Real-World Outcomes of Macular Buckling Surgery for Myopic Traction Maculopathy: A Decade of Clinical Experience

Real-World Outcomes da Cirurgia de Macular *Buckling* para a Maculopatia de Tração Miópica: Uma Década de Experiência Clínica

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ABSTRACT

INTRODUCTION: Myopic traction maculopathy (MTM) often presents as a therapeutic challenge. While pars plana vitrectomy (PPV) remains the mainstay treatment, macular buckling (MB) offers a promising alternative designed to counter the tractional force of the staphyloma. This study aims to evaluate the functional and structural outcomes of MB in treating MTM.

METHODS: A retrospective review was conducted on patients who underwent MB surgery between 2012 and 2023. Outcomes analyzed include anatomical success rates, best-corrected visual acuity (BCVA) expressed in decimal notation, axial length (AL), and surgical complications.

RESULTS: Of the 200 clinical files analyzed, 75% were female patients and 52% right eyes. According to the MTM staging system, retinal stages were stage 1 in 9.5%, stage 2 in 29%, stage 3 in 32%, and stage 4 in 24.5% of eyes. For the foveal stages, 44.5% of eyes were in stage a, 33% in stage b, and 22.5% in stage c, with 43.5% presenting epiretinal changes. Sixty nine percent underwent MB alone, while 31% had a combined procedure with PPV. There was a significant BCVA improvement of 0.21 diopters from preoperative to 1-year postoperative (n=64, p=0.001). When comparing the 1-year postoperative BCVA to the last appointment (n=56), the difference was only -0.01, with a mean follow-up of 41 months (p=0.593). BCVA improved in 76.6% of eyes, remained stable in 13.6%, and decreased in 9.7%. Anatomical assessments revealed the following for the fovea: 80.9% resolution, 9.9% improvement, and 8.0% no change and 1.2% deterioration. For the retina, there was 89.5% resolution, 9.3% improvement and 1.8% no change. The AL decreased from 31.18 mm preoperative to 29.78 mm postoperative (p <0.001). Postoperatively, 9.5% of eyes required surgery revision and 10% of the eyes required a further PPV. MB was removed in 7.4% (n=14) of patients. Atrophy progression was seen in 41.3% of operated eyes and in 51.1% of the fellow eyes. Regarding retinal stage 3 and 4 (n=122), macular reattachment was achieved in 100%. Macular hole closure was achieved in 92.9% of the cases with one intervention.

CONCLUSION: MB stands out as an effective and safe technique for MTM treatment in highly myopic eyes.

KEYWORDS: Macular Degeneration; Myopia, Degenerative; Retinal Detachment; Visual Acuity.

RESUMO

INTRODUÇÃO: A maculopatia de tração miópica (MTM) é frequentemente um desafio terapêutico. Enquanto a vitrectomia *pars plana* (VPP) continua a ser o *gold standard*, o *macular buckling* (MB) - projetado para contrapor a tração do estafiloma - oferece uma alternativa promissora. O objetivo deste estudo é avaliar os resultados funcionais e estruturais do MB no tratamento da MTM.

MÉTODOS: Foi realizada uma revisão de doentes operados entre 2012 e 2023. Os resultados analisados incluem sucesso anatómico, melhor acuidade visual corrigida (MAVC) em escala decimal, comprimento axial (CA) e complicações cirúrgicas.

RESULTADOS: Dos 200 casos analisados, 75% eram mulheres e 52% de olhos direitos. Segundo o sistema de estadiamento da MTM, os estágios retinianos foram: Estágio 1 em 9,5%, Estágio 2 em 29%, Estágio 3 em 32%, e Estágio 4 em 24,5% dos olhos. Em relação aos estágios foveais, 44,5% estavam no estágio a, 33% no estágio b e 22,5% no estágio c, com 43,5% exibindo alterações epirretinianas. Sessenta e nove por cento dos olhos realizaram MB, enquanto 31% foram combinados com PPV. A MAVC aumentou 0,21 dioptrias entre o pré-operatório e 1 ano após a cirurgia (n=64, p=0,001). Comparando a MAVC 1 ano pós-cirurgia com a última consulta (n=56), diferença foi de -0,01, p=0,593. A acuidade visual melhorou em 76,6% dos olhos, permaneceu estável em 13,6% e diminuiu em 9,7%. As avaliações anatómicas revelaram o seguinte para a fóvea: 80,9% de resolução, 9,9% de melhoria, 8,0% sem alteração e 1,2% de deterioração. Para a retina, existiu 89,5% de resolução, 9,3% de melhoria e 1,8% sem alteração. O CA mostrou redução de 31,18 mm no pré-operatório para 29,78 mm pós-operatório (p <0,001). Nove ponto cinco por cento dos olhos necessitaram de revisão cirúrgica e 10% requereram PPV adicional. O MB foi removido em 7,4% dos pacientes. Foi observada progressão da atrofia em 41,3% dos olhos operados e em 51,1% dos contralaterais. A reaplicação macular foi alcançada em 100%. O encerramento do buraco macular foi alcançado em 92,9% dos casos com uma única intervenção.

CONCLUSÃO: O *macular buckling* destaca-se como uma técnica eficaz e segura para o tratamento da MTM em olhos altos míopes.

PALAVRAS-CHAVE: Acuidade Visual; Degeneração Macular; Descolamento da Retina; Miopia Degenerativa.

INTRODUCTION

Myopic traction maculopathy (MTM) affects 9%-34% of highly myopic eyes and include as features macular schisis (MS), lamellar or full-thickness macular hole (FTMH), and macular detachment (MD).[1,2]

Complications like macular hole induced retinal detachment (MHRD) can culminate in irreversible vision loss.[3]

It is a progressive multifactorial disease, evolving from MS to MD in 34.5%-72%.[4–6] Primary factors include anterior traction and the progression of the posterior staphyloma (PS).[7] Preretinal elements, like posterior vitreous cortex, epiretinal membrane (ERM), and internal limiting membrane (ILM), exert anterior centrifugal and tangential forces on the macula.[8]

In 2021, Parolini *et al*[9,10] proposed a classification, subsequently validated internationally.[11] The MTM Staging System (MSS) identifies MTM as a progressively advancing disease, from the retina's inner to outer layers, potentially leading to MD. It has 12 stages, progressing vertically (1-4) and horizontally (a-c). Outer lamellar macular holes (o-LMHs) can manifest in stages 2, 3, and 4, while epiretinal irregularities can be present in any stage.

Treating MTM requires specialized approaches. Surgical success is limited in highly myopic eyes due to factors like PS traction, RPE dysfunction, extended axial length, and choroidal degeneration.[12] MHRD is challenging due to its recurrence propensity and suboptimal visual prognosis. Even with treatment, there is a risk of MH nonclosure, recurrence, or re-detachment. Furthermore, high myopia patients with FTMH need urgent surgical intervention as there's a risk of progression to MHRD. Multiple surgical methods, such as pars plana vitrectomy (PPV), combined with gas/silicone oil (SO) tamponade and ILM peeling/flap, macular buckling (MB), scleral imbrications, and suprachoroidal injections, are employed to counter these complications.[13,14] PPV, despite its widespread adoption for addressing the tangential and centripetal vitreous-induced tractions,[5] reveals its shortcomings when managing PS-induced stretching.[15] Moreover, it does

not inhibit the potential progression of macular hole (MH),[16] which is driven by PS as the vitreous cortex and retinal arterioles apply tangential traction.[17–19] ILM peeling with PPV can further introduce complications, including macular or extrafoveal retinal holes.[20–22] This highlights the potential of MB. Created to mitigate both the anteroposterior traction due to PS and tangential tractions by the vitreous cortex, MB—either as a standalone procedure or combined with PPV—proves effective.[19] By modifying and strengthening the posterior scleral wall, this method offers a direct mechanical countermeasure.[17–19] Moreover, it aids in the reattachment process in MD.[19]

In this paper we report our experience treating MTM with MB either independently or combined with PPV. The goal is to assess the functional and anatomical outcomes of these treatments. We focus on those undergoing their first surgery, excluding any rescue procedures.

METHODS

STUDY DESIGN AND PARTICIPANTS

Single-center retrospective study from 2012-2023 on highly myopic patients with MTM undergoing MB by a single surgeon (BP). Diagnosis was made by an experienced observer (BP) using fundoscopy, retinography, and OCT.

INCLUSION AND EXCLUSION CRITERIA

Were included highly myopic patients (spherical equivalent (SE) ≤ -6.0 diopters and/or AL ≥26.5 mm) with MTM, without prior surgeries, except uncomplicated lens extraction. Exclusion criteria encompassed trauma, intermediate or advanced age-related macular degeneration, proliferative and non-proliferative diabetic retinopathy with a history of clinically significant macular edema, retinal vascular occlusions, any optic neuropathy, or vision loss unrelated to MTM.

CLINICAL EVALUATIONS

Patients underwent preoperative and postoperative standard examinations, including slit lamp, ophthalmoscopy, fundus imaging, BCVA, axial length (AL) measurement, ocular motility assessment, and intraocular pressure (IOP) measurement. The IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany) was employed for AL measurements. For spectral domain optical coherence tomography (SD-OCT) assessments, the Swept Source Tricon (Topcon) was used up to July 2020. Thereafter, the (SS)-OCT Xephilio S1 (Canon, Tokyo, Japan) was adopted. Classification of MTM was consistent with the guidelines provided by Parolini *et al*.[10] Three investigators (BP, EL, JR) reviewed OCT images, resolving disagreements by consensus.

DATA COLLECTION AND OUTCOME MEASUREMENTS

Data was obtained by chart review. This encompassed demographics, best-corrected visual acuity (BCVA), MTM grading, AL pre/post-surgery, anterior segment evaluations, dilated fundus inspections, IOP measurements, color retinography, OCT results, and any postoperative complications. Staphyloma classification followed the Ohno-Matsui PS system.[23]

BCVA and OCT were recorded at preoperative, intermediate (3-6 months postoperative), 1-year postoperative, and the final visit. BCVA was recorded in decimal notation. OCT assessed both the broader retina (focusing on macular schisis and overall retinal status) and the fovea (focusing on layer structure and macular hole presence). Postoperative OCT was qualitatively evaluated against the baseline, determining if conditions resolved, improved, remained the same, or deteriorated.

To evaluate progression, fundus photography was employed. The fellow non-operated eye served as a control group for comparative analysis. Myopic maculopathy was classified into 5 stages according to the Meta-analysis of Pathologic Myopia (META-PM) Study Group recommendations.[23,24] Progression, as outlined by Fang *et al*,[25] was determined by an increase in the category of myopic maculopathy, development of a plus lesion, enlargement of a patchy atrophy or macular atrophy, increase in the number of lesions, or progression of peripapillary diffuse choroidal atrophy to macular diffuse choroidal atrophy, with this being the sole criterion for the enlargement of diffuse atrophy.

SURGICAL TECHNIQUE

Between 2012 and June 2020, off-label MB procedures were executed using a titanium stent combined with a silicone sponge. From July 2020 to the present, surgeries employed the AJL macular buckle (AJL Ophthalmic, Spain), made of PMMA coated with silicone. Independently of the buckle type, the standard surgical protocol entailed: 1) limbal paracentesis for IOP reduction; 2) temporal 180° peritomy of both the conjunctiva and Tenon's capsule from the inferotemporal quadrant to the superonasal quadrant; 3) lateral and superior rectus muscle isolation using either 4-0 silk or vicryl 0\0; 4) introduction of a 29G twinlight fiber optic into the pars plana at the 12 o'clock position and the integration of a second 29G fiber optic into the buckle's head (synergetic); 5) buckle insertion in the superotemporal quadrant; 6) buckle positioning and centering facilitated by the panoramic viewing system (PVS) and the surgical microscope; and 7) the affixing of the buckle with T-cron 6\0 sutures (Ethicon, Johnson & Johnson, Shanghai, China). To conclude, the precise positioning of the buckle was re-validated using both transillumination and direct PVS visualization.

Based on patient and OCT characteristics, either standalone MB or combination with PPV was selected.

ETHICAL CONSIDERATIONS

This study followed the 1976 Declaration of Helsinki and its updates. Participants gave written consent for data extraction and analysis, and all data were anonymized for privacy.

STATISTICAL EVALUATION

Due to missing BCVA data, we assessed BCVA changes within three intervals: preoperative to 1-year, preoperative to final, and 1-year to final. Numerical data, shown as mean and deviation, used t-tests, Mann-Whitney, paired t-tests, and Wilcoxon for comparisons. Categorical data, represented by frequency and percentage, used Chi-squared or Fisher's tests for group differences, and McNemar's tests for differences between operated and fellow eyes. Analyses were two-sided at 0.05 significance using RStudio 2023.03.01 on Windows 10.

RESULTS

Among 200 clinical records reviewed, 75% were from female patients, and 52% involved right eyes. The average age was 59 years (SD=11, range: 31-88). Mean SE preoperatively was –11.86 D (SD=8.2, range: –0.125 to –25.0); considering only phakic eyes mean SE was -17.5 D (SD=5.4, range: -4.4 to -25.0). Mean AL was 31.17 mm (SD=2.13, range: 26.12-37.54).

The MSS retinal stages were as follows: stage 1 in 9.5%, stage 2 in 29%, stage 3 in 32%, and stage 4 in 24.5%. For foveal stages, 44.5% were at stage a, 33% at stage b, and 22.5% at stage c, with 43.5% showing epiretinal changes. See Table 1 for a summary. PS was present in 94.5% of eyes. According to the Ohno-Matsui classification,[23] 47.1% had wide macular staphyloma, 33.9% narrow macular, 3.7% peripapillary, 4.8% inferior, and 9% other types. Sixty-nine percent (n=139) were treated solely with MB, while the remaining 31% (n=61) underwent a combined procedure with PPV. The distribution of surgery for each MSS classification stage is represented in Table 2. Six patients received SO tamponade (four with classification 4c, one with 4b, and one with 4a). ILM peeling was performed in 15 eyes, ILM inverted flap in 19, no maneuver in 3, and there was no information available in 25 eyes.

BCVA significantly improved from preoperative to intermediate and 1-year, as in Table 3. Preoperative BCVA was 0.25 (SD=0.192) and improved to 0.46 (SD=0.25) at 1-year (n=64), an increase of 0.21, p=0.001. At 1-year, the BCVA was

Table 1. Distribution of eyes across MSS categories.

		FOVEAL STAGE					
		A, normal profile		B, LMH		C, FTMH	
RETINAL STAGE	1. Inner-Outer Macular Schisis	15		4		--	
	2. Outer Macular Schisis	25		30		3	
				2b, n=27	2bO, n=3		
	3. Macular Schisis-detachment	31		24		9	
		3a, n=13	3aO, n=18	3b, n=10	3bO, n=14		
	4. Macular Detachment	18		8		33	
		4a, n=11	4aO, n=7	4b, n=6	4bO, n=2		

Table 2. Percentage distribution of eyes that underwent macular buckling (MB) alone for different MTM SS categories.

		FOVEAL STAGE		
		A, normal profile	B, LMH	C, FTMH
RETINAL STAGE	1. Inner-Outer Macular Schisis	73.3%	50.0%	--
	2. Outer Macular Schisis	92.0%	66.7%	0%
	3. Macular Schisis-detachment	83.9%	70.8%	44.4%
	4. Macular Detachment	83.3%	75.0%	57.6%

Table 3. Comparative analysis of BCVA across multiple timepoints relative to pre-operative values.

	Timepoint					
BCVA (N = 41)	Pre-op	Intermediate	Difference to pre-op	1-year	Difference to pre-op	p-value
Mean (SD)	0.24 (0.187)	0.35 (0.203)	+0.11 (0.152)	0.49 (0.235)	+0.24 (0.217)	<0.001*

* Friedman.

0.44 (SD=0.23) and 0.42 (SD=0.228) at the final visit (n=56, average 41-months), a difference of -0.01, *p*=0.593. For the final appointment (n=154, average 41-month follow-up), preoperative BCVA improved from a mean of 0.21 (SD=0.175) to 0.37 (SD=0.231), *p*<0.001. It improved for 76.6% of eyes, remained the same for 13.6%, and decreased for 9.7%.

No significant final BCVA difference existed between MB alone [0.39 (SD=0.24)] and MB combined with PPV [0.33 (SD=0.21)], p=0.185. In last assessment (average follow-up: 44 months, range: 6-160), foveal outcomes were: 80.9% resolved, 9.9% improved, 8.0% stable, 1.2% worsened. Retinal outcomes were: 89.5% resolved, 9.3% improved and 1.9% stable.

The average follow-up was 27 months (SD=35, range: 6-160); it extended beyond 12 months in 78.4% and 60 months in 28.8%. Postoperatively, AL reduced significantly by a mean of 1.39 mm (SD=1.019).

MTM STAGING SYSTEM 1A-B AND 2A-B, MACULAR SCHISIS WITHOUT FTMH

Seventy-four eyes categories 1a-b and 2a-b (MS without MD or FTMH) were examined. Of these 75.7% (n=56) underwent MB and 24.3% (n=18) had a combined procedure. At 1-year (n=62), 45.3% showed MS resolution, 50% improvement, and 4.7% stayed unchanged. By the final visit (average 67 months, range: 12-160), 87.1% had full schisis resolution, 9.7% improvement, and 3.2% were unchanged. At 1-year postoperative (n=20), the mean BCVA was 0.49 (SD=0.26), improving by 0.19 from preoperative. By the final visit (n=64, average 70 months, range: 14-120), the BCVA was 0.39 (SD=0.25), a 0.12 improvement from baseline. At this timepoint, vision improved in 67.2% of patients, was stable in 17.2%, and declined in 15.6%. No significant difference was observed between simple and combined surgeries in OCT and BCVA outcomes. Post-operatively, schisis worsened in 3 eyes but later resolved. One eye post combined procedure developed FTMH; no further surgeries were conducted on this eye, and no MD was noted. Two EMR cases occurred after MB. During follow-up, 8 eyes treated with MB needed a PPV due to macular traction, with or without ERM. None of the 35 eyes categorized as MSS 1a and 2a (foveoshisis with normal foveal profile) developed FTMH post-op. Last visit BCVA of MB only group (n=47) was 0.42 (SD=0.255), improving by 0.14; for BM plus PPV (n=18) was 0.36 (SD=0.218), improving by 0.14. Differences between groups were not statistically significant and the average follow-up was similar.

MTM STAGING SYSTEM RETINAL STAGE 3, MACULAR SCHISIS-DETACHMENT

Of the 64 eyes retina stage 3, 26.6% (n=17) underwent combined surgery and 73.4% (n=47) had MB. Of these, 9 had FTMH: 5 underwent combined surgery, while 4 were treated solely with MB. The reattachment rate was 100% with one intervention. However, 12.5% (n=8) required secondary procedures due to complications: 4 developed FTMH postoperatively, 1 had a MH that remained open, 1 showed ERM progression, 1 exhibited persistent macular traction, and 1 had an ILM flap dislocation. All eyes developing postoperative FTMH had prior o-LMH. One eye treated with MB alone had an exacerbation of MD with prolonged subretinal fluid (SRF) but resolved by 1-year without treatment. Another eye with extended SRF also resolved spontaneously. One-year postoperative (n=48), 47.9% had attached retinas without schisis, 47.9% improved, and 4.2% were stable. By the final visit (average 33 months, range: 12-120), 77.1% fully resolved and 22.9% improved. One-year BCVA (n=25) was 0.49 (SD=0.229), improving by 0.19. Of these, 84% of eyes showed improvement, 8% stayed consistent, and 8% experienced a decline. Final BCVA (n=41, average 43 months, range: 16-120) was 0.384 (SD=0.187), with a 0.18 improvement. Specifically, 78.0% of eyes exhibited improvement, 14.6% remained stable, while 6.3% showed a reduction in BCVA. Those with only MB (n=28) improved by 0.2 to a BCVA of 0.38 (SD=0.201). Those with BM plus PPV (n=14) improved by 0.15 to 0.365 (SD=0.17). No significant BCVA difference was noted between groups and follow-ups were similar.

MTM STAGING SYSTEM RETINAL STAGE 4, MACULAR DETACHMENT

Of the 58 eyes retina stage 4, 33 were attributed to FTMH. Fifty-eight percent (n=34) were managed with MB alone, while the remaining 41.4% (n=24) were treated with a combined approach. SO tamponade was used in 6 cases. Ten eyes underwent the ILM flap, 3 had ILM peeling, and in one case, no maneuver was employed. Data for others was not available. One surgery achieved 100% reattachment. Two eyes reattached without FTMH closure, one from each group. The eye from the combined group later experienced a macular redetachment necessitating additional PPV. One eye with a foveal grade B from the combined group developed a post-operative FTMH, though the macula stayed attached, and later underwent PPV. Four eyes required reoperation: two for unclosed FTMH, one post-procedure FTMH, and two redetachment. During the late postoperative phase, 2 FTMH reopened and another 2 FTMH developed. Notably, these patients did not undergo any further surgical intervention during the follow-up period. At the 1-year post-operative assessment (n = 51), retinal anatomy displayed complete resolution in 76.5% of cases, improvement in 21.5%, and no change in 2%. By the final evaluation (average 36 months, range: 12-120), complete resolution was noted in 88.2% of cases, improvement in 7.8%, no change in 3.9%, and none displayed worsening. No cases showed a deterioration. One-year mean BCVA (n=17) was 0.37 (SD=0.26) with an average 0.255 improvement. Within this group, 82.4% of eyes experienced improved vision, 11.8% saw no change, and 5.0% had a decline. Final BCVA (n=45, average 47 months, range: 16-120) was 0.3 (SD=0.21), improving by 0.19. In this set, 86.7% of eyes displayed improved vision, 9.8% remained stable, and 4.4% presented a

decline. Patients with only MB (n=27) had a final BCVA of 0.34 (SD=0.23), improving by 0.22. Those who were treated with BM plus PPV (n=18) had 0.25 (SD=0.15), improving by 0.14. Follow-up duration was similar, with no significant BCVA difference between groups.

MTM STAGING SYSTEM FOVEAL STAGE C, FULL-THICKNESS MACULAR HOLE

Of 45 eyes, 42 were associated with MD. The 3 eyes without MD received combined treatments without SO tamponade and all achieved MH closure without reopening. No further procedures were required. Regarding the 42 eyes with MD and FTMH, 57.1% had combined surgery and 42.9% MB alone. In the combined group 12 had inverted ILM flap, 3 ILM peeling and 2 no maneuver; 7 had no available data. SO tamponade was used in 7 cases. MH closure was achieved in 92.9% of cases with one intervention. In the MB group, closure rate was 88.9%, while in the combined group, it was 95.8%. This difference was not significant. Regarding unclosed MH, one was stage 3 and two stage 4. One unclosed MH from the combination group developed a MD. All closed after a subsequent PPV. Two FTMH reopened later and were not re-operated; no MD occurred. At 1-year postoperative anatomy evaluation (n=33), 81.8% of cases resolved, 15.2% improved, and 3% remained the same. At last visit (average 35 months, range 12-84), 72.7% resolved, 15.5% improved, 6.1% unchanged, with none deteriorating. Mean 1-year BCVA (n=11) was 0.32 with 0.16 improvement. In this cohort, 81.8% improved, 9.1% were stable, and 9.1% declined. Last visit (n=30, average 41 months, range:16-84) mean BCVA was 0.28D, improving by 0.16. Specifically, 88.7% improved, 10% stayed the same, and 3.3% declined. Regarding treatment comparison, the MB-only group (n=12) had a BCVA of 0.23 with a 0.11 improvement. The combined treatment (n=18) had 0.32 and improved by 0.19. No significant difference was seen between treatments and follow-up durations were similar.

COMPLICATIONS

A percentage of 9.5% of eyes needed immediate surgery revision, mainly due to MB decentration (70%). Early complications were 17%, increasing to 18% in the late postoperative period. Diplopia was the main complication, with rates of 8% in the early and 3.5% in the late postoperative period. In operated eyes examined with fundus photography pre- and post-surgery (n=70), 41.3% exhibited atrophy progression, including diffuse atrophy enlargement, over 58.1 months (range: 7-168). For non-operated eyes (n=45), this was 51.1% over 53.9 months (range: 12-120). New patchy atrophy developed in 15.71% of operated eyes and 11.11% of fellow eyes. There was no significant difference in atrophy rates between both groups. During follow-up, 4.5% developed a new FTMH, and 6.6% preoperative FTMH did not close. Ten percent underwent subsequent PPV for complications. The MB was removed in 7.4% (n=14), mostly due to extrusion (50%). The average time to extrusion was 33 months (range: 5-67). After buckle removal, the retina remained attached in all cases.

COMBINED PROCEDURES

Of the eyes treated with MB and PPV, 19.35% had early postoperative complications: 3 diplopia, 1 visual field change, 4 FTMH, 1 o-LMH, 1 subretinal hemorrhage, 1 flap dislocation, and 1 unresolved MH leading to MD. In the late postoperative phase, 12.9% faced complications: 2 unresolved diplopia, 1 cystoid macular edema (CME), 1 MD, 1 new FTMH, 1 reopened FTMH, and 2 choroidal neovascularization (CNV) cases. To address these, 11.3% underwent a PPV within an 8-month average (range: 5-16) due to: 1 unclosed MH, 1 macular detachment, 1 flap dislocation, and 4 FTMH. The late postoperative FTMH was not re-operated and did not develop MD.

MB ALONE

In patients receiving only MB, 14.38% had early postoperative complications: 2 unclosed FTMH, 13 diplopia, 1 CME, 1 worsened MD, 3 worsened schisis, 1 visual field change, and 1 implant extrusion. At final evaluation, 18.7% had complications: 1 retina vein occlusion, 3 CNV, 5 persistent diplopia, 6 extrusions, 1 vitreous hemorrhage with metamorphopsia, 4 FTMH, 3 ERM, and 3 schisis progressions without ERM. During follow-up, 9.4% required PPV in an average of 11 months (range: 1-24) due to 2 unclosed MH, 1 new FTMH, 8 postoperative schisis progressions (4 with ERM, 4 without), and 2 unreported cases. Three patients with later FTMH were not re-operated and did not develop MD.

DISCUSSION

In this study, we analyzed MTM cases operated on by a single surgeon from 2012-2023. Our findings, alongside other studies, suggest MB outperforms PPV.[26,27] MB proved safe and effective, enhancing visual outcomes and minimizing major complications. Our data underscored improvements in BCVA, using MB alone or with PPV. Compared to PPV, MB had fewer FTHM formations, higher rates of FTMH closure, and macular reattachment. However, issues like diplopia and MB misalignment arose, sometimes needing corrections. Macular atrophy was similar between our results and literature reports for eyes treated with PPV.

MTM, particularly FTMH and FD, is challenging to address. Though vitrectomy may provide brief relief, it does not address high myopia's core issue: eyeball elongation leading to stretching and scleral thinning. Macular buckling counters eyeball elongation, tackling both the internal vitreous traction and its root issue, enhancing RPE and neurosensory retina connection. Thus, macular buckling may be preferred for MD, especially in eyes with posterior staphyloma.[28]

Our study revealed a BCVA improvement in 76.6% of eyes, surpassing many PPV reports.[29–31] Post-surgery,

BCVA notably improved, showcasing immediate visual gains, which persisted from the 1-year mark to the final evaluation. Comparing MB alone to MB combined with PPV showed negligible differences in final BCVA. Given the similar results between the groups, coupled with deliberate non-randomized patient selection for each surgery group, it strongly implies that patient selection plays a pivotal role in determining the outcomes.

Evidence indicates that MB alone for FS cases can avert iatrogenic and postoperative MHs, complications linked to PPV with ILM peeling.[16,32] Our data concurs. Among our subjects, no eyes with FS with a normal foveal profile developed FTMH post-MB. Just one eye from combined procedures had a postoperative FTMH. Many experts recommend MB for FS with FTMHs.[26,33,34] A literature review by Alkabes *et al* [35] highlighted that PPV plus MB yielded higher success in these cases.

Compared to literature on PPV,[20,21] our MH closure rate surpassed others like Wakabayashi *et al*,[20] who reported 83% closure with PPV, while we achieved 93.3%. They noted an 11.6% MH formation rate versus our 4.5% for all eyes. However, our combined surgery had a 9.7% postoperative FTMH rate, similar to theirs, but dropped to 2.9% with only MB. Combined surgery was more effective in our study. It had fewer unclosed FTMHs (4.2%) *versus* MB alone (11.11%) and better final BCVA. Yet, these differences were not statistically significant.

In our study, we achieved 100% MD resolution, surpassing literature rates of 70%-96.7% for PPV, alone or combined with ILM peeling.[36,37] Literature reports varied reattachment rates for MD with FTMH: 80%-100% for M [38,39] and up to 100% with PPV and ILM flap.[40,41]

We had 100% reattachment in MSS stages 3-4c. In this group of eyes, when PPV and ILM flap is chosen, literature cites 80%-100% MH closure rates, but only 35% for ILM-peeling.[40,41] Our single-operation closure was 92.9%. Combining MB with PPV may enhance outcomes for challenging cases. *Versus* Zhao *et al*,[42] our rates outperformed theirs. They reported 82.8% and 66.7% rates for combined and MB-only treatments, respectively. We observed 95.8% for combined and 88.9% for MB only. This difference might stem from patient selection differences, given Zhao *et al* randomized their subjects.

Regarding MD without FTMH, 8.86% (n=7) developed a FTMH. Except for one case that presented with foveal stage b, all had o-LMH pre-operatively. Feng *et al* [37] reported 13.1% of secondary MH.

Among the FTMHs that reopened, did not closed and newly developed FTMHs, only one case of MD developed. This showcases MB's effectiveness in preventing further issues and highlights the significant role of PS and anteroposterior traction in MTM's.

After surgery, diplopia self-resolved in nearly half of patients. This may result from muscle oedema caused by traction, inflammation, or an immune reaction to the buckle. Two severe cases required buckle removal. Five eyes showed CNV, possibly from inflammation or buckle's compression causing localized choroidal hypoxia and ischaemia.[42,43]

While atrophy is often cited as a significant complication following MB surgery, our findings did not corroborate this assertion. We observed comparable atrophy progression in both operated and fellow eyes. In a study of MB versus PPV, Zhao *et al*[12] found a greater frequency of macular atrophy in patients who underwent PPV than those treated with MB. Several studies have emphasized the emergence of patchy atrophy after PPV, with development in 11.6% of MTM cases.[44] Lee *et al*[44] also observed a notable rise in the prevalence of diffuse chorioretinal atrophy.

A limitation of the technique is postoperative MB decentration, often requiring urgent reoperation, increasing risks and costs.

This study has several noteworthy limitations. Firstly, it was a retrospective study conducted at a single site, which introduces the risk of selection bias and may limit the generalizability of the findings to a broader myopic population. Secondly, the variability of the indentation was subjectively performed by the surgeon intraoperatively using intraoperative OCT. Additionally, the study did not explore the impact of the duration of MTM, which could be a crucial factor in the development of macular atrophy. The lack of standardization in surgical indications and procedures, driven by individual surgeon judgment, might introduce variability in outcomes. Lastly, the study did not investigate the correlation between postoperative anatomical macular findings observed through OCT and postoperative BCVA, which could provide a more comprehensive understanding of surgical outcomes. These limitations should be considered when interpreting the study's results and may warrant further research to address these aspects comprehensively.

In conclusion, this study underscores the long-term safety and efficacy of macular buckling, whether used alone or in combination with PPV, for highly myopic eyes. It proved significantly more successful in achieving retinal reattachments and MH closure compared to PPV, while also reducing the incidence of FTMH development postsurgery. The safety profile, including common concerns following macular buckling, was deemed acceptable in this series. In summary, macular buckling emerges as a viable initial treatment option for managing MTM.

CONTRIBUTORSHIP STATEMENT / DECLARAÇÃO DE CONTRIBUIÇÃO:

EL and JR: Data collection, data analysis, writing.
VM: Data collection.
LC and BP: Review of the scientific content of the article.
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EL e JR: Recolha de dados, análise de dados, escrita.
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Todos os autores aprovaram a versão final a ser publicada.

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Protection of Human and Animal Subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki as revised in 2013).

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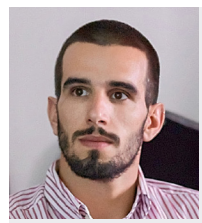
REFERENCES

1. Baba T, Ohno-Matsui K, Futagami S, et al. Prevalence and characteristics of foveal retinal detachment without macular hole in high myopia. Am J Ophthalmol. 2003;135:338-42. doi:10.1016/S0002-9394(02)01937-2
2. Panozzo G, Mercanti A. Optical coherence tomography findings in myopic traction maculopathy. Arch Ophthalmol. 2004;122:1455-60. doi:10.1001/ARCHOPHT.122.10.1455
3. Sun CB, Liu Z, Xue AQ, Yao K. Natural evolution from macular retinoschisis to full-thickness macular hole in highly myopic eyes. Eye. 2010;24:1787-91. doi:10.1038/EYE.2010.123
4. Fang X, Weng Y, Xu S, Chen Z, Liu J, Chen B, et al. Optical coherence tomographic characteristics and surgical outcome of eyes with myopic foveoschisis. Eye. 2009;23:1336-42. doi:10.1038/EYE.2008.291
5. Ikuno Y, Sayanagi K, Soga K, Oshima Y, Ohji M, Tano Y. Foveal anatomical status and surgical results in vitrectomy for myopic foveoschisis. Jpn J Ophthalmol. 2008;52:269-76. doi:10.1007/S10384-008-0544-8
6. Gaucher D, Haouchine B, Tadayoni R, Massin P, Erginay A, Benhamou N, et al. Long-term follow-up of high myopic foveoschisis: natural course and surgical outcome. Am J Ophthalmol. 2007;143:455-62. doi:10.1016/J.AJO.2006.10.053
7. Takano M, Kishi S. Foveal retinoschisis and retinal detachment in severely myopic eyes with posterior staphyloma. Am J Ophthalmol. 1999;128:472-6. doi:10.1016/S0002-9394(99)00186-5
8. Ouyang PB, Duan XC, Zhu XH. Diagnosis and treatment of myopic traction maculopathy. Int J Ophthalmol. 2012;5:754-8. doi:10.3980/J.ISSN.2222-3959.2012.06.19
9. Parolini B, Palmieri M, Finzi A, Frisina R. Proposal for the management of myopic traction maculopathy based on the new MTM staging system. Eur J Ophthalmol. 2021;31:3265-76. doi:10.1177/1120672120980943
10. Parolini B, Palmieri M, Finzi A, Besozzi G, Lucente A, Nava U, et al. The new Myopic Traction Maculopathy Staging System. Eur J Ophthalmol. 2021;31:1299-312. doi:10.1177/1120672120930590
11. Parolini B, Arevalo JF, Hassan T, Kaiser P, Rezaei KA, Singh R, et al. International Validation of Myopic Traction Maculopathy Staging System. Ophthalmic Surg Lasers Imaging Retina. 2023;54:153-7. doi:10.3928/23258160-20230217-01
12. Zhao X, Li Y, Ma W, Lian P, Yu X, Chen S, et al. Macular buckling versus vitrectomy on macular hole associated macular detachment in eyes with high myopia: a randomised trial. Br J Ophthalmol. 2022;106:582-6. doi:10.1136/BJOPHTHALMOL-2020-317800
13. Poole TA, Sudarsky RD. Suprachoroidal implantation for the treatment of retinal detachment. Ophthalmology. 1986;93:1408-12. doi:10.1016/S0161-6420(86)33553-X
14. Nakagawa N, Parel JM, Murray TG, Oshima K. Effect of scleral shortening on axial length. Arch Ophthalmol. 2000;118:965-8.
15. Liu B, Chen S, Li Y, Lian P, Zhao X, Yu X,et al. Comparison of macular buckling and vitrectomy for the treatment of macular schisis and associated macular detachment in high myopia: a randomized clinical trial. Acta Ophthalmol. 2020;98:e266-72. doi:10.1111/AOS.14260
16. Ripandelli G, Coppé AM, Fedeli R, Parisi V, D'Amico DJ, Stirpe M. Evaluation of primary surgical procedures for retinal detachment with macular hole in highly myopic eyes: a comparison [corrected] of vitrectomy versus posterior episcleral buckling surgery. Ophthalmology. 2001;108:2258-64. doi:10.1016/S0161-6420(01)00861-2
17. Theodossiadis GP, Sasoh M. Macular buckling for retinal detachment due to macular hole in highly myopic eyes with posterior staphyloma. Retina. 2002;22:129. doi:10.1097/00006982-200202000-00030
18. Theodossiadis GP, Theodossiadis PG. The macular buckling procedure in the treatment of retinal detachment in highly myopic eyes with macular hole and posterior staphyloma: mean follow-up of 15 years. Retina. 2005;25:285-9. doi:10.1097/00006982-200504000-00006
19. Wakabayashi T, Shiraki N, Tsuboi K, Oshima Y, Abe K, Yamamoto Y, et al. Risk Factors and Outcomes of Postoperative Macular Hole Formation after Vitrectomy for Myopic Traction Maculopathy: SCHISIS Report No. 2. Ophthalmol Retina. 2023;7:779-87. doi:10.1016/J.ORET.2023.05.017
20. Jain M, Narayanan R, Gopal L, Padhi TR, Behera UC, Panda KG, et al. Post-vitrectomy secondary macular holes: Risk factors, clinical features, and multivariate analysis of outcome predictors. Indian J Ophthalmol. 2023;71:2053-60. doi:10.4103/

IJO.IJO_1749_22
21. Palmieri M, Frisina R, Finzi A, Besozzi G, Parolini B. The Role of the Outer Lamellar Macular Hole in the Surgical Management of Myopic Traction Maculopathy. Ophthalmologica. 2021;244:229-36. doi:10.1159/000514993
22. Ohno-Matsui K, Lai TYY, Lai CC, Cheung CM. Updates of pathologic myopia. Prog Retin Eye Res. 2016;52:156-187. doi:10.1016/J.PRETEYERES.2015.12.001
23. Ohno-Matsui K, Kawasaki R, Jonas JB, Cheung CM, Saw SM, Verhoeven VJ, et al. International Photographic Classification and Grading System for Myopic Maculopathy. Am J Ophthalmol. 2015;159:877-883.e7. doi:10.1016/J.AJO.2015.01.022
24. Fang Y, Yokoi T, Nagaoka N, et al. Progression of Myopic Maculopathy during 18-Year Follow-up. Ophthalmology. 2018;125:863-877. doi:10.1016/J.OPHTHA.2017.12.005
25. Parolini B, Frisina R, Pinackatt S, Besozzi G, Lucente A, Nava U, et al. Indications and results of a new l-shaped macular buckle to support a posterior staphyloma in high myopia. Retina. 2015;35(12):2469-2482. doi:10.1097/IAE.0000000000000613
26. Mura M, Iannetta D, Buschini E, De Smet MD. T-shaped macular buckling combined with 25G pars plana vitrectomy for macular hole, macular schisis, and macular detachment in highly myopic eyes. Br J Ophthalmol. 2017;101:383-8. doi:10.1136/BJOPHTHALMOL-2015-308124
27. Ortisi E, Avitabile T, Bonfiglio V. Surgical management of retinal detachment because of macular hole in highly myopic eyes. Retina. 2012;32:1704-18. doi:10.1097/IAE.0B013E31826B671C
28. Kim CY, Kim MS, Kim KL, Woo SJ, Park KH. Prognostic factors related with surgical outcome of vitrectomy in myopic traction maculopathy. Korean J Ophthalmol. 2020;34:67-75. doi:10.3341/KJO.2019.0115
29. Taniuchi S, Hirakata A, Itoh Y, Hirota K, Inoue M. Vitrectomy with or without internal limiting membrane peeling for each stage of myopic traction maculopathy. Retina. 2013;33:2018-25. doi:10.1097/IAE.0B013E3182A4892B
30. Hwang JU, Joe SG, Lee JY, Kim JG, Yoon YH. Microincision vitrectomy surgery for myopic foveoschisis. Br J Ophthalmol. 2013;97:879-84. doi:10.1136/BJOPHTHALMOL-2012-302906
31. Ikuno Y, Sayanagi K, Ohji M, Kamei M, Gomi F, Harino S, et al. Vitrectomy and internal limiting membrane peeling for myopic foveoschisis. Am J Ophthalmol. 2004;137:719-24. doi:10.1016/j.ajo.2003.10.019
32. Devin F, Tsui I, Morin B, Duprat JP, Hubschman JP. T-shaped scleral buckle for macular detachments in high myopes. Retina. 2011;31:177-80. doi:10.1097/IAE.0B013E3181FC7E73
33. Burés-Jelstrup A, Alkabes M, Gómez-Resa M, Rios J, Corcóstegui B, Mateo C. Visual and anatomical outcome after macular buckling for macular hole with associated foveoschisis in highly myopic eyes. Br J Ophthalmol. 2014;98:104-9. doi:10.1136/BJOPHTHALMOL-2013-304016
34. Alkabes M, Pichi F, Nucci P, Massaro D, Dutra Medeiros M, Corcostegui B, et al. Anatomical and visual outcomes in high myopic macular hole (HM-MH) without retinal detachment: a review. Graefes Arch Clin Exp Ophthalmol. 2014;252:191-9. doi:10.1007/S00417-013-2555-5
35. Ma IH, Hsieh YT, Yeh PT, Yang CH, Yang CM. Long-term results and risk factors influencing outcome of gas tamponade for myopic foveoschisis with foveal detachment. Eye. 2020;34:392-9. doi:10.1038/S41433-019-0555-3
36. Feng J, Yu J, Chen Q, Zhou H, Chen F, Wang W, et al. Long-term surgical outcomes and prognostic factors of foveal detachment in pathologic myopia: based on the ATN classification. BMC Ophthalmol. 2022;22:175. doi:10.1186/S12886-022-02391-1
37. Alkabes M, Mateo C. Macular buckle technique in myopic traction maculopathy: a 16-year review of the literature and a comparison with vitreous surgery. Graefes Arch Clin Exp Ophthalmol. 2018;256:863-77. doi:10.1007/S00417-018-3947-3
38. Devin F, Tsui I, Morin B, Duprat JP, Hubschman JP. T-shaped scleral buckle for macular detachments in high myopes. Retina. 2011;31(1):177-180. doi:10.1097/IAE.0B013E3181FC7E73
39. Chen SN, Yang CM. Inverted Internal Limiting Membrane Insertion for Macular Hole-Associated Retinal Detachment in High Myopia. Am J Ophthalmol. 2016;162:99-106.e1. doi:10.1016/J.AJO.2015.11.013
40. Baba R, Wakabayashi Y, Umazume K, Ishikawa T, Yagi H, Muramatsu D, et al. Efficacy of the inverted internal limiting membrane flap technique with vitrectomy for retinal detachment associated with myopic macular holes. Retina. 2017;37:466-71. doi:10.1097/IAE.0000000000001211
41. Zhao X, Song H, Tanumiharjo S, Wang Y, Chen Y, Chen S, et al. Macular buckling alone versus combined inverted ILM flap on macular hole-associated macular detachment in patients with high myopia. Eye. 2023;37:2730-5. doi:10.1038/S41433-023-02406-1
42. Tang N, Zhao X, Chen J, Liu B, Lu L. Changes in the choroidal thickness after macular buckling in highly myopic eyes. Retina. 2021;41:1858-66. doi:10.1097/IAE.0000000000003125
43. Fang Y, Yokoi T, Shimada N, Du R, Shinohara K, Takahashi H, et al. Development of macular atrophy after pars plana vitrectomy for myopic traction maculopathy and macular hole retinal detachment in pathologic myopia. Retina. 2020;40:1881-93. doi:10.1097/IAE.0000000000002709
44. Lee KS, Lee JS, Koh HJ. Surgical outcomes of myopic traction maculopathy according to the international photographic classification for myopic maculopathy. Retina. 2020;40:1492-9. doi:10.1097/IAE.0000000000002642



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