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ORIGINAL RESEARCH ARTICLE

Macular hole surgery: the healing process of outer retinal layers to visual acuity recovery

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ABSTRACT

Purpose: To evaluate optical coherence tomography (OCT) modifications of outer retinal layers as determinants for functional recovery after surgery for idiopathic macular hole (IMH).

Methods: This prospective study included 23 eyes of 23 consecutive patients who underwent vitreoretinal surgery for IMH. We excluded patients with other retinal diseases. Baseline and follow-up evaluations at months 3 and 6 included complete ophthalmologic and instrumental evaluations. Functional evaluation was performed by Best Corrected Visual Acuity (BCVA) and Amsler test. Morphologic evaluation was performed by spectral-domain 3D-OCT (Topcon, Tokyo, Japan) for a deep analysis of retinal layers as well as central retinal thickness evaluation. A standard 23-G or 25-G vitreoretinal surgery was performed, completed by posterior hyaloid and inner limiting membrane peeling by means of vital dyes and gas tamponade. Statistical analysis was performed on collected data.

Results: The mean BCVA increased significantly from 0.57 ± 0.25 logMAR at baseline to 0.34 ± 0.22 logMAR at month 6. Intraretinal layers modification showed a progressive recomposition of inner segment/outer segment layer in 91% of patients at month 6. Retinal layers recomposition showed a progressive increase in all patients during follow-up from the immediate postoperative control to the last 6-month visit.

Conclusions: Optical coherence tomography examination appears useful to investigate visual recovery after macular hole surgery. To ensure postsurgical functional increase, recomposition of all retinal layers, in particular in the outer retina, is mandatory. This process could be slow and not immediately observable during follow-up examinations.

Keywords: Idiopathic macular hole, Macular surgery, Optical coherence tomography, Outer retinal layers

Introduction

Idiopathic macular hole (IMH) is one of the most important vitreoretinal disorders responsible for metamorphopsia and poor central vision in the elderly. Idiopathic macular holes are more common in women and the estimated incidence is reported to be 7.8/100,000 per year (1, 2). Kelly and Wendel first reported the successful closure of IMH with pars plana vitrectomy and fluid-gas exchange in 1991 (3). Nowadays, improvements in imaging resolution and acquisition of optical coherence tomography (OCT) have made it possible to study inner retinal changes after surgery and to correlate better the morphology with the improvement of visual acuity (VA). It is now possible to identify preoperative predictive factors for functional outcomes following IMH surgery (4).

The aim of our study was to describe the restoration of outer retinal layers from external limiting membrane (ELM), inner segment/outer segment junction (IS-OS), and cone outer segment tips (COST) to retinal pigment epithelium (RPE) after IMH surgery and its relation to visual acuity (VA).

Methods

In this prospective study, 23 eyes of 23 patients (8 men and 15 women, mean age at diagnosis 70.17 years [range 62-84]) were recruited consecutively at the Ophthalmology Clinic, Department of Surgical and Morphological Sciences, University of Insubria-Varese, Italy. We selected all patients who

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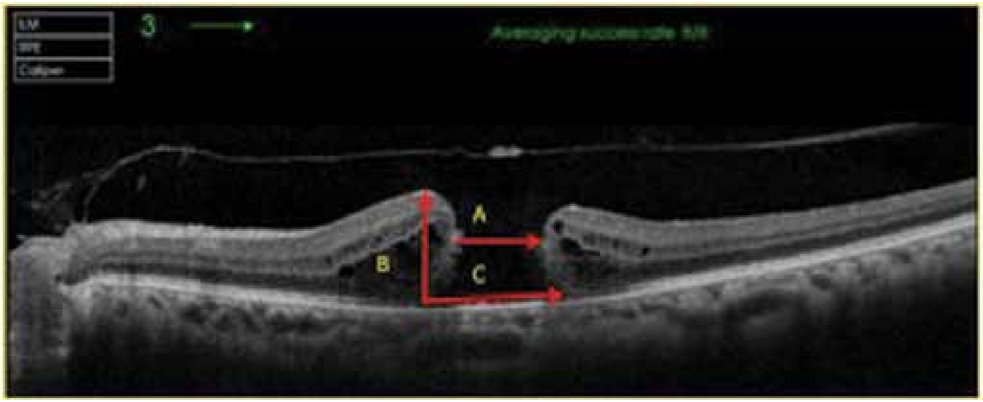

Fig. 1 - Baseline evaluation of optical coherence tomography B-scan of idiopathic macular hole. (**A**) Minimum hole diameter. (**B**) Height of the hole. (**C**) Basal diameter.

preoperatively complained of reduced VA and metamorphopsia associated with a diagnosis of IMH by funduscopic examination, confirmed by spectral-domain OCT (SD-OCT). Exclusion criteria were any type of previous laser or surgical macular treatments (including intravitreal injections of drugs), ischemic maculopathy, vascular retinopathies, glaucoma, or high myopia (>6 D). All patients signed written informed consent before inclusion in the study, including consent for surgery. This study was conducted in accordance with the tenets of the Declaration of Helsinki.

Patients were examined at baseline and postoperatively at 1, 3, and 6 months of follow-up. The functional examination included Best Corrected Visual Acuity (BCVA) and Amsler grid. Morphologic examination included fundus biomicroscopy and SD-OCT (3D-OCT TOPCON 2000, Tokyo, Japan). Spectral-domain OCT examination was performed preoperatively to evaluate the stage of the IMH according to the International Vitreomacular Traction Study Group Classification (5). Patients were divided into 3 groups: group A (small IMHs), 7 eyes; group B (medium IMHs), 9 eyes; and group C (large IMHs), 7 eyes.

Each OCT B-scan was studied by 2 different expert examiners (S.M.C. and S.D.). Minimum hole diameter (a), height (b), and base (c) value of macular hole were measured. Macular hole index, defined as the ratio of the hole height to the basal hole diameter (b/c), was evaluated (Fig. 1). High-resolution B-scan cross-line protocol allowed to evaluate the presence/absence of IS-OS line and COST line on the fovea and its modifications from baseline to follow-up visits.

All patients underwent 3-port pars plana vitrectomy by 23-G or 25-G sutureless technique (Constellation Vision System, Alcon, Fort Worth, TX, USA) performed by the same surgeon (C.A.). After the induction of posterior vitreous detachment, a complete vitrectomy was performed, completed by triamcinolone vitreal staining (Vitreal S, SOOFT, Rome, Italy) to identify posterior hyaloid macular or papillary adherence. Inner limiting membrane (ILM) was identified and peeled with intraocular forceps from the center macula by means of Brilliant Peel staining (Geuder, Heidelberg, Germany). Light beam was maintained focused in fovea the minimum time needed, reducing the light intensity (6). At the end of the surgery in all patients 20% SF_6 gas (7) was injected and face-down posturing was maintained for 3 days after surgery.

Statistical analysis was performed applying student *t* test and a significance of p≤0.05 was considered for compared data.

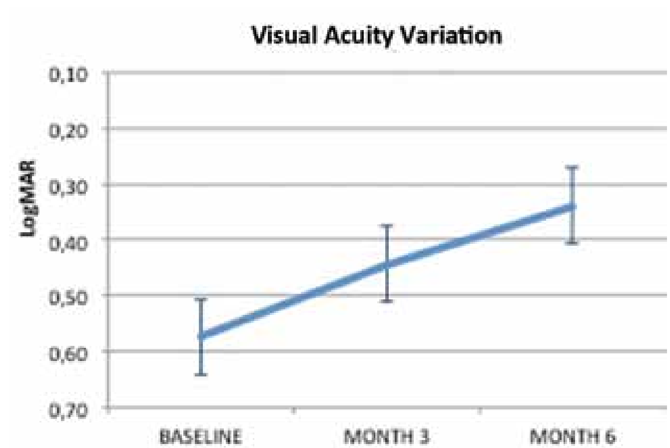

Fig. 2 - Visual acuity variation.

Results

Mean BVCA was 0.57 ± 0.25 logMAR at baseline, 0.44 ± 0.22 logMAR at month 3, and 0.34 ± 0.22 logMAR at month 6 (Fig. 2). All but 1 eye presented a complete closure of macular hole after the surgery, maintained until the end of follow-up.

At month 3 and at month 6 follow-up, OCT B-scan showed the recomposition of IS-OS band and COST line in the foveal region. At month 3 after surgery, IS-OS band and COST line integrity were present in 53.5% of patients; at month 6, IS-OS band and COST line recomposition were evident in 73.91% of patients (Fig. 3). In three patients, in the outer retinal layers, we observed the presence of an irregular line with lack of restoration of the IS-OS band and COST line and some hyperreflective spots corresponding to glial proliferation (Fig. 4).

No significant or substantial differences were reported among different groups, due to the small numbers of cohorts.

Discussion

Idiopathic macular hole is an anatomic defect in the fovea characterized by an interruption of all neural retinal layers from the ILM to the RPE. Gass (8, 9) published the first classification of this macular disease in the 1990s. It was a biomicroscopic classification integrated in the following years by OCT classification, following the introduction and the develop-

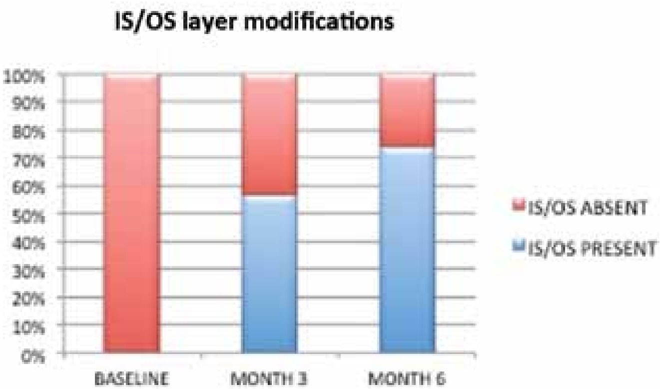

Fig. 3 - Recomposition of inner segment/outer segment junction band during follow-up.

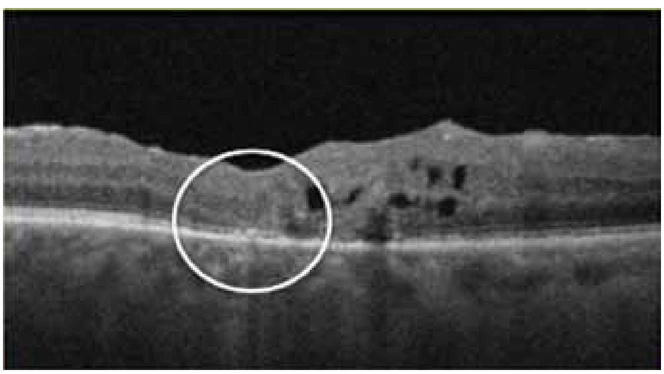

Fig. 4 - Glial proliferation after macular hole surgery. The inner segment/outer segment junction band and cone outer segment tips line in the foveal region are not visible.

ment of this technology and diagnostic software (10, 11). A panel of experts recently revised and published a new classification based on SD-OCT imaging, based on the experiences of clinical studies for ocriplasmin. They divided IMHs into 3 groups according to the minimum hole diameter measured by OCT: small IMH with an aperture size less than 250 µm, medium IMH with an aperture size between 250 and 400 µm, and large IMH with an aperture size more than 400 µm (5).

At the same time, the recent rapid development of OCT imaging technology has allowed obtaining images with a very high resolution. These features defined and recognized better and complete correspondences between OCT B-scans and histologic retinal layers. In particular, it is possible to study in detail outer retinal layers divided into 4 lines/bands; the presence of all 4 bands is correlated with good VA (12).

The first band seems to originate from the ELM, which is an assembly of junctional complexes between Muller cells and photoreceptors. The second band is often referred to as the IS-OS boundaries of the photoreceptors. The third band has been referred to as COST (13, 14), intermediate line (15), or the Verhoeff membrane (16). The fourth band represents the RPE. Spaide and Curcio (17) suggested that part of the fourth band is contributed by the Bruch membrane and the choriocapillaris.

The importance of the integrity of the IS-OS band has been underlined in many clinical studies and its integrity

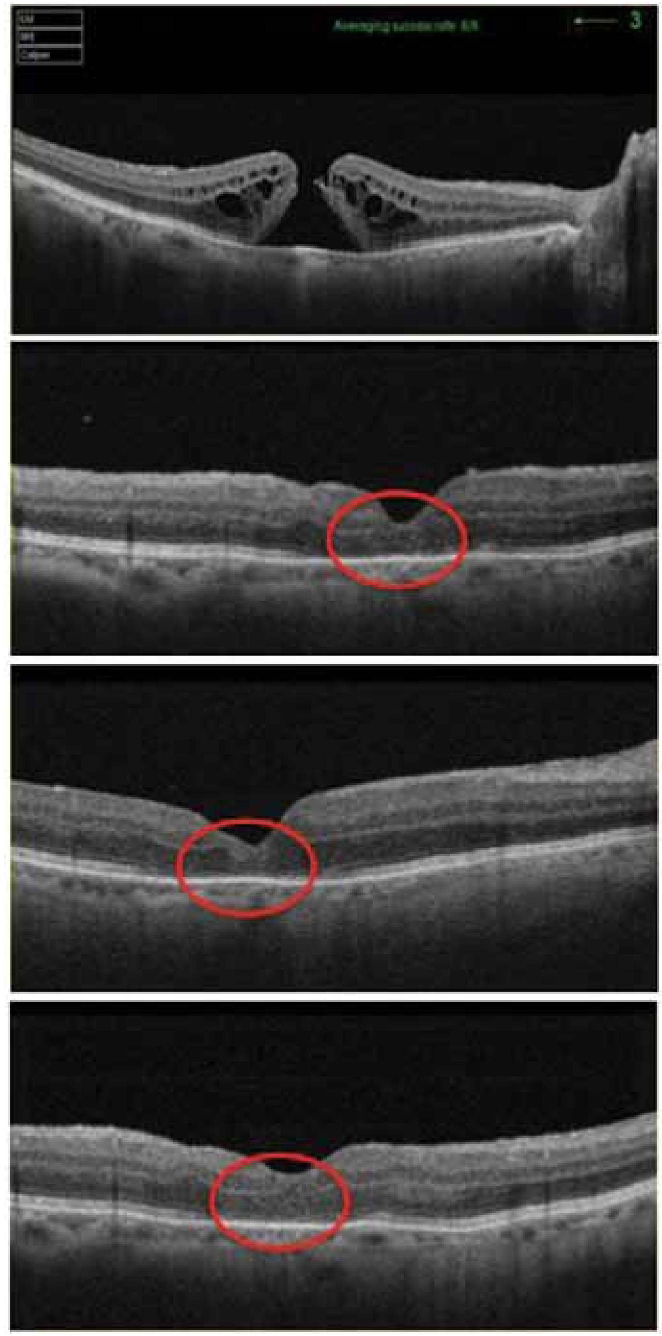

Fig. 5 - From above. Recomposition of outer retinal layers during follow-up. The healing process drives a progressive functional recovery.

seems to represent the normal alignment of the photoreceptors, which is essential for normal visual function (18). Several studies also found a correlation in terms of visual improvement to the presence of COST line after treatments for different types of macular diseases. Overall, the presence of all 4 bands is correlated with good VA (19-23).

In our study, we investigated the repair processes of IMH after surgery by means of OCT technology (Fig. 5). The first line appearing at month 1 follow-up is the ELM. The IS-OS

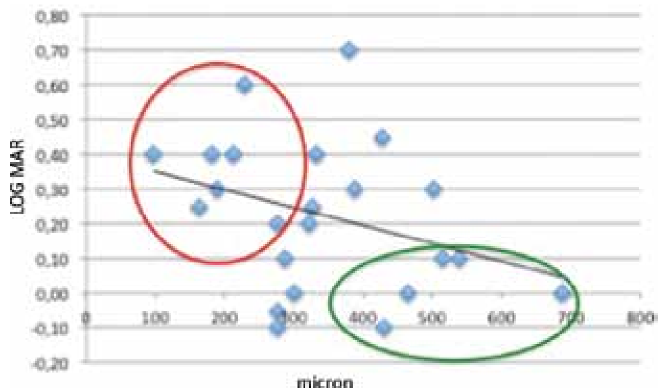

Fig. 6 - Correlation between best-corrected visual acuity variation and minimum hole diameter of idiopathic macular hole.

band is evident at month 3 in 53.3% of patients, related to a significant improvement in BCVA. This underlines the correlation between restoration and integrity of IS-OS band and VA increase (24-26). The IS-OS band was present at month 6 in 73.91% of patients with a further improvement of the BCVA. The complete restoration of COST line was seen only at month 6 in 5 patients; these patients presented a small IMH at baseline, and they had the best recovery of visual function at month 6 (27, 28).

Moreover, we correlated the variation of BCVA with the minimum diameter of the hole, and showed an inverse correlation between the dimension of macular hole and the final BCVA, underling the importance of a complete outer layer recomposition (Fig. 6).

On the other hand, our study revealed that anatomical closure of IMH did not always correspond with functional success. In 26.09% of patients, during the follow-up, OCT images showed absence of the IS-OS band with a low recovery of BCVA. Optical coherence tomography imaging revealed that the foveal defect was filled with hyperreflective lesions, instead of the recomposition of 4 bands in the outer retina (Fig. 4). These lesions were thought to be glial cell complexes that proliferate in excess as part of the healing process. Some authors suggest that successful restoration of foveal integrity relies on the balance between glial cell proliferation and centripetal reapproximation of the photoreceptors: if the photoreceptors reapproximate appropriately, integrity and proper alignment could be restored. If the glial proliferation process is faster than photoreceptor reapproximation, glial cells fill the foveal defect, and prevent further healing approximation of the photoreceptors. In this case, IS-OS line could not be completely restored (20, 23, 27-30).

This study has some limitations. First, there is a small number of participants, preventing statistical analysis among groups. The second limitation is related to the OCT study of outer retina during follow-up. The presence or the absence of the IS-OS band and the COST line were investigated by a subjective method that could create bias. However, our images were studied by 2 expert readers (S.D. and S.M.C.) and then compared. Automatic software that could recognize each retinal layer is not yet available. Recent SD-OCT instruments recognize ILM and RPE, to measure retinal thickness, ganglion cell layer, and retinal nerve fiber layer to calculate ganglion cell complex thickness.

In conclusion, SD-OCT allows evaluation of the healing process of foveal defect in IMHs. The restoration of IS-OS band and COST line in the early postsurgical period may reflect structural and functional recovery of the photoreceptors after macular hole surgery. More studies are necessary to define a good correlation with the improvement in VA.

Disclosures

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Conflict of interest: None of the authors has conflict of interest with this submission.

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