$; $P = 0.03$). These findings were all preoperative qualitative or quantitative evaluations. In our study, multivariate logistic regression analysis using postoperative ΔFT two weeks after surgery, measured by OCT, showed a weak correlation with the final visual result ($r = 0.127$, $P = 0.047$) and may allow the prediction of FPVA. We analyzed FPVA using postoperative variables after anatomically successful surgery for RD. Therefore, we excluded patients suspected of having preexisting ocular disease, which limited the number of patients (n = 39). Several other factors, such as postoperative macular recovery, persistent SRF, a short follow-up period and subsequent maculopathy may influence the data (ΔFT) ascertained by OCT. Great caution is required in interpreting this kind of data.

In conclusion, OCT is a useful noninvasive diagnostic tool that can detect the increased macular thickness not apparent on clinical examination. Increased macular thickness after RD surgery may persist for several months, and tends to cause delayed visual recovery.

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