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The relationship between the outer retina structure in the early postoperative period of vitrectomy and 3-month postoperative visual acuity in rhegmatogenous retinal detachment

Sora Itsukaichi, Kouhei Hashizume, Junfuku Nitta, Kenichi Murai and Daijiro Kurosaka

Department of Ophthalmology, School of Medicine, Iwate Medical University, Yahaba, Japan

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Abstract

Approximately 90% of rhegmatogenous retinal detachment (RRD) in retinal detachment is restored by the first vitreous surgery; however, in the case of RRD including the macula, the postoperative visual acuity prognosis varies and is difficult to predict. Here, we looked at the ellipsoid zone (EZ) near the fovea on optical coherence tomography (OCT) images to determine whether morphological recovery of the outer layer of the macula in the early postoperative period is associated with visual function after 3 months. Consequently, with the increase in brightness and thickness of the EZ 1 month after the operation, the visual acuity prognosis improved 3 months later. Therefore, the prognosis of visual acuity could be inferred by observing the outer layer of the retina on the OCT image 1 month after the operation.

Key words : *macula-off RRD, surgery of vitrectomy, ellipsoid zone, OCT, visual prognosis*

I. Introduction

Rhegmatogenous retinal detachment (RRD) is an important cause of visual impairment and requires surgical treatment. The three primary treatment alternatives include pneumatic retinopexy, pars plana vitrectomy, and scleral buckling [1]. When an RRD includes the macula, fovea's nerve retina and the retinal pigment epithelium detach, Disruption of nutritional supply to photoreceptor cells causes visual impairment [2]. Even with a good postoperative anatomic outcome, patients with macula-off RRD often have incomplete visual recovery [3, 4].

The retina is anatomically divided into 10 layers, and with the recent development of optical coherence tomography (OCT), it is possible to observe them. Of the high reflection lines observed on OCT, the ellipsoid zone (EZ), representing the high reflection line of the photoreceptor cell's inner and outer segment joints, reflects the outer photoreceptor cell's region of origin, which is

Corresponding author: Kouhei Hashizume
hassixi9898@yahoo.co.jp

part of the outer retina and is closely related to visual acuity [5, 6].

The macula retina does not change over time for retinal detachment with macula-on RRD. However, for macula-off RRD, the outer retina of the detached section is impaired. When the retina anatomically restores after retinal detachment surgery, the macula's general form and retinal functions are gradually restored. However, there are cases in which visual function impairments remains. On OCT, for macula-off RRD, the layer at the fovea structure is damaged, and the EZ is depicted as attenuation disappearance, or interruption [7]. However, when surgery anatomically restores it, there are cases where the EZ is gradually restored [8].

Previously, it was suggested that OCT's outer retina findings and visual acuity are related to retinal diseases that involve the macula [9]. It has been reported that the visual acuity after RRD surgery involving the macula and the thickness of ellipsoid zone of retinal pigment epithelium (EZ-RPE) are correlated [10-12] and that the postoperative visual acuity of the macular hole is correlated with the EZ luminosity on OCT [13]. However, there is still no report that considers whether visual prognosis can be predicted through the EZ findings of retinal detachment (RD) in the early postoperative period. The visual prognosis determines the quality of vision (QOV) of the patient and determines when the patient can return to work. Therefore, it is important from an economic standpoint when visual acuity restores and knowing the point at which the final visual acuity restoration can be predicted. In this study, we used OCT images of macula-off RRD to evaluate the outer retina's morphology at the fovea restoration in the early postoperative period, considering its relation to visual acuity.

II. Materials and Methods

This study was conducted using an opt-out method. It is performed with the approval from the Research Ethics Board at Iwate Medical University Hospital, Iwate, Japan, and the research was conducted in accordance with the guidelines of the Declaration of Helsinki. As this was a retrospective chart review study, no consent was obtained. This was a retrospective, consecutive, observational case series. Data were retrospectively extracted from the medical records of patients presenting with macula-off RRD between April 1, 2019, and March 31, 2020, at Iwate Medical University Hospital, Iwate, Japan. Patients with any of the following conditions were excluded; previous RD, re-detachment after surgery, less than 3 months of follow-up after surgery, and any known preceding macular disease that could affect the final visual acuity.

The collected date included demographic characteristics, visual acuity, lens status, and intraocular pressure. The best-corrected visual acuity was measured with a Landolt C chart, and the decimal values were converted to the logarithm of the minimal angle of resolution (logMAR) units. When a patient could not read text 1m away, visual acuity was measured by counting fingers or by hand movement and was converted to a logMAR value of 1.8 or 2.4, respectively.

All eyes were examined using the Heidelberg Spectralis OCT (Heidelberg Engineering, Heidelberg, Germany) with eye-tracking, and image averaging systems were used to obtain

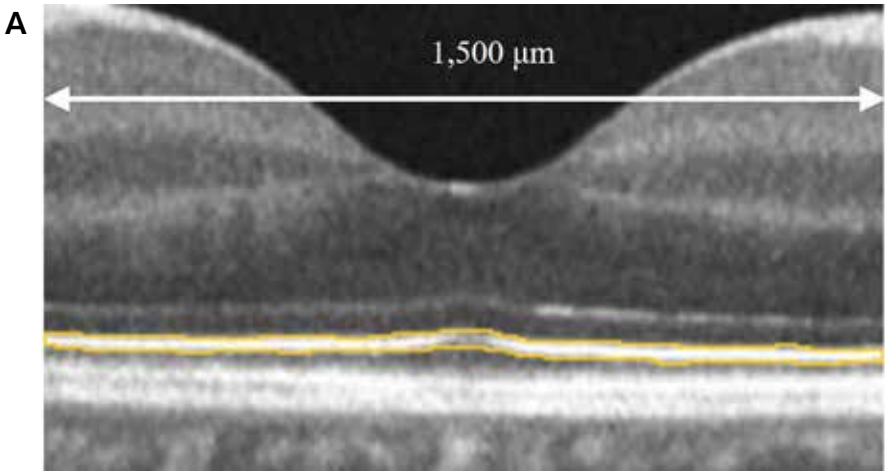

Fig. 1A. The ellipsoid zone (EZ) in the 1,500 μm scope centering around the fovea is manually selected.

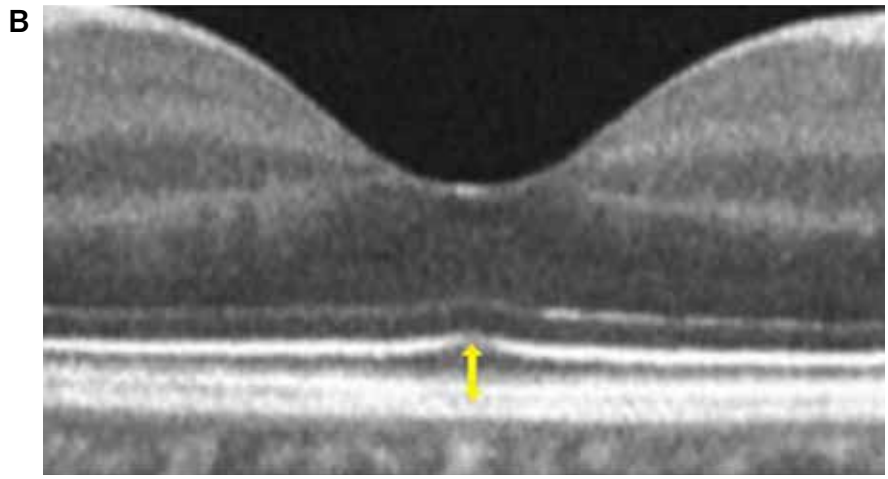

Fig. 1B. Distance between the outer edge of EZ and the inner edge of retinal pigment epithelium (RPE) (photoreceptor outer node length).

retinal images, 1 and 3 months after the surgery.

The horizontal dislocation was used for OCT image analysis. ImageJ software (Java-based image processing program, National Institutes of Health, Bethesda, Maryland, USA, and the Laboratory for Optical and Computational Instrumentation, University of Wisconsin, Wisconsin, USA) was used for the analysis. For EZ luminosity, the EZ in the 1,500 μm scope centered around the fovea was manually selected. The total luminosity of the selected EZ was set as the EZ luminosity of the macula (Fig. 1A). The distance from the EZ to the RPE in the fovea was determined by two authors (SI and KH) (Fig. 1B). For the continuous EZ, EZ with continuity in the 1,500 μ m scope centered around the fovea was deemed to have continuity, and a slight break or more was regarded as a disrupted EZ. A continuous EZ evaluation was performed by one of the authors (SI).

The visual acuity, EZ luminosity, and EZ-RPE thickness changes were analyzed using

Table 1. Baseline characteristics of patients who have undergone macula-off rhegmatogenous retinal detachment (RRD) surgery.

No. patients	32
Age, Years	59.4 ± 11
Gender	male: 25, female: 7
Operative method	V+C: 23, V: 9
Intraocular tamponade material	SF6: 25, C3F8: 1, Air: 0, Oil: 6
Operation time, minutes	62.3 ± 32.4
Preoperative VA	1.3501 ± 0.6484
1M VA	0.5129 ± 0.3085
3M VA	0.3665 ± 0.3877

VA, LogMAR visual acuity; 1M VA, visual acuity 1 month after surgery; 3M VA, visual acuity at 3 months after surgery; V + C, vitrectomy with cataract surgery; V, vitrectomy.
Values are mean ± S.D.

a paired t-test. Continuous EZ changes were analyzed using the chi-square test. Correlations among1-month postoperative EZ luminosity, EZ-RPE thickness, and 3-month postoperative visual acuity were analyzed using the Pearson's correlation coefficient. EZ continuity and 3-month postoperative visual acuity relations were analyzed using the t-test. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using SPSS software version 24 (SPSS Inc., Chicago, IL, USA).

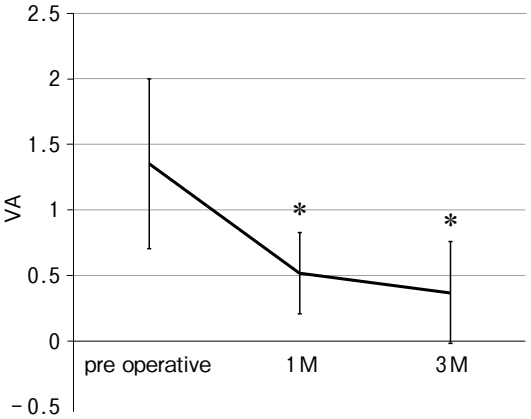

Fig. 2. Visual acuity (VA) improved significantly before surgery, 1 and 3 months after surgery ($p < 0.001$, Friedman test).

III. Results

There were 32 cases with 32 eyes. The average age was 59.4 ± 11.0 years, with 25 eyes in men and seven eyes in women. Twenty-three eyes underwent cataract surgeries simultaneously, while nine eyes had already been implanted with intraocular lens. For intraocular filling gas, 25 eyes had 20% sulfurhexafluoride, one eye had 15% perfluoropropane, and six eyes had silicon oil (Table 1). The visual acuities before the operation, 1 month after the operation, and 3 months after the operation were 1.350 ± 0.648, 0.513 ± 0.308, and 0.366 ± 0.388, respectively, and demonstrated significant improvements compared to that before the surgery ($p < 0.001$) (Fig. 2).

The luminosity of the EZ, 1 and 3 months after the operation was 54,700 ± 32,100 and 71,400 ± 39,900, respectively, which were significantly improved ($p < 0.001$). The EZ-RPE thickness, 1 and 3 months after the operation was 33 ± 12 μm and 41 ± 13 μm,

Table 2. Recovery of ellipsoid zone (EZ) by optical coherence tomography (OCT) findings for 1 and 3 months.

	1M	3M	p	Statistical Analysis
EZ luminosity	54700 ± 32100	71400 ± 39900	< 0.001	Paired t-test
EZ-RPE thickness, μm	33 ± 12	41 ± 13	< 0.001	Paired t-test
Continuous EZ	4/32	10/32	0.131	Chi-squared test

Outer retina findings in OCT one month and three months after surgery.
1M, one month after surgery; 3M, three months after surgery.
Values are mean ± S.D.

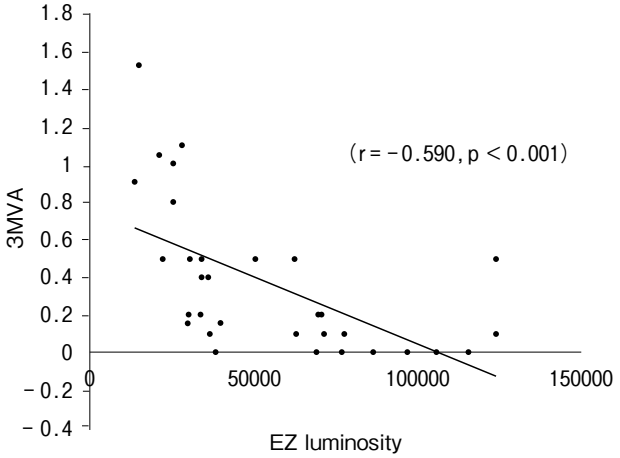

Fig. 3. A significant correlation is detected between the 1-month postoperative ellipsoid zone (EZ) luminosity and 3-month postoperative visual acuity (coefficient: -0.590, $p < 0.001$, Pearson's correlation coefficient).

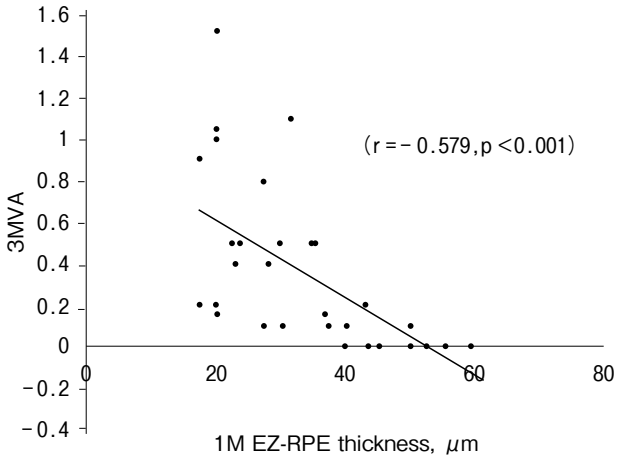

Fig. 4. A significant correlation is found between the 1-month postoperative ellipsoid zone- retinal pigment epithelium (EZ-RPE) thickness and 3-month postoperative visual acuity (coefficient: - 0.579, $p < 0.001$, Pearson's correlation coefficient).

respectively, which were restored significantly ($p < 0.001$). A continuous EZ, 1 month after the operation was observed in four out of 32 eyes; however, after 3 months, it was 10 out of 32 eyes ($p = 0.131$) (Table 2).

A significant correlation was found between the 1-month postoperative EZ luminosity and the 3-month postoperative visual acuity (coefficient: −0.590, $p < 0.001$, Pearson's correlation coefficient) (Fig. 3). One month after the operation, the higher the EZ luminosity was for cases, the better the visual acuity was three months later. A significant correlation was detected between the 1-month postoperative EZ-RPE thickness and 3-month postoperative visual acuity (coefficient: −0.579, $p < 0.001$, Pearson's correlation coefficient) (Fig. 4). One month after the operation, the thicker the EZ-RPE thickness, the better the visual acuity was three months. In contrast, there was no significant difference in the 3-month postoperative visual acuity from a continuous EZ, 1 month after the operation ($p = 0.150$).

IV. Discussion

RRD is a disease that occurs suddenly and lowers visual functions [14]. While surgical treatment is required, the development of surgical devices for vitrectomy in recent years has allowed retinal restorations at high probabilities. However, for macula-off RRD, anatomical restoration does not guarantee complete restoration of visual acuity because of damage to the retina of the fovea's retina [15]. The visual restoration of macula-off RRD varies [16]. The visual prognosis decide the patient's QOV and determines when the patient can return to work. Therefore, patients should predict early how much visual acuity is restored. This study found that the 3-month postoperative visual acuity was correlated with the EZ luminosity and EZ-RPE thickness on OCT images 1 month after the operation. It has been reported that RRD's postoperative visual acuity stabilizes in 3–6 months [17]. From these results, it was considered that the 1-month postoperative observation of the outer retina for the RRD involving the macula was useful for predicting visual prognosis.

For EZ luminosity and EZ-RPE thickness at 1 month, the luminosity was found to have stronger correlations in terms of visual acuity after 3 months. While the EZ luminosity measurements conducted in this study are complex, it is considered to be an index that more accurately expresses the outer retina conditions and damages. EZ-RPE thickness represents the photoreceptor outer segment volume [9]; however, its quality may not be expressed. In the early postoperative stages, it was considered that it might have included the outer segment thickness that was not functioning. In contrast, the section is the photoreceptor inner segment, which is rich in mitochondria [18-20]; therefore, the possibility that EZ luminosity reflects the mitochondrial volume, expressing the cell functions to a degree, was considered.

In this study, no significant relationship was found between the 1-month postoperative EZ continuity and 3-month postoperative visual acuity. However, only four out of 32 eyes were found to have a continuous EZ 1 month after the operation. Therefore, a statistically significant difference was not achieved. More cases are required to determine whether continuous EZ is effective for visual prognosis.

Because the study investigated a limited number of cases, it is necessary to target more cases in the future. Another consideration was that this study was retrospective cohort study, which required deliberation of long-term data after operation.

For macula-off RRD predicts EZ luminosity and thickness of the EZ-RPE visual acuity recovery 3 months after surgery by OCT image 1 month after surgery. Observing the outer retina in OCT images 1 month after the operation was considered to be possibly effective as one of the factors to predict visual prognosis.

Conflict of interest: The authors have no conflicts of interest to declare.

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裂孔原性網膜剥離に対する硝子体手術の術後早期における網膜外層の構造と術後３ヵ月後の視力の関係

五日市そら，橋爪公平，新田順福，
村井憲一，黒坂大次郎

岩手医科大学医学部，眼科学講座

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要旨

裂孔原性網膜剝離（RRD）は硝子体手術によって約 9 割が初回手術で復位するが，黄斑を含む RRD の場合，術後の視力予後はバラツキがあり予測がつきづらい．今回我々は，術後早期の黄斑部の網膜外層の形態学的な回復が，3 ヵ月後の視機能と関連するかどうかを中心窩付近の Ellipsoidzone（EZ）を OCT 画像で観察することで検討した．その結果，術後 1 ヵ月の EZ の輝度が高い症例や EZ の厚みが厚いほど 3 ヵ月後の視力予後が良好であった．このことから眼内充填ガスが消失する術後 1 ヵ月の OCT 画像で，網膜外層を観察することで視力予後が推察できる可能性が考えられた．