Timing of vitrectomy in myopic traction maculopathy: A long term follow up report of a hispanic population

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Abstract: Objective: To report the anatomic and functional outcomes in patients undergoing vitreous surgery for myopic traction maculopathy (MTM). This was a long-term follow-up study to determine the prevalence in fellow eyes.
Methods: A retrospective, comparative series of consecutive eyes that underwent macular surgery to treat MTM was performed; eyes were divided by groups (single eyes, first and fellow eyes). The preoperative and final best corrected visual acuity (BCVA) values were compared between groups and stages (one-way ANOVA) and within each group or stage (paired t-test). The fellow eye prevalence was identified.
Results: Sixty eyes of 39 patients, including 21 (53.85%) with bilateral disease, were included. Three eyes were in stage I (5.0%), 26 in stage II (43.33%), ten in stage III (16.67%), and 21 in stage IV (35.0%). The BCVA improved within each group or stage. The best results were obtained in fellow eyes. The results did not differ according to surgery variant, tamponade or the number of procedures.
Conclusion: Surgery improved the BCVA in eyes with all the stages of MTM. The final BCVA was better in cases that received surgery early. To improve functional results, reinforcing the detection of bilateral disease is necessary due to its frequency.

Keywords: Retina surgery, macula surgery, Spectral domain optical coherent tomography,

Introduction

High myopia is defined as an ocular axial length >26.5 mm.[1] Variations in the globe shape induced by pathologic myopia are responsible for the macular alterations; over time, these cause vision loss in high myopia.[2]

Myopic traction maculopathy (MTM) exists in the presence of posterior staphyloma (PS); Spaide defined PS as “an outpouching of the wall of the eye that has a radius of curvature that is less than the surrounding curvature of the wall of the eye”. Optical coherence tomography (OCT) is a non-invasive imaging tool that has improved our ability to detect changes at different levels of the posterior pole (PP). Longer wavelength (1.050–1.060 nm), deep penetrance swept-source (SS)-OCT offers clear visualization of the sclera and orbital fat tissue, thus facilitating morphological analysis of the PP.[3]

MTM was first described by Panozzo and Mercanti in 2004.[4] The presence of PS in highly myopic eyes plays a key role in the development of MTM, because the retina cannot match the scleral outpouching of the PP due to its greater rigidity. This Rigidity may be caused by vascular rigidity, epiretinal membranes (ERMs), vitreomacular traction (VMT) syndrome, vitreous remnants, or it may be due to the fact that retina, its vessels, and internal limiting membrane (ILM) seem to be less elastic than the surrounding tissues.[5]

The prevalence of myopic foveoschisis (MF) as the earliest stage of MTM is 9-34% in patients with pathological myopia; First described by Phillips in 1958, MF involves a progressive separation of retinal layers, which remain connected by Müller cells.[6]

Although MF may remain stable during long periods, it is considered a condition that slowly progresses to foveoretinal detachment (FRD) or macular hole (MH) formation without or with retinal detachment (RD) as a part of its natural history.[7] We report the anatomic and functional outcomes of vitreous surgery in a sample of Hispanic patients with MTM, compared by stage and timing.

Methods

Study Design

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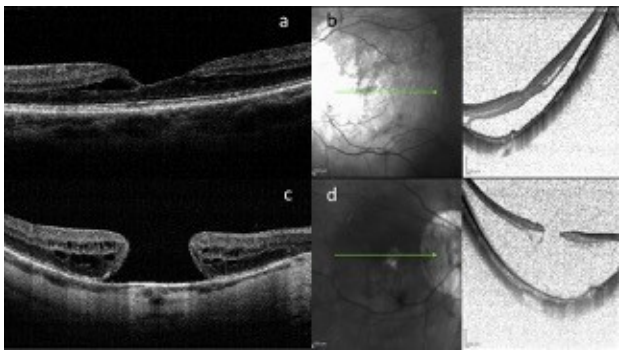

Figure 1. Stages of myopic traction maculopathy. (a) myopic foveoschisis (MF); (b) foveoretinal detachment (FRD); (c) myopic macular hole (MMH); (d) Macular hole associated with retinal detachment (MHRD).

Sixty consecutive, symptomatic highly myopic eyes with posterior staphyloma of 39 patients, 10 (25.64%) men and 29 (74.36%) women who had undergone vitreous surgery for MTM were retrospectively analyzed at the Retina Service of Retina Specialist SC at The American British Cowdray Hospital in Mexico City, from August 2001 to February 2020. This study was approved by the institutional review board. Eyes with an axial length >26.5 mm, a diagnosis of MTM confirmed with SD-OCT, a follow-up period of at least 6 months were included. Eyes with patchy foveal-affected chorioretinal atrophy or diffuse macular chorioretinal atrophy were not included.

Eyes were divided in three groups. 18 patients (30.0%) with only one eye affected were the single eye group. Twenty-one patients had both eyes involved; thus, 21 eyes (35.0%) were included in the first eye group, and 21 eyes (35.0%) were included in the fellow eye group.

All eyes were characterized into four stages according with the following SD-OCT findings: Stage I, Myopic foveoschisis (MF Group). Eyes with macular thickening due to internal or external foveoschisis or hyporeflective splitting between the thin and faintly reflective outer and the thicker, more reflective inner retina with column-like formations across the hyporeflective space but without FRD as a main characteristic, even though these eyes can depict posterior hyaloid remnants or the presence of ERMs. (**Figure 1, a**) Stage II, Foveoretinal detachment (FRD) group. Eyes that exhibit FRD as the main SD-OCT characteristic. (**Figure 1, b**) Stage III, myopic macular hole (MMH) group. Eyes with tomographic evidence of a full-thickness MH as the main tomographic sign without tomographic evidence of macular detachment. (**Figure 1, c**). Stage IV, macular hole retinal detachment (MHRD) group. Extension of extramacular RD defined by the number of retinal quadrants involved. (**Figure 1, d**)

Examination

All patients underwent general ophthalmic examination, best-corrected visual acuity (BCVA), biomicroscope slit lamp, assessment, contact lens fundus examination and indirect ophthalmoscopy. Cross-sectional images were acquired along horizontal and vertical planes through the foveal center with SD-OCT (Ret-vue-3.4 OCT, Optovue Inc. Fremont, CA. USA), SD-OCT (Spectralis OCT, Heidelberg Engineering. Germany), and with the Swept Source DRI OCT Triton (Topcon Medical Systems, Inc.) since 2019. The axial lengths were measured by Coherent Laser Interferometry (Zeiss IOL Master 500, 700; Carl Zeiss AG, Oberkochen, Germany) in 57 eyes (95.0%).

Surgical Procedures

A standard 23-,25-gauge vitrectomy was performed under local anesthesia by one of the authors (MAQR). After core vitrectomy and triamcinolone assisted (Kenalog 40 mg/mL, Bristol-Myers, NY) removal of cortical vitreous, macular surgery was performed using trypan blue 0.15% solution (Membrane Blue, Dutch Ophthalmic USA) to stain vitreous remnants and EMRs or 0.15 ml of 0.25 mg/ml (0.025%) solution (pH 7.4) of BBG dye to peel the ILM. Foveal-sparing ILM and inverted-flap ILM techniques were used. As tamponades, 20% SF6, 15% C3F8 or silicon were used.

The main anatomical and functional logMAR outcomes, number and type of procedure, and incidence of complications were analyzed. Anatomical success was defined by disappearance of foveoschisis, closure of the retinal hole or reattachment of the macula and retina. All eyes were followed-up for more than six months and examined between four to twelve months until the last follow-up visit.

Statistical Analysis

Values are presented as the means ± standard deviation. The Preoperative BCVA was compared with the final postoperative BCVA using a paired t-test; one-way ANOVA with post hoc Tukey's test and independent samples t-test were used for intergroup

Variable	Mean	Standard deviation
Age (years)	59.43	8.96
Axial length (mm)	29.00	5.54
Follow-up (months)	68.60	48.40
Preoperative BCVA (logMAR)	1.29	0.54
Final BCVA (logMAR)	0.56	0.43
	n	%
Female gender	29	74.36
Right eye	29	48.3
Phakic	31	51.7
Tamponade		
Gas	39	65.0
Silicon	21	35.0
Additional surgery	19	31.7
Complications	6	10.0

Table 1. General data in the sample (n=60 eyes).

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comparisons. Changes in the mean BCVA were compared between groups, stages, and type of tamponade. Data was stored and analyzed in the SPSS for Windows software, and $p<0.05$ was accepted as statistically significant.

Results

The mean age was 59.43 years; **Table 1** shows general data. Sixty eyes of 39 patients, 29 female patients (74.56%) y 10 male patients (25.65%), 31 eyes (51.67%) were phakic and 29 eyes (48.33%) were pseudophakic. 21 patients (53.85%) with bilateral myopic traction maculopathy and 18 patients (46.15%) with monocular condition. The stage of surgical intervention in the general group was as follow: Stage 1 group, three eyes (5.0%); stage II group 26 eyes (43.33%); stage III group, 10 eyes (16.67%) and stage IV group, 21 eyes (35.0%). Ten eyes in stage IV had an MHRD limited to the PP, seven had up to two, three had up to three, and one eye had a total detachment. Coherence laser interferometry mean axial length was 29.89±1.67mm (range of 27.19 mm to 33.32mm). 19 eyes (31.67%) underwent more than one surgical procedure. In 6 out of 60 eyes (10.33%) more than one complication was identified. The prevalence in the fellow eye was of 53.85% and the mean time period for surgery on the second eye was of 43±26.77 months (range from 2 to 99 months).

The mean observation time was 68.6 months; twenty-one patients (53.8%) developed bilateral disease. The annual incidence in the fellow eye was 0.1591. This means that every year, in a group of 100 patients with the disease in one eye, 15.91 will develop some degree of MTM in the contralateral eye, 47.73 contralateral eyes will develop some initial OCT signs of the condition in five years, so this is what we called cumulative annual eye risk. The stage in fellow eyes was I in two (9.52 %), II in 16 (76.19%), and III in 3 (14.29%). Only two fellow eyes (9.52%) required additional surgery.

Variable	Preoperative	Final	*p**
Stage			
I	0.86 ± 0.15	0.34 ± 0.11	0.075
II	0.91 ± 0.18	0.28 ± 0.18	< 0.001
III	1.26 ± 0.46	0.57 ± 0.41	0.001
IV	1.80 ± 0.47	0.95 ± 0.39	< 0.001
Group			
First eye	1.25 ± 0.52	0.60 ± 0.47	< 0.001
Fellow Eye	1.06 ± 0.38	0.41 ± 0.42	< 0.001
Single eye	1.55 ± 0.58	0.68 ± 0.36	< 0.001
Tamponade			
Gas	1.08 ± 0.38	0.42 ± 0.36	< 0.001
Silicon	1.68 ± 0.58	0.81 ± 0.44	< 0.001
Single surgery			
Yes	1.61 ± 0.56	0.85 ± 0.40	< 0.001
No	1.13 ± 0.45	0.43 ± 0.38	< 0.001

* Paired t test

Table 2. Comparison between preoperative and final BCVA by stage, group, and number of surgical procedures (logMAR, mean ± standard deviation).

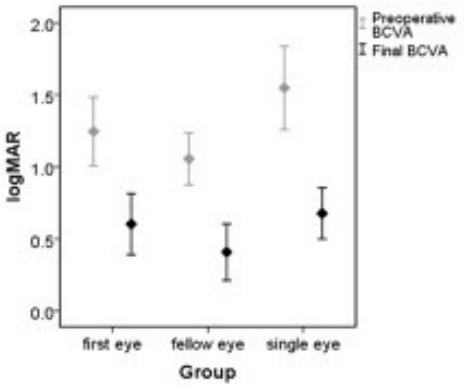

Figure 2. Mean and 95% confidence intervals of preoperative and final BCVA in each group. Mean change in BCVA did not differ between groups.

Functional comparison between groups

All the groups improved their mean BCVA after surgery (**Table 2**). The mean preoperative BCVA did not differ between first and fellow eyes and was higher in fellow eyes than in single eyes (**Table 3**); mean BCVA did not vary between groups (**Figure 2**).

Functional comparison among stages

Stages II-IV improved their mean BCVA after surgery (**Table 2**). The mean preoperative and final BCVA in stage II was higher than in those stages III and IV; the lowest mean preoperative and final BCVA were in stage IV (**Table 4**).

Functional results by type of tamponade

Eyes with any tamponade improved their mean BCVA (**Table 2**). The mean preoperative ($p< 0.001$) and final BCVA ($p < 0.001$) were higher in eyes with gas than in eyes with silicon (independent samples t-test).

Anatomical results

At the end of follow up period, 59 eyes (98.33%) had an attached retina; nine (15.0%) still had silicon. Nineteen eyes (31.67%) required additional surgery; their mean BCVA improved at the end of follow up (**Table 2**). Six eyes (10%) had one or more postoperative complications; three eyes had perimetric damage, including one from stage II and two from stage III. Three eyes in stage IV had rhematogenous RD (RRD) unrelated to the primary MMH, which required retinopexy and silicon tamponade; one of them ended up with severe proliferative vitreoretinopathy (PVR) due to endophthalmitis. One

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Variable	First eye (1)	Fellow eye (2)	Single eye (3)	p*	1 vs 2 p†	1 vs 3 p†	2 vs 3 p†
Preoperative	1.25 ± 0.52	1.06 ± 0.38	1.55 ± 0.58	0.17	0.69	0.18	0.03
Final	0.60 ± 0.47	0.41 ± 0.42	0.68 ± 0.36	0.12	0.30	0.84	0.13

* One-way ANOVA
† Tukey's post hoc test

Table 3. BCVA Comparison between groups (logMAR, mean ± standard deviation).

eye in stage IV had a fibrous recurrent ERM and needed further dissection. One eye in stage II had a residual symptomatic external foveoschisis that required ILM remnants peeling.

Structural (tomographic) results

Twenty eyes had a normal macula (33.33%) with all the OCT biomarkers; 15 (25.0%%) in stage II and three (5.0%) in stage III. Three eyes had all the OCT biomarkers and an ERM (5%).

Fourteen eyes (23.33%) had diffuse chorioretinal atrophy (DCRA); four presented the OCT biomarkers, but fluorescein angiography showed no choriocapillaris perfusion and only late staining of the choroidal and scleral tissue; one of these four eyes was in stage I, two were in stage II, and one was in stage IV. One eye in stage II had an ERM.

Two eyes with DCRA had residual MF, including one in stage II and one in stage IV; they had the main OCT biomarkers without posterior cortical or ILM remnants. Two eyes in stage IV and DCRA had an open but sealed MMH without OCT biomarkers and diffusely atrophic retinal pigmented epithelium (RPE).

Four eyes with DCRA also had a closed MH, they showed a discontinued IS/OS line without an apical cone segment line and diffuse macular thinning (DMT); one eye was in stage III, and three were in stage IV. One eye in stage III with DCRA had DMT (macular thickness <80 µm) without an IS/OS line or external macular structures.

Eight eyes (13.3%) had an open and sealed MMH without subretinal fluid around it, including one in stage III and seven in stage IV (**Figure 3**); none of them had foveal inner or outer neuroretinal layers or IS/OS line; two eyes in stage IV had DCRA.

Ten eyes had a closed MMH (16.7%), including three in stage III and seven in stage IV (**Figure 4**); four had DCRA, including one in stage III with a residual MF, one in stage IV with FRD (**Figure 4**) and one with severe DMT.

Three eyes had a residual MF (5%), including two in stage II that had OCT biomarkers; the other one was in stage III, had a sealed MH and only showed an RPE line and foveal contour.

Discussion

MTM resolved after vitrectomy in 83.3% of the sample; this proportion is similar to what Mao found in eyes without ILM peeling (84%); however, that study excluded eyes with MMH or MHRD.[8] In our study, 90% of eyes with MMH had anatomical success, this percentage is between the values that Zhang (84%)[9] and Wang (100%)[10] reported.

Most patients with stage I are asymptomatic, and this condition may persist for years before affecting vision.[3,7] Panozzo[4] found isolated MF in 14% of their patients, which did not differ from 5% of affected patients in our study.

MF is the earliest stage of MTM and a precursor of FRD.[8,11] Approximately 34.5%[12] to 41%[13] of cases progress to FRD, and 20.7% progress to partial-thickness MH.[12] Focal irregularities and external retinal thickening were described as precursors of an outer lamellar defect associated with focal RD.[13,14] In a prospective study of 8 eyes with macular retinoschisis (mean follow-up, 44 months), two eyes developed MMH, one had associated RD.[14]

Uchida reported that 80% of the eyes in this stage resolved with vitrectomy and gas tamponade, and 20% required ILM peeling.[15] In our study, three eyes with MF had a complete resolution of the disease, however, two required modified ILM peeling to achieve a good outcome; none of them progressed to FRD or MMH.

Baba [11] reported a 9% incidence of FRD in patients with posterior staphyloma, and Gaucher found this in 34.5%;[17] most of these patients have metamorphopsia and some level of progressive visual loss. An FRD may be a poor prognosis factor for MH formation.[12] Kim[16] identified it as the only prognostic variable for poor visual improvement and anatomical failure after vitrectomy for foveoschisis; Hattori added the preoperative BCVA.[18]

Surgery for FRD might cause foveal reattachment and visual improvement. Vitrectomy and gas without ILM removal works in primary cases and classical or modified ILM peeling techniques with gas are used for both refractory and primary cases.[19] Shimada reduced the risk of ILM peeling with his foveal-sparing ILM removal, which induced no macular holes, compared with 16.7% of eyes that developed one after non-foveal-sparing ILM removal.[20]

In our study, 43.3% of the eyes had FRD; none of them developed MMH during the follow-up, and 57.69% had a normal postoperative SD-OCT pattern. The best BCVA was in eyes treated with ILM peeling and foveal-sparing ILM peeling with gas.

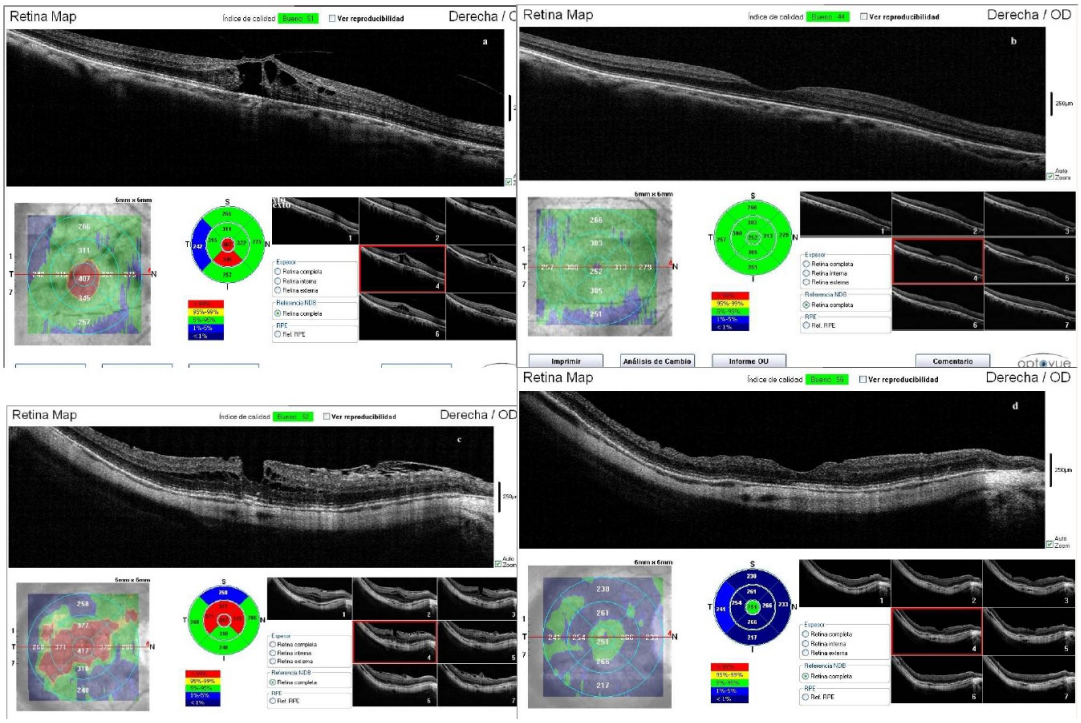

Figure 3. a, 42-year-old woman with high myopia and posterior staphyloma in both eyes. BCVA was 20/400 (logMAR 1.30) RE, 20/80 (logMAR 0.60) LE, axial length 32.10 mm RE. She had stage II MTM, the preoperative SD-OCT depicts vitreomacular traction, internal and external myopic foveoschisis (MF) with a shallow foveomacular detachment (FRD). The right eye underwent gas-vitrectomy with modified foveal-sparing internal limiting membrane peeling technique. One- year postoperative SD-OCT showed a normal SD-OCT profile without evidence of FRD. Postoperative BCVA of 20/30 (logMAR of 0.18) with all the OCT biomarkers present (b). 58-year-old highly myopic and very symptomatic woman with evidence of stage III MTM on his right eye. The preoperative BCVA was 20/800 (logMAR 1.60). RE axial length of 30.15 mm. The preoperative right eye SD-OCT depicts an epiretinal macular membrane (ERM), internal myopic foveoschisis (MF) and partial-thickness myopic macular hole (c). The right eye underwent silicon-vitrectomy with macular surgery consisted with epiretinal macular membrane peeling and modified inverted-flap internal limiting membrane peeling technique. 18-months after silicon removal surgery the right eye SD-OCT depicts a normal foveal profile with some temporal to the fovea ERM remnants and neuroretinal thinning (d) and final postoperative BCVA of 20/60 (logMAR 0.48).

A full-thickness MMH may develop spontaneously as a part of the disease's natural history, or during ILM removal; [9] its formation is always preceded by FRD, in which the foveola becomes extremely thin and exposed to the tangential traction of a tense ILM or posterior vitreous remnants.[17]

In our study, six eyes with full-thickness MMH were treated with ILM removal and four without it; the outcome did not vary between surgical techniques or tamponade used. The carefully inverted ILM flap manipulation seemed of paramount importance to close the holes. At the end of follow-up, 90% of these eyes had a closed macular hole; however, DCRA appeared in three cases; in one eye with silicon, the macular hole remained open but sealed without any progression; and one eye with silicon had a persistent outer layer foveoschisis with 20/40 vision.

RRD associated with MMH represents a challenge. Surgical approaches include vitrectomy and classical or modified ILM peeling with various tamponades; removing the ILM and ERMs may increase the flexibility of the detached retina, contributing to MH sealing even in eyes with posterior staphyloma.[21-23]

Vitrectomy success rates vary from 45-68% with long-acting gas to 79-89% with silicon oil tamponade.[24-28] In our study 14 of 21 eyes (35.0%) with RD required silicon oil and 17 required ILM removal; twenty (91.2%) achieved a complete retinal reattachment, regardless of the procedures required, and one developed RRD unrelated to the MH and complicated by infectious endophthalmitis. Eight eyes (38.1%) with open but sealed macular holes had silicon oil at the end of follow up period due to reoperations, gas-vitrectomy failure or refractory open MHs. Eyes with gas tamponade did not have open MH at the end of follow-up period.

Loss of chorioretinal tissue and RPE atrophy contribute to a deficient retinal reattachment and poor visual recovery.[25] Fang reported a 10.5% incidence of macular atrophy after vitrectomy, which was higher in eyes with MHRD compared with eyes with foveoschisis or macular detachment, but not with eyes that had a MH.[29] Twenty-three eyes in our study (38.9%) developed DCRA or DMT; the proportion in

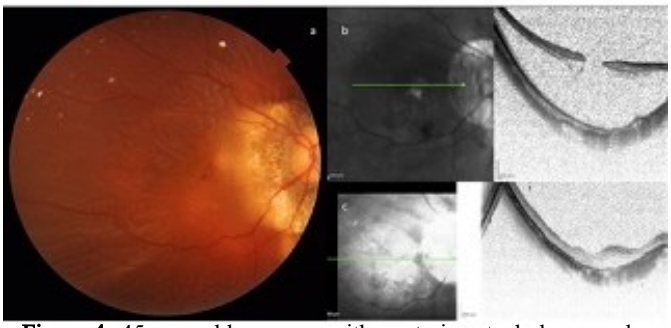

Figure 4. 45-year-old woman, with posterior staphyloma and 30.28 mm axial length, operated on the right eye for a MHRD. (a, b) She underwent 25 gauge three-port pars plana vitrectomy and macular modified internal limiting membrane peeling (inverted flap technique) with silicon tamponade. Preoperative BCVA was 5/200 (log MAR 1.60) and final BCVA after 24 months follow-up was 20/125 (log MAR 0.80). SD-OCT showed a closed and sealed myopic macular hole and some SD-OCT biomarkers such as internal and external retina layers lines and some residual external myopic foveoschisis. (c).

eyes with MHRD was higher than that in the rest. Although 33.3% of the sample had a normal macula at the end of follow-up, 96.7% had BCVA improvement. Lehman found that the main factor that influenced postoperative BCVA in eyes with foveoschisis after vitrectomy was the preoperative BCVA; that study only included eyes with stages I-III of the disease, and in our study, all those stages had visual improvement.[30]

In our study, the mean preoperative BCVA was low because of the mean of eyes in stage IV; eyes in stage II had better preoperative BCVA than eyes in stages III-IV. The mean final BCVA was also lower in eyes with stage IV. Although BCVA improved after surgery in eyes in stages II-IV, the mean change was not different among all stages; this mean was only higher in eyes with stage II than in eyes with stage IV. BCVA improved in all groups; intergroup comparison showed a lower mean preoperative BCVA in single than in fellow eyes; the mean change in the BCVA did not differ between groups. Two-thirds of the patients with disease in a single eye presented with RD; this could be the result of a missed diagnosis of earlier MTM stages, which highlights the need to reinforcing knowledge of the disease in general ophthalmic practice.

The strengths of the study include a long follow-up period, which allowed estimation of the approximate time of occurrence of the disease in the fellow eye and detection of early stages, and a significant group of fellow eyes that had a better final BCVA; most of them underwent surgery in the early stages, which led to better structural results; one additional strength is that we included the whole spectrum of MTM; as a result, one potential weakness was the asymmetry between stages, which limited comparing stage I. Another potential weakness was that the surgical technique was individualized; although intraoperative variables have less value than the preoperative BCVA for the anatomical and visual outcome,[44] we recognize that a standardized and randomized study might better define whether surgical variations lead to better outcomes.

A potential limitation is that the most important OCT biomarkers have not been standardized and correlated with functional results; we only described the best known OCT biomarkers of the different outcomes, but the study was not designed to identify how these variables are affected in this disease, whether they change after surgery and how they are correlated with the final BCVA. An additional limitation is the retrospective nature of this report; we designed a model to obtain an annual risk and a cumulative fellow eye risk for developing the disease, which should be regarded cautiously because theoretical models are ideally obtained from prospective studies.

Regardless of the criteria for deciding on surgery (stage or BCVA), the functional results were better in eyes with earlier interventions; this does not mean that eyes with more advanced stages or visual loss do not require surgery because there was overall BCVA improvement after single or multiple procedures. The high proportion of eyes with bilateral disease indicates that periodical and longitudinal follow-up could lead to better outcomes if the fellow eye receives early surgery.

Conclusion

In conclusion, accordingly with the anatomic and functional results on this report the BCVA improved in MTM after surgery regardless of preoperative BCVA, stage or surgical technique; interventions in eyes with earlier stages and a better BCVA offer better functional results, which require deliberate detection of the disease, especially in the fellow eyes of patients with unilateral disease. There was significant visual improvement when the eye is operated on in the early stages of this condition. By analyzing the prevalence and need for surgery in the second eye we can conclude that these highly myopic patients are at high risk of develop a profound and irreversible loss of vision when underwent surgery on the late stages of this myopic condition so careful

Variable	Stage I	Stage II	Stage III	Stage IV	p*	I vs. II p†	I vs III p†	I vs IV p†	II vs III p†	II vs IV p†	III vs IV p†
Preoperative	0.86 ± 0.15	0.91 ± 0.18)	1.26 ± 0.46	1.80 ± 0.47	0.13	0.99	0.33	< 0.001	0.06	< 0.001	0.001
Final	0.34 ± 0.11	0.28 ± 0.18	0.57 ± 0.41	0.95 ± 0.39	0.28	0.99	0.69	0.013	0.074	< 0.001	0.01

* One-way ANOVA
† Tukey's post hoc test

Table 4. BCVA comparison between stages (logMAR, mean ± standard deviation)

prospective and longitudinal evaluation on the fellow eye is advised to detect early stages of this condition and make up an early surgical choice from the different macular surgical variants in order to optimize visual outcomes. Further prospective randomized clinical trials will be needed to better establish the pathogenesis of MTM and determine the most appropriate surgical procedures to resolve this severe condition.

Conflicts of interests

No proprietary interests, no conflicts of interest, no financial disclosures or affiliations related to this study.

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