

# Eyelashes Artifact in Ultra-Widefield Optical Coherence Tomography Angiography

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**BACKGROUND AND OBJECTIVE:** To describe the presence of eyelashes artifact in ultra-widefield swept-source optical coherence tomography angiography (SS-OCTA) images.

**PATIENTS AND METHODS:** In this prospective, cross-sectional study, 52 healthy, young subjects were imaged with the SS-OCTA system. OCTA scans were taken in primary and extremes of gaze, and a montage was automatically created. The en face choriocapillaris images were then exported, and a semi-automated algorithm was used for subsequent quantitative analysis.

**RESULTS:** The authors noted the presence of some linear regions of reduced brightness, which were assumed to represent a shadow effect due to patient eyelashes. In order to quantify this effect, the authors performed a quantitative analysis of the superior and inferior regions in the retinal and choroidal vessels.

**CONCLUSIONS:** The authors' qualitative and quantitative analysis showed the presence of regions of false-positive hypoperfusion secondary to eyelashes artifacts. To the authors' knowledge, this represents the first description of this new type of shadowing artifact affecting OCTA images.

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## INTRODUCTION

The development of optical coherence tomography angiography (OCTA) has opened a new era in the analysis of the retinal and choroidal microvasculature, allowing the evaluation of the individual vascular plexuses at extremely high resolution. Using OCTA, many studies have investigated these plexuses highlighting vascular, structural, and functional alterations in healthy and pathologic eyes.<sup>1-5</sup> One of the main limitations of this technique is represented by the artifacts associated, which have been widely described and are known to be potential confounding factors in the vascular analysis.<sup>1,5-9</sup>

The recent introduction of high-speed swept-source OCTA (SS-OCTA) devices has significantly expanded the assessment of the vascular plexuses. Importantly, a higher-speed system allows the acquisition of a larger field of view, ensuring a wider investigation of the retinal and choroidal vessels. Therefore, this kind of technology grants to image from the macula to the far retinal periphery and is thus termed ultra-widefield OCTA imaging.

In recent years, several imaging modalities have been developed for acquiring ultra-widefield images, including fluorescein angiography, autofluorescence, and fundus color imaging.<sup>10</sup> However, the very large field of view obtained with ultra-widefield imaging commonly results in the patient's eyelashes appearing in the image.<sup>11-13</sup> In this case series, we describe the presence of eyelashes artifact in ultra-widefield SS-OCTA images. This represents the first description of this new type of shadowing artifact affecting OCTA images.

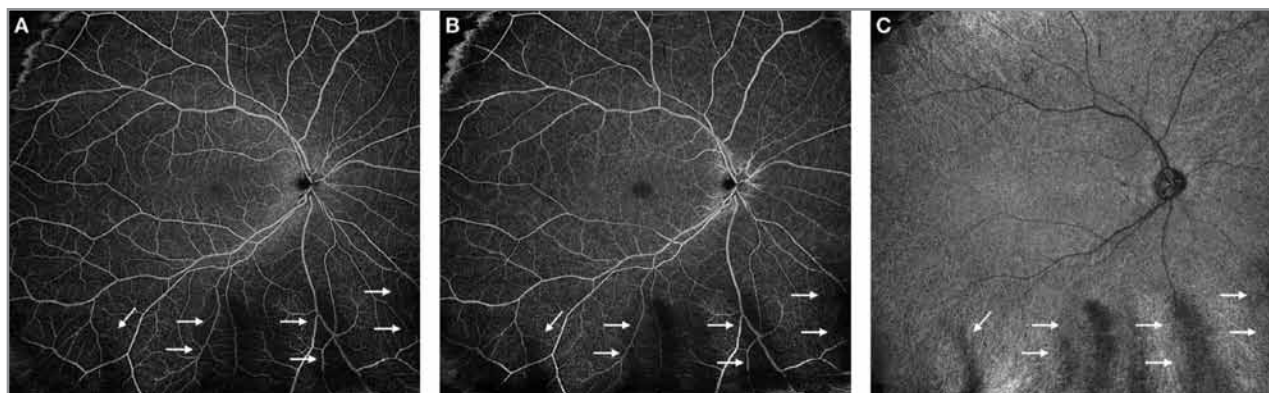
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**Figure 1.** A 23-year-old healthy man underwent ultra-widefield swept-source optical coherence tomography angiography (OCTA) imaging using the PLEX Elite 9000 device (Carl Zeiss Meditec Inc., Dublin, CA, USA). The obtained en face images of the superficial (A) and deep (B) retinal capillary plexuses, as well as the choriocapillaris (C), showed the presence of some linear regions of reduced brightness (indicated with white arrows). Given that these regions had the same shape in all the images and that were located in the inferior far retinal periphery, we concluded that these regions of false-positive hypoperfusion are secondary to shadowing artifacts due to superior eyelashes. Therefore, the assessment with ultra-widefield OCTA is still limited by significant shadowing artifacts, given that the very large depth of field may result in the patient's eyelashes to appear in the image.

### CASE SERIES

In this prospective case series, 55 healthy subjects between 18 and 40 years of age were enrolled and were imaged with the PLEX Elite 9000 device (Carl Zeiss Meditec, Dublin, CA). At the baseline, all patients received a complete ophthalmologic examination, which included the measurement of best-corrected visual acuity, intraocular pressure, and dilated ophthalmoscopy. Exclusion criteria were: (i) evidence or history of ocular diseases; (ii) evidence or history of systemic disorders, including diabetes and systemic hypertension; (iii) history of previous ocular surgery; (iv) ocular axial length (AL) greater than 26 mm.

For each eye, five 12 mm × 12 mm OCTA volume scans were acquired. These scans were acquired in five different gazes (central, nasal inferior, nasal superior, temporal inferior, and temporal superior) by moving the internal fixation light. Finally, the software included in the device automatically combined these five scans in a final montage image.

Subsequently, the obtained ultra-widefield OCTA en face images from different vascular layers (superficial retinal capillary plexus [SCP], deep retinal capillary plexus [DCP], and choriocapillaris [CC]) were exported and then imported into ImageJ software version 1.50 (National Institutes of Health, Bethesda, MD). Consequently, two experienced readers (EB and PV) graded all the ultra-widefield OCTA images (SCP, DCP, and CC) for the presence of localized, reduced brightness. The presence of reduced brightness was assessed in different regions (Figure 1) of the retina. Successively, the OCTA en

face images were binarized for quantitative analysis, as previously shown.<sup>14</sup>

All quantitative variables were reported as mean and standard deviation (SD) or median and interquartile range (IQR). To detect departures from normality distribution, Shapiro-Wilk's test was performed for all variables. Since SCP, DCP, and CC variables did not show a normal distribution, a non-parametric test was conducted to investigate regional differences in quantitative SCP, DCP, and CC variables. Statistical calculations were performed using Statistical Package for Social Sciences (version 20.0; SPSS Inc., Chicago, IL). The chosen level of statistical significance was a *P* value less than .05.

Of the 55 eyes (55 individuals) that were initially enrolled, 52 eyes met the required image quality criteria and were used in the analysis. Mean ± standard deviation (SD) age was 25.4 years ± 5.3 years (median: 24.5 years; range: 20.0 years to 40.0 years). Mean ± SD AL was 23.2 mm ± 1.0 mm (median: 23.9 mm; range: 21.8 mm to 25.9 mm).

Graders noted the presence of some linear regions of reduced brightness, which were assumed to represent a shadow effect due to patients' eyelashes. In details, the superior region of the SCP did not show changes in both the near/mid (zero of 52 eyes) and far periphery (zero of 52 eyes); however, the inferior region of SCP highlighted alterations in both the near/mid (two of 52 eyes; 3.8%) and far periphery (20 of 52 eyes; 38.4%). DCP analysis detected variations of the superior region both in the mid/near periphery (one of 52 eyes; 1.9%) and in the far periphery (four of 52 eyes; 7.6%). Moreover, the inferior region

**TABLE 1**  
**OCTA Tested Variables in the Analyzed Regions**

	Superior Far	Inferior Far	P Value
OCTA			
SCP Perfusion Density (%)	39.2 (38.2-40.2)	40.2 (38.5-41.0)	.348
DCP Perfusion Density (%)	39.0 (38.2-40.0)	31.1 (28.4-33.2)	< .0001
CC Flow void Area (%)	12.0 (10.0-13.5.)	26.7 (23.3-29.7)	< .0001

Data are presented as median (interquartile range).

OCTA = optical coherence tomography angiography; SCP = superficial capillary plexus; DCP = deep capillary plexus; CC = choriocapillaris

of the DCP was also changed both in the near/mid periphery in six out of 52 eyes (11.5%) and in the far periphery in 40 out of 52 eyes (76.9%). Finally, the CC investigation displayed the presence of the shadowing artifact in all the investigated regions, as follows: (i) three of 52 eyes (5.7%) in the superior region of the near/mid periphery; (ii) six of 52 eyes (11.5%) in the superior region of the far periphery; (iii) eight of 52 eyes (15.3%) in the inferior region of the near/mid periphery; and (iv) 43 of 52 eyes (82.6%) in the inferior region of the far periphery.

In order to quantify the effect of these shadowing artifacts on the retinal and CC perfusion in the far retinal periphery, we compared the perfusion density between the superior and inferior far retinal periphery regions. In the analysis investigating the SCP, no substantial differences were found between these two regions ( $P = .348$ ) (Table 1). On the contrary, in the DCP examination, the inferior region was characterized by a lower perfusion density in comparison with the superior region (median = 39.0% and interquartile range [IQR] = 38.2%-40.0% in the superior region, median = 31.1% and IQR = 28.4%-33.2% in the inferior region;  $P < .0001$ ). Similarly, at the CC level the perfusion density was significantly lower in the inferior region (median = 88.0% and IQR = 86.5%-90.0% in the superior region, median = 73.3% and IQR = 70.3%-76.7%;  $P < .0001$ ).

## DISCUSSION

In this case series, we described for the first time the presence of a new type of OCTA shadowing artifact secondary to patients' eyelashes. Importantly, we displayed that this artifact mainly affects the deep retinal capillary plexus and the choriocapillaris in the inferior far retinal periphery.

In the recent years, previous notable studies have demonstrated that various artifacts associated with OCTA imaging may cause an incorrect interpretation of OCTA images.<sup>1,7,8</sup> Of these artifacts, the erro-

neous segmentation of the vascular layers has been fully described and is known to mainly affect pathologic eyes.<sup>1,7,8</sup> The visualization of the retinal and choroidal layers may also be affected by projection artifacts. These projections commonly occur from major superficial retinal vessels, which can be seen in the deeper vascular layers as regions of false positive flow.<sup>1,8,9</sup> Several approaches have been developed to remove or reduce projection artifacts, and some of these techniques have been implemented in commercial instruments.<sup>1,6,8,9,15</sup> The shadowing artifact represents another important artifact that may affect the retinal and choroidal vascular layers.<sup>1,5,8</sup> This artifact occurs when light from the OCTA device is attenuated or blocked during its passage to the deeper layers of the retina/choroid, this causing regions of false-positive flow impairment. The shadowing artifact may be secondary to the presence of vitreous opacities, hemorrhage, pigment clumps, or scar tissue. Of note, these artifacts represent a significant limitation in eyes with age-related macular degeneration, since the presence of drusen or neovascularization may significantly attenuate the light reaching the CC.<sup>1</sup> Despite SS-OCTA devices employ a longer wavelength with better penetration of the vitreous and retina, with a consequent reduction in occurrence of shadowing artifacts,<sup>1,16</sup> signal attenuation may still occur.<sup>1,16,17</sup>

Using ultra-widefield SS-OCTA imaging, we add to the literature by describing a new type of shadowing artifact due to patients' eyelashes. In details, we noted that most of our case series ultra-widefield OCTA images were characterized by the presence of some linear regions of reduced brightness. Importantly, these regions had the same shape in both the retinal and CC OCTA images and were mainly located in the inferior far retinal periphery. Assuming that ultra-widefield imaging with other imaging modalities is known to be affected by a reduction in image quality in the inferior extreme periphery,<sup>11-13</sup>

we concluded that these regions of false-positive hypoperfusion are ascribable to shadowing artifacts due to superior eyelashes.

Furthermore, we compared the perfusion density between the superior and inferior far retinal periphery regions. We demonstrated that, although the SCP did not exhibit significant regional differences in perfusion density, both the DCP and CC were characterized by a significant lower perfusion density in the inferior regions. In agreement, the two graders displayed that the reduction in OCTA brightness in the inferior retinal periphery was more common in the deeper vascular layer (DCP and CC: 76.9% and 82.6%, respectively) than in the SCP (38.4%). Therefore, we speculate that the patients' eyelashes may cause an attenuation of the OCTA light reaching the SCP, which is further attenuated in the passage throughout the retina and retinal pigment epithelium. This aspect might explain why eyelashes cause a progressive reduction in OCTA image brightness (and consequently perfusion density) toward the deeper vascular layers.

A potential limitation to this study is that we were not able to exclude that differences in perfusion between superior and inferior regions are secondary to physiological regional differences in ocular perfusion, rather than eyelashes artifacts. However, our qualitative analysis did show that eyelashes artifact may reduce the visualization of peripheral vessels and this may have impacted, at least in part, the quantification of peripheral perfusion. Future studies employing strategies acted at reducing eyelashes artifacts will clarify this crucial aspect.

In summary, our qualitative and quantitative analysis showed the presence of regions of false-positive hypoperfusion secondary to eyelashes artifacts. These shadowing artifacts are common in the inferior far retinal periphery because of superior eyelashes. Therefore, the assessment with ultra-widefield OCTA is still limited by significant shadowing artifacts, given that the very large depth of field may result in the patient's eyelashes to appear in the image. Future studies with extended longitudinal follow-up and further analysis of ultra-widefield OCTA image may provide additional substantive information. These results should be considered in ultra-widefield OCTA-based studies of healthy and pathologic eyes.

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