# Foveal Microstructure and Functional Parameters in Lamellar Macular Hole

MICHELE REIBALDI, MARIACRISTINA PARRAVANO, MONICA VARANO, ANTONIO LONGO, TERESIO AVITABILE, MAURIZIO GIACINTO UVA, MARCO ZAGARI, MARIO TORO, FRANCESCO BOSCIA, BARBARA BOCCASSINI, ADELE CHIARAVALLOTI, CESARE MARIOTTI, AND ALFREDO REIBALDI

**• PURPOSE: To evaluate the morphologic features of the photoreceptor layer (by spectral-domain optical coherence tomography) and functional parameters in patients with a lamellar macular hole.**

**• DESIGN: Prospective, multicenter, observational case series.**

**• METHODS: Fifty-four patients with lamellar macular hole were enrolled in the study. All patients underwent a complete ophthalmologic examination, including best-corrected visual acuity (BCVA) testing, MP1 microperimetry, and spectral-domain optical coherence tomography. For each patient, 2 experienced masked observers evaluated the integrity of photoreceptor inner segment/outer segment (IS/OS) junction and external limiting membrane (ELM) line.**

**• RESULTS: Spectral-domain optical coherence tomography analysis showed complete integrity of the IS/OS junction and ELM line in 40 eyes (group A), partial or complete disruption of the IS/OS junction with an intact ELM line in 8 eyes (group B), and an alteration of both IS/OS junction and ELM line in 6 eyes (group C). Mean BCVA, total retinal sensitivity, and fixation stability were significantly better in groups A and B than in group C (both $P < .05$, Tukey–Kramer test), whereas there was no significant difference between groups A and B. Mean central retinal sensitivity was significantly different among all 3 groups (all $P < .05$, Tukey–Kramer test). The grade of integrity of the foveal photoreceptor layer was correlated significantly with mean BCVA ($r = -0.57$; $P < .001$), mean central retinal sensitivity ($r = 0.52$; $P < .001$), and total retinal sensitivity ($r = 0.44$; $P < .001$).**

**• CONCLUSIONS: In lamellar macular hole, the morphologic features of the foveal photoreceptor layer consistently are correlated with BCVA and central retinal sensitivity. Preservation of the ELM is related to the maintenance of visual acuity. (Am J Ophthalmol 2012;154:974–980. © 2012 by Elsevier Inc. All rights reserved.)**

Accepted for publication June 18, 2012.

From the Department of Ophthalmology, University of Catania, Catania, Italy (M.R., A.L., T.A., M.G.U., M.Z., M.T., A.R.); the G. B. Bietti Eye Foundation-IRCCS, Rome, Italy (M.P., M.V., B.B., A.C.); the Department of Ophthalmology, University of Bari, Bari, Italy (F.B.); and the Department of Ophthalmology, University of Ancona, Ancona, Italy (C.M.).

Inquiries to Michele Reibaldi, Department of Ophthalmology, University of Catania, Via S. Sofia 78, 95124 Catania, Italy; e-mail: mreibaldi@libero.it

THE TERM *LAMELLAR MACULAR HOLE* (LMH) TO DEscribe a macular lesion resulting from cystoid macular edema was introduced by Gass in 1975.[1] Subsequently, lamellar hole was described as an abortive process in the formation of a full-thickness macular hole; the patient has relatively preserved visual acuity, usually 20/40 or better, and a stable, round, well-circumscribed reddish macular lesion.[2,3]

Optical coherence tomography (OCT) evaluation has improved the diagnosis of lamellar holes, because it allows visualization of retinal anatomic features with near microscopic resolution.[4] With OCT investigation, LMHs are diagnosed easily, and their characteristic features of non–full-thickness defects of the macula with an irregular foveal contour and a schisis between inner and outer retinal layers, without any defect of the photoreceptor layer, have been defined as criteria for diagnosis.[4]

The introduction of spectral-domain (SD) OCT has improved the speed and sensitivity of the examination. SD OCT scanning at a higher resolution allows visualization of the intraretinal architectural morphologic features,[5,6] especially at the level of the external limiting membrane (ELM) and the photoreceptor inner segment/outer segment (IS/OS) junction, which may indicate the integrity of the photoreceptor layer.[7] The integrity of this layer has been found to correlate with maintenance of visual function in patients with a variety of retinal diseases, including age-related macular degeneration, macular hole, central serous chorioretinopathy, and diabetic macular edema.[8–11]

To characterize visual impairment, features of visual function other than the best-corrected visual acuity (BCVA) must be evaluated.[12,13] It has been shown that more detailed information about a patient's visual function can be gathered by microperimetry than by visual acuity measurement alone,[14] and that distance visual acuity can underestimate the functional benefit of a treatment as compared with microperimetry.[15,16] Microperimetry provides exact localization and quantification of retinal sensitivity in the entire macular region and automatic eye tracking for evaluating the fixation pattern.[17,18]

The purpose of this study was to investigate, in eyes with LMH, the morphologic features of foveal photoreceptors, in particular the status of the ELM line and the IS/OS junction, and to assess the correlation between morphologic changes and functional deficits as measured by visual acuity assessment and microperimetry.

  0002-9394/$36.00
http://dx.doi.org/10.1016/j.ajo.2012.06.008

## METHODS

IN THIS OBSERVATIONAL STUDY, WE INCLUDED ALL CONSECUTIVE patients with a diagnosis of LMH examined at the Department of Ophthalmology, University of Catania, Catania, Italy, and at the Fondazione G.B. Bietti, IRCCS, Rome, Italy, between January 2010 and May 2011. LMH were diagnosed based on SD OCT characteristics proposed by Witkin and associates.[19] Patients were enrolled if the following characteristics were present in at least 1 of the scans: (1) an irregular foveal contour; (2) a break in the inner fovea; (3) separation of the inner from the outer foveal retinal layers, leading to an intraretinal split; (4) absence of a full-thickness foveal defect.

Exclusion criteria were the presence in the affected eye of refractive errors of more than ± 5 diopters, astigmatism of more than 2 diopters, history of amblyopia, age-related macular degeneration, diabetes mellitus, retinal vascular occlusion, vitreous hemorrhage, a history of intraocular surgery other than uncomplicated cataract surgery, significant cataract graded at more than N03 or NC3 according to the Lens Opacity Classification Scheme,[20] and eyes with low-quality, unreliable OCT images. In cases of bilateral LMH, 1 eye was selected randomly.

All subjects received a complete ophthalmologic examination, including the measurement of BCVA, slit-lamp biomicroscopy, intraocular pressure determination, binocular indirect ophthalmoscopy, and fundus photography. BCVA was measured using Early Treatment Diabetic Retinopathy Study charts at 4 m distance by a single, independent, well-trained, experienced orthoptist in each center who was masked to the study. Vision results were quantified in logarithm of the minimal angle of resolution units. Each patient, on the same day, first underwent microperimetry and then underwent SD OCT examination.

In both centers, the MP-1 microperimeter (Nidek Technologies, Padua, Italy) was used. After the pupils were dilated (1% tropicamide), a reference frame was obtained with the integrated infrared camera. We used a 4-2 double-staircase test strategy with white background illumination set at 4 apostilbs and the starting stimulus light attenuation set at 10 dB. Then, a grid of 45 stimuli with a Goldmann III stimulus size and a time between stimuli of 1 second was projected onto the central 8 degrees. A bright red cross of 2 degrees was used for the fixation target. For assessment of fixation, the fundus movements were tracked during examination. The patient's mean retinal sensitivity (total sensitivity) and the mean sensitivity of the central 13 points within 2 degrees (central sensitivity) was calculated. Fixation stability was calculated as the percentage of fixation points within the 2-degree diameter circle. In all patients, microperimetry was performed twice within 1 week to rule out potential learning effects, and the second test was used for the analysis. Patients underwent a brief training session at the beginning of each test. All imaging sessions were performed after 5 minutes of visual adaptation. At each center, the examinations were carried out by the same experienced ophthalmologists (M.T., Catania; A.C., Rome). Both participating centers used the same MP1 software version (version 1.4.2). To avoid bias resulting from instrument variability, all microperimeters were calibrated accurately by the same experienced technician, and the parameters of the examination were standardized at the 2 centers.

**TABLE 1.** Demographic, Clinical, Optical Coherence Tomography, and Microperimetry Characteristics of Eyes with Lamellar Macular Hole

| | Study Group (n = 54) |
|---|---|
| Gender, n (%) | |
| Male | 20 (37%) |
| Female | 34 (63%) |
| Eye, n (%) | |
| Right | 29 (54%) |
| Left | 25 (46%) |
| Mean ± SD age (y) | 68 ± 8 |
| Mean ± SD BCVA (logMAR) | 0.15 ± 0.16 |
| Mean ± SD central retinal thickness (μm) | 308 ± 52 |
| Mean ± SD residual foveal thickness (μm) | 119 ± 38 |
| Epiretinal membrane, n (%) | 52 (96%) |
| Vitreofoveal separation, n (%) | 9 (17%) |
| Mean ± SD central retinal sensitivity (dB) | 16.0 ± 3.0 |
| Mean ± SD total retinal sensitivity (dB) | 17.0 ± 2.3 |
| Mean ± SD fixation stability (%) | 90.0 ± 10.4 |

BCVA = best-corrected visual acuity; logMAR = logarithm of the minimal angle of resolution; SD = standard deviation; y = year.

SD OCT images were obtained with the Spectralis OCT version 5.1.3.0 (Heidelberg Engineering, Heidelberg, Germany) with Heidelberg Eye Explorer version 1.6.2.0 (Heidelberg Engineering). At each center, all OCT examinations were carried out by a certified operator (M.Z., Catania; B.B., Rome) who was unaware of other information on the eyes. According to the protocol, radial 20-degree, 6-line scans centered on the fovea were obtained for each eye. More than 25 scans were averaged for each measurement. Only images with a quality score of more than 25 were selected as high-quality images. The integrity of the IS/OS and ELM was evaluated by using the photoreceptor IS/OS junction and ELM line on the gray-scale SD OCT images. Both the ELM line and the photoreceptor IS/OS junction were evaluated on each of the radial 6-line scans for 500 μm in either direction of the center of the fovea and were defined as intact when the line was continuous, disrupted when the line was interrupted by gaps shorter than 200 μm, or completely absent when the gaps were 200 μm or longer.[21,22] On the basis of the appearance of 2 lines, 6 levels of integrity were

**TABLE 2.** Difference in Best-corrected Visual Acuity, Retinal Sensitivity, and Fixation Stability among Eyes with Various Levels of Photoreceptor Integrity Detected by Spectral-Domain Optical Coherence Tomography in Eyes with Lamellar Macular Holes

| | Photoreceptor Layer Integrity | | | *P* Value | |
|---|---|---|---|---|---|
| | Eyes with Preserved IS/OS and ELM: Group A (n = 40) | Eyes with Disrupted IS/OS and Preserved ELM: Group B (n = 8) | Eyes with Disrupted IS/OS and ELM: Group C (n = 6) | ANOVA | Tukey–Kramer |
| BCVA, logMAR | 0.08 ± 0.05 | 0.13 ± 0.09 | 0.30 ± 0.11 | .000 | NS[a]<br>.000[bc] |
| Total sensitivity, dB | 17.7 ± 1.5 | 16.7 ± 2.5 | 13.1 ± 2.4 | .000 | NS[a]<br>.001[b]<br>.000[c] |
| Central sensitivity, dB | 17.1 ± 2 | 15 ± 3 | 10.5 ± 2.4 | .000 | .047[a]<br>.001[b]<br>.000[c] |
| Fixation stability, % | 92 ± 8 | 91 ± 11 | 78 ± 16 | .006 | NS[a]<br>.039[b]<br>.004[c] |

ANOVA = analysis of variance; BCVA = best-corrected visual acuity; ELM = external limiting membrane; IS/OS = photoreceptor inner segment and outer segment; logMAR = logarithm of the minimal angle of resolution; NS = not significant.

All data are presented as mean ± standard deviation unless otherwise noted.

[a]Group A vs group B.

[b]Group B vs group C.

[c]Group A vs group C.

described: VI, both the IS/OS junction and ELM line were intact; V, the IS/OS junction was disrupted, but the ELM line was intact; IV, the IS/OS junction was absent, but the ELM line was intact; III, both the IS/OS junction and the ELM line were disrupted; II, the IS/OS junction was absent and the ELM was disrupted; and I, both and the IS/OS junction and the ELM line were absent. According to the integrity of the foveal photoreceptor layer, the eyes were divided into 3 subgroups: group A, eyes with complete integrity of the IS/OS junction and the ELM line; group B, eyes with partial or complete disruption of the IS/OS junction with an intact ELM line; and group C, eyes with disruption of the ELM line. Two masked expert investigators at each center (M.R., A.L., Catania; M.V., M.P., Rome) interpreted the SD OCT images. When there was disagreement, a third investigator was consulted for the final decision.

• **STATISTICAL ANALYSIS:** All values were presented as mean ± standard deviation. Descriptive analysis was performed on the integrity of the IS/OS junction and the ELM line. The reliability of the IS/OS junction and ELM line grading was determined with weighted κ statistics and intraclass correlation coefficients (ICCs). The presence of correlation between the 6 levels of integrity of the foveal photoreceptor layer and BCVA and microperimetry parameters was tested by using the Spearman correlation coefficient. The analysis of variance was used to determine whether there were any differences in BCVA and microperimetry parameters among the 3 different subgroups (groups A, B, and C) on the basis of photoreceptor layer integrity; if significant, multiple comparisons were performed with the Tukey-Kramer test. A *P* value less than .05 was considered statistically significant. Statistical analysis of the data used the Statistical Packages for the Social Sciences version 17.0 for Windows (SPSS Inc, Chicago, Illinois, USA).

## RESULTS

SIXTY EYES OF 60 CONSECUTIVE PATIENTS WITH A DIAGNOSIS of LMH were evaluated; of these, 6 eyes were excluded (2 for other macular disease, 2 for refractive error more than ± 5 diopters, 1 for significant cataract, and 1 for previous vitrectomy). Therefore, 54 eyes of 54 patients met the study criteria and were enrolled. The demographic and clinical characteristics of the enrolled patients are reported in Table 1. High-quality SD OCT scans were obtained for each patient, and none were eliminated from the study secondary to inability to grade the photoreceptor layer. The ICC between observers for the grading of the IS/OS junction was 0.96 (95% confidence interval [CI], 0.92 to 0.97), and the ICC between observers for the status of the ELM line was 0.82 (95% CI, 0.70 to 0.89). The κ coefficient for the status of the IS/OS junction was 0.91 (95% CI, 0.78 to 1.03) and that for the status of the ELM line was 0.81 (95% CI, 0.56 to 1.07).

At SD OCT examination, 40 eyes (74%) showed complete integrity of the IS/OS junction and ELM line, whereas 14 eyes (26%) had alterations in the photorecep-

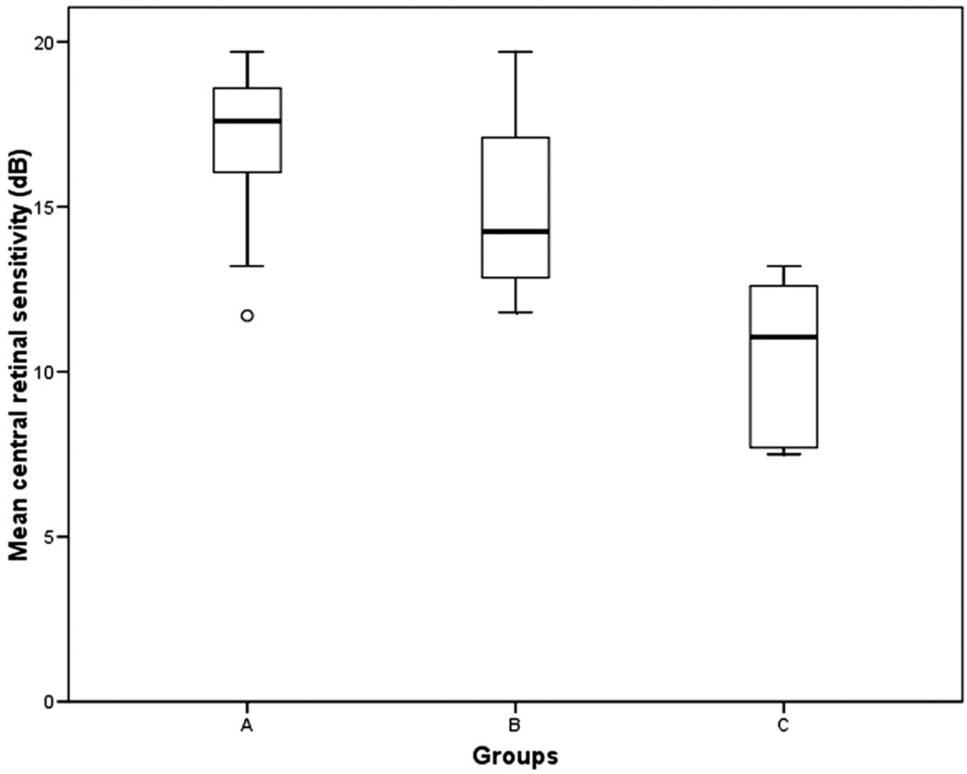


**FIGURE 1. Box plot showing the distribution of central retinal sensitivity measurements in eyes with preserved photoreceptor inner segment/outer segment (IS/OS) junction line and external limiting membrane (ELM) line (group A), in eyes with disrupted IS/OS junction and preserved ELM line (group B), and in eyes with disrupted IS/OS junction and ELM line (Group C).**

tor layer: in detail, 7 eyes (13%) had a disrupted IS/OS junction with an intact ELM line, 1 (2%) had a completely absent IS/OS junction with an intact ELM line, 2 (4%) had disrupted IS/OS junction and ELM line, 4 (7%) had an absent IS/OS junction and disrupted ELM line; no eye had a completely absent ELM line. Spearman regression analysis showed that the degree of integrity of the photoreceptor layer was correlated significantly with BCVA ($r = -0.57$; $P < .001$), total retinal sensitivity ($r = 0.44$; $P = .001$), and central retinal sensitivity ($r = 0.52$; $P < .001$), but not with fixation stability ($P =$ not significant).

Table 2 shows the subgroup analysis of groups A, B, and C according to the integrity of the photoreceptor layer. Mean BCVA, mean central retinal sensitivity, mean total retinal sensitivity, and mean fixation stability were significantly different among the 3 groups. For mean BCVA, mean total retinal sensitivity and mean fixation stability, the values for groups A and B were significantly higher than that for group C ($P < .05$, Tukey–Kramer test), whereas there was no significant difference between groups A and B ($P =$ not significant). The mean central retinal sensitivity in groups A and B was significantly higher than that in group C ($P < .001$, Tukey–Kramer test), and that in group A was significantly higher than that in group B ($P < .05$, Tukey–Kramer test; Figure 1). Examples of OCT and microperimetry findings of the patients in the groups A, B, and C are displayed in Figure 2.

## DISCUSSION

THIS STUDY SHOWED MICROSTRUCTURAL ALTERATIONS IN the photoreceptor layer in 26% of eyes with LMH; such changes were related with both BCVA and retinal sensitivity. The integrity of the photoreceptor layer has been found to correlate with visual acuity changes in patients with a variety of retinal diseases, including macular hole.[8–11] Very limited information is available regarding the foveal photoreceptor layer status in eyes with LMH. In 2 recent studies that evaluated the natural course of LMH and the functional results after surgical treatment, but were not specifically designed to explore the integrity of the photoreceptor layer, thinning and irregularity of the photoreceptor layers in some eyes with LMH were described.[23,24] Michalewska and associates, in a study evaluating the functional and anatomic results of pars plana vitrectomy in LMH, showed a disruption of the IS/OS junction before surgery in 10 (38%) of 26 cases, but the status of the ELM line and the relation between these changes and visual acuity was not assessed.[25]

In our prospective study, aiming to evaluate systematically the integrity of the photoreceptor layer, including both the IS/OS junction and ELM line, SD OCT analysis showed that 40 eyes (74%) had complete integrity of the IS/OS junction and ELM line, and 14 eyes (26%) had partial or complete alteration of the photoreceptor layer.

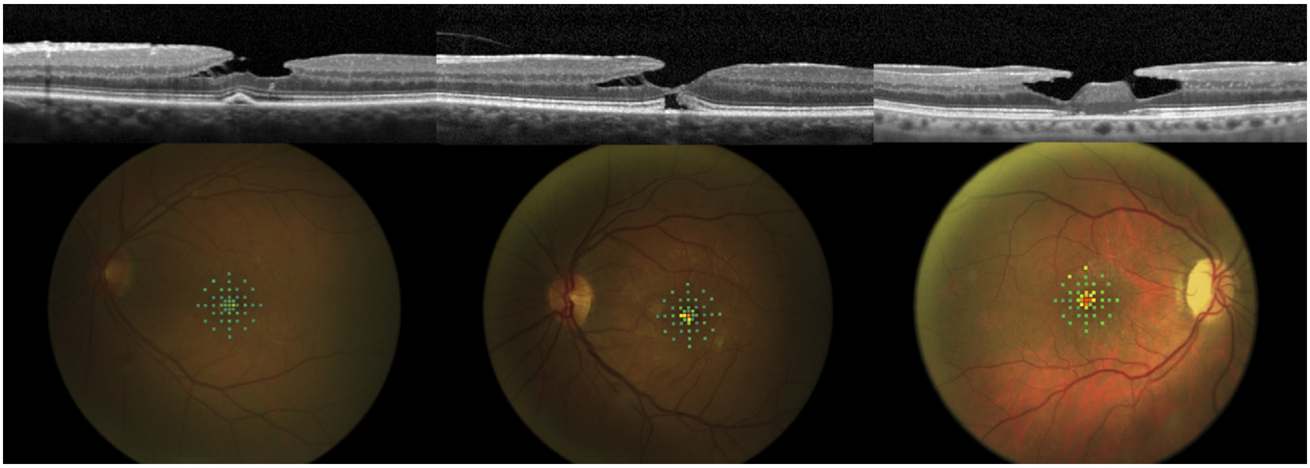

**FIGURE 2.** **Spectral-domain optical coherence tomography (SD OCT) and microperimetry images from patients with lamellar macular hole (LMH). (Left column) Images from the left eye of a 67-year-old woman with LMH: (Top) SD OCT image showing the integrity of the subfoveal photoreceptor inner segment/outer segment (IS/OS) junction line and of the external limiting membrane (ELM) line, and (Bottom) microperimetry image showing a mean retinal sensitivity of 19.6 dB and a fixation stability inside the 2 degrees of 97%. (Middle column) Images from the left eye of a 56-year-old man with LMH: (Top) SD OCT image showing the absence of the subfoveal IS/OS junction and the integrity of the ELM line, and (Bottom) microperimetry image showing a mean central retinal sensitivity of 16.5 dB and a fixation stability inside the 2 degrees of 95%. (Right column) Images from the right eye of a 62-year-old woman with LMH: (Top) SD OCT image showing the absence of the subfoveal IS/OS junction and ELM line, and (Bottom) microperimetry image showing a mean central retinal sensitivity of 12.5 dB and a fixation stability inside the 2 degrees of 87%.**

The current accepted OCT criteria for the diagnosis of LMH are: irregular foveal contour, break in the inner fovea, intraretinal split, and an absence of a full-thickness foveal defect, with intact foveal photoreceptors.[19] The results of our study and of previous studies suggest also considering the status of the photoreceptor layer in LMH.[24,25] The functional impact of LMH actually is quantified by visual acuity, even if this parameter represents just one of the aspects of macular function. Microperimetry is able to quantify foveal and perifoveal retinal sensitivity in an exact fundus-related fashion, thus adding detailed information regarding the degree and pattern of macular functional alteration.[7,8,26–28] In the current study, microstructural alterations in the photoreceptor layer were correlated significantly with BCVA and retinal sensitivity. Results of subgroup analysis showed that BCVA was significantly lower in eyes with disruption of the ELM line, suggesting that this is critical to the maintenance of function.

The finding of disruption of the IS/OS junction and the ELM at the fovea may indicate that morphologic changes in the photoreceptor layer are not limited to the photoreceptor IS/OS junction level, but extend toward the photoreceptor cell bodies and Müller cell cone at the foveola.[29] Indeed, it has been well documented that the back-reflection arising from the IS/OS junction represents the abrupt boundary between the IS structures and the highly organized OS, and the back-reflection from the ELM represents the border between the outermost aspect of the outer nuclear layer composed of photoreceptor cell bodies and the photoreceptor IS myoid portion.[29] In contrast, the finding of a disrupted IS/OS junction with an intact ELM presumably indicates that the morphologic changes in the photoreceptor layer are limited to the photoreceptor IS/OS junction level and do not extend to the cell bodies.[29]

Interestingly, only central retinal sensitivity was significantly different between the group with a preserved IS/OS junction and ELM and the group with disruption of the IS/OS junction only, suggesting that microperimetry is sensitive in identifying early morphologic alteration of the photoreceptor layer before BCVA is impaired.

An important consideration, given the growing literature regarding the photoreceptor layer, is how to evaluate disruption objectively and consistently. Currently, few data are available to address this issue. Most studies used trained observers to evaluate the IS/OS layer in a manner similar or identical to that used in this study.[14,30–35] In an effort to substantiate the reliability of grading in our study, all scans were graded in a masked fashion, and the reliability of IS/OS junction and ELM line grading between observers was determined with weighted κ statistics and ICCs. The κ statistic is a measure of intergrader concordance on categorical scales and adjusts for chance agreement.[36] The ICC is a separate measure of correlation between graders that takes into account the differences in individual ratings.[36] Previous studies have suggested that these 2 statistics provide 2 different types of information regarding agreement, and both were used to increase the confidence in our assessments.[21,36] The results of our study show excellent repeatability and suggest that this method could be an objective way to analyze the IS/OS junction line, as previous suggested,[21] and also the ELM line.

The progression of LMH usually is very slow.[23] Consequently, surgical treatment remains controversial, and some authors believe that there is no proof that surgical intervention is helpful,[4,37] whereas other studies have found vitrectomy with epiretinal membrane and internal limiting membrane removal to be beneficial with respect to the BCVA result and foveal OCT appearance.[19,24,37–39] The morphologic evaluation of the photoreceptor layer together with the assessment of the central retinal sensitivity allow longitudinal assessment of the LMH with early identification of morphologic and functional changes. Preservation of the ELM seems to be important in the potential preservation of visual acuity.

Limitations of this study include the small sample size and the subjective evaluation of the findings on SD OCT.

In conclusion, foveal photoreceptor layer integrity evaluated by SD OCT is closely associated with BCVA and retinal sensitivity in patients with LMH. Prospective studies are needed to understand better the morphologic and functional changes associated with LMH surgery.

ALL AUTHORS HAVE COMPLETED AND SUBMITTED THE ICMJE FORM FOR DISCLOSURE OF POTENTIAL CONFLICTS OF interest and the following were reported. Francesco Boscia has served as consultant for Alcon, Allergan, Bayer, and Novartis. The remaining authors have no financial interest to disclose. Involved in Design of study (M.R., M.P., M.V., A.L., T.A., M.G.U., F.B., C.M., A.R.); Conduct of study (M.R., M.P., M.V., A.L., M.Z., M.T., B.B., A.C.); Collection of data (M.R., M.P., M.V., M.Z., M.T., B.B., A.C.); Management of data (M.R., M.P., M.V., A.L., T.A., M.G.U., F.B., C.M., A.R.); Analysis of data (M.R., M.P., M.V., A.L., M.Z., M.T., F.B., F.B., A.C., C.M.); Interpretation of data (M.R., M.P., M.V., A.L., T.A., M.G.U., F.B., C.M., A.R.); Preparation of manuscript (M.R., M.P., M.V., A.L., A.C., C.M., A.R.); Review of manuscript (M.R., M.P., M.V., A.L., T.A., M.G.U., M.Z., M.T., F.B., C.M., A.R.); and Approval of manuscript (M.R., M.P., M.V., A.L., T.A., M.G.U., M.Z., M.T., F.B., B.B., A.C., C.M., A.R.). The present prospective study followed the tenets of Declaration of Helsinki and was approved by the institutional review board of the centers (i.e., Azienda ospedaliero-universitaria "Policlinico Vittorio-Emanuele," Catania, Italy, and G. B. Bietti Eye Foundation-IRCCS, Rome, Italy). All patients gave informed consent to participate in this research study. The authors thank Rhana Pike for editing the final draft of the manuscript.

## REFERENCES

1. Gass JD. Lamellar macular hole: a complication of cystoid macular edema after cataract extraction: a clinicopathologic case report. *Trans Am Ophthalmol Soc* 1975;73:231–250.
2. Takahashi H, Kishi S. Tomographic features of a lamellar macular hole formation and a lamellar hole that progressed to a full-thickness macular hole. *Am J Ophthalmol* 2000; 130(5):677–679.
3. Haouchine B, Massin P, Gaudric A. Foveal pseudocyst as the first step in macular hole formation: a prospective study by optical coherence tomography. *Ophthalmology* 2001;108(1): 15–22.
4. Haouchine B, Massin P, Tadayoni R, Erginay A, Gaudric A. Diagnosis of macular pseudoholes and lamellar macular holes by optical coherence tomography. *Am J Ophthalmol* 2004; 138(5):732–739.
5. Ko TH, Fujimoto JG, Schuman JS, et al. Comparison of ultrahigh- and standard-resolution optical coherence tomography for imaging macular pathology. *Ophthalmology* 2005; 112(11):1922.e1–e15.
6. Scholda C, Wirtitsch M, Hermann B, et al. Ultrahigh resolution optical coherence tomography of macular holes. *Retina* 2006;26(9):1034–1041.
7. Gloesmann M, Hermann B, Schubert C, et al. Histologic correlation of pig retina radial stratification with ultrahigh-resolution optical coherence tomography. *Invest Ophthalmol Vis Sci* 2003;44(4):1696–1703.
8. Chang LK, Koizumi H, Spaide RF. Disruption of the photoreceptor inner segment-outer segment junction in eyes with macular holes. *Retina* 2008;28(7):969–975.
9. Eandi CM, Chung JE, Cardillo-Piccolino F, Spaide RF. Optical coherence tomography in unilateral resolved central serous chorioretinopathy. *Retina* 2005;25(4):417–421.
10. Hayashi H, Yamashiro K, Tsujikawa A, Ota M, Otani A, Yoshimura N. Association between foveal photoreceptor integrity and visual outcome in neovascular age-related macular degeneration. *Am J Ophthalmol* 2009;148(1):83–89.
11. Sakamoto A, Nishijima K, Kita M, Oh H, Tsujikawa A, Yoshimura N. Association between foveal photoreceptor status and visual acuity after resolution of diabetic macular edema by pars plana vitrectomy. *Graefes Arch Clin Exp Ophthalmol* 2009;247(10):1325–1330.
12. Nussenblatt RB, Kaufman SC, Palestine AG, Davis MD, Ferris FL 3rd. Macular thickening and visual acuity: measurement in patients with cystoid macular oedema. *Ophthalmology* 1987;94(9):1134–1139.
13. Larsson J, Zhu M, Sutter F, Gilles MC. Relation between reduction of foveal thickness and visual acuity in diabetic macular oedema treated with intravitreal triamcinolone. *Am J Ophthalmol* 2005;139(5):802–806.
14. Dunavoelgyi R, Sacu S, Simader C, Pruente C, Schmidt-Erfurth U. Changes in macular sensitivity after reduced fluence photodynamic therapy combined with intravitreal triamcinolone. *Acta Ophthalmol* 2009;89(2):166–171.
15. Vujosevic S, Bottega E, Casciano M, Pilotto E, Convento E, Midena E. Microperimetry and fundus autofluorescence in diabetic macular edema: subthreshold micropulse diode laser versus modified early treatment diabetic retinopathy study laser photocoagulation. *Retina* 2010;30(6):908–916.
16. Reibaldi M, Boscia F, Avitabile T, et al. Functional retinal changes measured by microperimetry in standard-fluence vs low-fluence photodynamic therapy in chronic central serous chorioretinopathy. *Am J Ophthalmol* 2011;151(6): 953–956.
17. Springer C, Bültmann S, Völcker HE, Rohrschneider K. Fundus perimetry with the Micro Perimeter 1 in normal individuals: comparison with conventional threshold perimetry. *Ophthalmology* 2005;112(5):848–854.
18. Midena E, Radin PP, Pilotto E, Ghirlando A, Convento E, Varano M. Fixation pattern and macular sensitivity in eyes with subfoveal choroidal neovascularization secondary to

age-related macular degeneration. A microperimetry study. *Semin Ophthalmol* 2004;19(1–2):55–61.
19. Witkin AJ, Ko TH, Fujimoto JG, et al. Redefining lamellar holes and the vitreomacular interface: an ultrahigh-resolution optical coherence tomography study. *Ophthalmology* 2006;113(3):388–397.
20. Otani T, Kishi S. Tomographic findings of foveal hard exudates in diabetic macular edema. *Am J Ophthalmol* 2001; 131(1):50–54.
21. Maheshwary AS, Oster SF, Yuson RM, Cheng L, Mojana F, Freeman WR. The association between percent disruption of the photoreceptor inner segment-outer segment junction and visual acuity in diabetic macular edema. *Am J Ophthalmol* 2010;150(1):63–67.
22. Theodossiadis PG, Theodossiadis GP, Charonis A, Emfietzoglou I, Grigoropoulos VG, Liarakos VS. The photoreceptor layer as a prognostic factor for visual acuity in the secondary epiretinal membrane after retinal detachment surgery: imaging analysis by spectral-domain optical coherence tomography. *Am J Ophthalmol* 2011;151(6):973–980.
23. Theodossiadis PG, Grigoropoulos VG, Emfietzoglou I, et al. Evolution of lamellar macular hole studied by optical coherence tomography. *Graefes Arch Clin Exp Ophthalmol* 2009; 247(1):13–20.
24. Casparis H, Bovey EH. Surgical treatment of lamellar macular hole associated with epimacular membrane. *Retina* 2011; 31(9):1783–1790.
25. Michalewska Z, Michalewski J, Odrobina D, et al. Surgical treatment of lamellar macular holes. *Graefes Arch Clin Exp Ophthalmol* 2010;248(10):1395–1400.
26. Varano M, Scassa C. Scanning Laser Ophthalmoscope Microperimetry. *Semin Ophthalmol* 1998;13(4):203–209.
27. Schneider U, Inhoffen W, Gelisken F, Kreissig I. Assessment of visual function in choroidal neovascularization with scanning laser microperimetry and simultaneous indocyanine green angiography. *Graefes Arch Clin Exp Ophthalmol* 1996; 234(10):612–617.
28. Tezel TH, Del Priore LV, Flowers BE, et al. Correlation between scanning laser ophthalmoscope microperimetry and anatomic abnormalities in patients with subfoveal neovascularization. *Ophthalmology* 1996;103(11):1829–1836.
29. Wakabayashi T, Oshima Y, Fujimoto H, et al. Foveal microstructure and visual acuity after retinal detachment repair: imaging analysis by Fourier-domain optical coherence tomography. *Ophthalmology* 2009;116(3):519–528.
30. Murakami T, Tsujikawa A, Ohta M, et al. Photoreceptor status after resolved macular edema in branch retinal vein occlusion treated with tissue plasminogen activator. *Am J Ophthalmol* 2007;143(1):171–173.
31. Piccolino FC, de la Longrais RR, Ravera G, et al. The foveal photoreceptor layer and visual acuity loss in central serous chorioretinopathy. *Am J Ophthalmol* 2005;139(1):87–99.
32. Sandberg MA, Brockhurst RJ, Gaudio AR, Berson EL. The association between visual acuity and central retinal thickness in retinitis pigmentosa. *Invest Ophthalmol Vis Sci* 2005; 46(9):3349–3354.
33. Schocket LS, Witkin AJ, Fujimoto JG, et al. Ultrahigh-resolution optical coherence tomography in patients with decreased visual acuity after retinal detachment repair. *Ophthalmology* 2006;113(4):666–672.
34. Otani T, Kishi S. Tomographic findings of foveal hard exudates in diabetic macular edema. *Am J Ophthalmol* 2001; 131(1):50–54.
35. Oster S, Mojana F, Brar M, Yuson RM, Cheng L, Freeman WR. Disruption of the photoreceptor inner segment/outer segment layer on spectral domain optical coherence tomography is a predictor of poor visual acuity in patients with epiretinal membranes. *Retina* 2010;30(5):713–718.
36. Joeres S, Tsong JW, Updike PG, et al. Reproducibility of quantitative optical coherence tomography subanalysis in neovascular agerelated macular degeneration. *Invest Ophthalmol Vis Sci* 2007;48(9):4300–4307.
37. Kokame GT, Tokuhara KG. Surgical management of inner lamellar macular hole. *Ophthalmic Surg Lasers Imaging* 2007; 38(1):61–63.
38. Garretson BR, Pollack JS, Ruby AJ, Drenser KA, Williams GA, Sarrafizadeh R. Vitrectomy for a symptomatic lamellar macular hole. *Ophthalmology* 2008;115(5):884–886.
39. Hirakawa M, Uemura A, Nakano T, et al. Pars plana vitrectomy with gas tamponade for lamellar macular holes. *Am J Ophthalmol* 2005;140(6):1154–1155.

## Biosketch

Michele Reibaldi, MD, is an Assistant Professor in the Department of Ophthalmology at the University of Catania, Italy. He received his medical degree from University of Catania in 2000. He completed his general ophthalmology residency and his PhD at the University of Bari, Italy. Dr Reibaldi has authored several publications in peer-reviewed journals. His clinical and research interests include diseases and surgery of the retina and vitreous.