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Proposal for the management of myopic traction maculopathy based on the new MTM staging system

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Abstract

Purpose: To propose the Myopic Traction Maculopathy (MTM) management Table, based on the MTM Staging System (MSS).

Methods: A retrospective review of 157 eyes affected by MTM, operated with pars plana vitrectomy (PPV), or macular buckle (MB) or combined surgery (MB + PPV). Each case was classified according to the MSS. Anatomical results were evaluated with OCT at an intermediate follow-up (3–6 months) and at a final follow-up (2–8 years), considering changes both in the foveal and in the retinal pattern. The number and type of operations needed were noted. The surgical complications were reported.

Results: Primary surgery was MB for 83 eyes (52%), PPV for 36 (23%) and MB + PPV for 38 (24%). At intermediate follow-up, the retinal pattern was restored in 55.41% and foveal in 42.68%.

Further surgery was indicated as PPV in 25.48%, MB in 14.65%. At the final follow-up, the retinal pattern was restored in 96.16% and the foveal pattern in 87.90%.

BCVA improved at the final follow-up ($p < 0.05$). The complications of MB were not sight-threatening. The complications of PPV were FTMH in 67% cases in stages 2, 3, and 4. Cataract developed in 60% of phakic eyes. The complications of combined MB+PPV were cataract (56%) and PVR (5%).

Conclusions: Both PPV and MB may be used to treat MTM. PPV addresses the changes in the foveal pattern while MB addresses the changes in the retinal pattern. The MTM management table offers a proposal for the choice of type and timing of treatment customized per each stage of MTM.

Keywords

Myopic traction maculopathy, myopia, macular buckle, maculopathy, vitrectomy, retinoschisis, retinal detachment, macular hole

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Summary Statement

The Myopic Traction Maculopathy Management Table is presented to propose a practical guide to the treatment of MTM, based on the new MTM staging system (MSS).

Introduction

Myopic traction maculopathy (MTM) is one of the vision-threatening consequences that may develop from the progressive deformation of the posterior scleral eyewall in highly myopic eyes.[1] Although different authors have reported proposals of treatment of MTM with pars plana vitrectomy (PPV)[2–4] or macular buckle (MB),[5,6] comprehensive guidelines of management, from studies with long

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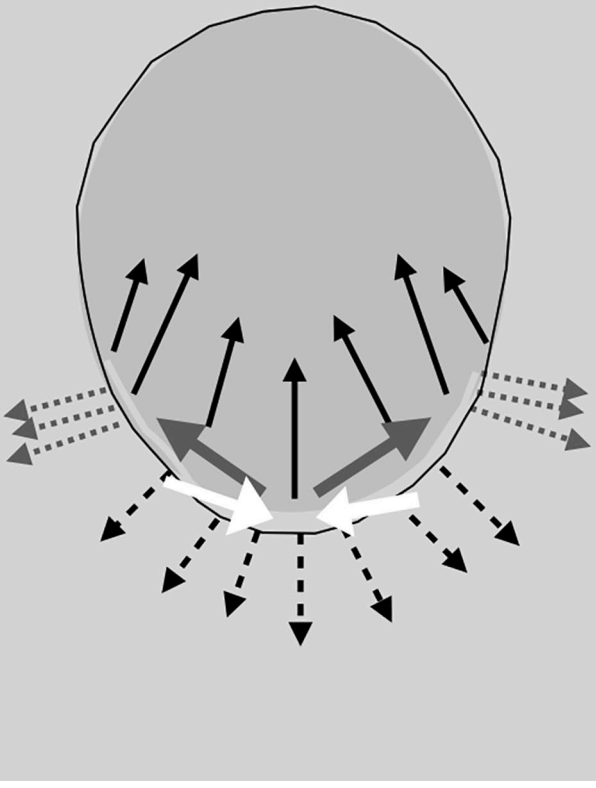

arrow color	type of force	direction of vector	exerted by	action
white	centri petal	to the fovea	intraretinal structure	holds the retina together
line black	centri fugal	to the anterior vitreous	vitreous	pull the retina anteriorly
dark grey	centri fugal	to the lateral orbit	vitreous	stretch and open the fovea
dotted gray	centri fugal	to the lateral orbit	lateral sclera	stretch and open the fovea
dashed black	centri fugal	to the posterior orbit	posterior sclera	pull the retina posteriorly

Figure 1. Schematic representation of the forces implicated in the evolution of MTM.

term follow-up, are still missing and the choice of the best treatment is still controversial.

Considering the center of the fovea our point of reference, we hypothesized that the anatomical changes in MTM are induced by tractional forces which are centrifugal with respect to the center of the fovea and we called them "MTM-inducing forces." We defined two types of centrifugal MTM-inducing forces: the ones perpendicular and the ones tangential to the retinal plane (Figure 1).

The centrifugal MTM-inducing forces **perpendicular** to the retinal plane are exerted by the scleral elongation, on one side, and by anteroposterior vitreous traction, on the other side. These forces induce anatomical modification into the retina, such as the maculoschisis (MS) and macular detachment (MD).

The centrifugal MTM-inducing forces **tangential** to the retinal plane are exerted by the scleral lateral enlargement, on one side, and by the vitreous adhesions to the retina plus the vitreoretinal interface tractions, on the other side. These forces induce anatomical modification into the fovea, such as the inner lamellar macular hole (I-LMH) and the full-thickness macular hole (FTMH).

Based on this hypothesis, we designed a new classification of MTM in stages and called it MTM Staging System (MSS). MSS was recently published and described elsewhere.[7] The MSS is aimed to summarize all the clinical pictures of MTM in four stages. Stage 1 is the inner maculoschisis (I-MS) or inner-outer maculoschisis(IO-MS); Stage 2 is a predominantly outer maculoschisis (O-MS); Stage 3 is a maculoschisis-detachment (MS-MD); Stage 4 is the stage with macular detachment without schisis (MD). Each of these four stages, which describe the evolution of MTM in a perpendicular direction to the macula, can be associated with an intact fovea (stage a), or with an evolution of MTM in a tangential direction to the macula that leads to an inner lamellar macular hole (stage b), or to a full-thickness macular hole (stage c).

To verify this hypothesis we evaluated the effect of different surgical techniques that could counteract the centrifugal MTM-inducing forces, by exerting a parallel force but in the opposite direction. The surgical treatments used in this study were: (1) macular buckle (MB); (2) pars plana vitrectomy (PPV); (3) a combination of MB and PPV (MB + PPV). The use of MB was aimed to counteract the

Table 1. Demographic and clinical data of patients.

MSS stage (retinal pattern)	number of eyes (% ot tot)	Age (years) mean ± SD	Baseline best corrected visual acuity (dec) mean ± SD	Axial length (mm) mean ± SD	MSS stage (foveal pattern)		
					a number of eyes (% ot tot)	b number of eyes (% ot tot)	c number of eyes (% ot tot)
1	33 (21)	53.1 ± 9.2	0.33 ± 0.20	32.25 ± 1.7	16 (10)	9 (6)	8 (5)
2	44 (27)	58.6 ± 10.6	0.21 ± 0.20	31.1 ± 2.1	16 (10)	27 (17)	1 (1)
3	48 (31)	62.25 ± 9.4	0.16 ± 0.14	32 ± 2.2	28 (18)	13 (8)	7 (4)
4	32 (20)	61 ± 10.9	0.12 ± 0.12	29.9 ± 1.9	12 (8)	3 (2)	17 (11)
Total	157	58.74 ± 10.25	0.20 ± 0.18	31.2 ± 2.3	72 (46)	52 (33)	33 (21)

MTM-inducing forces perpendicular to the retinal plane, by exerting a pushing effect from the sclera toward the retina. The use of PPV was aimed to counteract the MTM-inducing forces exerted by the vitreous tangentially and perpendicularly to the retinal plane.

The final goal of the present study was to identify which was the most efficient treatment per each stage of the disease and to propose guidelines of management of MTM that could offer the highest anatomical success with one surgery and the lowest rate of complications.

Methods

We retrospectively reviewed a series of 281 eyes from 273 patients affected by MTM. All the eyes underwent MB, PPV, or MB combined to PPV (MB + PPV) performed by one surgeon (BP), between 2006 and 2018. The choice of treatment was left up to the surgeon. At the time of surgery, there was not a specific criterion to choose among the surgical techniques, because no technique appeared to be more efficient than others. Therefore, every type of surgery could be performed for every stage of the disease. Besides, at the time of surgery, no staging and classification were available. Six months after surgery, at the reevaluation, the surgeon could decide whether to apply a second surgery or observation, based on the anatomical and functional result of the primary surgery.

The analysis of the results was performed in January 2020, after collecting preoperative and postoperative data on age, gender, decimal best-corrected visual acuity (BCVA), axial length (AL) measurement and the MSS stage. All the patients underwent optical coherence tomography (OCT) scans (Cirrus®, Carl Zeiss Meditec Inc, Dublin, CA, USA; Topcon Triton® by Topcon, Tokyo, Japan; Spectralis®, Heidelberg Engineering, Germany), and, when available, wide-field color fundus photography (CX-1, Canon Inc., Japan; Daytona®, Optos Inc., USA; Clarus 500®, Carl Zeiss Meditec Inc, Dublin, CA, USA).

We excluded eyes without at least 2 years of follow-up and cases for which the preoperative and postoperative data could not be completely retrieved. Therefore, only 157 eyes of 148 patients (115 females, 33 males) were included in the analysis. Table 1 summarizes the data regarding the eyes included into the study.

Data were analyzed preoperatively, at 3–6 months post-op (intermediate follow-up), and at least two years post-op (final follow-up). The intermediate follow-up represents the result of the first surgery. The final follow-up represents the result of one or more surgeries after at least 2 years after the first intervention.

The anatomical results were judged in terms of change in the foveal profile (foveal pattern) and change in the retinal profile (retinal pattern). The retinal pattern was judged as *resolved* when the schisis or the detachment were no longer visible, *improved* when the schisis or the detachment were still detectable but less significantly, *unchanged* when no change was observable and *worsened* when the schisis was thicker then preoperatively or when the detachment appeared more elevated then preoperatively. The foveal profile was judged as *resolved* when the I-LMH or the FTMH were no longer visible and *improved* when they were reduced in size but still visible. *Worsened* when the size of the hole was increased and when a LMH or a FTMH, not present preoperatively, appeared postoperatively. Complications were listed as well.

The MB technique was described elsewhere.[5] PPV was associated with ILM peeling from 2006 to 2016 and with ILM flap from 2016 to 2018 only in the presence of an I-LMH or a FTMH. When ILM peeling was applied, the ILM was stained with Doubledyne™ (Alfa Intes, Casoria, Italy) for 1 min. No peeling nor ILM manipulations were performed in cases presenting without foveal splitting, that is, a foveal-sparing technique was applied. The tamponade was either air in stage a or gas in stage b or c. The choice of the glossary and the terminology was provided in a previous paper.[7]

Results

Among the 157 eyes, included in our study, 83 eyes (53%), 36 eyes (23%), and 38 eyes (24%) were assigned to MB-group, PPV-group and MB + PPV group respectively, based on the first surgical treatment they received. At the intermediate follow-up, 64 eyes received further surgical indications. Table 2 reports the need for further treatment divided by the original surgery type and by preoperative MSS stage. The need for further surgery can be considered a measure of the success of the prior surgery.

Table 2. Surgery type per stage and numbers of reoperations.

MSS Stage	No. of MB (No. of late PPV−No. of late MB)	No. of PPV (No. of late PPV−No. of late MB)	No of MB + PPV (No of late PPV−No. of late MB)	Total
1a	12 (2–0)	0 (0–0)	4 (0–0)	16
1b	2 (0–0)	6 (2–0)	1 (0–0)	9
1c	0 (0–0)	8 (0–3)	0 (0–0)	8
2a	14 (6–0)	1 (1–1)	1 (0–0)	16
2b	15 (3–0)	2 (2–1)	10 (0–0)	27
2c	0 (0–0)	0 (0–0)	1 (0–0)	1
3a	11 (1–0)	15 (10–14)	2 (1–0)	28
3b	6 (2–0)	0 (0–0)	7 (4–0)	13
3c	1 (0–0)	3 (3–3)	3 (0–0)	7
4a	11 (0–0)	0 (0–0)	1 (0–0)	12
4b	1 (0–0)	0 (0–0)	2 (2–0)	3
4c	10 (0–0)	1 (1–1)	6 (0–0)	17
TOT	83 (1–4)	36 (19–23)	38 (7–0)	157

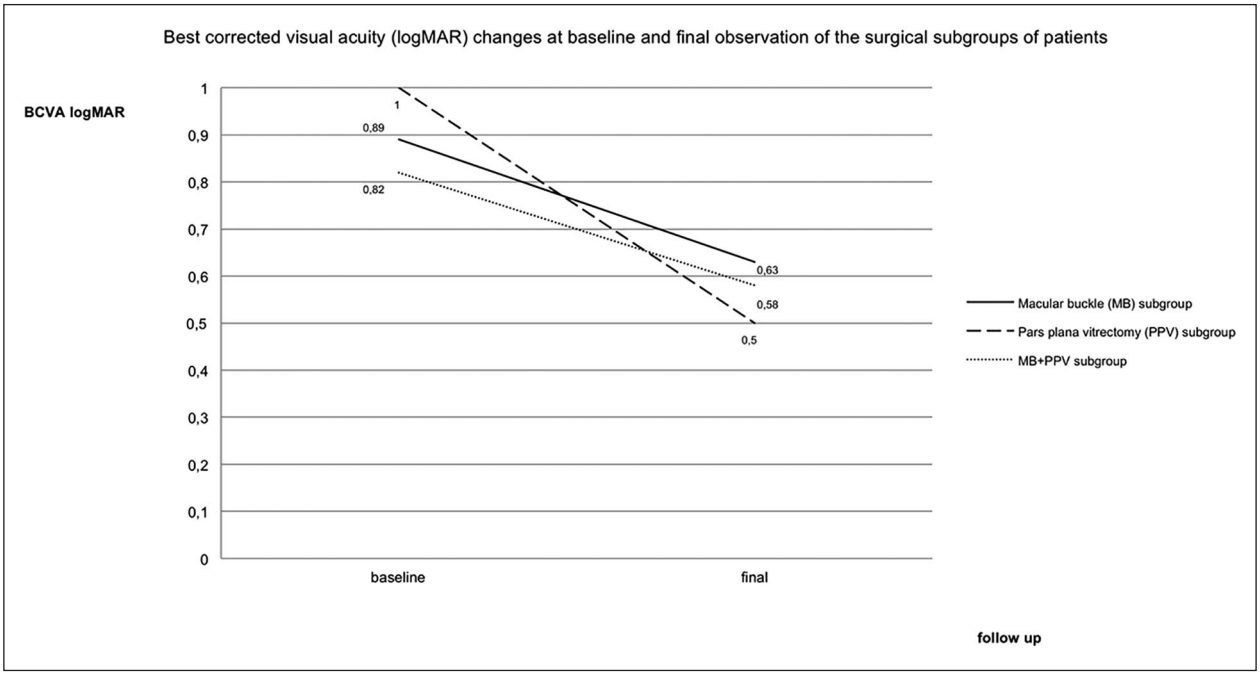

Figure 2. The graph shows how BCVA significantly improved, from baseline to the final follow-up ($p < 0.05$), in the interventional groups of the macular buckle, pars plana vitrectomy and combined surgery.

BCVA significantly improved, from baseline at the final follow-up, in all the groups ($p < 0.05$), as shown in the graphs in Figure 2 and Table 3. The average AL was reduced of 1.6 mm at the final follow-up, in patients who underwent MB alone or combined. The decrease in AL was not statistically significant ($p = 1.02$). We have no data regarding the change of AL at the intermediate follow-up.

In stage 1 (Table 4), both MB and PPV (Figure 3) resolved the retinal and the foveal pattern in 100% and 93% of cases respectively, at the final follow-up. Eyes operated with MB received additional PPV in 14% of cases, 6 months after MB. Eyes operated with PPV received additional PPV in 14% and additional MB in 21% of cases. Combined MB+PPV resolved the retinal and foveal pattern in 100% of eyes without further surgery.

In stage 2 (Table 5), MB resolved, improved and left unchanged the retinal pattern in 90%, 7% and 3% of eyes respectively. MB resolved, improved and left unchanged the foveal pattern in 79%, 7%, and 14% of eyes respectively. PPV was performed in nine cases (31%), treated originally with MB, because no improvement had been observed in the retinal pattern at the intermediate follow-up. We observed a quick and complete resolution of the macular schisis in these eyes after PPV. However, the eyes

in Stage 2a treated exclusively with MB, which refused further treatment, as well reached the disappearance of the macular schisis, with an improvement of the retinal pattern within 1 year.

PPV resolved retinal and foveal pattern in 75% and improved in 25% of eyes. PPV required a second PPV in 100% of cases and a MB in 66%. Combined MB + PPV resolved the retinal pattern in 100% of cases, while resolved and improved the foveal pattern in 92% and 8% of eyes respectively, without need for further surgery.

In Stage 3 (Table 6), MB resolved retinal pattern in 100% of eyes. The foveal pattern was resolved or left unchanged in 89% and in 11% of eyes. PPV was added to 17% of eyes originally treated with MB. The eyes in stage 3b and 3bO, operated only with MB, showed a progressive relief of the perpendicular component of traction. The schisis detachment and, when present, the O-LMH improved within 3 months and the retinal pattern was restored completely with no further surgery in six months. The I-LMH remained unchanged.

All the 18 eyes (100%) operated with PPV, obtained a resolved retinal and foveal pattern at the final follow-up, but only with further MB in 94% and further PPV in 72% of eyes. In three eyes in stage 3a, operated only with PPV, the detachment remained unchanged for more than 1 year without any resolution of the retinal pattern. Interestingly, when a MB was implanted in a second step, the foveal detachment resolved, and the retinal pattern was restored within 2 weeks postoperatively (Figure 4). The 15 eyes operated with PPV showed partial restoration of the retinal pattern. However, 13 eyes in stage 3a (87% of the eyes operated with PPV in this stage) ended in an iatrogenic FTMH.

At the final follow-up, MB + PPV resolved the retinal pattern in 100%, and the foveal pattern in 92% of eyes, while 8% of eyes remained unchanged. A second PPV was offered in 42% of eyes in this group.

Eyes in stage 3a and 3b operated with MB + PPV had a recovery of the retinal pattern but the foveal pattern in some eyes worsened for the appearance of an iatrogenic FTMH. Two eyes in stage 3b+, with a limited foveal detachment, had a temporary worsening of the detachment after combined MB + PPV. The foveal detachment disappeared slowly and progressively within 3 months.

In Stage 4 (Table 7), MB resolved retinal pattern in 95% of eyes and left it unchanged in 5%. The foveal pattern was resolved in 82%, improved in 9% and left unchanged in 9% of eyes. No eyes were further operated

Table 3. Average BCVA: preoperative and at the final follow-up.

MSS stage	BCVA preoperative (decimal)	BCVA final (decimal)
1a	0.42	0.58
1b	0.34	0.5
1c	0.12	0.35
2a	0.27	0.39
2b	0.17	0.25
2c	0.1	0.2
3a	0.35	0.41
3b	0.25	0.38
3c	0.13	0.27
4a	0.15	0.28
4b	0.2	0.33
4c	0.08	0.19

Table 4. Surgical results in MSS stage 1.

Stage 1		Retina		fovea	
Surgery	Outcome	Intermediate number (% of surgical group)	Final number (% of surgical group)	Intermediate number (% of surgical group)	Final number (% of surgical group)
MB *n*. (%)	Resolved	0	14 (100)	1 (7)	13 (93)
	Improved	14 (100)	0	9 (64)	0
	Unchanged	0	0	2 (14)	1 (7)
	Worsened	0	0	2 (14)	0
	Total	14			
PPV *n*. (%)	Resolved	10 (71)	14 (100)	10 (71)	13 (93)
	Improved	4 (29)	0	3 (22)	0
	Unchanged	0	0	1 (7)	1 (7)
	Worsened	0	0	0	0
	Total	14			
MB + PPV *n*. (%)	Resolved	5	5 (100)	4 (80)	5 (100)
	Improved	0	0	1 (20)	0
	Unchanged	0	0	0	0
	Worsened	0	0	0	0
	Total	5			
$p < 0.05$		0.0051	0.0051	0.0614	0.3187

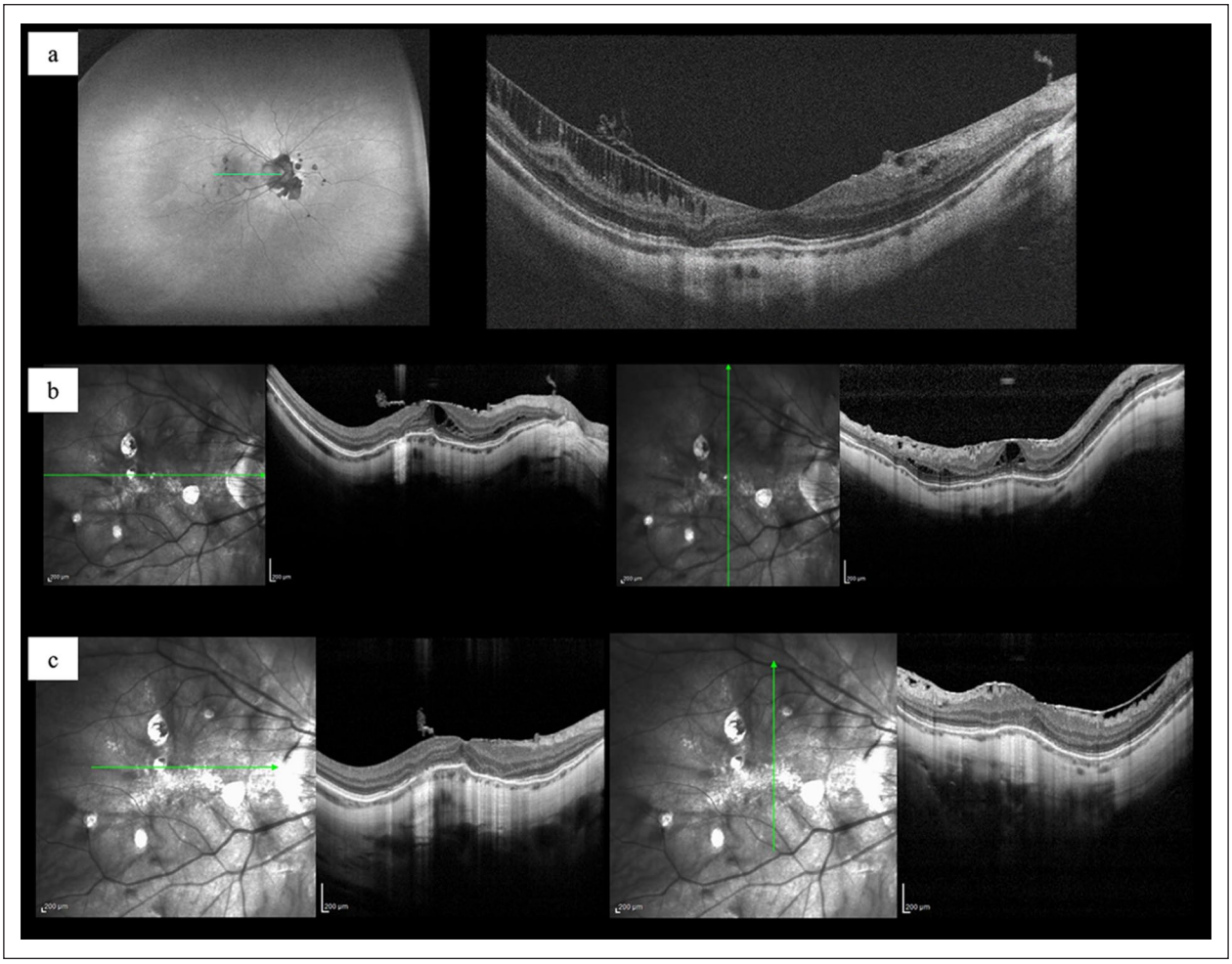

Figure 3. (a) Eye affected by MTM Stage MSS 1a+ in a 44-year-old female. Autofluorescence image, which shows a patchy atrophy pattern Category 3 according to the International Photographic Classification and Grading System. No signs of staphyloma. The OCT shows inner macular schisis in the temporal extrafoveal area with epiretinal abnormalities, (b) horizontal and vertical OCT, 1 month after MB. The temporal inner schisis is no longer visible, although some schisis is still present in the nasal and inferior macula. An inner schisis is visible in the fovea. The epiretinal abnormality is still well shown and even more evident in the nasal side of the macula, and (c) horizontal and vertical OCT, 1 year after MB. The extrafoveal and foveal inner schisis are no longer visible. The epiretinal abnormality is still well shown.

with MB nor PPV, despite in two eyes the resolution of the schisis was slower because of a slight decentration of the buckle. The only eye originally operated with PPV had a worsening and needed a combined MB + PPV to resolve both the retinal and the foveal pattern. All the eyes operated with MB + PPV, presented a resolved retinal pattern. The foveal pattern needed a further PPV in two eyes (22%) staged 4b after 6 months. Interestingly, one case was operated with combined MB + PPV without ILM peeling and showed a successful resolution. However, 3 months later, the patient asked to remove the MB for discomfort and episodes of pain. Immediately after MB removal, she experienced visual loss and a new appearance of schisis and detachment. The eyes in stage 4c, treated only with MB reached 100% retinal reattachment but only 60% reached hole closure. One eye operated only with MB obtained a restoration of the retina and the foveal patterns with a complete hole closure. However, a newly formed macular hole appeared 3 years after the first surgery. The eye was treated with PPV and ILM flap to successfully close the hole.

Complications

The complications of MB were not sight-threatening.

The complications of the cases of MB, used alone as first treatment, were temporary iatrogenic inner schisis (I-LMH) in two cases in stage 1a MSS, superficial extrusion of the lateral arm of the MB in 6% of cases and diplopia in 1.3% of cases. Extrusion and diplopia were more common with the first model of MB used before 2011 and reduced to 3% and 0.2% respectively with the smaller model used since 2011, as previously reported.[5,6]

Table 5. Surgical results in MSS stage 2.

Stage 2		Retina		Fovea	
Surgery	Outcome	Intermediate number (% of surgical group)	Final number (% of surgical group)	Intermediate number (% of surgical group)	Final number (% of surgical group)
MB *n.* (%)	Resolved	11 (40)	26 (90)	5 (17)	23 (79)
	Improved	16 (55)	2 (7)	12 (41)	2 (7)
	Unchanged	2 (7)	1 (3)	8 (28)	4 (14)
	Worsened	0	0	4 (14)	0
	Total	29			
PPV *n.* (%)	Resolved	0	2 (66)	0 (0)	2 (66)
	Improved	1 (33)	1 (33)	1 (33)	1 (33)
	Unchanged	1 (33)	0	1 (33)	0
	Worsened	1 (33)	0	1 (33)	0
	Total	3			
MB + PPV *n.* (%)	Resolved	11 (92)	12 (100)	9 (76)	11 (92)
	Improved	1 (8)	0	1 (8)	1 (8)
	Unchanged	0	0	1 (8)	0
	Worsened	0	0	1 (8)	0
	Total	12			
$p < 0.05$		0.0004	0.2813	0.0333	0.1537

Table 6. Surgical results in MSS stage 3.

Stage 3		Retina		Fovea	
Surgery	outcome	Intermediate number (% of surgical group)	Final number (% of surgical group)	Intermediate number (% of surgical group)	Final number (% of surgical group)
MB *n.* (%)	Resolved	10 (56)	18 (100)	8 (44)	16 (89)
	Improved	8 (44)	0	7 (39)	0
	Unchanged	0	0	3 (17)	2 (11)
	Worsened	0	0	0	0
	Total	18			
PPV *n.* (%)	Resolved	4 (22)	18 (100)	0	18 (100)
	Improved	1 (6)	0	0	0
	Unchanged	2 (11)	0	2 (12)	0
	Worsened	11 (61)	0	15 (88)	0
	Total	18			
MB + PPV *n.* (%)	Resolved	8 (69)	12 (100)	5 (38.5)	11 (92)
	Improved	3 (23)	0	3 (23)	0
	Unchanged	1 (8)	0	0	1 (8)
	Worsened	0	0	4 (38.5)	0
	Total	12			
$p < 0.05$		<0.0001	0.2946	<0.0001	0.3857

A FTMH appeared 3 years after surgery in one case of stage 3a MSS and in two cases of stage 4 MSS, although operated with MB alone with an initial resolution of the case. Two cases, treated in stage 2a with MB, developed a temporary foveal detachment, which disappeared spontaneously within the first 6 months after surgery.

The complications of PPV were FTMH in 67% cases in stage 2, 3, and in the only eye in stage 4b operated with PPV.

The three cases in stage 3c switched to stage 4c. Cataract developed in 60% of phakic eyes. One case in stage 2b showed a temporary foveal detachment which spontaneously disappeared in 6 months.

The complications of combined MB + PPV were cataract in 56% and PVR appeared in 5%.

Three eyes in Stage 3b and 3bO, operated with combined MB + PPV, showed relief in the schisis and detachment but ended with a FTMH on flat retina. One case was

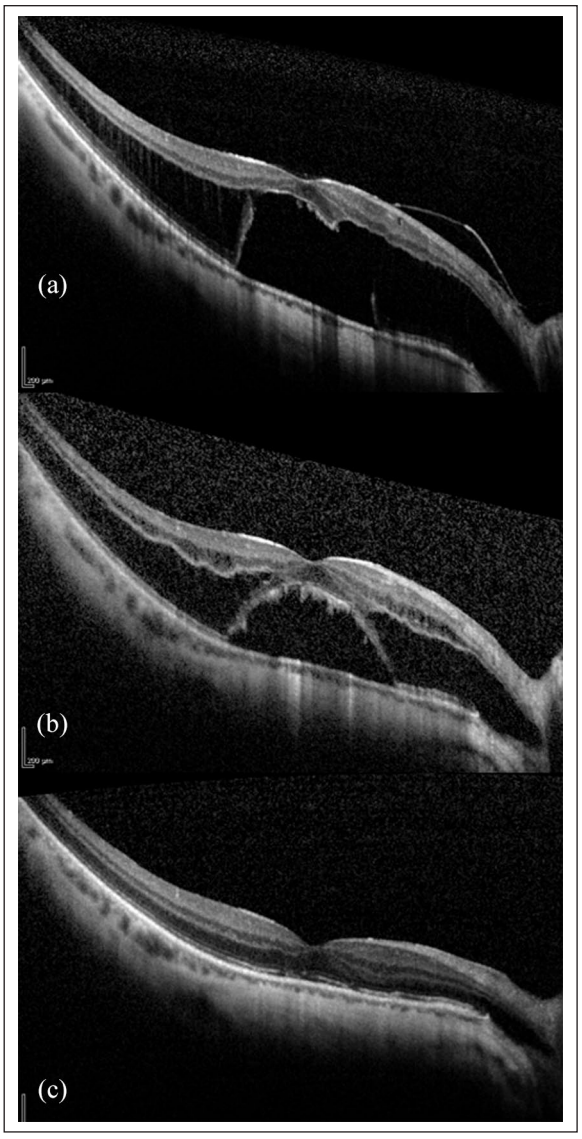

Figure 4. (a) Eye affected by MTM Stage MSS 3aO, in a 58-year-old male. The O-MS, the O-LMH and the detachment are well visible, (b) horizontal scan taken 9 months after PPV surgery. The schisis, the detachment is unchanged. The O-LMH is however resolved, and (c) horizontal scan taken 2 weeks after MB surgery and 1 year after PPV. The schisis and the detachment are resolved. The foveal indentation is flat and horizontal.

managed by repositioning the dislocated ILM flap, two cases with an ILM autologous transplant (Figure 5).

Discussion

The idea of preventing axial elongation and scleral growth by the placement of material over the posterior part of the eye was proposed many years before the description of MTM.[8–12] MB was then abandoned, mainly due to the challenges and complications linked to the surgical technique.

Pars plana vitrectomy (PPV) for macular detachment with FTMH was first proposed in 1982.[13] Many authors published afterwards,[2–4] proposing PPV as the intervention of choice, with the rationale of eliminating the tangential tractions. However, PPV showed a limited efficacy and points of weakness in high myopia remained with any tamponade,[14] mainly because of the high rate of retinal detachment recurrence, failure to close the hole and risk to induce an iatrogenic macular hole.[4] Recently, the use of a foveal-sparing ILM peeling has been proposed to treat MTM and reduce the risk of iatrogenic FTMH.[15–17]

The dissatisfaction of the results of PPV left open the way to a new course of publications on buckling the macula, which started again, after 20 years, in 2000.[12,18,19] Although the reattachment rate with MB was reported to be very high, the rate of hole closure was unknown because of the lack of study with OCT. Alkabes and Mateo[20] recently published a 16-year review on MB for MTM and compared the results with PPV, showing a high success rate with MB. More recent literature[21] added to PPV the technique of inverted ILM flaps reporting a higher success rate to close the holes.

This study aimed to identify the most efficient treatment per each stage of MTM selecting among PPV, MB or combined MB + PPV, and to propose guidelines of management of MTM that could offer the highest anatomical and functional improvement. Our observations and the results are therefore discussed using the MTM stage of the MTM Staging System (MSS) that has recently been published.[7]

Our final treatment selection, proposed in the MTM management Table, was built on the evaluation of the anatomical and functional results, that could be reached with the least number of surgeries, balanced with the evaluation of the complications of the three approaches, per each stage. We also considered the complications that might occur late in years after surgery, to offer good advice for a long-lasting result.

In **stage 1**, a good functional and anatomical result in the retina was obtained with every technique at the end of the follow-up. The foveal pattern could be improved or resolved in a high percentage of cases with PPV or with MB + PPV. It should be highlighted that, when applying MB alone to cases with only inner macular schisis and without foveal abnormalities (stage 1a), we observed the temporary induction of a schisis in the center of the macula, where the action of the MB was more evident. This means that, by applying a perpendicular force to treat a predominantly tangential MTM-inducing force, we induced a complication within the inner retina.

Furthermore, eyes in stage 1a were associated with high preoperative BCVA with an average 0.42 decimal. In a previous paper, we have published that the time taken to shift from stage 1 to stage 2 is 1 year or more.[7] We, therefore, recommend observing patients in stage 1a without intervention for an unfavorable ratio benefit/complications.

We recommend treating stage 1b with PPV when vision is dropping significantly and to treat stage 1c with PPV. In fact, in stages 1b and 1c, the foveal impairment causes the

Table 7. Surgical results in MSS Stage 4.

Stage 4		Retina		Fovea	
Surgery	Outcome	Intermediate number (% of surgical group)	Final number (% of surgical group)	Intermediate number (% of surgical group)	Final number (% of surgical group)
MB *n*. (%)	Resolved	18 (82)	21 (95)	16 (73)	18 (82)
	Improved	2 (9)	1 (4)	4 (18)	2 (9)
	Unchanged	1 (4)	0	2 (9)	2 (9)
	Worsened	0	0	0	0
	Total	22			
PPV *n*. (%)	Resolved	0	1 (100)	0	1 (100)
	Improved	0	0	0	0
	Unchanged	0	0	0	0
	Worsened	1 (100)	0	1 (100)	0
	Total	1			
MB + PPV *n*. (%)	Resolved	9 (100)	8 (89)	8 (89)	7 (78)
	Improved	0	0	0	0
	Unchanged	0	1 (11)	1 (11)	2 (22)
	Worsened	0	0	0	0
	Total	9			
$p < 0.05$		<0.0001	0.5044	<0.0001	0.7019

loss of vision more than the schisis of the retinal layers. Tangential MTM-inducing forces should be counteracted with tangential centripetal forces such as the one exerted by PPV and maneuvers on the ILM.

In **stage 2**, a worsening of the macular-schisis occurs affecting predominantly the outer retinal layers.

Since eyes in stage 2a might retain a good vision for a long time. Since surgery might lead to complications, we advise observing cases in stage 2a every 6 months without treatment. When BCVA starts to drop significantly we suggest to apply MB only. PPV can be proposed to treat residual epiretinal abnormalities inducing poor quality of vision due to metamorphopsia.

In stage 2b and 2c, the compromised foveal architecture may be the major cause of vision loss. Despite the foveal architecture may be restores only by PPV and ILM manipulations, we think that in stage 2b apply MB first to resolve the macular schisis is the safer approach. Once the schisis is solved, PPV should be applied when I-LMH causes persistent low BCVA.[22–24] Stage 2c should receive combined MB + PPV. However, we cannot comment in this paper on the results of MB alone or PPV alone in stage 2c because of a lack of data.

The foveal pattern remained unchanged in the eyes in stages 2b and 2c operated with only MB, although obtaining a resolution of the retinal pattern. This most likely for the untreated tangential tractions with MB. However, in some cases who received MB only, the retinal pattern improved progressively within 1 year and we did not perform any further treatment because of the good satisfaction of the patients in terms of visual gain, despite the staging of the foveal pattern remained unchanged.

Regarding **stage 3**, eyes in stage 3a operated only with MB had a relief of the perpendicular MTM-inducing force. The macular schisis and the detachment showed overall improvement with the restoration of the retinal pattern within 3 months. Even some cases in stage 3a+ showed relief of traction and did not require further surgery for the epiretinal abnormalities.

Eyes in stage 3a operated only with PPV were the group that needed more reoperations for lack of improvement or iatrogenic complications such as FTMH.

For the eyes in stage 3b and 3bO, MB could counteract only the perpendicular MTM-inducing forces and not the tangential ones.

Given the analysis of the results in stage 3, we advise to treat stage 3a only with MB, 3b with MB and delayed PPV only if needed, and 3c with combined MB + PPV.

In **stage 4**, we advise to treat stage 4a with MB, 4b with MB and delayed PPV if needed, and stage 4c with MB + PPV. Stage 4c is the stage where the perpendicular and tangential MTM-inducing forces are combined. If the treatment counteracts only one component, the untreated component will make itself evident over time.

BCVA improved overall and significantly with every surgical technique but only at the final follow-up, when anatomical success was obtained. This is an important achievement in eyes with PM and MTM. However, we think that BCVA cannot be used as the only or primary outcome and parameter of success since it can be influenced by the anterior segment media opacity of by the entity of choroidal atrophy and neovascularization at the posterior pole. Therefore, the decision to operate should be taken considering the visual potential of our patient.

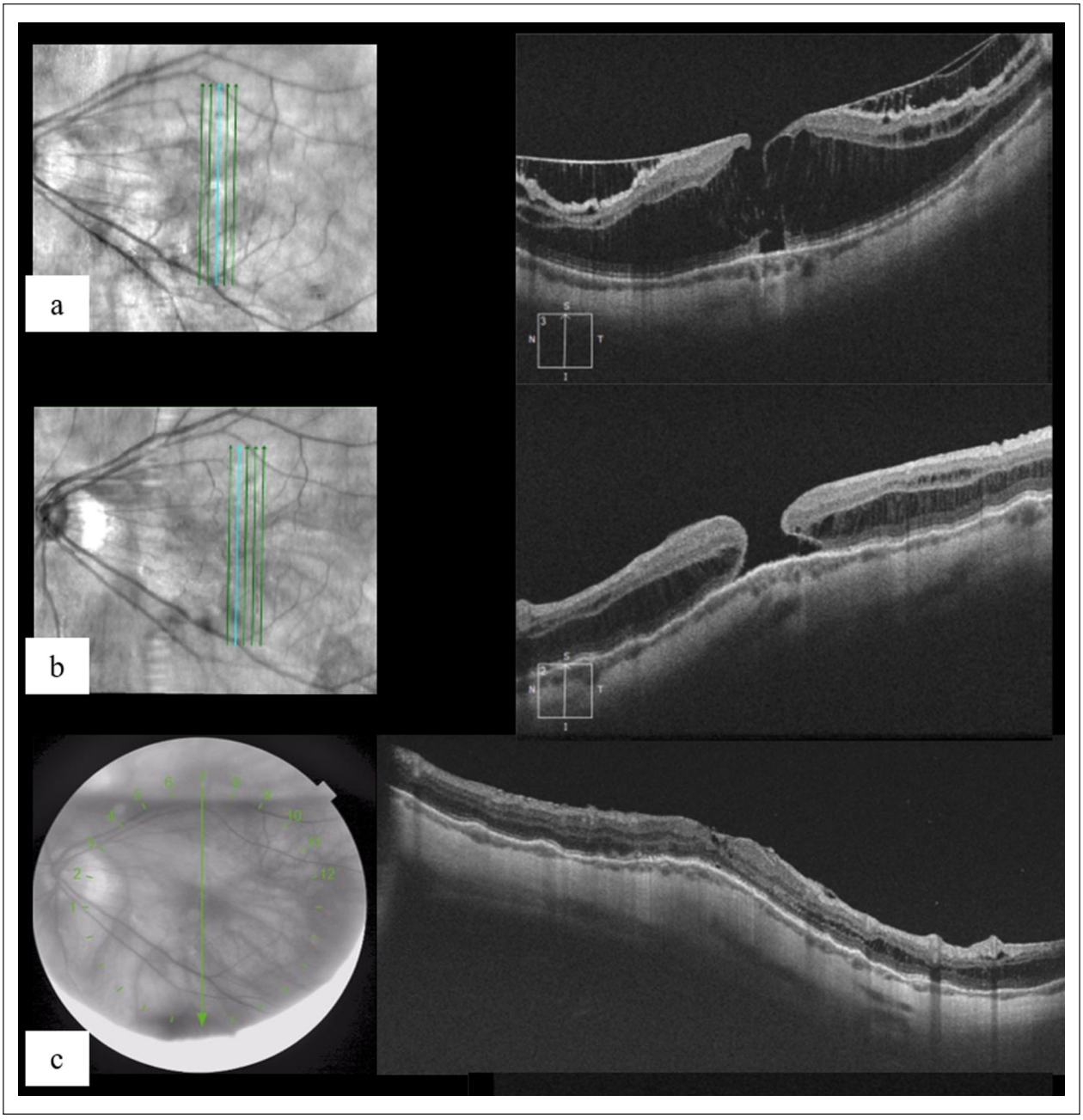

Figure 5. (a) Eye affected by MTM Stage MSS 3bO+, in a 58-year-old female. Preoperative vertical OCT scan. The O-MS, the I-LMH, the O-LMH and the initial foveal detachment are visible. The case is in transition between 3b+ and 3c+. The epiretinal abnormalities are well visible, (b) horizontal scan taken 2 weeks after combined MB+PPV surgery and ILM peeling with ILM flap. The O-MS has improved. The epiretinal abnormalities are removed. A FTMH is open, and (c) vertical scan taken 2 months after PPV and repositioning the ILM flap. The O-MS, the ILMH, the I-LMH and the foveal detachment are improved.

BCVA improvements were better in patients that underwent PPV because they had a compromised foveal architecture (foveal patterns b and c) which may be restored only by PPV and ILM manipulations.

However, even in these cases, PPV can be added at a later time only if needed, thus avoiding the possible side effects of PPV and restoring the foveal pattern on an attached retina not affected by schisis nor detachment.

Despite the concept of exerting an equal and opposite force to counteract the ones that cause the evolution of the disease seems quite logical, we observed that limited foveal detachments might worsen temporarily with MB. The foveal detachment resolves progressively with no further surgery. Mateo and Burés-Jelstrup[25] had shown this phenomenon, considering the appearance of foveal detachment and O-LMH an indication for immediate

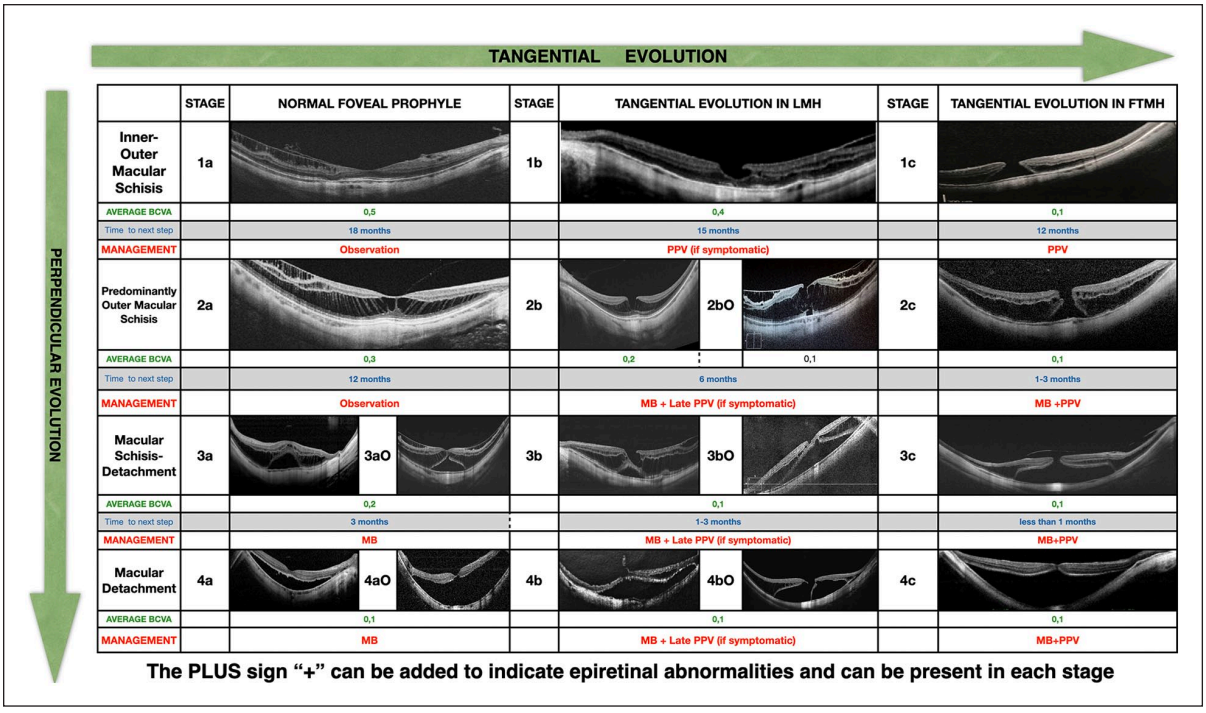

Figure 6. Myopic traction maculopathy (MTM) management table, based on the MTM staging system (MSS).
MB: macular buckle; PPV: pars plana vitrectomy; MB + PPV: combined MB and PPV; MB and late PPV: MB and, later and only if needed, PPV.

PPV. Our cases of increased foveal detachment were followed with no further surgery and yet progressively resolved. It is not simple to explain the temporary foveal detachment induced by the MB. Our first hypothesis was that it represented a temporary RPE decompensation, since the choroidal thickening observed after MB (personal communication which was not measured in the present study). Nevertheless, we have observed a worsening of a foveal detachment in a Stage 3b operated with combined MB+PPV and a temporary foveal detachment even in a case in Stage 2b operated only with PPV without MB. In both cases, the detachment resolved without further surgery. At the moment, we do not have a clear explanation for this phenomenon.

In summary, we are convinced that MTM cannot be treated with the same surgical approach as a whole.

We think that treatment should counteract all the MTM inducing forces. As visible in the MSS Table,[7] one force might prevail on the other, leading to different MTM Stages. Therefore, the treatment should be customized based of the preoperative stage considering the predominant MTM-inducing force. The effectiveness of the chosen treatment should be judged by observing the improvement of the stage of MTM.

The meticulous analysis of the results reported was not aimed to a comparison between the outcomes of MB and PPV but to provide physicians suggestions of management of MTM. The MTM management Table (Figure 6) is aimed to obtain the best possible result with the least number of operations possible, customizing the surgical approach according to the stage of the disease.

This is the first study reporting the surgical results in such a high number of patients affected by MTM. Based on our analysis we think that the debate "buckle versus vitrectomy" has no meaning.

Our study had some limitations. Being this a retrospective study, the choice of the surgical technique was up to the surgeon since the MSS staging system had not yet been identified neither a comprehensive classification of this disease was available. A high percentage of patients reported in the study were operated with MB because these were patients with long follow-up and reliable preoperative and postoperative data. Another limit of this study is the low number of eyes operated with PPV in certain stages and the lack of a similar number of cases per each stage. However, we think that our results compare with the results reported in literature.

Further longitudinal evaluations of the surgical techniques are needed to improve our knowledge of this complex disease and the effect of treatment.

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