Retinal Vessel Density and Foveal Avascular Zone Analysis in Patients with Psoriasis: An Optical Coherence Tomography Angiography Study

Muhammed Altinisik[1], Faruk Bicak[1], Emine Mutlu[2], Emin Kurt[3], Huseyin Mayali[4], Aylin Türel Ermertcan[5]

ABSTRACT

Purpose: To investigate optical coherence tomography angiography (OCTA) findings in patients with psoriasis.

Materials and Methods: The study included 31 treatment-naive psoriasis patients without ocular involvement and 29 age- and sex- matched controls. Psoriasis was classified using the psoriasis area and severity index (PASI) score. Superficial and deep vascular densities (SVD, DVD), foveal avascular zone (FAZ) area, perimetry, foveal density (FD) 300µm around the FAZ, central macular thickness (CMT) and subfoveal choroidal thickness (SFCT) were measured with the Optovue OCTA device. The groups were compared statistically.

Results: There was no difference between groups regarding age and gender (p:0,6 ve 0,2 respectively). Of the cases with psoriasis, 16% had arthritis and 45% had nail involvement. Median (min-max) disease duration was 10 years (1-48 years) and PASI score was 10 (2,20-42). The mean SVD and DVD were comparable between the groups (p:0,73 and 0,97 respectively). There was no significant difference in mean FAZ area, perimetry and FD between the patients and the controls. There was no correlation between the OCTA metrics and the severity, duration, nail and joint involvement of the disease (p>0,05 for all values). Additionally there was no significant difference between mild and severe psoriasis cases (p>0.05).

Conclusion: OCTA is a promising technique for imaging the retinal microvascular system in psoriasis cases. However, it seems to have a limited role in detecting early subclinical changes in cases without ocular involvement.

Key words: Foveal avascular zone, optical coherence tomography angiography, PASI score, psoriasis, vascular density.

INTRODUCTION

Systemic inflammatory diseases are chronic conditions which progress with sysemic inflammatory diseases, remissions and acute exaceerbations and cause systemic comorbidities. Despite advanced diagnostic tools, it is still challenging to predict acute eexacerbations and systemic comorbidities which may lead permanent complications. In this context, there are ongoing studies to identify subclinical findings with predictive value[1].

Psoriasis is a Th1-mediated chronic inflammatory disease with a prevalence of 2-3% world wide, which primarily cutaneous tissue. The etiology hasn't been elucidated[2]. It accompanies to several comorbidities such as psoriatic arthritis, metabolic syndrome, diabetes mellitus (DM), hypertension, atherosclerosis and dyslipidemia[3].

Psoriasis leads ocular complications such as xerophthalmia, conjunctivitis, episcleritis, cataract and uveitis[4]. Although anterior segment complications are well-known, there is limited data about posterior segment change. In this regard, clinical presentations such as optic neuritis, vasculitis, cystoid macular edema, retinal vein occlusion and birdshot chorioretinopathy as well as subclinical alterations such as impaired visual field or electrophysiological testing have been reported[5-9].

The early diagnosis and management of organ involvements acute exacerbations is one of the factors in multi-systemic chronic diseases. Such involvements not always follow a certain order. Although psoriasis starts with primary skin involvement; followed by articular involvement and uveitis, uveitis may precede arthritis or skin involvement

1- MD, Manisa Celal Bayar University, Ophthalmology, Manisa, Turkey
2- MD, Manisa Celal Bayar University, Dermatology, Manisa, Turkey
3- Prof. MD, Manisa Celal Bayar University, Ophthalmology, Manisa, Turkey
4- Assist. Prof. MD, Manisa Celal Bayar University, Ophthalmology, Manisa, Turkey
5- Assoc. Prof. MD, Manisa Celal Bayar University, Dermatology, Manisa, Turkey

Received: 13.12.2020
Accepted: 21.01.2021
Ret-Vit 2021; 30:257-264
DOİ: 10.37845/ret.vit.2021.30.45

Correspondence Adress:
Muhammed Altinisik
Manisa Celal Bayar University, Ophthalmology, Manisa, Turkey
Phone: +90 554 524 9070
E-mail: dr.maltinisik@gmail.com

in 10% of the cases[4]. Thus, psoriasis cases are screened for risk factors and clinical symptoms periodically. The screening algorithm have been evolved towards detection of subclinical findings using non-invasive methods in vivo. For this purpose, several tools from simple methods such as questionnaire to advanced imaging modalities such as spectral domain optical coherence tomography (SD-OCT[10, 11].

The SD-OCT is a non-invasive optical imaging modality that allows us to obtain high-resolution in vivo retinal and choroidal images[11]. It was used to detect subclinical ocular changes in psoriasis cases and subfoveal choroidal thickness (SFCT) was analyzed using enhanced depth imaging (EDI) module[6, 11-13]. In these studies, it was shown that subclinical structural changes were shown in psoriasis cases without ocular symptoms by SD-OCT; in a current study, authors pointed out optical coherence tomography angiography (OCTA) for assessment of retinal vascular system[7].

The OCTA is a novel technology that allows rapid, 3-dimensional and high--resolution imaging of retinal vascular system by discriminating mobile erythrocyte from stable tissues without need for contrast material injection. It provides quantitative data about superficial and deep capillary plexus (SCP and DCP), vascular density (VD) and foveal avascular phase (FAZ) in the retina[14]. Currently, predictive and diagnostic value of OCTA parameters are being investigated in systemic inflammatory diseases[15-17]. The dermatologists are familiar to SD-OCT and OCTA as they use these modalities in imaging and follow-up of skin lesions[18, 19].

In this study, we aimed to investigate structural and vascular effects of systemic inflammation on retina and choroid in plaque psoriasis without ocular involvement and to determine their relationship with age, gender, disease duration, severity and localization.

MATERIAL AND METHOD

This cross-sectional case-control study was approved by Institutional Ethics Committee. The study was conducted in accordance to tenets of Helsinki Declaration. All patients gave informed consent.

The study included patients with plaque psoriasis (aged ≥18 years) who were followed in the dermatology clinic and referred to us for routine ophthalmological examination with OCTA scan between August, 2018 and August, 2019. In addition, age- and sex-matched healthy individuals were employed as controls..

The study included patients 1) who did not receive any systemic or ocular treatment within prior 6 months; 2) who had spherical equivalent (spherical value±1 cylindrical value) <±3 diopter; 3) who had best-corrected value (BCVA) of 20/20 as measured by Snellen chart; 4) who had IOP>21 mmHg as measured by pneumotonometer; 5) who had body mass index within normal range (18-25 kg/m^2).

The patients with other systemic diseases (autoimmune diseases, DM, renal disease, hypertension, cardiovascular disease etc.), smokers, those with history of previous ocular surgery or trauma; those with any ocular pathology (conjunctivitis, cataract, glaucoma, uveitis, retinal pathology etc.) and those with signal quality<7/10 or images with artifact were excluded.

Study Protocol

The diagnosis of psoriasis was made based on histopathological and clinical findings. In all patients, demographic and clinical data including gender, age, disease duration, disease severity, nail and joint involvement were recorded.

The disease severity was measured using Psoriasis Area and Severity Index (PASI). The psoriasis cases were stratified into two groups according to PASI scores: mild (PASI score≤10) and severe (PASI score>10).

In all cases, thorough ophthalmological examination was performed, including BCVA measurement, anterior and posterior segment examination by biomicroscopy and IOP measurement by pneumotonometer. The cases with BCVA of 20/20 and IOP<21 mmHg and no pathological finding in anterior and posterior segment were included to the study.

Macular images were obtained at same times of day (09:00-12:00) by same researcher without pupil dilation using SD-OCTA device (RTVue XR Avanti AngioVue, Optovue Inc, California, USA). Superficial (SVD) and deep vascular density (DVD), FAZ area, PAZ perimeter, foveal density (FD), SFCT and central macular thickness (CMT) from right eye were included to the analyses. .

Technical procedures

RTVue XR Avant is a SD-OCT-based imaging modality that can performed 70.000 A scan per second at 840 nm wavelength using bandwidth of 45 nm. It uses split spectrum amplitude decorrelation angiography (SSADA) technique to improve signal: noise ratio and to obtain en-face images of retinal vascular system by detecting decorrelation in B-scan images.

Fovea-centered scan protocol were used in all OCTA acquisitions. Three-dimensional images were obtained from two consecutive B scans at same section using 304x304 A scan protocol. Retinal layers were segmented using AngioVue software of device in automated manner. Manuel correction was performed when needed. The slab localized at 9 µm superior to inner limiting membrane and inner plexiform layer was identified as SCP while the slab localized at 9 µm superior to inner plexiform and 9 µm inferior to outer plexiform layer was identified as DCP. In both plexuses, VD (%) values were calculated by device in an automated manner. After reformating images according to contrast (tresholding), VD (%) is defined as the ratio of area involved by vessel images to whole area (Figure 1).

FAZ margins were identifed in automated manner. Manuel correction was performed when needed. FAZ area (mm^2), FAZ perimeter (mm) and foveal density (FD, %) were calculated by AngioVue software of device in an automated manner. FD is defined as VD of the circle (3 mm in size) that surrounded FAZ (Figure 1).

Simultaneously, choroidal images were obtained using EDI-OCT module. The SFCT was measured at subfoveal region by two researchers (M.A. and F.B.) blinded to clinical characteristics of cases. The distance between posterior margin of hyper-reflective retinal pigment epithelium and choroidoscleral junction was defined as SFCT (Figure 2). The measurement was repeated if there was a difference more than 15% between measuurements. The measurements were performed at same times of day to minimize errors resulting from daily variation and diurnal rhythm.

The CMT was measured using macular mapping protocol in an automated manner. It was defined as mean retinal thickness in a center-based circle (1000 µm in diameter).

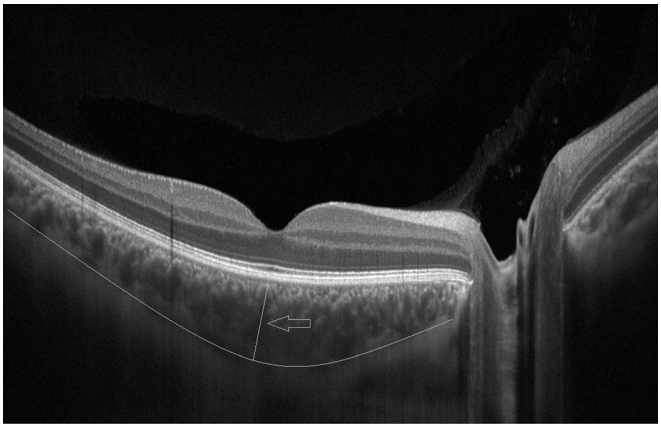

Figure 2: *Choroidal thickness measurement by EDI-OCT. The distance between posterior margin of hyper-reflective retinal pigment epithelium and choroidoscleral junction was defined as SFCT (arrow).*

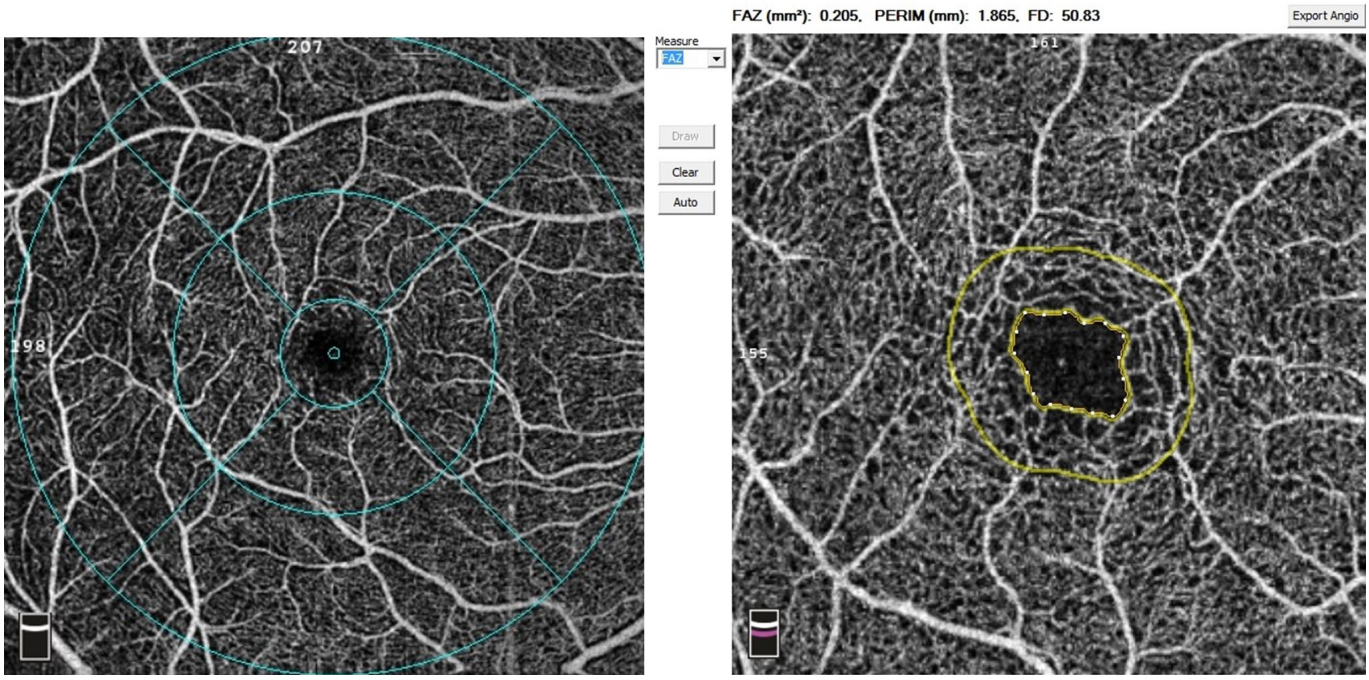

Figure 1: *In left side, retinal vascular area surrounded by 3 circles with diameters of 1, 3 and 6 mm exposed to en face OCTA imaging of superficial capillary plexus is seen in left side. After reformating images according to contrast (tresholding), VD (%) is defined as the ratio of area involved by vessel images to whole area. In the right side, FAZ parameters, FAZ area, FAZ perimeter, and FD identified by OCTA in an automated manner are seen. FD is defined as VD of the circle (3 mm in size) that surrounded FAZ.*

The PASI score (0-72) was calculated based on lesion severity (erythema, induration and desquamation and percent area involved in four bodily regions (head, trunk, upper and lower extremities) by an experienced dermatologist (A.T.E).[20]

Statistical analysis

All statistical analyses were performed using SPSS version 24.0 (SPSS Inc. Chicago, IL, USA). The numerical data are presented as mean ± standard deviation whereas categorical data are expressed as count (%) unless otherwise specified. The categorical variables were compared using x^2 test. The normal distribution of numerical variables were tested using Kolmogorov-Smirnov test. Independent samples t test was used to compare groups with normal distribution while Mann Whitney U test was used to compare groups with skewed distribution. Kruskall-Wallis test was used to compare psoriasis subgroups (mild and severe) and controls. Mann Whitney U test with Bonferonni correction was used to compare binary variables found to be significant. Pearson's or Spearman's correlation test was used to assess correlation between variables based on distribution pattern. The correlation was defined as weak if r is <0.3, moderate if r is between 0.3 and 07, and strong if r is >0.7. A p value <0.05 was considered as statistically significant.

FINDINGS

The study included 60 eyes from 31 cases with plaque psoriasis an 29 healthy individuals. Table 1 summarizes demographic characteristics. There was no significant difference in mean age and gender distribution between groups (p>0.05 for all).

There was articular involvement in 5 (16.1%) and nail involvement in 14 patients with psoriasis (45.2%). Median mean duration (min-max) was 10 years (1-48 years) while PASI score was 11.3±7.4 (median: [102.20-42]). Based on PASI Score, there were 16 mild cases (51.6%) and 15 severe cases (48.4%). The BCVA was 20/20 in all cases. No abnormal finding was detected in anterior and posterior segment examination.

No automated segmentation error was observed in determination of retinal layers and FAZ borders on OCTA. The signal quality was >0.8.

No significant difference was found regarding OCTA metrics, SFCT and CMT between psoriasis cases and healthy individuals (p>0.05 for all) (Table 2).

When psoriasis cases were stratified as severe and mild and compared with healthy individuals, no significant difference was observed between measurements (p>0.05 for all). Nail involvement incidence was significantly higher in severe psoriasis cases (p=0.02) (Table 3).

No linear correlation was detected between disease duration, PASI score, articular involvement and nail involvement and OCTA and OCT parameters (p>0.05 for all). A moderate, positive correlation was detected between disease duration and nail involvement (r:0.485; p=0.006). The PASI score was increased by increasing nail involvement (r=0.402; p=0.025).

Table 1:

	Psoriasis (31)	Control (29)	p value
Mean age (Yıl)	44.74±10.81	43.21±12.22	0.608 *
Gender Male Female	 20 (64.5%) 11 (35.5%)	 14 (48.3%) 15 (51.7%)	0.205 £
Arthritis + -	 5 (16.1%) 26 (83.9%)	 ø	 Ø
Nail involvement + -	 14 (45.2%) 17 (54.8%)	 ø	 ø
Disease duration (Year)	10 (1-48)	ø	ø
PASI (Score)	11.3 ± 7.4	ø	ø

PASI: Psoriasis Area and Severity Index
* Independent t test
£ Chi-square test
Disease duration is presented as [median (min-max)].

Table 2:

	Control (n:29)	Psoriasis (n:31)	p value
SVD (%)	51.61 ± 2.49	51.95 ± 2.13	0.728¥
DVD (%)	56.56 ± 5.34	56.6 ± 4.79	0.971*
FAZ alanı (mm^2)	0.29 ± 0.12	0.24 ± 0.1	0.403¥
FAZ çevresi (mm)	2.07 ± 0.45	1.88 ± 0.41	0.091*
FD (%)	55.46 ± 3.57	55.16 ± 3.59	0.473¥
SFCT(µm)	280.66 ± 77.28	289.16 ± 90.48	0.698*
CMT (µm)	285.93 ± 11.73	290.23 ± 11.58	0.159*

SVD: Superficial vasculardensity. **DVD:** Deep vascular density. **FAZ:** Foveal avascular zone. **FD:** Foveal density. **SFCT:** Subfoveal choroidal thickness. **CMT:** Central macular thickness.
* Independent t test
¥ Mann Whitney test

Table 3:

	Control group (n:29)	Mild Psoriasis (n:16)	Severe Psoriasis (n:15)	p value*
Demographic characteristics				
Age (Year)	43.21 ± 12.22	47.88 ± 9.84	41.4 ± 11.11	0.15
Gender (M/F)	14/15	11/5	9/6	0.39
Arthitis (+/-)	ø	3/13	2/13	0.68
Nail involvement (+/-)	ø	4/12	10/5	**0.02**
Duration (Year)	ø	9.13 ± 8.05	16.2 ± 13.25	0.08
EDI-OKT ve OCTA measurements				
SVD (%)	51.61 ± 2.49	51.69 ± 2.21	52.22 ± 2.08	0.73
DVD (%)	56.56 ± 5.34	56.13 ± 4.74	57.11 ± 4.96	0.94
FAZ area (mm^2)	0.29 ± 0.12	0.24 ± 0.08	0.24 ± 0.12	0.71
FAZ perimeter (mm)	2.07 ± 0.45	1.88 ± 0.34	1.89 ± 0.48	0.49
FD (%)	55.46 ± 3.57	55.68 ± 3.22	54.61 ± 3.99	0.65
CMT (µm)	285.93 ± 11.73	291.25 ± 10.12	289.13 ± 13.22	0.28
SFCT (µm)	280.66 ± 77.28	311.44 ± 100.59	265.4 ± 74.36	0.43

M: Male. **F:** Female. **SVD:** Superficial vasculardensity. **DVD:** Deep vascular density. **FAZ:** Foveal avascular zone. **FD:** Foveal density. **SFCt:** Subfoveal choroidal thickness. **CMT:** Central macular thickness.
* Numerical variables were analyzed using Kruskal-Wallis test while categorical variables wee analyzed using Chi-square test. Bold values indicate statistical significance.

DISCUSSION

When treatment-naive plaque psoriasis cases without ocular involvement were compared with age- and sex-matched healthy individuals in our study, it was seen that there was no significant difference in SD-OCT and OCTA metrics between two groups. It was seen that this result did not change when psoriasis cases were classified as mild and severe psoriasis according to PASI Score. No correlation was detected between disease duration, PASI score and OCTA, OCT parameters. Moderate positive correlations were detected between nail involvement rate and disease duration as well as PASI score.

Invasive methods such as biopsy, laser Doppler flow meter and videocapillaroscopic are used to assess micro-vascular involvement in dermatological lesions while invasive dye-based angiography as well as non-invasive methods such as OCTA have been used to visualize retinal vascular system[14, 18, 19]. In our study, it was aimed to assess potential retinal micro-vascular changes secondary to psoriasis using OCTA.

Psoriasis is a chronic inflammatory disease characterized by variable clinical presentation, which primarily involves skin and joints but progresses with multi-sysemic comorbidities. It is highly informed to predict prognosis and comorbidities early for treatment[2, 3, 7, 21].

The comorbidities are more frequently seen in moderate-to-severe cases[3]. The most important factors implied in the etiopathogenesis of comorbidities are increased inflammation, insulin resistance and endothelial dysfunction. The mechanisms leading these pathologies are termed as psoriatic march phenomenon[22]. On the other hand, it has been reported that cytokines such as TNF-α and INF-γ have neurotoxic effects and can lead ischemia-reperfusion injury and that they can induce release of growth factors such as vascular endothelial growth factor (VGEF) from endothelial cells[23, 24].

It was reported that ocular involvement are seen by 10-67% in cases with psoriasis[2, 25]. Since the disease is an epithelial disease primarily, eyelid and conjunctiva are primary involvement sites. Clinical presentations related to anterior segment such as anterior uveitis, xerophthalmia, conjunctivitis are most frequent involvements[26, 27]. Posterior segment complications such as optic neuritis, vasculitis, cystoid macular edema, retinal vein occlusion and birdshot chorioretinopathy were also presented[5, 6, 8].

Ocular findings are more commonly seen during exacerbation period and accompany to articular involvement[7]. However, there are cases presented with ocular comorbidities without skin involvement or arthritis[2]. There is a consensus that there is a need for inter-

disciplinary approach including mainly ophthalmology and rheumatology given the atypical involvement patterns and multi-systemic nature[4].

Current trend in multi-systemic disorders is to identify subclinical findings with predictive values before onset of clinical presentation using multimodal non-invasive methods. These methods reveal possibility for early diagnosis and treatment, providing significant cues regarding pathogenesis of diseases[7].

It was shown that some subclinical changes may be present impaired visual field, loss of retinal sensitivity and abnormal electrophysiological tests in psoriasis cases without ocular symptoms[7, 8, 28-30].

These studies are accelerated by SD-OCT in last decade. OCT is a non-invasive imaging modality which is based on interferometric measurement of light, in which dermatologists are familiar due to use in imaging of skin lesions[18]. It is considered as a promising modality to assess inflammation in systemic inflammatory diseases and SFCT and CMT were analyzed as potential biomarkers[1].

In our study, no significant difference was seen in CMT between cases with psoriasis and healthy individuals. The results were similar for cases with mild and severe psoriasis. In the literature, a consensus that CMT is not a sensitive biomarker for inflammation has been emerging in agreement with our study[1]. Although retinal dysfunction is observed in cases with psoriasis, it was observed that CMT and thickness of ganglion cell layer and inner plexiform layer was not changed[7, 11, 12]. It was shown that retinal thickness showed significant changes in only cases with comorbidities such as metabolic syndrome[6].

The lack of retinal thickness accompanying to functional abnormalities may be due to the fact that CMT measurements are not sensitive parameters to reflect small inflammatory changes. Thus, the finding that there was no change in CMT and retinal nerve fiber layer in cases with psoriasis while ganglion cell layer thickness was decreased may be a finding that confirms this hypothesis[6].

In our study, no significant difference was observed in SFCT between groups. In addition, there was a reduction in SFCT in cases with severe psoriasis but the difference did not reach statistical significance.

After introduction of SFCT measurement by EDI-OCT in the literature, the predictive value of SFCT as biomarker of inflammation have been investigated in many studies[1]. The lack of auto-regulation in SFCT was in favor while the fact that SFCT was affected by gender, age and axial length was against its value as biomarker[1].

At this point, data indicating SFCT was increased secondary to TNF-α at acute period of systemic inflammatory diseases while choroidal tissue was thinned via atrophy due to inflammatory micro-angiopathy at chronic period[1, 11].

In the literature, it was seen that there are contradictory results reporting no change[12, 13] or increase[11] in SFCT in psoriasis cases. In the study reporting increased SFCT, mean PASI score was 17 and mean disease duration was 16 years while mean PASI score was 5 and mean disease duration was 2.5 years in the study reporting no change in SFCT[11, 13]. Thus, it was speculated that confounding factors such as disease duration, disease severity, activity and treatment may have role in contradictory results[6, 12, 13].

In our studies, follow-up duration and PASI scores were comparable with those reported in Ersan et al.[12]. In the study by Ersan et al., no significant difference was found between healthy individuals and cases with psoriasis in agreement with our study while they reported increased SFCT in cases with severe psoriasis on contrary to our study[12]. In both studies, small sample size can lead contradictory results, comprising an important limitation. In these studies, it was reported that there was no correlation between disease duration and SFCT or PASI score[11, 13].

The OCTA is a novel technology that allows rapid, 3-dimensional and high--resolution imaging of retinal vascular system. High-resolution imaging of retinal vascular system provides a chance to reveal important cues for understanding pathogenesis of systemic diseases[14]. There are increasing numbers of studies in uveitis and systemic inflammatory diseases[15, 16, 31].

In our study, no significant change was observed in OCTA metrics in cases with psoriasis. It was reported that no significant change was observed in these parameters in the quiescent phase of disease in systemic inflammatory disorders such as Familial Mediterranean fever, inflammatory bowel disease or Behçet's disease[15, 16, 31].

The rational underlying OCTA analysis in psoriasis is the likelihood that comorbidities such as increased systemic inflammation, angiogenesis, atherosclerosis and endothelial dysfunction can affect ocular and retinal vascular system[23, 24]. Akkurt et al. reported that ocular circulation was affected using orbital Doppler sonography[32]. On the other hand, posterior segment complications such as optic neuropathy, visual field alterations, prolonged visual evoked potential, vasculitis and branch retinal vein occlusion[4, 5, 8, 28, 29].

However, no quantitative change was observed in vascular system in psoriasis cases, which can theoretically involve vascularity, in our pilot study using OCTA. It will be helpful to analyze potential causes in the future studies.

The vascular system is affected by a mechanisms that can be summarized as inflammatory micro-angiopathy due to increased vascular inflammation and thromboembolic alterations in inflammatory diseases[1]. In cases psoriasis, it was reported that micro-angiopathy may develop in retinal vascular system since it is an auto-immune or immune-mediated inflammatory reaction[5]. On the other hand, it was reported that increased leptin level, which causes intima-media thickening, can be a predisposing factor in cases with psoriasis[33, 34]. However, lacking of auto-regulation in retinal vascular system may lead compensation at a certain level. Thus, it was reported that retinal may have more limited role as inflammation marker compared to SFCT and macula may not be affected despite SFCT change[1, 12]. Thus, it may needed that inflammation should reach above a certain threshold for OCTA metrics to reflect inflammatory changes. In fact, no quantitative change was detected in quiescent periods regarding ocular findings in other inflammatory disorders[15, 16]. There is a need for OCTA analysis in cases such as pustular psoriasis since ocular complications are seen more frequently in exacerbations of psoriasis.

In the literature, there are contradictory results regarding relationship between PASI score and severity of ocular involvement. There are studies reporting higher impairment in visual field testing and xerophthalmia parameters by increasing PASI score while there are studies reporting no correlation between PASI score and severity of ocular involvement[6, 8, 9, 25]. In our study, no correlation was detected between OCT and OCTA metrics and PASI score, nail involvement or articular involvement ($p>0.05$ for all). The PASI scores compatible with moderate severity and inclusion of patients with mild-to-moderate disease in our study may have lead failure to demonstrate significant difference. There is need for randomized, controlled studies including cases with ocular involvement to clarify these contradictions.

A major limitation was small sample size in our study. This led to weaker statistical power in subgroup analyses.

Since OCTA is a novel technology, there is no established consensus about reliability and validity of outcomes provided among clinicians. In the analysis of inflammatory diseases, it provides quantitative data such as VD, FD and FAZ area as well as qualitative data such as perifoveal ischemia, FAS irregularity, perifoveal capillary tortuosity and capillary disorganization[31]. Although no significant changes are observed in quantitative data, some predictive findings can be seen among qualitative data. Thus, there is need for studies assessing qualitative parameters using OCTA images obtained by 3x3 mm module.

Other limitations included widely distributed time period of inclusion, measurements solely performed in subfoveal areas despite variable choroidal and macular topography, OCTA artifacts and lack of analysis of inflammatory blood parameters.

In conclusion, OCTA is a simple, non-invasive and promising technique for retinal micro-vascular system imaging in cases with plaque psoriasis as it is the case in many inflammatory diseases. However, it has a limited role for detection of early subclinical changes in cases without ocular involvement. When compared to healthy individuals, no significant difference was detected in VD, FAZ metrics, CMT and SFCT in treatment-naive psoriasis cases.

There is need for multimodal studies involving cases with psoriasis at different stages and ocular involvement, in which retina and choroid are assessed using OCT in structural manner and using OCTA in vascular manner.

REFERENCES

1. Steiner M, Esteban-Ortega M del M, Muñoz-Fernández S. Choroidal and retinal thickness in systemic autoimmune and inflammatory diseases: A review. Surv Ophthalmol 2019; 64: 757-69.
2. Rajguru JP, Maya D, Kumar D, et al. Update on psoriasis: A review. J Fam Med Prim Care 2020; 9: 20-4.
3. Kalkan G. [Comorbidities in psoriasis: The recognition of psoriasis as a systemic disease and current management]. Turkderm-Turk Arch Dermatol Venereol 2017; 51: 71-7.
4. Au S-C, Yaniv S, Gottlieb AB. Psoriatic Eye Manifestations. J Psoriasis Psoriatic Arthritis 2018; 17: 169-79.
5. Yen YC, Weng SF, Lai FJ, et al. Risk of retinal vein occlusion in patients with psoriasis. Retina 2015; 35: 1786-94.
6. Korkmaz S, Guclu H, Hatipoglu S, et al. Metabolic Syndrome May Exacerbate Macular and Retinal Damage in Psoriasis Vulgaris. Ocul Immunol Inflamm 2019; 27: 798-804.
7. Chimenti MS, Triggianese P, Salandri G, et al. A Multimodal Eye Assessment in Psoriatic Arthritis Patients sine-Psoriasis: Evidence for a Potential Association with Systemic Inflammation. J Clin Med 2020; 9: 719.
8. Deniz Demir H, Kalkan G, Kurt S, et al. Relationship between retinal sensitivity and disease activity in patients with psoriasis vulgaris. Clinics 2015; 70: 14-1.

9. Campanati A, Neri P, Giuliodori K, et al. Psoriasis beyond the skin surface: a pilot study on the ocular involvement. Int Ophthalmol 2015; 35: 331-40.
10. Doğan S, Atakan N, Koç Yıldırım S, et al. [Evaluation of psoriasis patients with a rheumatologic questionnaire efficiently aids in early detection of psoriatic arthritis]. Turkderm-Turk Arch Dermatol Venereol 2017; 51: 88-91.
11. Turkcu FM, Sahin A, Yuksel H, et al. Evaluation of choroidal thickness in psoriasis using optical coherence tomography. Int Ophthalmol 2016; 36: 851-4.
12. Ersan I, Kilic S, Arikan S, et al. Evaluation of Macular Ganglion Cell-inner Plexiform Layer and Choroid in Psoriasis Patients Using Enhanced Depth Imaging Spectral Domain Optical Coherence Tomography. Ocul Immunol Inflamm 2017; 25: 520-4.
13. Kilic R, Kurt A, Acer E, et al. Choroidal thickness in psoriasis. Int Ophthalmol 2017; 37: 173-7.
14. Spaide R, Fujimoto J, Waheed N, et al. Optical coherence tomography angiography. Prog Retin Eye Res 2017; 101: 985-8.
15. Nakayama LF, Bergamo VC, Conti ML, et al. The retinal foveal avascular zone as a systemic biomarker to evaluate inflammatory bowel disease control. Int J Retin Vitr 2019; 5: 4-7.
16. Çavdarli C, Çavdarli B, Topcu-Yilmaz P, et al. Optical coherence tomography-angiographic vascular densities in Familial Mediterranean Fever (FMF) Patients with M694V Mutations. Ophthalmic Genet 2020; 1-6.
17. Goker YS, Yılmaz S, Kızıltoprak H, et al. Quantitative Analysis of Optical Coherence Tomography Angiography Features in Patients with Nonocular Behcet's Disease. Curr Eye Res 2019; 44: 212-8.
18. Morsy H, Kamp S, Thrane L, et al. Optical coherence tomography imaging of psoriasis vulgaris: correlation with histology and disease severity. Arch Dermatol Res 2010; 302: 105-11.
19. Deegan AJ, Talebi-Liasi F, Song S, et al. Optical coherence tomography angiography of normal skin and inflammatory dermatologic conditions. Lasers Surg Med 2018; 50: 183-93.
20. Schmitt J, Wozel G. The psoriasis area and severity index is the adequate criterion to define severity in chronic plaque-type psoriasis. Dermatology 2005; 210: 194-9.
21. Özyurt K, Ertaş R, Ertaş ŞK. [Treatment of Psoriatic Arthritis and Turkish Psoriasis Treatment Guideline-2016]. J Anatol Med Res 2018; 3: 62-7.
22. Boehncke WH, Boehncke S, Tobin AM, et al. The 'psoriatic march': A concept of how severe psoriasis may drive cardiovascular comorbidity. Exp Dermatol 2011; 20: 303-7.
23. Davidovici BB, Sattar N, Jörg PC, et al. Psoriasis and systemic inflammatory diseases: Potential mechanistic links between skin disease and co-morbid conditions. J Invest Dermatol 2010; 130: 1785-96.
24. Heidenreich R, Röcken M, Ghoreschi K. Angiogenesis drives psoriasis pathogenesis. Int J Exp Pathol 2009; 90: 232-48.
25. Ghalamkarpour F, Baradaran-Rafii A, Sadoughi MM, et al. Ocular findings in patients with psoriasis: is it related to the side effects of treatment or to psoriasis itself? A case-control study. J Dermatolog Treat 2020; 31: 27-32.
26. Demerdjieva Z, Mazhdrakova I, Tsankov N. Ocular changes in patients with psoriasis. Clin Dermatol 2019; 37: 663-7.
27. Rehal B, Modjtahedi BS, Morse LS, et al. Ocular psoriasis. J Am Acad Dermatol 2011; 65: 1202-12.
28. Shoeibi N, Taheri AR, Nikandish M, et al. Electrophysiologic evaluation of retinal function in patients with psoriasis and vitiligo. Doc Ophthalmol 2014; 128: 131-6.
29. Perossini M, Turio E, Perossini T, et al. Pattern VEP alterations in psoriatic patients may indicate a subclinic optic neuritis. Doc Ophthalmol 2005; 110: 203-7.
30. Grzybowski A, Grzybowski G, Druzdz A, et al. Visual evoked potentials in patients with psoriasis vulgaris. Doc Ophthalmol 2001; 103: 187-94.
31. Koca S, Onan D, Kalaycı D, et al. Comparison of Optical Coherence Tomography Angiography Findings in Patients with Behçet's Disease and Healthy Controls. Ocul Immunol Inflamm 2019; 0: 1-8.
32. Akkurt ZM, Gümüş H, Aktürk A, et al. Evaluation of orbital arteries with colour Doppler ultrasonography in patients with psoriasis. Clin Exp Dermatol 2015; 40: 507-12.
33. Ciccone M, Vettor R, Pannacciulli N, et al. Plasma leptin is independently associated with the intima-media thickness of the common carotid artery. Int J Obes 2001; 25: 805-10.
34. Chen YJ, Wu CY, Shen JL, et al. Psoriasis independently associated with hyperleptinemia contributing to metabolic syndrome. Arch Dermatol 2008; 144: 1571-5.