Original Article

Merits of multicolor imaging for tractional retinal detachment

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Purpose: To compare multicolor imaging (MCI) with Optos color fundus photography (OCFP) for the evaluation of morphology and extent of preretinal membranes in diabetic tractional retinal detachments (TRD). **Methods:** In this retrospective study, 30 eyes with diabetic TRDs were imaged using the MCI feature of the Heidelberg Spectralis Spectral-domain optical coherence tomography (SD-OCT) and color photo using the Optos Daytona ultra-widefield fundus camera. Two investigators independently graded and determined the agreeability between the two modalities with respect to the extent of the TRD and preretinal membranes on the SD-OCT B-scan images. **Results:** The MCI provided better visualization of the attachments and traction points of the posterior hyaloid face and preretinal membranes and is comparable to the SD-OCT B-scan images. The inter-rater agreeability rates for OCFP had a Kappa (κ) value of 0.37, while the MCI had a κ value of 0.46. When comparing between images of different wavelengths, grading using infrared reflectance (IR) had a poor agreement (−0.04 ± 0.04) while green reflectance (GR) (0.46 ± 0.32) and blue reflectance (BR) (0.53 ± 0.19) had a moderate agreement. The composite MCI and GR images also had comparatively higher intraclass coefficient when compared to the OCFP (0.25 [−0.09–0.55]) and IR (−0.03 [−0.39–0.34]) images. **Conclusion:** MCI is more sensitive for determining the extent of TRDs and for the detection of secondary membranes when compared to OCFP, thus, aiding in better surgical planning.

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Advances in retinal imaging have provided insights into many ocular pathologies, thereby, improving the management of retinal diseases and allowing accurate, reproducible documentation of retinal abnormalities.[1] While the clinical examination is paramount, imaging does have its advantages and applications. Besides being an educative tool, it helps in medical and surgical planning and monitoring, and for medicolegal aspects and telemedicine. Color fundus photos (CFP) using various modalities and different fields of view closely resemble clinical examination findings but have limitations like compromised depth perception, resolution, and contrast. Compared to the standard fundus cameras, the images produced by the scanning laser ophthalmoscopy (SLO) have a higher resolution due to reduced light scatter. In addition, confocal SLO (cSLO) systems allow image acquisition at different planes and higher contrast due to the suppression of light scatter. Furthermore, the images can be acquired through a nonmydriatic pupil.[2]

The 'multicolor' imaging module (MCI) developed for the Spectralis Spectral-domain optical coherence tomography (Spectralis SD-OCT, Heidelberg Engineering, Heidelberg, Germany) uses the cSLO to capture three simultaneous reflectance images using three monochromatic laser sources: Blue reflectance (BR; 488 nm), green reflectance (GR; 515 nm), and infrared reflectance (IR; 820 nm). These different wavelengths of light penetrate the retinal surfaces at different depths to demonstrate details at various layers of the retina. The BR delineates pathologies of the inner retina and the vitreoretinal interface such as the epiretinal membranes, retinal nerve fiber layer thinning, and macular pigmentary changes. The GR images focus on deeper details such as retinal blood vessels and intraretinal lipid exudation and the IR images predominantly visualize structures at the level of the outer retina and choroid.[3] Hence, we compared the clinical use of MCI in the evaluation of tractional retinal detachments (TRD) secondary to proliferative diabetic retinopathy (PDR) and compared it with the images of the Optos ultra-widefield camera (Optos Daytona, Optos PLC, United Kingdom) which also uses cSLO to provide high-resolution images.[4]

Methods

Patients presenting to the vitreoretinal department of a tertiary referral care center between March 2019 and December 2019 were included in this study, which was approved by the Institute Ethics Committee and the Institute Research Board and adhered to the tenets of the Declaration of Helsinki. In this retrospective analysis, 30 eyes of 22 patients diagnosed

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with advanced PDR and TRD with gradable images on both Optos color fundus photography (OCFP) and MCI, which had been performed on the same day were included. The image acquisition included BR, IR, and GR of MCI and raster and radial SD-OCT B-scans done on the Spectralis to document the morphological extent of the TRD.

Assessment of TRD

The diagnosis of macular TRD was confirmed on clinical examination by a senior specialist. The SD-OCT and MCI images were saved as TIFF files and the OCFP as high-resolution JPEG files and were analyzed. The TRD was noted as a grayish-white membrane on the OCFP and as a greenish-gray membrane on the MCI, with varying intensities of gray and green depending on the wavelength. The extent of the membranes on all the wavelengths was compared to the extent of the membranes on the SD-OCT B-scan. The OCFP was zoomed in to match the MCI image using anatomical landmarks like the vascular arcades and optic disk. Two investigators (SGK and NR) independently compared the delineability of the tractional area and preretinal membranes between the OCFP and MCI images of each wavelength to the extent of the same on SD-OCT. The extent of identification and delineability of the preretinal membranes were divided into the following three scores based on the agreeability between the imaging modalities.

Not matching: 0; Matching, but less than SD-OCT: 1; Matching SD-OCT: 2.

The MCI images were also analyzed and described qualitatively by an experienced retina specialist (SGK).

Statistical analysis

All the statistics were performed using the MedCalc (v19.2.6) statistical software. An intraclass correlation coefficient (ICC) and inter-rater agreement between the findings of both observers were calculated.

Results

The mean age of the patients was 49.5 ± 9.31 years, range 38–73 years, with 22 being males and 1 being female. The preretinal membranes were better appreciated on the MCI when compared to the OCFP [Fig. 1]. The BR images showed the gross extent of these membranes and the TRD with a better delineability of the hyaloid status beyond the TRD when compared to the GR and IR [Fig. 2]. The GR images added further clarity to the anteroposterior extent or the thickness of the tractional elements when compared to the BR images. The vascularity within the membranes was also well appreciated on both the BR and GR images [Fig. 3]. Though there was a poor delineation of the thicker preretinal membranes on the IR images due to their primary location, there was a marginally better appreciation of the retinal traction, visible as darker shadows with elevated retinal vasculature and the preretinal secondary membranes seen as a faint preretinal darker membranous hue [Fig. 4].

The agreeability between the graders was statistically analyzed as follows:

The inter-rater agreement uses the statistic Kappa (κ) to calculate the rate of agreement between the two graders. The grading using OCFP had a κ value of 0.37 which is considered as a fair agreement, while the MCI had a κ value of 0.46. When comparing images of different wavelengths, grading using IR had a poor agreement (−0.04 ± 0.04), while the GR (0.46 ± 0.32) and BR (0.53 ± 0.19) had a moderate agreement [Table 1].

Intraclass coefficient

A higher ICC value indicates good reliability of measurements. In this study, each image was graded by the same raters and the absolute agreement was noted between them. The ICC of a single rater (ICC[a]) was the highest (0.54 [0.24–0.75]) for the BR images. The composite MCI and GR images also had a comparatively higher ICCs compared to the OCFP (0.25 [–0.09–0.55]) and IR (–0.03 [–0.39–0.34]) images. The ICC of the average of the two ratings is generally higher than the single measure. It was higher for the BR images (0.7 [0.38–0.85]). The composite MCI and GR images also had a reasonable agreement (0.64 [0.24–0.83]) between the graders. Whereas the ICC average measure was lower for the OCFP and IR images [Table 2].

Grading scores

Optos color fundus photo versus multicolor imaging

When the OCFP images were used for grading, 70% had a score of 2, but 30% had a score of 1. When the MCI was used for grading, 93.3% had a score of 2, while 6.7% had a score of 1 [Table 3].

IR versus BR versus GR

Between the different wavelength images, the BR (93.9%) and GR (90%) images had a score of 2, while it was 3.3% for the IR images. Both the BR and GR images had a good agreement between the raters compared to the IR images [Table 4].

Table 1: Inter-rater agreement represented using Kappa ± SEM and 95% confidence interval

Parameters	Grader 1 vs. Grader 2 (Kappa±SEM)	95% CI	Strength of Agreement
Grading of OCFP	0.37±0.16	0.05-0.7	Fair
Grading of MCI	0.46±0.32	−0.16-1	Moderate
IR	−0.04±0.04	−0.13-0.03	Poor
GR	0.46±0.32	−0.16-1	Moderate
BR	0.53±0.19	0.15-0.91	Moderate

OCFP=Optos color fundus photography; MCI=multicolor imaging; IR=infrared reflectance (820 nm); BR=blue reflectance (488 nm); GR=green reflectance (515 nm)

Table 2: Intraclass coefficient for single and averaged ratings represented with 95% confidence interval

Parameters	ICC[a]	95% CI	ICC[b]	95% CI
Grading of OCFP	0.25	−0.09-0.55	0.48	−0.21-0.71
Grading of MCI	0.47	0.13-0.7	0.64	0.24-0.83
IR	−0.03	−0.39-0.34	−0.05	−1.29-0.50
GR	0.47	0.13-0.71	0.64	0.24-0.83
BR	0.54	0.24-0.75	0.7	0.38-0.85

[a]Estimates the reliability of single ratings; [b]Estimates the reliability of averages of two ratings; ICC=Intraclass coefficient; OCFP=Optos color fundus photography; MCI=multicolor imaging; IR=infrared reflectance (820 nm); BR=blue reflectance (488 nm); GR=green reflectance (515 nm)

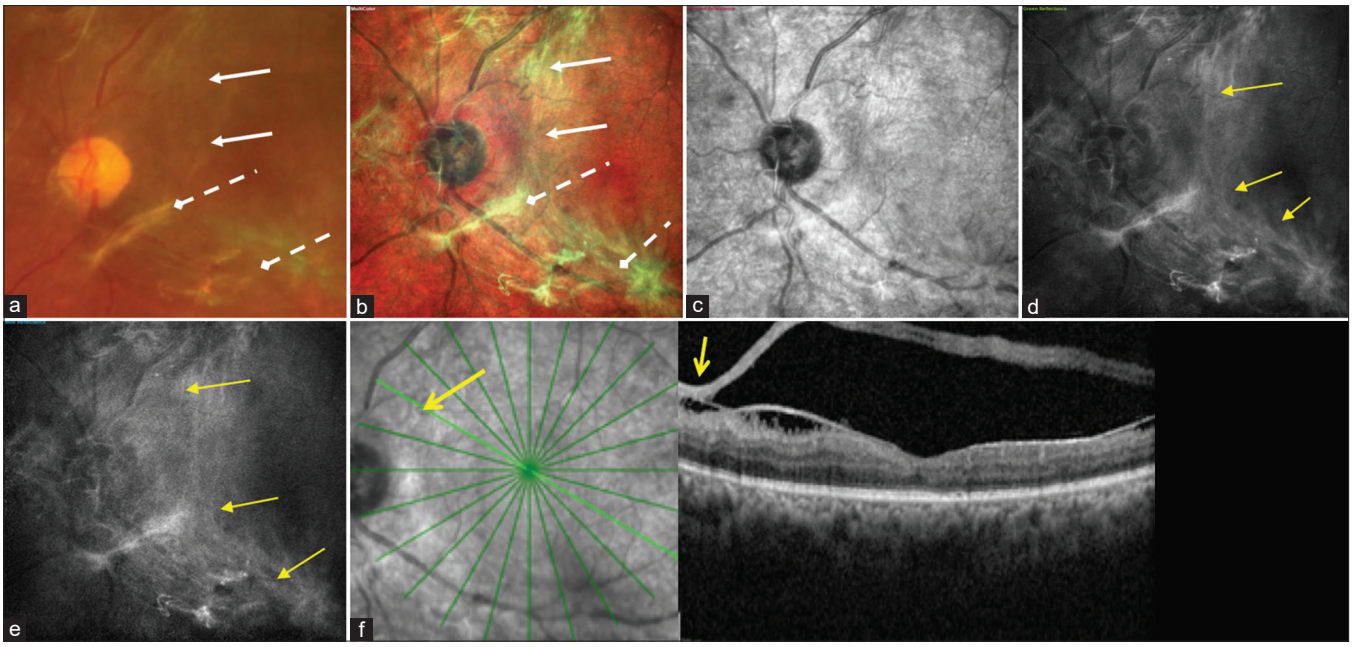

Figure 1: A comparison of the (a) Optos color fundus photo (OCFP) with the (b) multicolor image (MCI) showing prominent fibrovascular preretinal membranes (white dashed arrows). White arrows point out subtle membranes visible on the MCI image, but not on the OCFP. The infrared reflectance (c) shows no clear evidence of the preretinal membranes. The yellow arrows in the green reflectance (d) and blue reflectance (e) point toward the approximate extent of the preretinal membranes and on the spectral-domain optical coherence tomography (f), the extent of the taut posterior hyaloid attachment

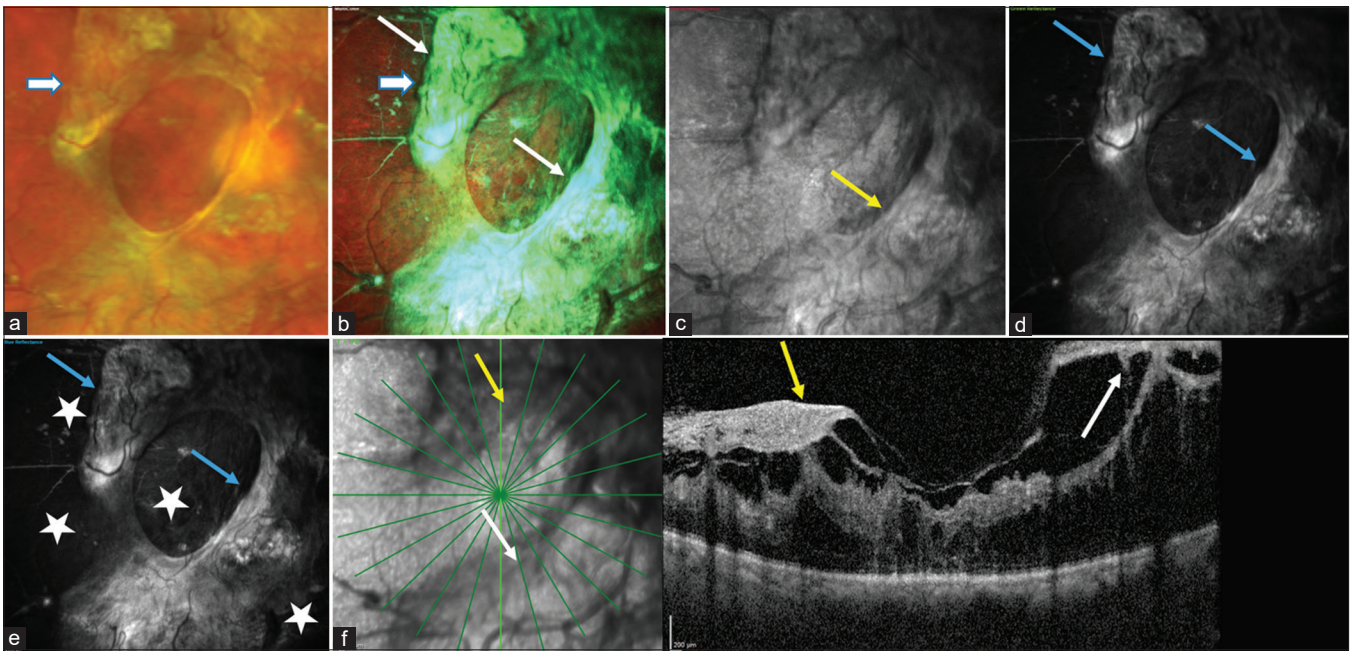

Figure 2: A comparison of the (a) Optos color fundus photo with a better delineated preretinal membrane (white solid arrows) on the (b) multicolor image. The infrared reflectance (c) shows no clear evidence of the preretinal membranes (yellow arrow) but vascularity is obvious. The blue arrows in the green (d) and blue reflectance (e) depict a well-delineated membrane with better posterior hyaloid face visibility (white stars) on the blue reflectance. On the spectral-domain optical coherence tomography (f), a thicker preretinal membrane is seen superiorly (yellow arrows) than inferiorly (white arrows)

Discussion

Clinical examination and appropriate documentation of retinal findings help to understand the disease, plan interventions, prognosticate treatment outcomes, for patient counseling and document follow-ups. CFP with a single bright flash have been used commonly but have poor contrast and a limited field of view. An OCFP, which uses a cSLO system, has brighter and better contrast and widefield images (200°) amenable for zooming on to the

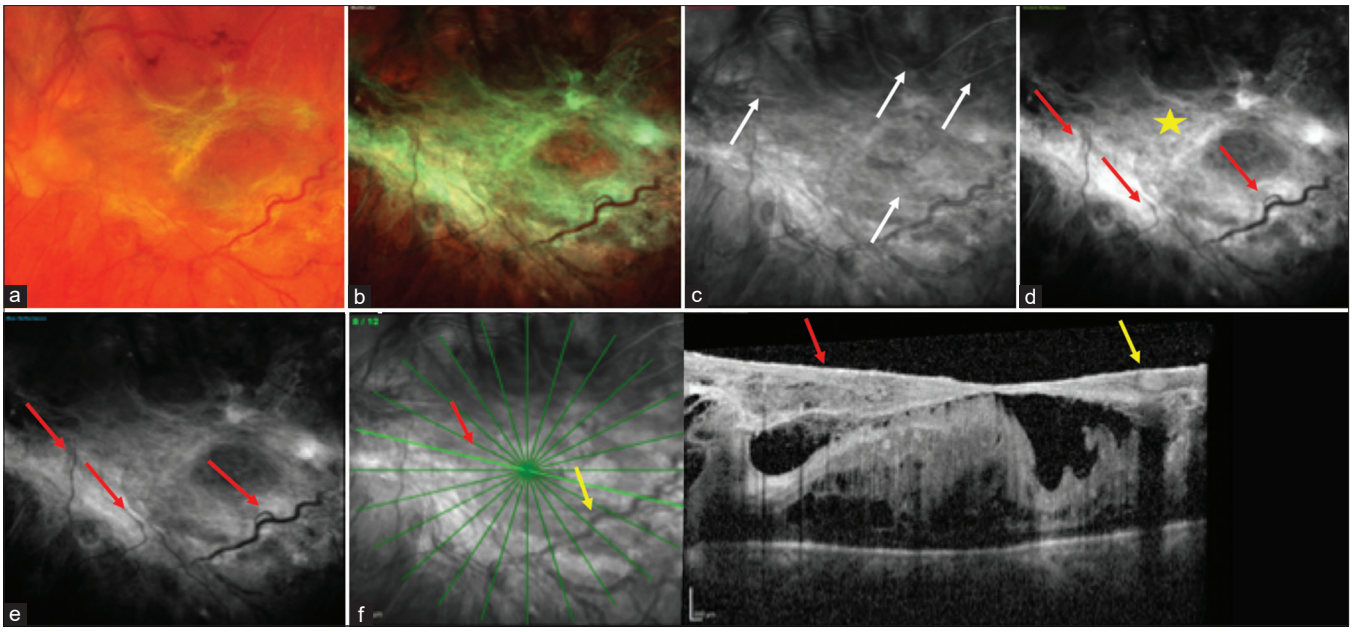

Figure 3: A comparison of the (a) Optos color fundus photo with a better delineated preretinal membrane on the (b) multicolor image. The infrared reflectance (c) shows the prominence of the preretinal vasculature (white arrows). The green reflectance (d) highlights the thickness of the membrane (yellow star) and vascularity (red arrows). The blue reflectance (e) delineates the vascularity (red arrows) and posterior hyaloid face (white stars). On the spectral-domain optical coherence tomography (f), thick preretinal membranes and their relationship to the underlying retina is well defined (yellow and white arrows)

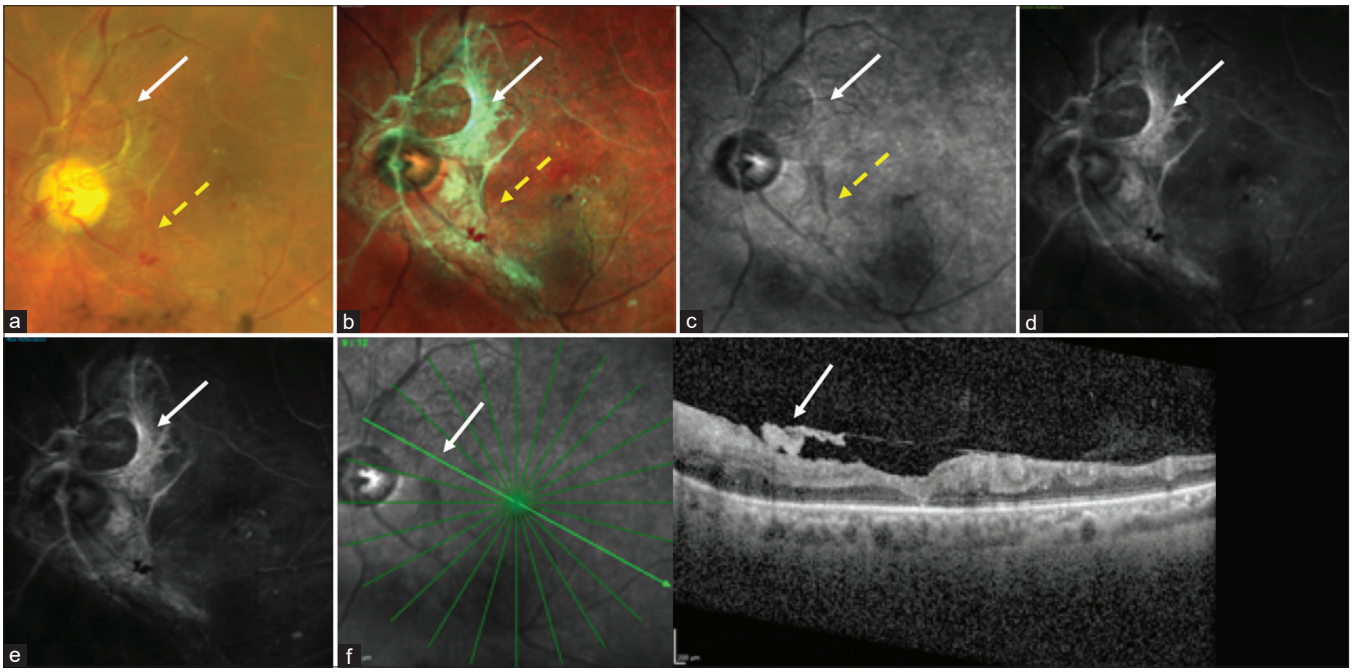

Figure 4: A comparison of the (a) Optos color fundus photo with the (b) multicolor image (MCI) showing better delineation of the preretinal membrane on the MCI. The infrared reflectance (c) shows a better delineation of the preretinal vasculature (yellow dashed arrows), while the green reflectance (d) and blue reflectance (e) delineate the fibrous component of the membrane better (white arrows). On the spectral-domain optical coherence tomography (f) images, the thick vascular preretinal membrane and its relationship to the underlying retina is well defined (white arrows)

area of interest, albeit having the disadvantage of using pseudo colors.[2,4] Multicolor imaging with Spectralis using the combined cSLO + SD-OCT platform has an added advantage of simultaneous SD-OCT B-scan and MCI up to 55° with a single device in a nonmydriatic pupil. With its variable penetrance, MCI can add to the understanding of preretinal structures and their relationship to the underlying retina. Though the color rendering of the MCI is not similar to what is seen on fundus examination, a composite MCI encompasses all the preretinal and retinal elements in one

Table 3: Optos color fundus photo grading vs. multicolor image between the two graders

OCFP Grader 1	OCFP Grader 2				MCI Grader 1	MCI Grader 2		
	0	1	2	Total		1	2	Total
1	1	18	2	21 (70.0%)	1	1	1	2 (6.7%)
2	1	4	4	9 (30.0%)	2	1	27	28 (93.3%)
	2	22	6	30		2	28	30
	−6.70%	−73.30%	−20.00%			−6.75%	−93.9%	

OCFP=Optos color fundus photography; MCI=multicolor imaging

Table 4: Frequency table showing the grading between two raters for each of the reflectance. Grading between the two graders for each of the reflectance

IR Grader 1	IR Grader 2			Total
	0	1	2	
0	0	3	0	3 (10.0%)
1	1	25	0	26 (86.7%)
2	0	1	0	1 (3.3%)
	1	29	0	30
	3.3%	96.7%	0%	
BR Grader 1	**BR Grader 2**			**Total**
	1	2		
1	3	0		3 (10.0%)
2	4	23		27 (90.0%)
	7	23		30
	23.3%	76.7%		
GR Grader 1	**GR Grader 2**			**Total**
	1	2		
1	1	1		
2	1	27		2 (6.7%)
	2	28		28 (93.3%)
	6.7%	93.3%		30

IR=infrared reflectance (820 nm); BR=blue reflectance (488 nm); GR=green reflectance (515 nm)

image. It has a definite advantage over the OCFP in estimating the depth, contrast, extent, and characteristics of a tractional membrane and is comparable to the extent of the membrane on the corresponding SD-OCT B-scan. This is due to the variable penetrance and simultaneous reflectance of three monochromatic sources of laser light that replace a single point laser source as in a regular cSLO technology of OCFP.[4,5]

The available literature on MCI in retinal disorders, premacular pathology in particular, and a comparison with other concurrent diagnostic modalities have established its emerging utility. In this study, we studied the enface features of macular TRD on MCI and compared it with the OCFP and correlated it with the extent of the preretinal membranes on an SD-OCT B-scan. We found that MCI is superior to OCFP in understanding the extent and characteristics of a macular TRD and is comparable to the SD-OCT B-scan. The enface abilities of MCI, especially BR and GR, aid greatly in understanding the traction elements, the actual extent of the pathology at different depths, and involvement of the retinal tissue, thus, complementing the SD-OCT B-scan in surgical decisions and planning. The images in the BR and GR appear grayish and greenish depending on the elevation plane. The intramembranous vascularity can also be delineated. While the BR images help in understanding the posterior hyaloid face details around the tractional membranes, the GR images reveal the thickness and elevation points of the preretinal membranes more precisely, with the more elevated areas having a more greenish hue. The IR images downplay the extent of the preretinal membranes as the scans are more posterior and toward the outer retina. The IR images depict areas of retinal elevation and traction as darker shadows with poorly defined borders, consistent with the extent of the TRD, comparable to the SD-OCT B-scans, and even show the subtle secondary membranes over the posterior pole with changes in the surface retinal vascularity. A composite MCI combining all the three reflectances provides a fair understanding of the extent and depth of preretinal membranes and traction as a pseudocolor image with the greener hue representing thicker and more elevated membranes.

Our study showed a 70% match between the OCFP and SD-OCT and a 93.3% match when the MCI was used. The agreement between the graders was higher for the MCI compared to the OCFP and higher for the GR and BR images for the preretinal membranes compared to the IR and OCFP. There is no absolute value for good agreement and it mostly depends on the nature of the study. In the current study, it can be concluded that MCI, especially BR and GR, had a better agreement between the two graders and that the MCI-based grading was more comparable to the SD-OCT than the OCFP images. The IR images were found to affect the κ value significantly. With a larger sample size or if only the BR and GR images are considered, the inter-rater agreement is expected to be higher.

The previous studies have explored the utility and application of MCI in various retinal conditions. Ji Hun Song *et al*.[5] compared MCI and CFP for the evaluation of epiretinal membrane and found that the rate of delineability of the epiretinal membranes (ERM) was higher for the MCI than for the CFP, for both investigators 970.8% versus 52.6% and 73.4% versus 53.6%0, which was similar to the observations in our study. In another study, the enface retinal imaging of the ERM acquired with the Heidelberg retina angiograph (HRA2) allowed a better visualization for the preoperative evaluation compared to the SD-OCT-based thickness maps or pseudocolor images acquired with Optomap.[6] Another study comparing the visualization of ERMs using MCI and conventional white light flood CFP concluded that the ERMs were better visualized on MCI. They found that the CFP failed to detect ERM in

11.4% of the eyes when the mean central retina thickness was <413 microns and the GR provided better detection of the surface folds (5.54 ± 2.12) compared to the BR (4.2 ± 2.34) and IR (1.2 ± 0.9).[7] We found that the foveal center, fine preretinal membranes, and tractional points of the posterior hyaloid face were better seen on the MCI when compared to the OCFP.

Conclusion

Multicolor imaging is a sensitive modality to identify the extent and morphology of the preretinal membranes and gives a better delineation of the pathology when compared to the conventional and ultra-widefield CFP. It can be an aid for surgical planning of macular tractional detachments along with the SD-OCT B-scan features allowing a better understanding of the tractional elements leading to improved outcomes.

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Conflicts of interest

There are no conflicts of interest.

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