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Changes in Choroidal Thickness and Volume in Patients with Diabetic Retinopathy after Panretinal Photocoagulation by Using a Choroidal Thickness Map

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Abstract

Objectives: We aimed to investigate the short-term changes in macular choroidal thickness and volume after Panretinal Photocoagulation (PRP) in patients with Proliferative Diabetic Retinopathy (PDR) using a choroidal thickness map with Spectral-Domain Optical Coherence Tomography (SD-OCT).

Methods: In this retrospective study, we reviewed the charts of patients who received PRP for diabetic retinopathy. Central volume scans using a 25-scan pattern and macular thickness map protocols were subsequently performed using the Spectralis OCT before and 1 month after PRP. Retinal thickness was measured by automated segmentation and choroidal thickness was obtained using a volume scan program with manual segmentation. For segmentation of the choroidal layer, the reference lines of the retinal boundary were adjusted to the choroidal boundary. Macular thickness maps were divided into nine sectors according to the ETDRS layout and analyzed to evaluate changes in macular thickness and volume.

Results: In all, 49 patients (49 eyes) with early PDR were included. The mean central retinal thickness and mean total retinal volume of all ETDRS subfields increased 1 month post-PRP (308.06 ± 50.75 μm, 9.72 mm^3) compared with before PRP (279.84 ± 26.62 μm, 9.19 mm^3; $P<0.001$). Mean central choroidal thickness and mean total choroidal volume of all ETDRS subfields showed no significant change 1 month after PRP (302.57 ± 43.11 μm, 8.16 mm^3) compared with before PRP (298.43 ± 43.67 μm, 8.12 mm^3; $P=0.120$ and $P=0.353$, respectively). In all nine sectors, including the central 1-mm circle, choroidal thickness and volume showed no significant changes post-PRP treatment ($P>0.05$).

Conclusion: In the macular region, retinal thickness increased and choroidal thickness did not change 1 month after PRP. These results indicate that PRP may have little or no effect on the change in macular choroidal thickness or volume in patients with early PDR, although whether PRP causes a significant change in choroidal blood flow in the macular region is unclear.

Keywords: Choroid; Diabetic retinopathy; Optical coherence tomography; Photocoagulation; Retina

Introduction

Panretinal Photocoagulation (PRP) has been approved as an effective treatment for stopping retinal neovascularization in patients with severe diabetic retinopathy [1-3]. This treatment constitutes performing multiple laser photocoagulation sessions on the peripheral retina with the purpose of destroying photoreceptor and retinal pigment epithelium cells under the treated retina. While PRP damages photoreceptor and the retinal pigment epithelium layer, the inner retina remains relatively preserved, and PRP is used to prevent permanent severe visual loss [4-6]. Although PRP has been shown to reduce moderate vision loss by 50%, it can also induce macular edema and subsequently decrease vision [7-9].

Although it has been presumed that post-laser release of inflammatory factors, accumulation of leukocytes in the non-photocoagulated retina, up-regulation of angiogenic growth factors, and increased retinal blood flow in the macula may be possible pathogenetic mechanisms responsible for the development of macular edema following PRP, the exact mechanism is poorly understood and remains unclear [7,10-13]. Although many previous studies have focused on the effects of PRP on changes in retinal thickness or retinal blood flow, far less attention has been paid to the effects of PRP on the choroid [14-17]. Moreover, to our knowledge, there has been no study investigating topographic changes of the macular choroid before and after PRP.

In the past few years, Optical Coherence Tomography (OCT) has become an essential tool for precisely evaluating macular thickness as OCT permits enhanced depth imaging for evaluating the choroid [18]. Through Spectral-Domain Optical Coherence Tomography (SD-OCT), it is possible to assess the choroid using thickness mapping to better understand choroidal changes [19].

Therefore, the purpose of this study was: (1) to investigate the short-term effects of PRP on macular topographic changes; and (2) to evaluate changes in macular choroidal thickness and volume after PRP in patients with PDR using choroidal thickness mapping with SD-OCT.

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Materials and Methods

Subjects

In this retrospective study, we reviewed the medical records of patients who received PRP for diabetic retinopathy at the Seoul National University Bundang Hospital. The review period included all consecutive patients treated with PRP between November 2010 and October 2011 who met the following inclusion criteria: (1) age greater than 30 years; (2) newly diagnosed with early PDR; (3) no history of or clinical evidence of prior PRP; and (4) no presence of vitreous hemorrhage. Major exclusion criteria included the following: (1) other retinal diseases aside from diabetic retinopathy; (2) previous treatment for diabetic macular edema with focal/grid laser or intravitreal injection within the past 6 months; (3) any intraocular surgery within the past 6 months or previous pars plana vitrectomy; (4) uncontrolled hypertension; (5) a history of pancreatic transplant or chronic renal failure requiring dialysis or kidney transplant; (6) severe cataracts or media opacity that could influence performing the laser treatment; and (7) macular edema defined as a central foveal thickness >300 μm. The macular thickness and volume profiles of the retina and choroid were measured at baseline (pre-PRP) and 1 month after PRP. When both eyes were eligible for our study, both eyes of each patient were evaluated; however, only one eye of the patients was randomly selected for statistical analysis. Additionally, the subjects were divided into an argon laser treatment group and a pattern scanning laser (PASCAL; OptiMedica Corp., Santa Clara, CA, USA) system treatment group for the comparison.

PRP treatment

All patients who had early PDR received PRP using a traditional argon laser or PASCAL laser photocoagulator. All PRP procedures were performed in a dark room approximately 30 min after the study eye was pharmacologically dilated with 1% tropicamide and 2.5% phenylephrine. All eyes were anesthetized with topical 0.5% proparacaine eye drops. For the argon laser group, an argon green laser was used with a retinal spot size of 200 μm and an intensity of 200 mW–600 mW until a gray burn spot was evident. The duration of the application was 0.1–0.2 s, and the total number of spots was approximately 2,000–2,400. The majority of patients opted to divide the treatment over two or three sessions. For the PASCAL laser group, PASCAL laser photocoagulation was performed using the Super Quad 160 fundus laser lens (Volk Optical, Inc, Mentor, OH, USA) with an approximate 2X spot-size magnification. Settings were as follows: 200-μm spot size, 20 ms pulse duration, and power increased from 400 mW until a gray-white lesion was attained. Burns were placed one burn width apart, and the total number of spots was approximately 2,400–4,000. All patients completed the entire treatment in two sessions.

Optical coherence tomography scanning protocols

Central volume scan using a 25 scan pattern and macular thickness map protocols were performed subsequently with the Spectralis OCT (Heidelberg Engineering, Heidelberg, Germany). This OCT device combines an SD-OCT and a cSLO in one single instrument, which allows very precise registration of the A scans. The acquisition rate of the Spectralis OCT is 40,000 A scans per second. The optical depth resolution is 7 μm and the digital transverse and axial resolutions are 14 and 3.9 μm, respectively. A volumetric assessment of the central retinal structures consisting of 25 single horizontal axial scans was performed (scanning area: 6×6 mm, centered at the fovea). This protocol was chosen because it is one of the most often used in clinical practice, and because protocols with higher numbers of scans were not applicable for reasons including patient cooperation and time. For each horizontal scan, 10 B scans at the same position were averaged to reduce speckle noise. An internal fixation point was used to increase the chance that one scan was centered in the fovea. Retinal thickness by the Spectral is OCT was calculated by automated segmentation using OCT software as the distance between the first signal from the vitreo retinal interface and the signal from the outer border of the retinal pigment epithelium (RPE). Segmentation quality assessment was performed frame by frame to ensure that there was no segmentation algorithm failure and centering of the measurements on the thinnest part of the fovea was ensured. Additionally, the Spectralis OCT provides a circular map analysis analogous to the one by Cirrus OCT 3. This macular thickness maps were divided into nine sectors according to the ETDRS layout; namely, the 1,000 μm central ring and the four quadrants of the inner and outer rings. The subfields comprised the central subfield, nasal inner macula, superior inner macula, temporal inner macula, inferior inner macula, nasal outer macula, superior outer macula, temporal outer macula, and inferior outer macula. The diameters of the inner and outer rings were 3,000 μm and 6,000 μm, respectively. Analysis was performed to evaluate changes in macular thickness and volume for each ETDRS subfield.

Measurements of choroidal thickness profiles

Choroidal thicknesses were obtained by a volume scan program using manual segmentation. To evaluate the choroidal image, central volume scans in a 25 scan pattern and macular thickness map protocols

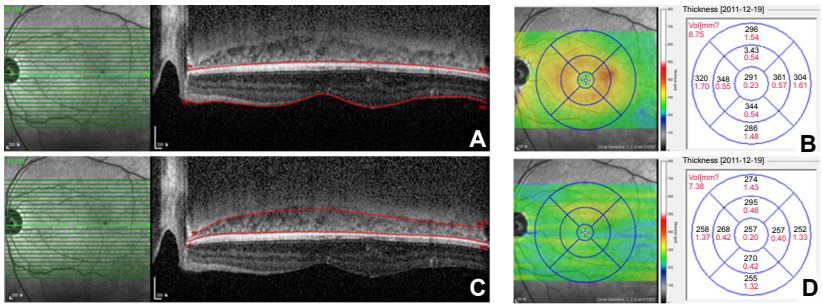

Figure 1: A, B Retinal thickness was measured by automated segmentation using OCT software and the topographic map (**B**) of retinal thickness and volume was automatically generated by the OCT software. **C, D** The choroidal thicknesses were obtained using a volume scan program with manual segmentation. For segmentation of the choroidal layer, the reference lines of the retinal boundary (internal limiting membrane–retinal pigment epithelium) were adjusted to the choroidal boundary (retinal pigment epithelium–choroid/sclera junction) in each of the 25 volume scans. A topographic map (**D**) of choroidal thickness and volume was automatically generated by the OCT software.

were also applied using the Spectralis OCT. For accurate choroidal imaging, the enhanced depth imaging technique was used, in which the zero delay line was moved to the choroid level. For segmentation of the choroidal boundary, the built-in segmentation-modifying tool was used by two masked, well-trained analysts (D.J.H, K.H.P). The automatically plotted reference lines of the retinal boundary (internal limiting membrane–RPE) were adjusted to the choroidal boundary (RPE–choroid/sclera junction) in each set of the 25 volume scans as described previously (Figure 1). Choroidal thickness was defined as the perpendicular distance between the posterior edge of the hyper-reflective RPE and the choroid/sclera junction. Choroidal thickness and volume were calculated automatically and the colored topographic map with nine subfields of choroidal thickness and volume were automatically generated by the OCT software.

Ethics statement

The study was approved by the institutional review board of Seoul National University Bundang Hospital, and the study was carried out in accordance with the tenets of the Declaration of Helsinki.

Statistical analyses

Characteristics	Value
Number of patients (eyes)	49 (49 eyes)
Age, mean ± SD	54.1 ± 10.5
Sex. Male/female	28:21
Duration of diabetes (years), mean ± SD	10.6 ± 8.3
HbA1c (%), mean ± SD	8.8 ± 1.7
Hypertension, no, %	24 (49%)

Table 1: Clinical characteristics of patients at baseline.

Statistical analyses were performed using a commercially available software package (IBM SPSS Statistics 18; SPSS Inc., Chicago, IL, USA). Significant differences between baseline and 1 month after PRP were evaluated using the paired *t*-test and Wilcoxon signed rank test for normally distributed data and data that were not normally distributed, respectively. Significant differences of mean macular thickness and volume at each of the ETDRS subfields between the two subgroups were evaluated using the Mann–Whitney test for nonparametric data. Statistical significance was defined as $P<0.05$.

Results

In all, 49 eyes of 49 diabetic patients with early PDR were reviewed. All patients underwent SD-OCT before and 1 month after completing PRP treatment. Patient ages ranged from 34 years to 88 years (mean, 54.1 ± 10.5 years). Mean duration of diabetes mellitus was 10.6 ± 8.3 years and hemoglobin A1c levels averaged 8.8% ± 1.7% before PRP. The baseline characteristics of our patients are shown in Table 1. The mean ± standard deviation of visual acuity, converted to logarithm of the minimal angle of resolution, was 0.17 ± 0.15 before PRP and 0.19 ± 0.16 at 1 month after PRP. No statistically significant difference in visual acuity was observed (P=0.105). In Figure 2, changes in macular thickness and volume after PRP are summarized.

Retinal thickness and volume after panretinal photocoagulation

Retinal thickness of the central 1 mm circle and the mean total retinal volume of all ETDRS subfields increased at 1 month after PRP (308.06 ± 50.75 μm, 9.72 ± 0.82 mm^3) compared with before PRP (279.84 ± 26.62 μm, 9.19 ± 0.63 mm^3, $P<0.001$). The inner 3 mm circle thickness increased from 348.27 ± 21.25 μm at baseline to 369.06 ± 31.94 μm 1 month after PRP ($P<0.001$). The outer 6 mm circle thickness

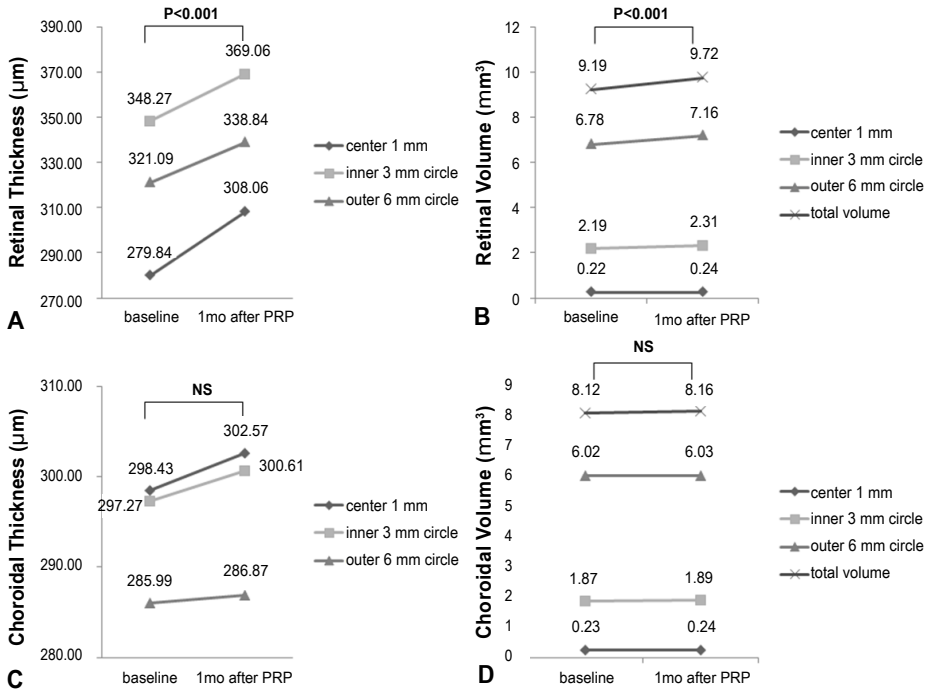

Figure 2: A, B Retinal thickness and volume measurements at baseline and 1 month after panretinal photocoagulation (PRP). Significant change in the mean thickness and volume was observed between baseline and 1 month after PRP. **C, D** Choroidal thickness and volume at baseline and 1 month after PRP. No significant change was shown after PRP. NS, not significant.

also increased from 321.09 ± 24.67 μm at baseline to 338.84 ± 29.38 μm 1 month after PRP (P<0.001). In both the inner and outer circle, each superior, nasal, inferior, and temporal quadrant showed increases in retinal thickness and volume (P<0.001; Table 2).

Choroidal thickness and volume after panretinal photocoagulation

Choroidal thickness of the central 1 mm circle and the mean total choroidal volume of all ETDRS subfields did not change significantly at 1 month post-PRP (302.57 ± 43.11 μm, 8.16 ± 1.17 mm^3) compared with before PRP (298.43 ± 43.67 μm, 8.12 ± 1.10 mm^3; P=0.120 and P=0.353, respectively). The inner 3 mm circle thickness did not change from 297.27 ± 40.06 μm at baseline to 300.61 ± 41.53 μm 1 month after PRP (P = 0.067). The outer 6 mm circle thickness did not show a significant change from 285.99 ± 40.36 μm at baseline to 286.87 ± 42.68 μm 1 month after PRP (P=0.602). In the inner and outer circle, each superior, nasal, inferior, and temporal quadrant did not show any significant change in either choroidal thickness or volume (P>0.05; Table 2).

Argon laser versus PASCAL laser: subgroup comparison of macular changes after panretinal photocoagulation

In the subgroup analysis, both the argon laser treatment and PASCAL laser treatment groups showed similar results (Table 3). In both groups, retinal thickness and macula volume increased significantly compared with before PRP treatment. However, choroidal thickness and volume parameters did not show any significant change between subgroups. Furthermore, there was no difference between these groups with respect to the macular (retinal or choroidal) thickness and volume at baseline and 1 month after PRP treatment (P>0.05). Macular topographic (thickness and volume) changes in the retina or choroid in the argon group were higher than in the PASCAL group, but this difference was not significant (P>0.05).

Discussion

In the current study, we provide evidence that PRP does not cause choroidal thickness changes in the macular region, although retinal thickness increased in patients with early PDR and without macular edema. Retinal thickness and retinal volume of all ETDRS subfields increased 1 month after PRP compared to before PRP; however, choroidal thickness and volume of all ETDRS subfields did not undergo significant changes after PRP treatment. Although the exact reason for this lack of effect on choroidal thickness or volume in the macula region after PRP remains unclear, we could consider two possibilities: first, it is possible that no changes occurred in either choroidal blood flow

		Retina			Choroid	
	before PRP	**after PRP**	***p*value**	**before PRP**	**after PRP**	***p*value**
Thickness						
center 1 mm circle	279.84 ± 26.62	308.06 ± 50.75	**<0.001**	298.43 ± 43.67	302.57 ± 43.11	0.120
inner 1-3 mm circle						
Average	348.27 ± 21.25	369.06 ± 31.94	**<0.001**	297.27 ± 40.06	300.61 ± 41.53	0.067
Sup	350.24 ± 26.49	371.82 ± 39.03	**<0.001**	302.88 ± 40.73	307.69 ± 42.93	0.107
Nasal	351.51 ± 22.59	367.71 ± 29.94	**<0.001**	282.37 ± 42.33	284.59 ± 42.80	0.338
Inf	346.16 ± 21.44	361.53 ± 25.03	**<0.001**	307.22 ± 48.58	309.76 ± 50.98	0.367
Temp	345.16 ± 23.20	375.18 ± 48.84	**<0.001**	296.59±39.58	300.39 ± 40.65	0.055
outer 3-6 mm circle						
Avg	321.09 ± 24.67	338.84 ± 29.38	**<0.001**	285.99 ± 40.36	286.87 ± 42.68	0.602
Sup	327.02 ± 29.68	344.98 ± 34.55	**<0.001**	312.69 ± 45.07	313.82 ± 46.88	0.705
Nasal	331.86 ± 23.50	346.33 ± 27.00	**<0.001**	241.35 ± 44.13	243.49 ± 45.47	0.255
Inf	306.24 ± 27.94	321.78 ± 30.47	**<0.001**	308.35 ± 52.77	308.45 ± 54.01	0.971
Temp	319.24 ± 30.04	342.27 ± 43.54	**<0.001**	281.57 ± 37.47	281.71 ± 40.49	0.949
Volume						
total	9.19 ± 0.63	9.72 ± 0.82	**<0.001**	8.12 ± 1.10	8.16 ± 1.17	0.353
center 1 mm circle	0.22 ± 0.02	0.24 ± 0.04	**<0.001**	0.23 ± 0.03	0.24 ± 0.03	0.182
inner 1-3 mm circle						
Average	2.19 ± 0.13	2.31 ± 0.20	**<0.001**	1.87 ± 0.25	1.89 ± 0.26	0.078
Sup	0.55 ± 0.04	0.58 ± 0.06	**<0.001**	0.48 ± 0.06	0.48 ± 0.07	0.098
Nasal	0.55 ± 0.04	0.58 ± 0.05	**<0.001**	0.44 ± 0.07	0.45 ± 0.07	0.429
Inf	0.54 ± 0.03	0.57 ± 0.04	**<0.001**	0.49 ± 0.08	0.49 ± 0.08	0.395
Temp	0.54 ± 0.04	0.59 ± 0.08	**<0.001**	0.47 ± 0.06	0.47 ± 0.06	0.079
outer 3-6 mm circle						
Avg	6.78 ± 0.51	7.16 ± 0.62	**<0.001**	6.02 ± 0.85	6.03 ± 0.90	0.674
Sup	1.72 ± 0.15	1.82 ± 0.18	**<0.001**	1.64 ± 0.23	1.64 ± 0.24	0.855
Nasal	1.76 ± 0.13	1.83 ± 0.14	**<0.001**	1.28 ± 0.24	1.29 ± 0.24	0.294
Inf	1.61 ± 0.15	1.69 ± 0.16	**<0.001**	1.61 ± 0.27	1.61 ± 0.28	0.922
Temp	1.69 ± 0.16	1.81 ± 0.23	**<0.001**	1.49 ± 0.20	1.49 ± 0.21	0.823

PRP: Panretinal Photocoagulation

Table 2: Changes in macular thickness and volume after panretinal photocoagulation.

	Total	Argon group	PASCAL group	*P* value
	N=49 eyes	N=26 eyes	N=23 eyes	
Before PRP				
Retinal thickness	279.84 ± 26.62	280.19 ± 26.86	279.43 ± 26.95	0.922
Choroidal thickness	298.43 ± 43.67	295.96 ± 29.89	301.22 ± 55.95	0.690
Total retinal volume	9.19 ± 0.63	9.20 ± 0.69	9.18 ± 0.56	0.906
Total choroidal volume	8.12 ± 1.10	8.17 ± 1.03	8.06 ± 1.20	0.726
After PRP				
Retinal thickness	308.06 ± 50.75	314.11 ± 63.33	301.22±31.13	0.594
Choroidal thickness	302.57 ± 43.11	300.31 ± 24.29	305.13 ± 58.08	0.714
Total retinal volume	9.72 ± 0.82	9.82 ± 1.00	9.61 ± 0.55	0.343
Total choroidal volume	8.16 ± 1.17	8.22 ± 1.08	8.08 ± 1.27	0.682
Change after PRP				
△Retinal thickness	28.22 ± 39.90	33.92 ± 50.45	21.78 ± 22.37	0.293
△Choroidal thickness	3.65 ± 18.05	4.35 ± 20.94	3.91 ± 15.25	0.935
△Total retinal volume	0.53 ± 0.39	0.62 ± 0.47	0.43 ± 0.24	0.071
△Total choroidal volume	0.04 ± 0.30	0.05 ± 0.27	0.03 ± 0.35	0.766

PRP: Panretinal Photocoagulation

Table 3: Subgroup comparison (argon laser vs. PASCAL laser) of topographic changes after panretinal photocoagulation.

or choroidal thickness in the macula. We attempted to examine each of the EDI-OCT scans to identify specific choroidal vessels that may have shown notable changes in diameter after PRP, but this was not uniformly true for all participants and no changes in either the thickness of the choriocapillary layer or the entire choroid were observed. In the peripheral PRP-treated region, morphological studies have reported that the choriocapillaris is obliterated suggesting that choroidal blood flow in the photocoagulated area decreases following PRP [20-22]. Thus, in this case, it is reasonable that the redistribution of choroidal blood flow might occur only in the photocoagulated peripheral retina 1 month after PRP.

Second, there is the possibility that, despite no change in choroidal thickness in the macula, choroidal blood flow in the macula increased. In the choroid, an increase in blood flow may not necessarily result in an increase in thickness, although Landa et al. [23] showed that retinal blood flow significantly correlated with retinal, but not choroidal, thickness. Additionally, there have been no reports investigating changes in thickness using choroidal thickness mapping in the macular region after PRP. Therefore, the lack of significant change observed in our study does not entirely exclude the possibility that PRP induces changes in choroidal blood flow in the macula; PRP may bring about a change in choroidal blood flow in the macular region in eyes with diabetic retinopathy to an extent that is not great enough to cause a noticeable change in choroidal thickness mapping measured by SD-OCT. Recently, there are two report investigating subfoveal choroidal thickness after PRP using EDI-OCT [24, 25]; they interpreted changes of subfoveal choroidal thickness as an increment[24] or decrement[25] in choroidal blood flow with relatively small number of patients . However, they measured choroidal thickness using a subfoveal "point-to-point" method; this method offers only limited information regarding the topographic characteristics of choroidal thickness or volume of the macula. Additionally, cautious interpretation and comparisons between the two studies (Cho et al. [24] and ours) is required because the former study measured choroidal thickness only after 1-week (not 1 month) and not only were patients with PDR but also those with severe non-proliferative diabetic retinopathy were enrolled in their study. In our study, which used SD-OCT, no changes in choroidal thickness were observed. Therefore, it is unlikely that changes in choroidal blood flow in response to PRP are sufficient to cause detectable thickness changes in the choroid of the macula region measured by SD-OCT.

Interestingly, Vance et al. [26] reported that sildenafil citrate increased choroidal thickness, as measured by EDI-OCT, in eight healthy subjects due to the vasodilatory effect of sildenafil citrate on choroidal circulation. Although they did not measure choroidal blood flow and only measured subfoveal choroidal thickness in healthy subjects, their results indicate that increased choroidal circulation may be associated with increased choroidal thickness. In contrast, in 19 chick eyes recovering from form deprivation myopia, Fitzgerald et al. [27] reported that increased choroidal blood flow preceded increases in choroidal thickness, which was measured by a scan ultrasonography. They also demonstrated that the increases in choroidal blood flow were transient during recovery. Their results suggest that changes in choroidal blood flow may not correlate with changes in choroidal thickness. Considering these findings, there may be a relationship between choroidal blood flow changes and choroidal thickness; however, in diabetic retinopathy, a correlation between changes in choroidal blood flow and choroidal thickness is still inconclusive. Therefore, further clinical studies are needed to fully elucidate this relationship.

Our results showed that changes in retinal thickness did not correlate with choroidal thickness. Consequently, the effect of PRP on the macular region may be different between the retina and choroid, suggesting that the retina is more vulnerable to PRP induced thickness increases than the choroid. Although differential effects of post-PRP release of inflammatory factors or angiogenic growth factors, such as vascular endothelial growth factor, on the retina or choroid may be an additional possible mechanism responsible for the discrepancy in changes in the retina and choroid, the exact mechanism remains unclear.

The present study revealed that both the argon laser group and the PASCAL group showed similar results: neither the baseline SD-OCT parameters nor changes after PRP were significantly different. In both groups, retinal thickness increased and choroidal thickness did not change. Therefore, it is possible that there were no differences in the effects on the macula between argon laser and PASCAL. However, changes in macular thickness or volume in the argon group were higher than in the PASCAL group, even though these differences were not statistically significant. Thus, alternatively, it may be that these differences were not statistically significant only because of the small sample size or an unknown bias associated with the retrospective study design. Additionally, to date, there have been no reports supporting our findings or comparing retinal or choroidal thickness changes using two different laser settings. On the basis of these factors, it is difficult to draw definitive conclusions.

Recently, Shin et al. [19] introduced innovative methods that provide a topographic map of choroidal thickness and volume using a commercial SD-OCT (3D OCT-2000, Topcon, Tokyo, Japan) device with a six point radial scan protocol. In the current study, we used a different OCT device, namely Spectralis OCT, and it requires more time to perform manual segmentation because it has more scan lines (6 versus 25). However, manual segmentation for each set of the 25 volume scans enabled us to generate a reliable topographic map of choroidal thickness. In addition, we could obtain choroidal volume measurements with the ETDRS layout, including total macular choroidal volume. For investigating the effects of PRP on the choroid, which supports blood flow volume approximately 40 times greater than the retinal vasculature and is the sole source of metabolic exchange for the avascular retinal fovea, evaluating total macular choroidal volume might reflect

choroidal vascular changes more accurately than only evaluating the fovea [28,29]. More recently, other investigators have studied choroidal thickness in various chorioretinal diseases by using swept-source OCT at a longer wavelength, which allows long-penetration imaging with high acquisition speed and contrast [30-34]. Currently, evaluation of the choroid using choroidal mapping protocols with OCT may help us elucidate the pathophysiology of diabetic choroidopathy and investigate the therapeutic effects on the choroid following PRP.

Our study has several limitations, which are mainly due to its retrospective nature. First, because the number of study patients was small, this study had limited statistical power to confirm the lack of effect of PRP on choroidal thickness or volume. Additionally, we could not definitely determine if choroidal thickness is associated with the development of macular edema induced by PRP for the same reason. Another large-scale study is needed to confirm our findings. Second, we only investigated the effects of PRP for the relatively short-term period of 1 month, which precludes estimation of long-term effects. The potentially controversial time effect issue is therefore valid. The time interval between the last PRP and the date in which macular topography is measured using SD-OCT appears to be a very important factor, as the effect of PRP on macular topography can weaken with time. For this study, we wanted to evaluate only the short-term (1 month) effects of PRP to minimize bias originating from other confounding factors, such as variations in blood glucose level and changes in systemic medication during following PRP. Finally, our results comparing different laser types should be interpreted with caution due to the retrospective nature of the study as well as the small sample size. Even in the same laser group, time to complete PRP and PRP parameters varied slightly on a case by case basis, although SD-OCT measurement were performed exactly 1 month after completing PRP in all patients.

In summary, in the macular region, retinal thickness increased and choroidal thickness did not change 1 month after PRP. This result is consistent with previous studies that report increased macular retinal thickness after PRP in eyes with severe diabetic retinopathy, and this increase likely has little correlation with changes in macular choroidal thickness [14,17,29]. Our results indicate that PRP may have little or no effect on changes in macular choroidal thickness or volume in patients with severe diabetic retinopathy, although whether PRP causes a significant change in choroidal blood flow in the macular region remains unclear. Further prospective, well-designed clinical studies with large sample sizes are needed to elucidate the effects of PRP on choroidal topographic changes in the macular region and confirm our findings that PRP had no effect on choroidal thickness in patients with diabetic retinopathy. Further studies are also needed to examine whether these topographic choroidal changes on OCT are correlated with changes in choroidal blood flow in patients with diabetic retinopathy.

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