Effects of a Lutein Supplement on the Plasma Lutein Concentration and Macular Pigment in Patients With Central Serous Chorioretinopathy

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Purpose. To investigate the effects of lutein supplementation on plasma lutein concentrations and the macular pigment optical density (MPOD) in central serous chorioretinopathy (CSC).

Methods. In this double-masked placebo-controlled study, 20 patients received lutein 20 mg/d and 19 received placebo. The plasma lutein concentration and MPOD using autofluorescence spectrometry (density unit, DU) were measured at baseline and 1 and 4 months.

Results. The mean plasma lutein concentrations and MPOD values in the lutein and control groups, respectively, were 91.5 and 78.2 ng/mL and 0.444 and 0.437 DU at baseline; 204.9 and 79.3 ng/mL and 0.460 and 0.442 DU at 1 month; and 228.0 and 78.4 ng/mL and 0.441 and 0.421 DU at 4 months. The plasma concentration in the lutein group was significantly higher than in controls at 1 and 4 months ($P < 0.0001$ for both comparisons); however, the MPOD values did not differ significantly between groups at 1 ($P = 0.479$) or 4 months ($P = 0.883$). In patients with a plasma lutein concentration below the mean level in 20 age-matched healthy subjects (mean 105.3 ng/mL; $n = 13$ in lutein group, $n = 15$ in control group), the control MPOD values significantly ($P = 0.0430$) decreased at 4 months (mean baseline, 0.437 DU; 4 months, 0.404 DU). The MPOD in the lutein group remained at the baseline level (mean baseline, 0.426 DU; 4 months, 0.438 DU) ($P = 0.6542$).

Conclusions. The MPOD did not increase in patients with CSC with short-term lutein supplementation; however, among patients with low plasma lutein, supplemental lutein prevented a decline in MPOD that was observed in control subjects (www.umin.ac.jp/ctr number, UMIN000005849).

Keywords: lutein supplement, macular pigment, central serous chorioretinopathy, plasma lutein, autofluorescence

Carotenoid can scavenge oxygen radicals and quench singlet oxygen and may have beneficial effects on human health.[1–5] Three carotenoids (i.e., lutein, zeathanthin, and meso-zeaxanthin) comprise the macular pigment, which is distributed in Henle's fiber layer and the inner retinal layer, and the signal peak of the macular pigment is seen at the fovea in normal eyes.[6] Macular pigment absorbs blue light and protects the photoreceptors from photochemical damage and is essential for retinal health.[7]

Decreased macular pigment has been reported previously in macular diseases, including age-related maculopathy, AMD, and central serous chorioretinopathy (CSC).[8–11] Central serous chorioretinopathy is characterized by a focal serous retinal detachment in the macular area and is often seen in 20- to 50-year-old healthy men. The pathogenesis of CSC remains unknown; however, the etiology includes steroid use and type A behavior.[12] Sasamoto et al.[10] reported reductions in the macular pigment optical density (MPOD) in eyes with CSC. Interestingly, a slight reduction in MPOD also was seen in the fellow eyes of those with CSC. The reason for bilateral MPOD reductions in patients with CSC is unknown.

Supplemental lutein has been given to subjects with diseases in which a lack of macular pigment is thought to be etiologically important, including early and late AMD, and supplementation has resulted in increased MPOD and serum lutein concentrations.[13–19] However, lutein supplementation in patients with CSC has never been evaluated.

We conducted a prospective, placebo-controlled study to investigate the effects of 4 months of lutein supplementation in patients with CSC on MPOD and on the plasma lutein concentration.

Subjects and Methods

Forty-four patients (39 men, 5 women) (mean age, 49 ± 10 years; range, 35–65 years) diagnosed with CSC who visited Osaka University Medical Hospital from March 2011 to June 2012 were prospectively enrolled. All patients provided informed consent. The study adhered to the tenets of the Declaration of Helsinki. The local ethics committee of the Osaka University Medical Hospital approved this study (no. UMIN000005849).

The exclusion criteria were previous regular intake of lutein and/or zeaxanthin, corticosteroid treatment, and sufficient disturbance of the ocular media to render valid measurement of the ocular media impossible. Eyes with other retinal

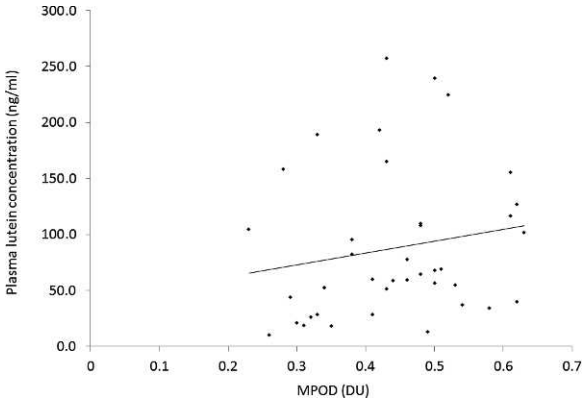

FIGURE 1. Scatterplot of plasma lutein concentrations and macular pigment optical density values in 39 patients with CSC.

disorders, such as AMD, polypoidal choroidal vasculopathy, retinal vein occlusion, or diabetic retinopathy, were excluded.

All patients underwent complete ophthalmic examinations, including measurement of the best-corrected visual acuity (BCVA) using a Landolt C chart, color fundus photography, fundus autofluorescence (FAF), fluorescein angiography (FA), indocyanine green angiography (ICGA) (Topcon TRC50LX, Tokyo, Japan), optical coherence tomography (OCT) imaging (Spectralis Heidelberg Retina Angiograph [HRA]+OCT; Heidelberg Engineering, Heidelberg, Germany; Cirrus OCT; Zeiss, Dublin, CA, USA; DRI-OCT; Topcon, Tokyo, Japan), and measurement of the macular pigment. Fundus autofluorescence measurements were performed with HRA2 using an excitation light with a wavelength of 488 nm and an emission band-pass filter starting at 500 nm. The macular pigment was measured using a modified confocal HRA classic instrument as described below.

Study Design

The study was a randomized, double-masked, placebo-controlled trial in patients with CSC. Lutein (Sante Lutax 20; Santen, Osaka, Japan) and placebo were randomized 1:1. The dosage was one tablet (lutein 20 mg or placebo) once daily for 4 months.

At baseline and 1 and 4 months, the BCVA and MPOD were measured, OCT was performed, and serum samples were obtained. All subjects were questioned about regular intake of lutein or placebo and other medications at all visits.

To study the plasma lutein concentration in healthy subjects without retinal and macular diseases or cataract, 20 healthy age-matched volunteers were recruited (14 men, 6 women; mean age, 49.0 ± 9.7 years; range, 30–68 years; 30–39 years, 5 subjects; 40–49 years, 5 subjects; 50–59 years, 7 subjects; and 60 years and older, 3 subjects) whose BCVA exceeded 0.9 at study enrollment.

MPOD Measurement

Before measurement of the macular pigment, the pupils were dilated with 0.5% tropicamide and 2.5% phenylephrine eye drops, and MPOD was determined by autofluorescence spectrometry with two wavelengths (488- and 514-nm excitation wavelengths and a band-pass filter at the 530-nm wavelength) as described previously.[20,21] The system software creates an averaged autofluorescence image from two videos consisting of 16 images. Macular pigment absorption is higher in the 488-nm wavelength than in the 514-nm wavelength; thus, subtraction of the autofluorescence signals between these two images provides the MPOD map in the central retina. Data were excluded if there was a decrease in the number of effective pixels (<150/225 pixels) due to poor fixation, as reported previously.[10] The density was expressed in optical density units (DU). We used the mean optical density as the MPOD within a 1-degree diameter circle centered on the fovea.

Measurement of Plasma Lutein Concentration

The plasma lutein concentration was measured using an (LC-2010C; Shimadzu Corp., Kyoto, Japan). Plasma samples were extracted with a mixture of methyl tertiary butyl ether (4:1) and centrifuged at 1800*g* for 10 minutes at 4°C. After evaporation of the organic layer under a nitrogen gas stream, the residue was dissolved in a 0.2-mL mobile phase solution for HPLC injection. The column was an Inertsil ODS-3 (5-μm particle size, 4.6-mm inside diameter × 250 mm; GL Science, Tokyo, Japan). The column temperature was 40°C. A mobile phase containing acetonitrile, 0.1 M ammonium acetate and methanol, and dichloromethane (71:22:7, vol/vol/vol) was used. The flow rate was 1.0 mL/min. The 450-nm wavelength was used.

Data Analysis

To study the effect of lutein supplementation on the MPOD and plasma lutein concentration in patients with CSC, we compared the lutein group and placebo-controlled group. Statistical analysis was performed using JMP version 9 software (SAS Institute, Cary, NC, USA). *P* less than 0.05 was considered significant.

RESULTS

Among 44 patients with CSC, five patients were excluded from the final analysis: two patients had not been examined periodically, one patient stopped taking the supplement due to a persistent stomachache, one patient had a blood sampling error, and one patient had an unexpectedly higher value (558.4 ng/mL) than the other subjects. The data from 39 patients were analyzed: 20 patients in the lutein group (19 men, 1 woman; mean age, 51.2 ± 9.0 years) and 19 patients in the placebo-controlled group (16 men, 3 women; mean age, 46.6 ± 8.3 years). During the study, 23 eyes with CSC were observed, 5 eyes underwent laser photocoagulation (laser irradiation parameters: 100 μm, 100 mw, 0.1–0.2 seconds), and 11 eyes underwent photodynamic therapy (PDT) (when leakage close to the fovea, reduced-fluence PDT was selected). Subretinal fluid was present at baseline in all study eyes and resolved in 18 (46%) eyes at 1 month and 25 (64%) eyes at 4 months.

Background of Patients With CSC and Comparison With Healthy Volunteers

At baseline, the mean plasma lutein concentration of all patients with CSC was 85.0 ± 66.6 ng/mL (range, 10.5–257.5 ng/mL; 95% confidence interval [CI] 63.4–106.6 ng/mL), the mean MPOD was 0.441 ± 0.104 DU (range, 0.23–0.63 DU; 95% CI 0.407–0.478 DU), and the mean decimal BCVA was 1.0 (range, 0.2–1.5). There was no significant ($P = 0.5119$) correlation between the MPOD and plasma lutein concentration at baseline (Fig. 1).

When classified by the time after the onset of visual symptoms or the time after diagnosis, acute CSC (less than 6 months after onset) was diagnosed in 16 eyes and chronic CSC (more than 6 months after onset) in 23 eyes. The mean plasma lutein concentrations were 94.6 ± 74.6 ng/mL (range, 18.2–

Table 1. Patient Background

	Lutein Group	Placebo	*P* Value
Patient	20	19	
Men/women	19/1	16/3	0.342
Age, y (range)	51.2 ± 9.0 (35–69)	46.6 ± 8.3 (35–65)	0.108
Eyes, right/left	6/14	9/10	0.333
BCVA	0.98 ± 0.35 (0.2–1.5)	1.04 ± 0.34 (0.4–1.5)	0.549
MPOD, DU	0.444 ± 0.118 (0.26–0.62)	0.437 ± 0.101 (0.23–0.63)	0.863
Plasma lutein concentration, ng/mL	91.5 ± 74.2 (10.5–257.5)	78.2 ± 58.9 (12.8–224.6)	0.540
Central macular thickness	367.2 ± 95.0 (247–569)	370.7 ± 108.7 (236–560)	0.915

257.5 ng/mL; 95% CI 54.9–134.4 ng/mL) in acute CSC and 78.3 ± 61.4 ng/mL (range, 10.5–239.9 ng/mL; 95% CI 51.8–104.9 ng/mL); the difference between the two was not significant ($P = 0.4603$). The mean MPOD was 0.433 ± 0.085 DU (range, 0.31–0.63 DU; 95% CI 0.388–0.478 DU) in acute CSC and 0.446 ± 0.125 DU (range, 0.23–0.62 DU; 95% CI 0.392–0.500 DU) in chronic CSC; the difference between the two was not significant ($P = 0.7289$).

In 20 healthy volunteers, the plasma lutein concentration was 105.3 ± 45.1 ng/mL (range, 57.5–218 ng/mL; 95% CI 84.2–126.4 ng/mL), which was significantly higher ($P = 0.0056$, Welch's *t*-test) than in the patients with CSC. In addition, 13 (33%) patients with CSC had a level below 50 ng/mL, which is the minimal plasma lutein concentration in healthy subjects.

Comparison of Plasma Lutein Concentration and MPOD Between Lutein and Placebo-Controlled Groups After Lutein Intake in Patients With CSC

At baseline, the plasma lutein concentration was 91.5 ± 74.2 ng/mL in the lutein group and 78.2 ± 58.9 ng/mL in the placebo-controlled group. The MPOD was 0.444 ± 0.118 DU in the lutein group and 0.437 ± 0.101 DU in the placebo-controlled group. The patient characteristics are shown in Table 1.

In the lutein group, the plasma lutein concentration significantly increased to 204.9 ± 98.5 ng/mL at 1 month ($P < 0.001$, paired *t*-test) and 228.0 ± 161.2 ng/mL at 4 months ($P = 0.001$, paired *t*-test) from baseline values (Table 2; Fig. 2). In the placebo-controlled group, the plasma lutein concentration was 79.3 ± 58.5 ng/mL at 1 month and 78.4 ± 67.3 ng/mL at 4 months, which were not significantly ($P = 0.942$ and 0.984, respectively, paired *t*-test) different from baseline.

Comparison between the lutein group and placebo-controlled group revealed significant ($P < 0.001$, ANOVA) differences in terms of plasma lutein concentrations at 1 and 4 months.

The MPOD values in the lutein group were 0.460 ± 0.106 DU at 1 month and 0.441 ± 0.124 DU at 4 months, and in the placebo-controlled group were 0.442 ± 0.096 DU at 1 month and 0.421 ± 0.127 DU at 4 months (Table 2; Fig. 3). In the lutein group, there was no significant ($P = 0.479$ and $P = 0.883$, respectively, paired *t*-test) increase in MPOD from baseline at 1 and 4 months. A comparison of the lutein and placebo-controlled groups showed no significant ($P = 0.667$ and $P = 0.617$, respectively, ANOVA) differences in terms of MPOD at months 1 and 4.

The subretinal fluid resolved in 12 eyes in the lutein group at 1 and 4 months. The mean MPOD values of these 12 eyes were 0.411 ± 0.112 DU (range, 0.26–0.62 DU; 95% CI 0.340–0.482 DU) at baseline, 0.440 ± 0.098 DU (range, 0.28–0.58 DU; 95% CI 0.378–0.502 DU) at 1 month, and 0.423 ± 0.120 DU (range, 0.21–0.57 DU; 95% CI 0.350–0.503 DU) at 4 months. In this subgroup, there was no significant ($P = 0.5776$, paired *t*-test) difference in the MPOD between 1 and 4 months.

Comparison of Plasma Lutein Concentration and MPOD in Low Plasma Lutein in Patients With CSC

Based on the mean plasma lutein concentration level (105.3 ng/mL) in healthy subjects, the patients with CSC with a mean plasma lutein level lower than normal were recruited for subanalysis. Twenty-eight (72%) patients were included (13 in the lutein group and 15 in the placebo-controlled group). In the lutein group, the mean plasma lutein concentration was 46.3 ± 26.9 ng/mL at baseline, 169.7 ± 92.1 ng/mL at 1 month, and 190.8 ± 104.1 ng/mL at 4 months (Table 3; Fig. 4). There were significant ($P < 0.0001$ for both comparisons, paired *t*-test) increases at 1 and 4 months in the lutein group from baseline. In the placebo-controlled group (Table 3), there were no significant differences ($P = 0.9442$ and $P = 0.6897$, respectively, paired *t*-test) in the plasma lutein concentrations at 1 and 4 months. The mean MPOD in the lutein group (baseline, 0.426 DU) increased slightly at 1 (0.454 DU) and 4 months (0.438 DU); however, no significant differences were seen at 1 and 4 months ($P = 0.8684$ and $P = 0.6542$, respectively, paired *t*-test). In the placebo-controlled group, the mean MPOD values were 0.437 DU at baseline, 0.431 DU at 1 month, and 0.404 at 4 months (Table 3; Fig. 5). The decrease at 4 months in the placebo group was significant ($P = 0.0430$).

Discussion

Patients with CSC had a lower plasma lutein concentration compared with healthy subjects in the current study. In this placebo-controlled lutein supplement study, the mean plasma lutein concentration increased significantly by 2-fold 1 month after lutein intake; unfortunately, no increase in the MPOD occurred in the lutein group. Interestingly, in the subanalysis among patients with low plasma lutein levels, the MPOD value in the placebo-controlled group significantly decreased from baseline at 4 months. However, the MPOD value in the lutein group slightly increased at 1 and 4 months from baseline but did not reach significance. Based on the subgroup analysis, in patients with CSC with a low plasma lutein concentration, lutein supplementation contributed to maintenance of MPOD that was not seen in patients with CSC receiving placebo.

The lower plasma lutein concentration in early AMD was caused by low dietary intake of carotenoids in the Age-Related Eye Disease Study and the Carotenoids in Age-Related Eye Disease Study.[22,23] In patients with CSC, the plasma lutein concentration level is unknown because no previous research has been conducted in this regard. Obana et al.[9] reported that the plasma lutein concentration in 100 healthy subjects in Japan was a mean of 257 ng/mL. In the current study, the mean plasma lutein concentration in healthy volunteers was 105 ng/mL, which was less than half of that reported by Obana et al.[9]

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TABLE 2. Plasma Lutein Concentrations and MPOD Values in Patients With CSC

	Lutein Group ($n = 20$)				Placebo Group ($n = 19$)			
	Plasma Lutein Concentration		MPOD		Plasma Lutein Concentration		MPOD	
	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI
Baseline	91.5 ± 74.2 (10.5–257.5)	56.8–126.2	0.444 ± 0.118 (0.26–0.62)	0.388–0.499	78.2 ± 58.9 (12.8–224.6)	49.8–106.6	0.437 ± 0.101 (0.23–0.63)	0.391–0.491
1 mo	204.9 ± 98.5 (43.2–373.9)	158.8–251.0	0.460 ± 0.106 (0.26–0.60)	0.410–0.509	79.3 ± 58.5 (8.6–226.9)	51.1–107.5	0.442 ± 0.096 (0.24–0.60)	0.396–0.489
4 mo	228.0 ± 161.2 (48.6–798.4)	152.5–303.5	0.441 ± 0.124 (0.20–0.60)	0.383–0.498	78.4 ± 67.3 (6.5–231.2)	46.0–110.9	0.421 ± 0.127 (0.24–0.66)	0.359–0.482

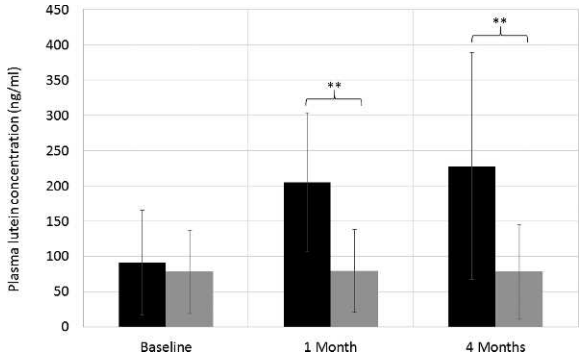

FIGURE 2. The bar graph shows the mean plasma lutein concentrations in the lutein group and placebo-controlled group. One month and 4 months after lutein supplementation, the plasma lutein concentration is significantly (**) higher in the lutein group (*black bars*) than in the placebo-controlled group (*gray bars*).

in a large number of volunteers. In the small number of subjects between healthy and CSC in the current study, the lower plasma lutein concentration in patients with CSC compared with healthy subjects was a valuable result, which may support the view that a relative lack of circulating lutein represents a risk for development of CSC.

In one study of patients with CSC, serum analysis showed significantly lower dehydroepiandrosterone sulfate and antioxidant capacity in those patients.[24] However, the carotenoid level in patients with CSC has not been investigated previously. Intestinal absorption and accumulation of carotenoids differ greatly among individuals.[25] The normal level or range of serum carotenoids in healthy people is unknown. Based on the low plasma lutein concentration in patients with CSC compared with healthy subjects, a possible explanation is that decreased lower antioxidant capacity may waste circulating carotenoids based on a previous blood study in patients with CSC.[24] Psychological stress also might inhibit intestinal lutein absorption. An unbalanced diet due to overwork might result in reduced vegetable intake in patients with CSC. However, these are speculations, because no previous studies of these factors have been conducted. Further serum monitoring is needed to investigate circulating carotenoid in patients with CSC.

The goal of the current study was to increase MPOD in patients with CSC prompted by a previous study that reported low MPOD values in this patient population (mean MPOD, 0.548 DU in 94 healthy controls; 0.542 DU in 74 patients with acute CSC; and 0.386 DU in 123 patients with chronic CSC).[10]

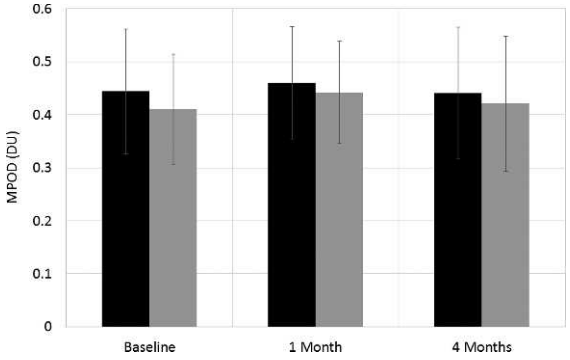

FIGURE 3. The bar graph shows the mean macular pigment optical density in the lutein group (*black bars*) and placebo-controlled group (*gray bars*). There are no significant differences between the groups at 1 and 4 months.

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Table 3. Subanalysis of Plasma Lutein Concentration Lower Than Mean Plasma Lutein Concentration in Healthy Volunteers

	Lutein Group ($n = 13$)				Placebo Group ($n = 15$)			
	Plasma Lutein Concentration		MPOD		Plasma Lutein Concentration		MPOD	
	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI
Baseline	46.3 ± 26.9 (10.5–95.4)	30.0–62.5	0.426 ± 0.121 (0.26–0.62)	0.353–0.499	53.1 ± 27.5 (12.8–104.9)	37.8–68.3	0.437 ± 0.108 (0.23–0.63)	0.377–0.497
1 mo	169.7 ± 92.1 (43.2–373.9)	114.0–225.4	0.454 ± 0.106 (0.28–0.62)	0.390–0.518	75.1 ± 51.4 (8.6–212.2)	46.6–103.5	0.431 ± 0.107 (0.24–0.60)	0.371–0.490
4 mo	190.8 ± 104.1 (48.6–365.4)	127.9–253.7	0.438 ± 0.123 (0.21–0.58)	0.364–0.513	59.7 ± 50.0 (6.5–171.3)	32.0–87.4	0.404 ± 0.109 (0.24–0.60)	0.344–0.464

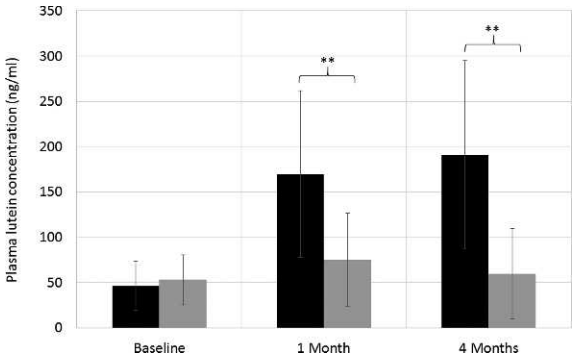

Figure 4. The bar graph shows the mean plasma lutein concentrations in the lutein group (*black bars*) and placebo-controlled group (*gray bars*) in a subanalysis of plasma lutein concentrations that are lower than the mean plasma lutein level in healthy subjects. One and 4 months after lutein supplementation, the plasma lutein concentrations are significantly (**) higher in the lutein group than in the placebo-controlled group. In the lutein group, the plasma lutein concentration increased 3-fold at 1 month and 4-fold at 4 months from baseline.

Unfortunately, 4-month supplementation with 20 mg lutein in the current study failed to increase MPOD (0.444 DU at baseline, 0.460 DU at 1 month, and 0.441 DU at 4 months) despite previous lutein supplementation studies that reported dose-dependent increases in the plasma lutein concentration and macular pigment in healthy subjects and those with AMD.[13,14,26,27] In the current study, a two-fold increase in the plasma lutein concentration reached a plateau at 1 month similar to previous reports[14,18]; however, no significant MPOD increase occurred. The most plausible reason is that subretinal fluid impairs capture, accumulation, and/or stabilization of the macular carotenoids within the retina. However, MPOD did not increase in 12 eyes in the lutein group without subretinal fluid at 1 and 4 months. Based on the small number of patients with CSC with no subretinal fluid during the study period (1 through 4 months), 3 months of lutein supplementation in eyes with CSC after resolution of subretinal fluid may be inadequate to increase the MPOD or the subretinal fluid might disrupt the lutein binding protein in the cone inner segments and axons.[28,29] To increase MPOD in eyes with CSC and prevent subretinal fluid interference, lutein intake after

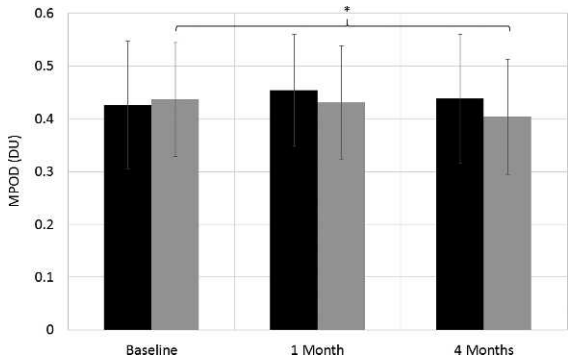

Figure 5. The bar graph shows the mean macular pigment optical density (MPOD) in the lutein group (*black bars*) and placebo-controlled group (*gray bars*) in a subanalysis of plasma lutein concentrations that are lower than the mean plasma lutein level in healthy subjects. There are no significant differences in the MPOD values between the lutein and placebo-controlled groups at 1 and 4 months. The MPOD is maintained at the baseline level in the lutein group. The MPOD value significantly (*) decreased 4 months from baseline in the placebo-controlled group.

resolution of subretinal fluid and/or longer intake time might be required. Also, it is possible the addition of meso-zeaxanthin to the formulation might enhance response, as appears to the case in eyes with early AMD.[30]

The MPOD subanalysis results in patients with lower plasma lutein levels than the mean plasma lutein level in healthy volunteers is interesting. The MPOD value in the placebo group significantly decreased 4 months after baseline. However, the MPOD value in the lutein group increased slightly from baseline. In patients with CSC with low plasma lutein levels, lutein supplementation might be an essential adjunct therapy. Obtaining serum samples is necessary to identify patients with low plasma lutein levels. It would be ideal to estimate the individual plasma lutein levels from an MPOD evaluation to identify these patients. Unfortunately, there was no correlation between the MPOD and plasma lutein concentration in the current study. Approximately 70% of patients had a lower plasma lutein concentration compared with the mean level of healthy subjects; 13 (33%) patients had less than half of the mean lutein concentration of healthy subjects in the current study. Based on these results, lutein supplementation for patients with CSC should be encouraged to maintain the MPOD level despite the absence of information about the plasma lutein level.

The current study had several limitations. We did not evaluate the subretinal fluid volume, which may affect lutein transport from the choroid to the retina. We did not classify acute and chronic CSC in the final analysis due to the limited number of subjects (i.e., in eyes with chronic CSC, the efficacy of lutein supplementation might be weaker than in those with acute CSC or healthy subjects). We did not consider treatment during the study. Photodynamic therapy affects the choroidal circulation, which reduces lutein uptake from the choroid to the retina. Lutein supplementation in the current study was limited to 4 months, and longer supplementation might be important for increasing MPOD in patients with CSC. Finally, only lutein was studied. Vitamins C and E and zinc together with lutein might accelerate retinal lutein uptake in patients with CSC. Further study is needed to investigate the efficacy of other supplement formulas.

In conclusion, lutein deficiency might not be recognized in patients with CSC. Lutein supplementation maintained the MPOD in patients with CSC with low plasma lutein levels. Further investigation is needed, and formulations containing all three macular carotenoids should be studied for response.

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