ORIGINAL ARTICLE/KLİNİK ÇALIŞMA

Spectral-Domain Optical Coherence Tomographic Analysis of Macula in Cases with Successfully Repaired Macula-off Retinal Detachment

Başarıyla Tedavi Edilmiş Maküla Tutulumu Olan Retina Dekolmanı Olgularında Makülanın Spectral-Domain Optik Koherens Tomografik Analizi

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ABSTRACT

Purpose: To evaluate the visual outcome and the spectral-domain optical coherence tomography (SD-OCT) findings at the fovea after successful rhegmatogenous retinal detachment (RRD) repair.

Materials and Methods: Fifty-nine eyes of fifty-nine patients with successfully repaired macula-off RRD were evaluated by SD-OCT. Patients were divided into three groups based on their surgery types; scleral buckling surgery (thirty eyes), pars plana vitrectomy (twenty eyes) and pneumatic retinopexy (nine eyes). The postoperative best-corrected visual acuity (BCVA) and micro-structural findings at the fovea were evaluated.

Results: The SD-OCT was obtained after a mean of 30.03±27.5 months from the repair. Main foveal abnormalities were the disruption of the junction between the photoreceptor inner and outer segments (IS/OS) in fifteen (25.4%) eyes, while IS/OS line was intact in forty-four (74.6%) eyes. The disruption of external limiting membrane (ELM) was detected in eleven (18.6%) eyes. The postoperative BCVA in logMAR was significantly correlated with the integrity of the photoreceptor IS/OS and ELM signals detected by SD-OCT (p<0.001), (0.36±0.31 in cases without disrupted IS/OS line versus 0.94±0.43 in cases with disrupted IS/OS line). However, the BCVA and the micro-structural foveal findings did not vary among the different surgical techniques.

Conclusions: The integrity of the photoreceptor IS/OS junction and ELM signals detected by SD-OCT may account for visual restoration in patients with preoperative macula-off RRDs. The surgical technique does not have any influence on the visual acuity or foveal micro-structural findings.

Key Words: Optical coherence tomography, spectral-domain optical coherence tomography, retinal detachment, macula-off retinal detachment.

ÖZ

Amaç: Başarılı yırtıklı retina dekolmanı (YRD) tedavisi sonrası görsel sonuç ve foveada spektral-domain optik koherens tomografi (SD-OKT) bulgularını değerlendirmek.

Gereç ve Yöntem: Başarılya tedavi edilmiş makula tutulumlu YRD olan ellidokuz hastanın ellidokuz gözü anatomik olarak başarıyla tedavi edildikten sonra SD-OKT ile değerlendirildi. Hastalar cerrahinin tipine gore üç gruba ayrıldı; skleral çökertme cerrahisi (otuz göz), pars plana vitrektomi (yirmi göz) ve pnömatik retinopeksi (dokuz göz). Cerrahi sonrası en iyi düzeltilmiş görme keskinliği (EİDGK) ve foveadaki mikroyapısal bulgular değerlendirildi.

Bulgular: SD-OKT tedaviden ortalama 30.03±27.5 ay sonra alındı. Esas fovea anormallikleri olarak onbeş gözde (%25.4) fotoreseptör iç ve dış segmentleri arasındaki birleşkenin (İS/DS) bozulması iken, kırkdört gözde (%74.6) İS/DS çizgisi sağlamdı. Dış limitan membranın (DLM) bozulması onbir gözde (%18.6) tespit edildi. Cerrahi sonrası EİDGK (logMAR), SD-OKT ile elde edilen fotoreseptör İS/DS ve DLM sinyallerinin bütünlüğü ile anlamlı olarak ilişkiliydi (p<0.001), (İS/DS çizgisinin bütünlüğü bozulmamış olgularda 0.36±0.31'a, bozulmuş İS/DS çizgisi olan olgularda 0.94±0.43). Ancak, EİDGK ve mikroyapısal fovea bulguları farklı cerrahi teknikler arasında farklılık göstermedi.

Sonuç: Fotoreseptör İS/DS birleşkesinin bütünlüğü ve SD-OKT ile elde edilen DLM sinyalleri, cerrahi öncesi makula tutulumu olan YRD hastalarında, görsel düzelme açısından önemli olabilir. Cerrahi tekniğin görme keskinliği veya foveadaki mikroyapısal değişiklikler üzerine etkisi yoktur.

Anahtar Kelimeler: Optik koherens tomografi, spektral-domain optik koherens tomografi, retina dekolmanı, makula tutulumu olan retina dekolmanı.

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INTRODUCTION

Scleral buckling (SB) with cryoretinopexy, pars plana vitrectomy (PPV) and pneumatic retinopexy (PR) are well accepted methods for the treatment of rhegmatogenous retinal detachment (RRD) with high reattachment rates.[1] Reduced postoperative visual acuity; however may occur after anatomically successful repair of RRD, especially if the macula was involved before surgery. This reduced acuity may be explained by the presence of clinically visible pathologies such as epiretinal membranes (ERMs), cystoid macular edema, macular hole, and retinal folds.[2,3] However, it may not be possible to interpret the incomplete visual recovery in some cases, if the retina seems clinically normal.[3]

Time-domain optical coherence tomography (OCT) may detect changes such as subclinical sub-retinal fluid (SRF) and increased foveal thickness, which may not be seen clinically. However, especially with the improved resolution of spectral-domain (SD)-OCT, it is possible to acquire visualization of foveal microstructures particularly at the level of photoreceptor layer and to identify the pathologic changes.[4-6] The highly reflective bands over the retinal pigment epithelium (RPE); the external limiting membrane (ELM) at the posterior border of the outer nuclear layer (ONL), and the back-reflection line that arises from the inner segment/outer segment (IS/OS) junction can be used as a guide for the evaluation of the photoreceptor layer integrity.[7]

The aim of the current study was to evaluate the visual outcomes and changes in the foveal microstructures detected by SD-OCT in successfully repaired RRD cases with different surgical techniques.

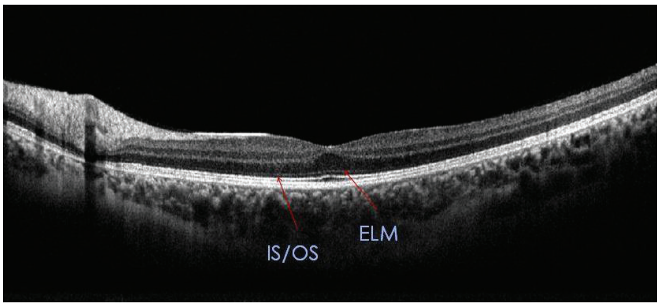

Figure 1: *The back reflection from IS/OS is formed by the connecting cilia between IS and OS and the back reflection from ELM represents zonular adherents which join the IS to the Muller cells.*

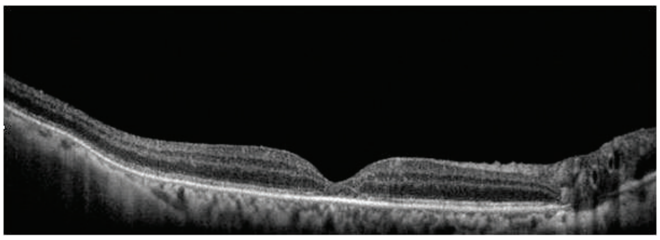

Figure 2: *Disruption of both ELM and IS/OS.*

MATERIALS AND METHODS

This was a prospective study including patients who underwent anatomically successful repair for primary RRD between January 1998 and December 2010. All the procedures pertaining to the study have been conducted in accordance with the Declaration of Helsinki and local laws and regulations. All the eyes had a macula-off RRD (defined as a retinal detachment (RD) involving the fovea). All the patients enrolled in this study underwent a comprehensive ophthalmologic examination, including the best-corrected visual acuity (BCVA) assessment using Early Treatment Diabetic Retinopathy Study chart, intraocular pressure measurement, binocular indirect ophthalmoscopy, and slit-lamp bio-microscopy. The patients underwent SD-OCT (OCT/SLO 2006; OTI inc., Toronto, Canada) examination after a detailed explanation of the study was provided and informed consent was obtained.

Inclusion criteria were as follows:

1) Macula-off RRD (defined as a RRD involving the fovea) prior to the retinal surgery,

2) Successfully repaired primary RRD by a single, uncomplicated surgical procedure (sclera buckling surgery, primary pars plana vitrectomy with gas tamponade or pneumatic retinopexy),

3) Follow-up of at least six months after surgery,

4) Follow-up of at least six months after cataract surgery in patients who underwent cataract surgery following retinal procedures.

Exclusion criteria were as follows:

1) Pre-existing macular disease,

2) Diabetes mellitus and a history of retinal vascular occlusion in the affected eye,

3) Patients with proliferative vitreo-retinopathy,

4) Previous intraocular surgery,

5) Postoperative media opacities,

6) Traumatic RRD,

7) RRD associated with giant retinal tears or vitreous hemorrhage,

8) Use of silicone oil as a tamponade.

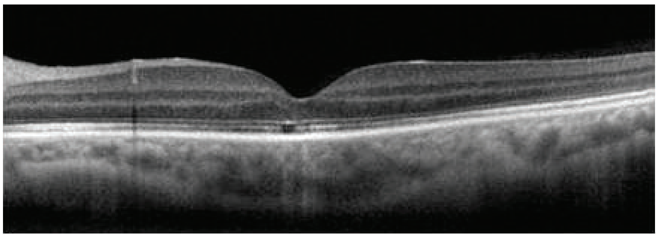

Figure 3: *Disruption IS/OS and intact ELM.*

Table 1: *Baseline characteristics of all cases.*

Number of eyes included	59	
Mean age in years (range)	58.1±13.05 (26-83)	
Sex (female/male)	35/24	
Mean BCVA in logMAR	0.68±0.82	
Mean time (months) of the SD-OCT from the operation (range)	30.03±27.50 (6-156	
Number of surgical procedures performed (%)	SB	30 (51%)
	PPV	20 (34%)
	PR	9 (15%)

BCVA; Best Corrected Visual Acuity, SD-OCT; Spectral-Domain Optical Coherence Tomography, SB; Scleral Buckling, PPV;Pars Plana Vitrectomy, PR; Pneumatic Retinopexy.

The spectral-domain OCT images of patients, who met the inclusion criteria, were evaluated. The presence or absence of vitreo-retinal interface abnormalities, intra-retinal or SRF were noted. Micro-structural changes in the photoreceptor layer were defined as disruption or loss of the back-reflection line corresponding to the photoreceptor IS/OS junction, the ELM, or both (Figure1-3).

The judgment was performed on each scan of the radial six-line scan, along with a 2-mm-diameter area centered on the fovea. Central foveal retinal thickness (CFT) was measured automatically from the topography program by the OCT software. In addition, CFT was determined using the OCT software manually and the average of the measurements obtained automatically and manually was calculated. Cases with IS/OS line disruption were compared with ones without IS/OS line disruption regarding the BCVA and average CFT. Cases with disrupted ELM were compared with ones with intact ELM regarding the BCVA and CFT. Patients were divided into three groups based on their surgery types:

1) Scleral buckling surgery,

2) Primary pars plana vitrectomy and 14% perfluoropropane (14% C_3F_8) gas tamponade,

3) Pneumatic retinopexy.

These three groups were compared with each other regarding the BCVA, CFT, and OCT findings. The preoperative baseline characteristics and type of surgery performed were documented by reviewing the patients' charts.

Statistical analysis was performed using Statistical Package for the Social Sciences 15.0 (SPSS Inc., Chicago, IL). All measurements were evaluated by the Shapiro-Wilk test for normality. However, the number of subjects in the subgroups were less than twenty, so non-parametric tests, namely Mann-Whitney U test, Kruskal-Wallis test, Pearson chi-square or exact chi-square, were used for the statistical analysis. Spearman's correlation coefficient was calculated to investigate the relationship between the preoperative period and postoperative visual acuity. Significance was attributed when $p<0.05$.

RESULTS

Fifty-nine eyes of fifty-nine patients with anatomically successful repair of RRD met the inclusion criteria. Preoperatively, all eyes had a macula-off RRD (defined as a RRD involving the fovea). All eyes achieved anatomic success with one surgery. The preoperative period of initiation of visual symptoms was 17.41±17.49 days. This preoperative period and the postoperative visual acuity were not correlated ($p>0.05$). The time interval between the SD-OCT images obtained, and the retinal surgery was 30.03±27.50 (6-156) months.

The preoperative baseline characteristics of the fifty-nine eyes are summarized in table 1.

The postoperative spectral-domain OCT findings are presented in table 2. IS/OS line was not disrupted in 44 cases, while it was disrupted in 15 cases.

Table 2: *Postoperative spectral-domain optical coherence tomography findings.*

N. Cases with epiretinal membrane (%)	11 (18.6%)
N. Cases with intra-retinal-sub-retinal fluid (%)	3 (5.0%)
N. Cases with IS/OS line disruption (%)	15 (25.4%)
N. Cases with ELM disruption (%)	11 (18.6%)
N. Cases with IS/OS line (+), ELM (+) (%)	44 (74.5%)
N. Cases with IS/OS line (-), ELM (-) (%)	11 (18.6%)
N. Cases with IS/OS line (-), ELM (+) (%)	4 (6.7%)

N;Number Of Cases, IS/OS;Inner Segments/Outer Segments, ELM;External Limiting Membrane, (+);Undisrupted, (-);Disrupted.

Table 3: *BCVA, CMT, IS/OS line disruption, epiretinal membrane formation and intra-retinal-sub-retinal fluid formation in different surgical groups. Statistical analysis was performed using Kruskal-Wallis, Pearson chi-square or exact chi-square.*

	PPV (n=20)	SB (n=30)	PR (n=9)	P value
Mean BCVA in logMAR [median values (25th and 75th percentile values)]	0.56 ±0.4 [0.40 (0.17-0.70)]	0.52±0.46 [0.52 (0.22-0.78)]	0.34±0.42 [0.15 (0.05-0.55)]	0.22
Mean CMT in μm [median values (25th and 75th percentile values)]	219.80±99.24 [203 (167-248.50)]	199.17±58.20 [195.50 (173.50-217)]	161.67±67.91 [162 (114.50-200)]	0.09
IS/OS line disruption	9 (45%)	5 (16.7%)	1 (11.1%)	0.52
Epiretinal membrane formation	4 (20.0%)	5 (16.7%)	2 (22.2%)	1.0
Intra-retinal-sub-retinal fluid formation	1 (5.0%)	2 (7%)	0	1.0

BCVA; Best Corrected Visual Acuity, CMT; Central Macular Thickness, IS/OS; Inner Segments/Outer Segments, PPV; Pars Plana Vitrectomy, SB; Sclera Buckling, PR; Pneumatic Retinopexy.

Table 4: *Comparison of cases with and without disrupted IS/OS line. The median, 25th and 75th percentile values are given in parentheses. Statistical analysis was performed using Mann-Whitney U t-test.*

	IS/OS line (+) cases (n=44)	IS/OS line (-) cases (n=15)	P value
Mean BCVA in logMAR	0.36±0.31 [0.30 (0.11-0.52)]	0.94±0.43 [1.00 (0.52-1.30)]	<0.001
Mean automatically determined CMT in μ	208.45±76.98 [196 (165-238)]	203.73±83.50 [211 (150-244)]	0.83
Average of mean automatically and manually determined CMT in μ	200.95±75.99 [194 (162.50-220)]	198.93±82.36 [210 (150-241)]	0.81
Mean manually determined CMT in μ	193.41±75.98 [191 (161-219)]	194.00±81.42 [200 (148-235)]	0.80

BCVA; Best Corrected Visual Acuity, CMT; Central Macular Thickness And IS/OS; Inner Segments/Outer Segments.

Table 5: *Comparison of cases with and without disrupted ELM. The median, 25th and 75th percentile values are given in parentheses. Statistical analysis was performed using Mann-Whitney U test.*

	Undisrupted ELM cases (n=48)	Disrupted ELM cases (n=11)	P value
Mean BCVA in logMAR	0.38±0.32 [0.30 (0.15-0.66)]	1.03±0.45 1.00 (0.52-1.30)	<0.001
Mean CMT in μ	201.48±73.22 [195 (165.25-220)]	195.90±95.42 [210 (140-241)]	0.915

BCVA; Best Corrected Visual Acuity, CMT; Central Macular Thickness And ELM; External Limiting Membrane.

The BCVA, CFT, and OCT findings in different surgical groups are presented in table 3. The type of surgery performed had no effect on the BCVA and OCT findings (p>0.05 for all comparisons).

Comparison of cases with and without disrupted IS/OS line and with and without disrupted ELM are presented in table 4,5, respectively.

The postoperative visual acuity was significantly lower in cases with disrupted IS/OS line (p<0.001) and was worst in cases with disrupted ELM.

DISCUSSION

As an important feature of SD-OCT, foveal microstructural changes such as losses of IS/OS junction and ELM after successful RRD repair and their negative correlation with visual acuity outcome have been recently described.[8-11] We encountered disruption of the IS/OS junction in 25.4% and disruption of ELM in 18.6% of eyes on SD-OCT imaging.

The disruption of the IS/OS junction or ELM observed on SD-OCT imaging was associated with statistically significant lower visual acuities.

In our study, we also demonstrated that cases with disruption of both ELM and IS/OS had the lowest VA. We also compared the three different well accepted surgical techniques for the treatment of RRD (SB, PV, and PR) with regard to postoperative foveal micro-structural changes by SD-OCT. To the best of our knowledge, there are no previous studies comparing these three surgical techniques for that aspect. There were no significant difference between the surgical techniques and macular morphology (p>0.05).

The disruption of IS/OS junction together with ELM could be the indication of the extension of morphological changes from photoreceptor IS/OS junction to photoreceptor cell bodies and Muller cells as suggested by previous studies.[9,10]

In our series, no eyes showed disrupted ELM with an intact IS/OS junction, suggesting that the first retinal injury resulting from retinal detachment may be in the photoreceptor outer segment and this may be followed by the degeneration of the photoreceptor cell bodies.

In a study by Smith et al. high-resolution SD-OCT revealed varying degrees of photoreceptor disruption in 76% of the 17 eyes, at least 3 months after anatomically successful reattachment for macula-off RRD.[12] A similar ratio was also obtained by the SD-OCT images taken one to eighty-four months (median, five months) postoperatively and distortion of IS/OS junction was seen in 82% of the patients.[2]

We detected much less IS/OS disruption in our cases (25.4%). This difference may be explained by the longer time interval between the surgical repair of RRD and OCT measurements (mean of 30.03±27.5 months, range: 6-156) and possible restoration of IS/OS junction in our cases.

Shimoda et al. showed that the percentage of eyes with a continuous IS/OS line increased from 5% to 50% at six months after foveal reattachment, whereas the percentage of eyes with a disrupted IS/OS line decreased from 55% to 17%. These results suggest that the cone outer segments may be gradually restored after retinal reattachment.[13]

Several postoperative factors such as ERMs, cystoid macular edema, and persistent SRF may be detected clinically causing incomplete visual acuity recovery after anatomically successful RRD repair.[14,15] Previous studies with time-domain OCTs have focused on subclinical, persistent SRF occurrence in a substantial number of patients after RRD surgery.[8,13,16-18]

It has been demonstrated that SRF tends to disappear spontaneously within one year in the majority of cases. Wolfensberger TJ reported that fluid was still present in 11% of cases at twelve months after SB surgery, while OCT examination one month after vitrectomy showed a completely attached fovea with no subfoveal fluid in all cases.[18] Gibran SK et al., reported that, 36% and 9% of cases that underwent SB surgery had a persistent foveal detachment at six and twelve months, respectively.[17] No foveal abnormality was seen at six and twelve months after PPV.[17]

Shimoda et al. showed that at sixth months, 33% eyes had SRF after PPV surgery.[13] In our study, three eyes (5%), (one out of twenty eyes in PPV group, two out of thirty eyes in SB group and none in PR group) showed persistent SRF after a mean interval of 30.03±27.5 months between surgery and OCT examination. There were no statistically significant association between the occurrence of persistent SRF and the three surgical techniques.

We detected less persistent SRF than the previous studies, most likely due to the long mean time interval between the surgical repair and the SD-OCT examinations. A relationship between low postoperative visual acuity and persistent foveal detachment has been noted previously; while no relation was reported in others.[8,19] We cannot comment on this due to few numbers of cases with persistent SRF in our study.

The strengths of this paper include the prospective design of the study and the relatively large number of eyes examined. SD-OCT findings of the subjects at least six months after successful retinal surgery were evaluated. However, the time intervals between the retinal surgery and the SD-OCT examinations were variable among cases, being 30.03±27.50 (6-156) months. This is the main limitation of the study. If we could take the SD-OCT images at fairly constant intervals after the RRD repair, we could have stated that our long-term, mid-term or short-term findings are related to the visual recovery. In some cases SD-OCT images were taken in a year after surgery, while they were obtained after five years in some cases. It is possible that the SD-OCT findings may alter in time.

In conclusion, SD-OCT is valuable for evaluating foveal micro-structural changes after retinal detachment surgery. The integrity and restoration of the IS/OS junction and ELM may account for visual restoration. Different surgical techniques do not seem to have effect on the integrity of foveal micro-structures.

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