Review Article

Current concepts of macular buckle in myopic traction maculopathy

Pradeep Susvar, Gitanjli Sood

Since its introduction by Charles L. Schepens, macular buckle (MB) surgery has evolved over the past 60 years. Optical coherence tomography (OCT) has given a paradigm shift to the understanding of myopic macula, thereby helping in objective evaluation of the various manifestation of traction maculopathy. Staphyloma evaluation by ultrasound, wide-field fundus photography, and MRI scans along with OCT has led to the resurgence of MB surgery in the treatment of myopic traction maculopathy (MTM). Various surgical techniques with different buckle materials are being performed with encouraging anatomical and functional success rates. This article reviews the literature to explain the current concept of MB surgery based on its evolution, different kinds of buckle materials, rationale for planning MB surgery, and different surgical techniques for the management of MTM.

Key words: Foveal schisis, macular buckle, macular retinal detachment, myopic macular hole, myopic traction maculopathy, posterior staphyloma, spectral-domain optical coherence tomography, vitrectomy

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Myopic maculopathy is one of the major causes of visual impairment and legal blindness, more commonly in Asian population but also noted in the Western population.[1,2] The impact of myopic maculopathy on visual impairment is important because it is often bilateral, irreversible, and frequently affects individuals during their most productive years. Maculopathy manifests as focal pathology such as lacquer cracks, choroidal neovascular membrane (CNVM), generalized degenerative changes in retinal pigment epithelium (RPE), and choroid and tractional changes at the retina. They can be managed medically or surgically, where intervention could be vitrectomy or macular buckling.[3,4]

In this article, we attempt to bring out the current situation of macular buckle (MB) surgery by reviewing the literature. We discuss the historical perspectives of various MBs, importance of posterior staphyloma (PS) evaluation as prerequisite for the surgery, evolution of optical coherence tomography (OCT) and its current utility, rationale in the choice of surgery and its indications, adjunctive investigations required for buckling, review of various buckle elements used worldwide, and anatomical and functional outcome of the surgical procedures.

Historical Perspectives

Macular buckle

Using a radially placed polyethylene tube in 1957, Charles L. Schepens described macular buckling for the first time.[5] In 1966, Rosengren[6] described a silver ring and plomb technique to indent the macula. Theodossiadis[7] used a silastic sponge rod, which was placed between the inferior oblique insertion and the optic nerve.

Machemer introduced vitrectomy in 1980. Over the time, improvisation of instruments and visualization lenses lead to better surgical maneuvers such as posterior vitreous detachment (PVD), internal limiting membrane (ILM) peeling, and tamponading agents. However, anatomical results showed the primary success rate limited to 50–73.3% with vitrectomy in high myopic eyes[8] that had PS. This leads to the resurgence of interest in MB procedures. Fig. 1 depicts the evolution of the MB technique.

Posterior staphyloma

PS is now considered an established and important pathological feature for the onset and progression of myopic maculopathy.[9] To study, its characteristic is equally important for surgical placement of MB in the management of myopic traction maculopathy (MTM).

Antonio Scarpa, a skilled anatomist, first described PS as early as 1801.[10] Von Graefe is credited with the first study of PS in his ophthalmoscopic and histopathologic investigation in two myopic eyes in 1857.[11]

First classification of PS by Brian J. Curtin[11] was a major contribution to the literature. It was based on subjective observation of 250 patients with only binocular stereoscopic ophthalmoscopy and a fundus drawing. He classified them into two types: primary (type I–V) and compound (type VI–X), as determined by the location, size, and severity. Although type I (involving optic nerve head and macula) and

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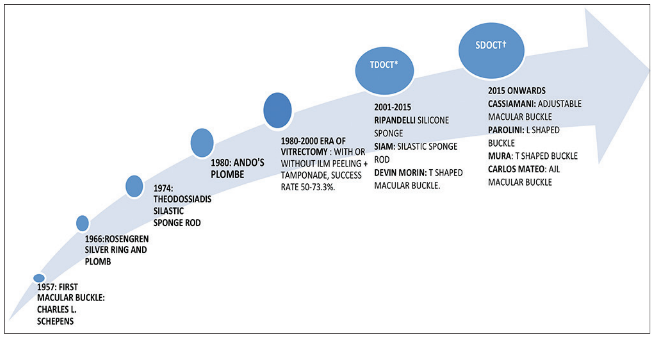


Figure 1: Historical depiction of macular buckling

type II (involving macula) are the most common primary staphylomas, type IX is associated with more of pathological changes and is progressive. A recent study of 198 eyes of 105 patients by Ohno-Matsui[12] gave a significant change to the concept of staphyloma with objective assessment by newer imaging tools using the wide-field Optos fundus imaging and three-dimensional (3D) magnetic resonance imaging (MRI). They categorized staphyloma into five types, namely, wide macular (type 1), narrow macular (type 2), peripapillary (type 3), nasal (type 4), inferior (Type 5), and others (other than type 1–5). They reported MRI showed that 50% of high myopia had no staphyloma, and wide macular was the most common type of staphyloma noted in the series.

Role of OCT: Standardizing Indications for Macular Buckling in MTM

The pathoanatomical features of MTM were not characterized before the era of OCT, leading to incomplete understanding of the pathogenesis.[13] This was because the identification of the early stages of MTM was clinically difficult with biomicroscopy alone.[13] Clear view of the vitreoretinal interface usually is challenging because of the thin retina and chorioretinal atrophy (CRA) behind PS. At the beginning of the year 2000, Gallemore *et al*.[14] demonstrated sensitivity of the OCT over biomicroscopy in detecting the subtle changes. Thereafter, OCT has become an absolutely essential and integral tool in the management of MTM.

The term myopic foveoschisis (MF) was first coined in 1999 by Takano and Kishi[9] to describe the splitting of the inner retinal layers in eyes with high myopia and PS. This study was conducted on time-domain OCT (TD-OCT).

Panozzo and Mercanti[13] in 2004 proposed to unify all of the pathological features generated by traction in the myopic environment under the term MTM.

For evaluating individuals with high myopia, spectral-domain OCT (SD-OCT) is currently the standard tool for diagnosis of MF and other macular changes as evidenced by Gohil *et al*.[15] in their clinical review on MF. The natural course of myopic maculopathy is now established based on many longitudinal OCT studies.

Thus, pathogenesis of the maculopathy was reestablished based on the OCT changes. Macular hole formation is probably a secondary phenomenon occurring after a variable period of few months to several years following the development of MF and foveal detachment (FD).[15]

Currently, general consensus is that there is a good level of consensus that surgical intervention should be considered when there is progressive visual decline from MF.[15]

The development of enhanced-depth imaging (EDI) by pushing the zero delay line toward the choroid–sclera junction in SD-OCT allows the visualization of changes in choroid in high myopia.[16]

Swept-source OCT (SS-OCT) is a recent evolution of OCT, using a fast wavelength scanning light source. Lim *et al*.[17] compared SD-OCT with SS-OCT and noted the advantages in scanning pathological myopia. Greater depth scans (for evaluating the staphyloma architecture) along with longer scans (for evaluating the extent of the retinoschisis) are useful in presurgical planning in cases of MTMs associated with PS.

Ng *et al*.[16] with their study to image sclera opine that SS-OCT is preferred over EDI-OCT for imaging of the sclera. This feature is best utilized in evaluating the buckle placement after surgery to look for the sclerochoroidal changes with the indentation. We performed SS-OCT for all our patients undergoing MB as pre- and postoperative evaluation and noted the advantages of both depth and length of the scans.

Current Utility of OCT in MB Surgery for MTM

Anatomical success rates for vitrectomy and MB surgery were falsely high in the pre-OCT studies, following which, Ikuno *et al*.[8] conducted a comparative study between the two surgeries with OCT and redefined the success rates based on TD-OCT assessment of macular changes.

SD-OCT is currently the standard tool for diagnosis of MTM and its management.[15] Serial SD-OCT scans observed over a period help a clinician to decide for the timing of surgical intervention in cases of chronic changes.

SS-OCT, a newer technology, has an edge over the SD-OCT scans, particularly in evaluating the staphyloma contour in addition to the myopic macular changes.[18]

Presurgical documentation by SD-OCT of all the components of MTM[19,20] – retinoschisis, posterior cortical vitreous attachment, lamellar macular hole (LMH), full-thickness macular hole (FTMH), epiretinal membrane (ERM), neurosensory detachment (NSD), subretinal fluid (SRF), and macular detachment – is important to decide for either vitrectomy or MB surgery. Staphyloma depth and extension is identified by either SD-EDI or SS-OCT scans.[16,18,20]

Table 1 shows the comparison of all major studies that have documented OCT changes in patients operated for MTM using either MB or vitrectomy, or a combination of both.

The anatomical outcome of the surgical intervention is measured by three main changes on OCT, namely, resolution of schisis, reattachment of fovea and macula, and closure of macular hole.[21-34] Of the three anatomical changes, most studies have noted success between 80% and 100% for foveal attachment (resorption of SRF) and resolution of schisis.[21,24,25,27,29,31,34] Closure of macular hole ranged between 60% and 80% in these studies.[23,26] An interesting fact noted in all these studies is the high rate of anatomical restoration of the macula consensus with any of the types of buckle element used.

Table 1: Evaluation of various studies documenting the change on OCT in MTM

Author	Year	Clinical features	No	OCT	Surgery	Resolution of OCT features
Ripandelli *et al.*[21]	2001	HM-MH-RD	30	TDOCT	V (15), MB (15)	Reattachment 73.3% in V group, 93.3% in MB group. MH closed 100% in MB group, FD resolves first followed by FS in about 2-21 months
Kobayashi *et al.*[35]	2003	HM-FS-FD	9	TDOCT	V + ILM + Gas	Foveal attachment and resolution of schisis 2 weeks to months. 14 cases had OCT scan. 12 had indentation of buckle and 10 had complete closure of hole.
Baba *et al.*[23]	2006	HM-FS-FD	6	TDOCT	MB: Plombe	FS resolved in 100%. MH closed in 36%.
Ando *et al.*[36]	2007	HM-MH-RD	58	TDOCT	V (28), MB (30)	11 cases of FS group after surgery 4 had complete resolution, 4 partial, 3 developed macular hole
Ikuno *et al.*[37]	2008	HM-FD (17) FS (16)-MH (11) HM- FS (13*+4)	44	TDOCT	V+ILM+Gas	6 eyes of MH group 3 developed RD and were operated Complete resolution of FS and detachment in all All cases in Si Implant and 7 in plombe had complete resolution of schisis.
Gaucher *et al.*[38]	2007	FD (10), LMH (6)	29	TDOCT and SDOCT	V+Gas, ILM: One patient only V+ILM±Gas	Attachment in all.
Kumagai *et al.*[39]	2010	HM-FS+RD (27) FS (12)	39	SDOCT	V+Plombe + Gas (10)	Reattachment was faster in plombe and within 8 weeks in Si Implant.
Mateo *et al.*[26]	2012	HM-FS-FD (13)-LH (8)	16	TDOCT	V+Si Implant + Gas (6)	100% reattachment rate and hole closure of 60% in both groups
Tian *et al.*[29]	2013	HM-MH-ReRD	5	TDOCT	MB	Reattachment in all 5 cases Hole closed in 2/5 cases
Parolini *et al.*[40]	2015	HM, MH-MD (15), MD (17), FS (18)	50	SDOCT	V+MB (20), MB (30)	11 eyes hole closed and schisis resolved at 1 month and in the rest at 3 months. Mean central retinal thickness same at baseline and follow up. Macular hole closure 90.5%
Cassiamani *et al.*[33]	2016	HM-FS-FTMH	15	SDOCT	MB	Reattachment rate 100%
Mura *et al.*[31]	2016	HM-MH (5), MH+FS (5) MH+MD (11)	21	SDOCT	MB±V	Retinal reattachment rates at 1 year and macular hole closure rate at 2 years were higher in combined group (93%, 26%) as compared to only vit group (73%, 3.85%)
Ma *et al.*[34]	2017	HM-MH-RD	98	SDOCT	V+ILM=Gas (52) V + ILM + Gas + MB (46)	

FS=Foveoschisis, HM=High myopia, LMH=Lamellar macular hole, MD=Macular detachment, RD=Retinal detachment, Re RD=Recurrent retinal detachment, Si implant=Silicone implant. *These cases had tractional premacular component

The time to complete foveal reattachment on OCT after macular buckling has been noted to ranges between 2 weeks and 3 months.[23,26]

In our unpublished case series of MB for MTM, we have noted closure of macular hole, resorption of SRF, and resolution of schisis in 85% cases as early as third postoperative day; the percentage is higher in vitrectomy combined with buckle group. They have remained stable till the last follow-up of up to 3 years [Fig. 2].

PS Evaluation: An Essential Prerequisite for MB

PS is present in 90% of the patients with high myopia, and the prevalence of staphylomas is significantly higher in older patients than in younger patients.[41,42] The OCT studies have already established the progression of myopic schisis to FD to macular hole formation with PS.

Dr. Fumitaka Ando,[43] who innovated the Ando's plombe, hypothesized in his original article that the buckling of the macular area relieves the anteroposterior vitreoretinal traction and overcomes the geometric imbalance between the neurosensory retina and the RPE–choroid–sclera complex due to PS. Thus, it facilitates the adhesion between the relevant tissues and, as a result, not only does the macular hole closure but retinal reattachment was also achieved.[36]

In a study of 198 eyes of 105 patients with high myopia, Ohno-Matsui[12] described the importance of wide-field fundus imaging complemented by the utility of 3D MRI in visualizing the characteristics of staphyloma. These investigations would be a prerequisite to decide for the type of surgery best suitable for MTM documented on OCT. The assessment of the grade and the depth of staphyloma using the combination of OCT and ultrasound helps the surgeon to decide for performing vitrectomy alone, MB alone, or a combination of both.

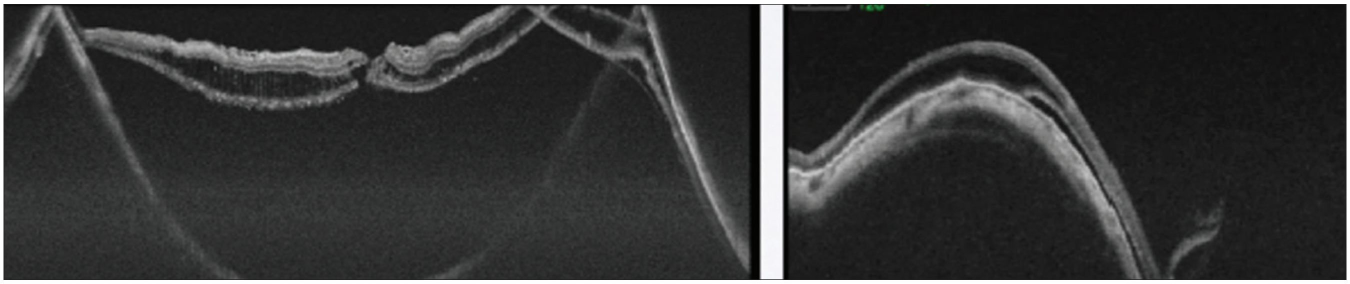


Figure 2: SS-OCT scan showing the deep posterior staphyloma having macular hole with macular detachment and shortened schitic retina of recent onset, underwent vitrectomy + MB. Postoperative scan showing macular indentation by the buckle with closure of the hole and resorption of SRF

In their brief study, Oie *et al.*[44] noted that eyes with type II PS have a higher risk of developing macular hole with retinal detachment (MHRD) as the vitreous cortex at the macula generally causes tangential traction and is believed to result in MHRD. Centripetal vector force is larger in eyes with localized PS such as type II (Curtin's classification). Similarly, in a study of 104 highly myopic eyes with MHRD, Morita *et al*.[45] reported that type II constituted 61% and type I 19%.

In our unpublished MB surgery case series, we have observed that the staphyloma characteristics by its type, grade, depth, and extent are important factors noted in a case of MTM planned for the surgery. In the series, we had patients with more of type I staphyloma, followed by type II and type IX. Our results showed that patients with type II and type IX staphyloma have better structural and functional outcome after the surgery as compared to those with type I staphyloma. Further studies based on the preoperative wide-field fundus photography and possible MRI scans may help to prognosticate the possible outcomes after MB surgery.

Adjunctive Investigation for MB Surgery

The advantages of the spectral-domain and swept-source technologies in the present era of OCT have already been discussed. OCT is an essential guide for the surgical decision-making in MTMs and also for postsurgical assessment of the macula indented by the buckle element. Apart from the OCT, it is important to perform the A-scan and B-scan ultrasound[21,32,46] to look carefully at the staphyloma contour and measure the axial length within and outside the staphyloma. Grading of the staphyloma helps to estimate the depth of the insertion of the buckle posteriorly for an optimal securing of the anchor suture onto the sclera. Steidl and Pruett[47] proposed the staphyloma grading, based on the combination of fundus photography, A-scan ultrasound, and B-scan ultrasound. Staphyloma is graded[47] as mild (0–2 mm), moderate (2–4 mm), severe (4–6 mm), and very severe (>6 mm). Fundus montage or wide-angle fundus images and the newer Optos fundus images help the surgeon to evaluate the type of staphyloma. We have already discussed the major contribution from Ohno Mutsui[12] to visualize the characteristics and types of staphyloma by wide-field fundus imaging combined with 3D MRI. This would guide the surgeon for passing and placement of the buckle element posteriorly to precisely support the convexity. Visual fields and microperimetry tests would help in assessing the function by measuring the mean retinal sensitivity (MRS) increase and fixation stability along with best corrected visual acuity (BCVA).[33]

Rationale and Indications of Surgery for MTM

Rationale 1

Fujimoto *et al.*[20] studied SD-OCT biomarkers of foveoschisis developing macular detachment or FD. They observed that posterior ectasia of the RPE and the choroid, resulting from PS, sclerotic retinal arterioles, and a firm inflexible ILM that cannot lengthen, may together enhance the inward traction exerted by the retinal arterioles, leading to FD. They noted that strong ILM attachment at the periphery of the macula is the precursor for the foveal retinal detachment.

Rationale 2

Spaide[46] 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." Staphyloma is much more reliable indicator of pathological myopia than axial length and is present in almost 50% of cases.[48,49]

Translating these two pathoanatomy to the surgical anatomy, management of MTM depends on the primary etiology responsible – the three vector forces acting at the macula, namely, tangential traction on the inner retinal surface (abnormal rigid ILM, stretched retinal vessels, or ERM), anteroposterior traction of the vitreous, and posterior scleral ectasia (staphyloma).[22,24,36]

The anteroposterior traction caused by the vitreous is addressed with conventional vitrectomy. The tangential force is negated by peeling of the ILM, complete PVD from the disk and macula, and removal of ERM, if present. Thus, in cases having isolated or a combination of macular schisis, lamellar holes, NSDs, and even full-thickness hole with a small SRF component, one can achieve an optimal and even complete surgical success by conventional vitrectomies.[35,37-39,50] Surgery should ensure a complete separation of all posterior cortical layers with relatively large ILM peeling for the surgical success. Here again, the staphyloma component should be minimal or shallow to go for vitrectomy alone without the need for buckle support.

Cases having macular tractional changes, which have progressed and worsened recently or have not been successful by vitrectomy, warrant closer look at the third component of the tractional force acting at the macula – the staphyloma-related scleral – retinal mismatch.[23,24,28,34] Such cases require MB to support the staphyloma. The buckle supports the posterior globe to counteract all the aforementioned tractional mechanisms

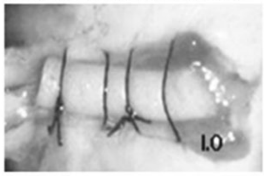
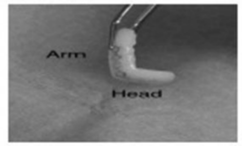
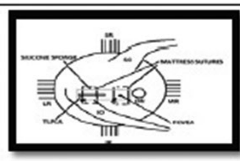
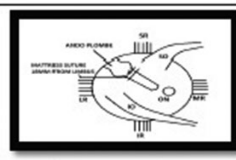
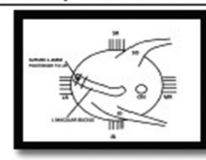
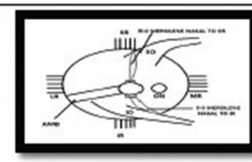
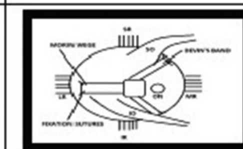
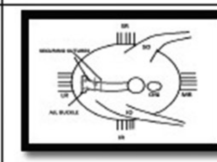
TYPE OF MACULAR BUCKLE	SILASTIC SPONGE ROD 	ANDO'S PLOMBE 	L SHAPED MACULAR BUCKLE 	ADJUSTABLE MACULAR BUCKLE 	DEVIN MORINS T SHAPED BUCKLE 	AJL MACULAR BUCKLE 
BUCKLE DETAILS	12*2mm Silastic sponge	Silicone plate with stainless steel wire 5 different sizes (21-29mm length) Plate size 5*5mm)	Silicone sponge 3cm long and 5mm thick and 7mm large with malleable Ti stent (15mm Silicone rubber)	radial exoplant. Handle (2*2*10mm) with plate quadrangular (4*4mm) or circularmeridional (5mm)	T Shaped (Morin Devin T'-shaped macular wedge)	PMMA material covered by silicone The arm's length and curvature is customized.
PROCEDURE	 All 4 recti and IO tagged, SO severed Globe exposed to bring the posterior pole into view. Two mattress sutures placed at posterior pole,nasal one around fovea(5/6-0 Dacron)	 Lateral cantotomy done Check ligaments severed -Suture placed 16 mm from limbus in between SO and IO to hold plate -SRF drainage required -IO to visualise indent	 Buckle is slid head down along the lateral rectus muscle from the STQ. The tail is sutured with matress suture (6-0 μ) -Chandelier light used -0.3ml SF6 used in all	 SR, LR, IR tagged. LR disinserted. Suture (5-0 mersilene) passed through 2 lateral wingelets. After positionig plate under macula with support from handle, the indentation is done and sutures finally tied anterior to equator nasal to SR, IR	 Tag the SR, IR, LR and IO with 2-0 Mersilene. 2mm band is passed under LR, IO and IR and fixed inferiorly. Plate is threaded and superior band passed under SR Plate passes under LR and macular indent finalised. Free end of plate sutured under LR and band nasal to SR	 All recti tagged and buckle is slid underneath the LR muscle(25G optical fibre fixed for illumination) or from ST quadrant. After positioning fixed with 5-0 ethibond under LR.
ADVANTAGE		Advantages: easy to insert the buckle, shape memory, customization of buckle with its embedded wire and eliminates the need for sutures on the staphylomatous sclera near macular area	It can be easily prepared in the operation theatre and the technique can be performed without the need of specially designed buckles, which are not available easily in all countries.	No direct posterior suture, buckle indent can be titrated by pulling two sutures.	Allows the adjustment for lengthening or shortening the band anteriorly while sliding the macular plate in the coronal plane; does not require posterior sutures or direct access to the posterior pole, no need for muscle disinsertion	Customized to individual patients eye, supplied with an optic fiber light probe for accurate positioning of the head under the fovea
DISADVANTAGE	Direct sutering at posterior pole, difficult globe exposure, Fat prolapse, vessel injury, globe perforation	Stiffness, limitations in adjustment of height,long-term safety of metal wire.	Include the unknown long-term safety of the titanium inside the orbit	Requires muscle discinsertion.	Possibility of improper alignment under the fovea.	Price and availability

Figure 3: Enumeration of various types of MB elements and techniques

involved in the pathophysiology. It changes the configuration of the concave profile of PS to a planoconvex protruding contour, thereby relieving all three tractions: anteroposterior, tangential traction, and sclera–retina mismatch.[23,31,34,51]

In literature, three important indications of MTM that require surgical intervention are as follows:

1. Full thickness with or without macular detachment (MHRD)
2. Macular foveoschisis with macular detachment (MRD)
3. LMH with schisis.

Patients with MF retain relatively good vision, but once a lamellar hole develops, an FD will develop in a short time, followed by a decrease in vision due to macular hole. The development of FD is an indication of poor prognosis; therefore, surgery at this stage may preempt the development of LMH or FTMH.[38,39]

Indications for the buckle surgery in our series were the same. We noted better functional and structural outcomes of MB in patients that had recent progression in their symptoms. The other signs noted on OCT were recent progression of the preexisting schisis, presence of NSD or SRF under the fovea, formation of the hole on serial scans, and most importantly presence of significant component of staphyloma.

Various Buckle Elements Described in the Literature

Many surgeons have tried various buckle elements and described their inherent ease and difficulties[21-28] [Fig. 3]. In this review, it would be worthy to mention the first specifically designed solid silicone plate, named macular plombe (called "Ando's plombe"), designed by Japanese surgeon Dr. Fumitaka Ando.[36,43] The plombe consists of a T-shaped semirigid silicone rubber rod internally reinforced with titanium wires and an indenting head at one end. Ando's buckle became the most popular design because of the relative ease of implant. Its embedded wire, in fact, allows buckling customization, shape memory, and eliminates the need for sutures on the posterior staphylomatous sclera.[51]

Buckle elements can be commercially available sponges sutured to the sclera as described by Theodossiadis and Theodossiadis[22] and Siam *et al*.[25] These sponges could be reinforced by the orthodontic metal wire (Mortada[52]) or titanium stent (Parolini *et al.*[40]), which gives both rigidity and flexibility to navigate and secure the buckle under the macula. One of the commercially available buckle elements, Morin–Devin T-shaped macular wedge,[24] is made up of solid silicone Morin wedge macular plate transected by a Devin band to form a T shape, which has been studied by us ourselves and by Mura *et al*.[31]

In our experience with the T-shaped buckle (France Chirurgie Instrumentation [FCI]), we have noted the advantages and ease of the techniques described by the authors.[24] Fig. 4 explains the surgical steps of the Morin–Devin buckle placement.

Mateo *et al*.[28] also modified the Ando's plombe with an illuminated light pipe for precise localization. Adjustable buckles have been tried by Stirpe *et al*.[51] with the advantage of temporarily securing suture knots and titrating the height during the postsurgery period.

Tracing the evolution of MB, it is seen that MB elements and techniques gradually had inherent "material-related" problems[52] along with "technique-related" challenges and difficulties.[40] For instance, drawback of Ando's plombe included its stiffness, limitations in the fine adjustment of buckling height, a less accurate centering, and a tendency toward reducing its effect with time. The presence of a metal wire, although embedded in silicone, also poses questions of long-term safety and medical imaging interference.[51]

Outcome of the Surgical Procedures for Managing MTM using MB

Primary macular buckling,[22-25,29] vitrectomy,[35,37-39,50] and a combination of two[21,27,30,31,34,36,40,52] are the three commonly performed surgeries for MTM using various types of buckle materials. Decision to plan one among the three can be based on the combination of morphological changes on OCT and staphyloma characteristics. Treatment-naïve, postvitrectomy, and silicone oil-filled eyes also add to the aforementioned factors to decide for a primary or combined (vitrectomy with MB) surgery.

On literature review [Tables 2-4], we could segregate the studies based on three types of surgery: MB alone, vitrectomy (with or without ILM peeling), and a combination of MB with vitrectomy. Some studies also evaluated MB results in failed vitrectomy cases.[24,29,52] We have had the experience of performing all three types of surgery and are analyzing our results (unpublished observations).

Studies evaluated for only MB surgery

Literature search of only MB was performed and was relatively less compared to those of combined surgeries. One of the large series (25 eyes) and with longest follow-up of 15 years (10–19 years) is the study by Theodossiadis and Theodossiadis.[22]

MHRD was the most common indication for performing MB surgery alone in the studies conducted by Theodossiadis (Italy),[22] Baba *et al*. (Japan),[23] Morin-Devin *et al*. (France),[24] Siam *et al*. (Egypt),[25] and Tian *et al*.(China).[29] Except Theodossiadis and Theodossiadis,[22] OCT was used to analyze outcomes. Silastic sponge was the material used by Theodossiadis and Theodossiadis,[22] Siam *et al*.,[25] and Tian *et al*.[29] Baba *et al*.[23] had cases of only MRD without macular hole and used a plombe probably similar to Ando's plombe.

Anatomical resolution of the SRF and closure of the hole ranged from 2 weeks to 6 months and the authors quote 100% anatomical success over a period of time. However, the functional outcome was stabilization of the visual acuity in all these studies. This is explained by the preexisting CRA at the macula. Three studies of macular buckling were available in failed vitrectomy cases,[24,29,52] among which two series had silicone oil *in situ* during the macular buckling (Morin-Devin *et al*.[24] and Tian *et al*.[29]). Tian *et al*.[29] studied exclusively the silicone-filled eyes undergoing MB surgery in their series using silastic sponge. Silicone oil was removed either during the buckle procedure or within a month after surgery. The anatomical success was noted to be 79% and had stabilization of the vision.[24]

Table 2: Studies that evaluated only MB surgery for varied indications of myopic tractional maculopathy

Author	Year	Clinical features	No. of eyes compared	AXL	Staphyloma/ Ref. error	Follow-up	Surgery	Salient features	Complications
Theodossiadis and Theodossiadis[22]	2005	HM-MH-RD	25	28-32	+(8: Ty1, 17: II)/−9 to −18	10-19 years	MB	Hole closure and reattachment 22 of 25; vision improved in 23; 100% success after second surgery	Perforation (5), tear (1), hemorrhage (2)
Baba *et al.*[23]	2006	HM-FS-FD	6	27.2-31.2 (29)	+	9-47 months (25.7)	MB: Plombe	Mean retinal thickness significantly reduced in all patients and VA improved >2 lines in 4; foveal attachment takes 2 weeks to 3 months	CNVM (1), subretinal hemorrhage (1)
Morin *et al.*[24]	2011	HM-MHRD (11) MSRD (3)	14	27-33 mm	±9 to −31	6 months to 9 years	T-shaped MB (six failed vitrectomy)	79% anatomical success, vision unchanged; 6 eyes had failed vitrectomy; 11 of 14 reattachment rate	Retinal hemorrhage (1), peripheral hemorrhagic CD (1)
Siam *et al.*[25]	2012	MHRD	26		+		MB (silastic sponge rod)	Reattachment rates were better if primary surgery oil was used (91-100%) as compared to gas (63-91%)	Prolapse of fat (6), vessel injury, perforation (4), submacular hemorrhage (1)
Tian *et al.*[29]	2013	HM-MH-ReRD	5	>30 mm	±9 to −15.5	9-28 months	MB (silicone sponge)	All cases have attachment after surgery hole 2 of 5	Hyphema (1)
Mortada[52]	2013	HM-MH-ReRD	15		NA		L-shaped MB	All cases had failed vitrectomy; after MB 100% reattachment rate and hole closure	Extrusion (1)

HM=High myopia, MH=Macular hole, RD=Retinal detachment, FS=Foveoschisis, FD=Foveal detachment, MHRD=Macular hole RD, MSRD=Macular schisis RD, ReRD=Recurrent RD, MB=Macular buckle, VA=Visual acuity, CNVM=Choroidal neovascular membrane, CD=Choriodal detachment

Ripandelli *et al.*[21] and Ando *et al.*[36] are the only two studies that have conducted a comparative study for eyes with MHRD between vitrectomy versus MB in their series of 30 and 58 eyes, respectively. They noted the anatomical success rate of 93.3% in MB group compared to 73.3–83.3% in vitrectomy group. Visual improvement was also noted to be better in MB group. In our unpublished case series of MB-alone procedure using Morin–Devin T-shaped buckle, we had 72.5% anatomical success and 85% functional stability and improvement in 3-year follow-up [Fig. 5].

Table 3: Studies in which vitrectomy with or without ILM peeling and tamponade was evaluated in management of myopic tractional maculopathy

Author	Year	Clinical features	No. of eyes compared	AXL	Staphyloma/ Ref. error	Follow-up	Surgery	Salient features	Complications
Kobayashi and Kishi[35]	2003	HM-FS-FD	9		+	6-24.5 months	V + ILM + gas	There was reduction in FS and FD and increase in BCVA; foveal detachment resolves first followed by schisis and takes 2-21 months; incidence of MHRD is 40% in fellow eye	FTMH (1)
Ikuno *et al*.[37]	2008	HM-FD (17)-FS (16)-MH (11)	44		NA	NA	V + ILM + gas	BCVA improved >2 lines in FD group (81%), FS (50%), and MH (45%); retinoschisis has delayed visual recovery and MH mostly don not improve vision, so such stage should be avoided	Persistent MH (7), new MH (2), inferior RD (2)
Gaucher *et al*.[38]	2007	FS (13)-FD (10)-LMH (6)	29 (11 surgery)		+	NA	V + gas ILM: one patient only	Eyes with premacular structure had progressive increase in schisis; 11 eyes that were operated improved vision; MH developed in 9 of 29 eyes on follow-up	FTMH (3)
Kumagai *et al*.[39]	2010	HM-FS + RD (27) FS (12)	39		+(16)	NA	V + ILM±gas	Eyes with FS and FD better increase in VA; complete reattachment and resolution of schisis in all eyes; better in shorter eyes with better pre-op vision	CNVM (1), CRA (5)

HM=High myopia, FS=Foveoschisis, FD=Foveal detachment, MH=Macular hole, LMH=Lamellar macular hole, RD=Retinal detachment, BCVA=Best corrected visual acuity, MHRD=Macular Hole RD, VA=Visual acuity, FTMH=Full-thickness macular hole, CNVM=Choroidal neovascular membrane, CRA=Chorioretinal atrophy

Studies evaluated for combined MB and vitrectomy

The combination of vitrectomy and MB allows to treat tangential and anteroposterior tractions of MTM simultaneously.[26]

Series from Mortada[52] had 15 patients undergoing (re) vitrectomy with MB for postvitrectomy recurrent retinal detachment and open macular hole, having 100% retinal attachment success. Mateo *et al*.[27] analyzed the results for non-MHRD cases having only macular schisis (no hole) in 39 eyes and noted similar 100% OCT-based anatomical success. Burés-Jelstrup *et al*.[30] from the same Mateo group had similar anatomical closure rate of 100% and vision improvement of 81.25% in cases having macular schisis and macular hole. Highlight is that vitrectomy combined with MB was performed for cases with maculopathy alone without retinal detachment, suggesting that the internal tangential relief by vitrectomy will have a complimentary effect when combined with the buckle support. Mura *et al*.[31] in their series of 21 eyes of all subtypes of maculopathy noted 100% anatomical success in reattaching the macula and 71.4% in visual stability. Cases included postvitrectomy eyes also.

So far, the only prospective randomized study of 98 eyes having MHRD, which compared vitrectomy (52 eyes, group 1) versus "vitrectomy and MB" (46 eyes, group 2), is conducted by Ma *et al*.[34] from China. Group 2 had faster reattachment and higher hole closure rate than group 1 during the follow-up of 2 years. No difference in visual improvement was noted. Easily available silicone buckle sutured to the band buckle was used as the macular buckling.[34]

Surgical technique and the time taken for the buckle alone were reported to be faster, safer, easier, and, above all, effective compared to vitrectomy combined with buckle.[26,40] The authors[26] are also convinced that the presence of an MB and a flattened posterior sclera lowers the risk of inducing an iatrogenic macular hole during vitrectomy with or without ILM peeling. The authors[40] are moreover convinced that a good model of MB could prevent all the long-term complications linked to the progressive worsening of the staphyloma such as atrophy of the RPE.

In our series of unpublished results of vitrectomy combined with MB, we had anatomical success of hole closure, resorption of SRF, and visual improvement in 80% cases.

Studies evaluating only vitrectomy

Ikuno *et al*.[37] analyzed 44 eyes with MF operated by vitrectomy with ILM peeling and gas tamponade. Three groups of

Table 4: Studies in which macular buckle and vitrectomy with or without ILM peeling and tamponade were evaluated either in combination or groups in management of myopic tractional maculopathy

Author	Year	Clinical features	No. of eyes	AXL	Staphyloma/ Ref. error	Follow-up	Surgery	Salient features	Complications
Ripandelli *et al.*[21]	2001	HM-MH-RD	30	NA	+/(−19-30: 24.7 D)	-	V (15) PEBP: silicone exoplant (15)	Retinal reattachment and hole closure was seen in 14 of 15 eyes in MB and 11 of 15 in V group; BCVA was not changed in V cases but improved statistically in MB group	Choroidal effusion (2)
Ando *et al.*[36]	2007	HM-MH-RD	58	NA	+/(−10 to−20 D)	V (44.1) MB (52.8)	V (28) MB: solid silicone plate (30)	Final success rate was 100% in MB group and 86% in V group; mean BCVA improved in both groups and more in MB group	Metamorphopsia
Burés-Jelstrup *et al.*[30]	2014	HM-MH-FS	16	−28.34-31.48 mm	NA/−8 to−23.75	7-86 months	MB + V (Ando)	MH closed in all cases and BCVA improved in 81.25%	Mild-to-moderate ocular motility restriction; conjunctival erosion (5)
Parolini *et al.*[40]	2015	HMMH-MD (15) MD (17)	50	26.15-33.87 mm	+	3 month-3 year	V+MB (20) MB (30) + gas L-shaped buckle	Both groups were comparable in terms of retinal attachment (100%), schisis resolution (100%), and hole closure (60%)	Diplopia (3), buckle shortening (6), RPE alterations (6)
Mura *et al.*[31]	2017	HM-MH (5)-MH + FS (5) MH + MD (11)	21	27.78-35.90 mm	+	3-19 months (7)	MB±V (T-shaped)	BCVA improved in 71.4% of cases; MH closure rate was 90.5% and retinal reattachment 100%; all cases had vitrectomy before or after	Diplopia (1)
Ma *et al.*[34]	2017	HM-MH-RD	98	30-37.50 mm	+	1-24 months	V + ILM + gas (52) V + ILM + gas + MB (46)	Retinal reattachment rate and hole closure rate were significantly higher in group with MB; after 2 years there was detachment in 5 eyes with MB and 13 without; reopening of hole in 2 cases	ReRD (18)

HM=High myopia, MH=Macular hole, RD=Retinal detachment, FS=Foveoschisis, FD=Foveal detachment, MD=Macular detachment, LH=Lamellar hole, MHRD=Macular hole RD, MSRD=Macular schisis RD, ReRD=Recurrent RD, BCVA=Best corrected visual acuity, V=Vitrectomy, MB=Macular buckle

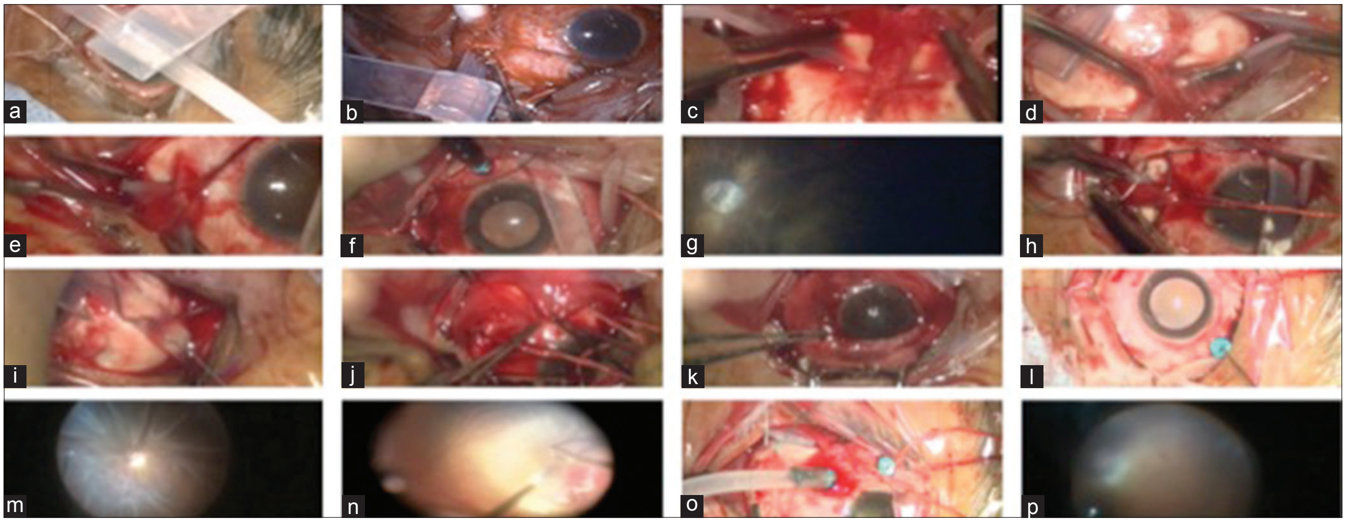


Figure 4: Surgical steps of the placement of Morin–Devin T-shaped macular buckle. (a) Threading of Morin band into the Devin wedge. (b) Passing the band under the lateral rectus. (c) Passing one end of band under inferior rectus muscle. (d) Tagging the superior rectus and oblique muscle together and passing the other of band underneath it. (e) The flatter end of wedge is adjusted under lateral rectus with wedge toward the macula. (f) Insertion of 25-G Chandelier light. (g) Adjusting the macular indention under direct visualization. (h) Finalizing the suture of plate end under lateral rectus on either side. (i) The nasal end of bands is marked on sclera after adjusting the indentation and sutured, and the free edges trimmed. (j) Conjunctiva is liberally mobilized. (k) Suturing of conjunctiva and tenon in two layers carefully. In combined cases with vitrectomy, the Morin–Devin wedge is passed in similar manner followed by (l) 25-G sclerotomies made 3.5 mm from limbus. (m) Vitrectomy is performed with posterior vitreous detachment followed by fluid gas exchange. (n) ILM peeling using forceps, followed by adjustment of buckle under air. (o) Finalizing the sutures of MB. (p) Silicone oil infusion and buckle indent appreciated at posterior pole

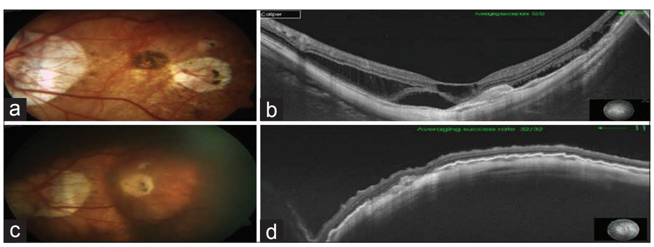


Figure 5: A 48-year-old man, bilateral high myopia (−12 D). Color Fundus photo: (a) myopic fundus with patchy areas of chorioretinal atrophy and scarring and (b) SS-OCT demonstrating retinoschisis with foveal detachment and juxtafoveal scarred CNVM. Patient underwent macular buckle alone for recent worsening of symptoms. Postoperative 6 weeks fundus photo: (c) myopic fundus with buckle indent at macular area and (d) SS-OCT demonstrating the resolution of schisis, foveal reattachment, good indent, and stabilization of vision

maculopathy were analyzed: FD, retinoschisis, and macular hole. Most significant anatomical and visual improvement was noted in FD followed by retinoschisis. Macular hole did not close nor had a visual improvement in majority of the cases. In a similar study, Kumagai *et al*.[39] from Japan noted the same outcomes in their study of 39 eyes of macular foveoschisis without macular hole.

Both the studies suggest that FD subtype benefits mostly from vitrectomy compared to the other two pathologies: retinoschisis and macular hole.

The rationale of the vitrectomy is that strong surface vascular folds[15] and the cortical vitreous remnants adherent along to ILM[53] get relieved by good PVD induction from the posterior retina and a complete ILM peel.

Functional outcomes with MB

Previous studies,[21,27,30,31,34,36] mentioned so far irrespective of the material or type of surgery, have shown 60–80% functional success in terms of BCVA improvement with a reasonable long follow-up ranging between 2 and 15 years. The structural changes – RPE disturbance and CRA[22,24] – occurring at the indentation site, added to the preexisting maculopathy changes within the staphyloma, are of concern. Not many studies have evaluated the long-term effects of MB with regard to changes at the outer retina–choroid complex.

Apart from the BCVA, color vision testing, visual fields, and microperimetry are some of the available tests for functional assessment. Sasoh *et al*.[54] is first of such study evaluating the functional outcome by visual fields following MB surgery. They studied 33 eyes of retinal detachment with FTMH in staphyloma eyes and noted significant increase in (sensitivity at each isopter) the area size for V4 isopter following MB surgery postoperatively.

Recently, Cacciamani *et al*.[33] conducted a prospective study of a newer adjustable MB placement. They assessed MRS, fixation site, and stability using microperimetry. They reported that majority of patients had significant increase in MRS of central 10°, reduction in the microscotoma, and increase in the fixation stability within 2°. Although 100% anatomical closure of FTMH was achieved, they clarify that the RPE atrophic changes at the indented areas after the buckle positioning did not increase the microscotomas and had a good central stable fixation. They commented that the indentation variability, in terms of relative height and shape, did certainly occur, which may influence either anatomical or functional outcomes.

The functional success is better assessed by objective measurements and should include color vision, microperimetry, and visual fields other than corrected visual acuity as MTM is a complex multifactorial disorder.

Surgical consequence and complications in MB

An unavoidable consequence of the buckle is its indentation at the PS, resulting in change in the axial length and the myopic refraction of the eye.[32] This refractive change can be minimal or of significance to the final BCVA. Patients who have previously undergone refractive procedures will have a hyperopic shift with the remodeling of the posterior globe. Use of silicone oil as a tamponade in a vitrectomy combined with buckle cases induces refractive changes due to oil. Consequently, the remodeling of the globe and use of silicone oil tamponade pose a challenge for intraocular lens (IOL) power calculations while planning a cataract extraction. Parolini *et al*.[40] recommended performing cataract surgery and IOL implantation after placing an MB for more predictable IOL calculation. In our series, we removed silicone oil first, followed by cataract surgery for a more accurate IOL power calculation.

Some techniques involve unavoidable muscle disinsertion during the buckle placement. Siam *et al*.[25] described severing the superior oblique muscle; Theodossiadis[22] and Ripandelli *et al*.[21] described disinsertion of the lateral rectus before buckle placement. Posterior suturing at macula was noted to be of concern in studies by Siam *et al*.[25] and Ripandelli *et al*.[21]

Globe perforation,[25] choroidal detachment, and suprachoroidal hemorrhage are the most sight-threatening intraoperative complications,[22,25,26] whereas motility restriction,[26] optic nerve abutment, and buckle extrusion[26,40] are described to occur in the long-term studies. Other commonly reported complications are spontaneously resolving subretinal or macular hemorrhage, RPE atrophic changes, CRA at the buckle indentation area, macular hemorrhage, and CNVM.[30]

In his study of 58 eyes with more than 3-year follow-up, Ando[36] reported no major sight-threatening complications with the Ando's plombe. Theodossiadis and Theodossiadis[22] in their 15-year follow-up study of buckle surgery did not notice any serious post-op complications, except for an iatrogenic tear in one case and localized chorioretinal hemorrhage in two other cases, which occurred during suturing of the sponge managed conservatively.

Devin *et al*.[24] observed peripheral hemorrhagic choroidal detachment in one eye and macular hemorrhage in another. Siam *et al*.[25] encountered numerous difficulties, including prolapse of orbital fat during exposure of optic nerve sheath, injury of one of the vortex veins or ciliary vessels, suture tears, inadvertent perforation, submacular hemorrhage, and malposition of buckle.

Mortada[52] used a sponge incorporated inside with titanium wire and noted ocular mobility restrictions, which were due to the large size of the material. Over the years, the buckle material and design has undergone modifications leading to a safer and technically easier surgery.[31,34]

We had one case of inferior retinal detachment at 6 weeks after the resolution of intraoperative hemorrhagic choroidal detachment despite the buckle indentation present at the macula, reopening of the macular hole in one case in our case series.

Conclusion

MB procedure has evolved significantly with different types of material and techniques used by various surgeons from different parts of the world over the past 60 years while straddling the pre- and post-vitrectomy era. The advent of high-resolution OCT with greater depth penetration has aided in understanding MTM, which is now well established as a progressive pathological event secondary to the evolution of PS in individuals with high myopia. Irrespective of the material and the technique, the surgery *per se* has shown 80–100% anatomical success in resolving macular schisis and detachment. It has been proposed to prevent macular hole formation if performed at an earlier stage when there is a recent onset of progressive increase in schisis with detachment or visual loss. Macular buckling has led to good functional outcomes measured not only as stabilization of the visual acuity but also as an improvement in MRS, reduction in microscotomas, and improvement in foveal fixation. The use of adjunctive investigations such as MRI and wide-field imaging may help in better strategic planning preoperatively leading to better and consistent outcomes. The future of macular buckling will depend on continuous refining of the surgical technique, development of imaging algorithms and materials that can customize the MB according to an individual eye's PS morphology, and wider adoption of the procedure by vitreoretinal surgeons.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

References

1. Liu HH, Xu L, Wang XR, Wand S, You QS, Jonas JB. Prevalence and progression of myopic retinopathy in Chinese adults: The Beijing eye study. Ophthalmology 2010;117:1763-8.
2. Buch H, Vinding T, La Cour M, Appleyard M, Jensen GB, Nielsen NV. Prevalence and causes of visual impairment and blindness among 9980 Scandinavian adults: The Copenhagen city eye study. Ophthalmology 2004;111:53-61.
3. Hayashi K, Ohno-Matsui K, Shimada N, Moriyama M, Kojima A, Hayashi W, *et al.* Long-term pattern of progression of myopic maculopathy: A natural history study. Ophthalmology 2010;117:1595-611, see also 1611.e1–4.

4. Shih Y-F, Ho T-C, Hsiao CK, Lin LL-K. Visual outcomes for high myopic patients with or without myopic maculopathy: A 10 year follow up study. Br J Ophthalmol 2006;90:546-50.
5. Schepens CL, Okamura ID, Brockhurst RJ. The scleral buckling procedures. I. Surgical techniques and management. AMA Arch Ophthalmol 1957;58:797-811.
6. Rosengren B. The silver plomb method in macular holes. Trans Ophthalmol Soc UK 1966;86:49-53.
7. Theodossiadis GP. [A simplified technique for the surgical treatment of retinal detachments resulting from macula holes (author's transl.)]. Klin Monbl Augenheilkd 1973;162:719-28.
8. Ikuno Y, Sayanagi K, Oshima T, Gomi F, Kusaka S, Kamei M, *et al.* Optical coherence tomographic findings of macular holes and retinal detachment after vitrectomy in highly myopic eyes. Am J Ophthalmol 2003;136:477-81.
9. Takano M, Kishi S. Foveal retinoschisis and retinal detachment in severely myopic eyes with posterior staphyloma. Am J Ophthalmol 1999;128:472-6.
10. Shah VP, Wang N-K. Myopia: A historical perspective. In: Spaide RF, Ohno-Matsui K, Yannuzzi LA, editors. Pathologic myopia. New York: Springer; 2014. p. 1-11.
11. Curtin BJ. The posterior staphyloma of pathologic myopia. Trans Am Ophthalmol Soc 1977;75:67-86.
12. Ohno-Matsui K. Proposed classification of posterior staphylomas based on analyses of eye shape by three-dimensional magnetic resonance imaging and wide-field fundus imaging. Ophthalmology 2014;121:1798-809.
13. Panozzo G, Mercanti A. Optical coherence tomography findings in myopic traction maculopathy. Arch Ophthalmol 2004;122:1455-60.
14. Gallemore RP, Jumper M, McCuen BW, Jaffe GJ, Postel EA, Toth CA. Diagnosis of vitreoretinal adhesions in macular disease with optical coherence tomography. Retina (Philadelphia, Pa.) 2000;20:115-20.
15. Gohil R, Sivaprasad S, Han LT, Mathew R, Kiousis G, Yang Y. Myopic foveoschisis: A clinical review. Eye (Lond) 2015;29:593-601.
16. Ng DS, Cheung CY, Luk FO, Mohamed S, Brelen ME, Yam JC, *et al.* Advances of optical coherence tomography in myopia and pathologic myopia. Eye (Lond) 2016;30:901-16.
17. Lim LS, Cheung G, Lee SY. Comparison of spectral domain and swept-source optical coherence tomography in pathological myopia. Eye (Lond) 2014;28:488-91.
18. Ho M, Liu DTL, Chan VCK, Lam DSC. Choroidal thickness measurement in myopic eyes by enhanced depth optical coherence tomography. Ophthalmology 2013;120:1909-14.
19. Faghihi H, Hajizadeh F, Riazi-Esfahani M. Optical coherence tomographic findings in highly myopic eyes. J Ophthalmic Vis Res 2010;5:110-21.
20. Fujimoto M, Hangai M, Suda K, Yoshimura N. Features associated with foveal retinal detachment in myopic macular retinoschisis. Am J Ophthalmol 2010;150:863-70.
21. 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; discussion 2265.
22. 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 (Philadelphia, Pa.) 2005;25:285-9.
23. Baba T, Tanaka S, Maesawa A, Teramatsu T, Noda Y, Yamamoto S. Scleral buckling with macular plombe for eyes with myopic macular retinoschisis and retinal detachment without macular hole. Am J Ophthalmol 2006;142:483-7.
24. Devin F, Tsui I, Morin B, Duprat J-P, Hubschman J-P. T-shaped scleral buckle for macular detachments in high myopes. Retina (Philadelphia, Pa.) 2011;31:177-80.
25. Siam ALH, El Maamoun TA, Ali MH. Macular buckling for myopic macular hole retinal detachment: A new approach. Retina (Philadelphia, Pa.) 2012;32:748-53.
26. Mateo C, Burés-Jelstrup A, Navarro R, Corcóstegui B. Macular buckling for eyes with myopic foveoschisis secondary to posterior staphyloma. Retina (Philadelphia, Pa.) 2012;32:1121-8.
27. Mateo C, Gómez-Resa MV, Burés-Jelstrup A, Alkabes M. Surgical outcomes of macular buckling techniques for macular retinoschisis in highly myopic eyes. Saudi J Ophthalmol 2013;27:235-9.
28. Mateo C, Dutra MM, Alkabes M, Burés-Jelstrup A, Postorino M, Corcóstegui B. Illuminated Ando plombe for optimal positioning in highly myopic eyes with vitreoretinal diseases secondary to posterior staphyloma. JAMA Ophthalmol 2013;131:1359-62.
29. Tian J, Tang L-S, Guo X-J, Luo Y-H. Episcleral macular buckling for posterior retinal detachment in silicone oil filled eyes associated with myopic macular hole. Int J Ophthalmol 2013;6:165-8.
30. Burés-Jelstrup A, Alkabes M, Gómez-Resa, 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.
31. 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.
32. Liu B, Ma W, Li Y, Luo Y, Jin C, Liang X, *et al.* Macular buckling using a three-armed silicone capsule for foveoschisis associated with high myopia. Retina (Philadelphia, Pa.) 2016;36:1919-26.
33. Cacciamani A, Lazzeri S, Rossi T, Scarinci F, Parravano M, Ripandelli G, *et al.* Adjustable macular buckling for full-thickness macular hole with foveoschisis in highly myopic eyes: Long-term anatomical and functional results. Retina (Philadelphia, Pa.) 2016;36:709-16.
34. Ma J, Li H, Ding X, Tanumiharjo S, Lu L. Effectiveness of combined macular buckle under direct vision and vitrectomy with ILM peeling in refractory macular hole retinal detachment with extreme high axial myopia: A 24-month comparative study. Br J Ophthalmol 2017;101:1386-94.
35. Kobayashi H, Kishi, S. Vitreous surgery for highly myopic eyes with foveal detachment and retinoschisis. Ophthalmology 2003;110:1702-7.
36. Ando F, Ohba N, Touura K, Hirose H. Anatomical and visual outcomes after episcleral macular buckling compared with those after pars plana vitrectomy for retinal detachment caused by macular hole in highly myopic eyes. Retina (Philadelphia, Pa.) 2007;27:37-44.
37. 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.
38. 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.
39. Kumagai K, Furukawa M, Ogino N, Larson E. Factors correlated with postoperative visual acuity after vitrectomy and internal limiting membrane peeling for myopic foveoschisis. Retina (Philadelphia, Pa.) 2010;30:874-80.
40. Parolini B, Frisina R, Pinackatt S, Gasparotti R, Gatti E, Baldi A, *et al.* Indications and results of a new l-shaped macular buckle to support a posterior staphyloma in high myopia. Retina (Philadelphia, Pa.) 2015;35:2469-82.

41. Hsiang HW, Ohno-Matsui K, Shimada N, Hayashi K, Moriyama M, Yoshida T, *et al.* Clinical characteristics of posterior staphyloma in eyes with pathologic myopia. Am J Ophthalmol 2008;146:102-10.
42. Curtin BJ. The Myopias: Basic Science and Clinical Management. Philadelphia, PA: Harper & Row; 1985.
43. Ando F. Use of a special macular explant in surgery for retinal detachment with macular hole. Jpn J Ophthalmol 1980;24:29-34.
44. Oie Y, Ikuno Y, Fujikado T, Tano Y. Relation of posterior staphyloma in highly myopic eyes with macular hole and retinal detachment. Jpn J Ophthalmol 2005;49:530-2.
45. Morita H, Ideta H, Ito K, Yonemoto J, Sasaki K, Tanaka S. Causative factors of retinal detachment in macular holes. Retina (Philadelphia, Pa.) 1991;11:281-4.
46. Spaide RF. The sclera and induced abnormalities in myopia. In: Spaide R, Ohno-Matsui K, Yannuzzi L, editors. Pathologic myopia. New York, NY: Springer; 2014.
47. Steidl SM, Pruett RC. Macular complications associated with posterior staphyloma. Am J Ophthalmol 1997;123:181-7.
48. 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;159:877-83.e7.
49. Ohno-Matsui K, Alkabes M, Salinas C, Mateo C, Moriyama M, Cao K, *et al.* Features of posterior staphylomas analyzed in wide-field fundus images in patients with unilateral and bilateral pathologic myopia. Retina (Philadelphia, Pa.) 2017;37:477-86.
50. Wang S, Peng Q, Zhao P. SD-OCT use in myopic retinoschisis pre- and post-vitrectomy. Optom Vis Sci 2012;89:678-83.
51. Stirpe M, Ripandelli G, Rossi T, Cacciamani A, Orciuolo M. A new adjustable macular buckle designed for highly myopic eyes. Retina (Philadelphia, Pa.) 2012;32:1424-7.
52. Mortada HA. A novel episcleral macular buckling: Wire-strengthened sponge exoplant for recurrent macular hole and retinal detachment in high myopic eyes. Med Hypothesis Discov Innov Ophthalmol 2013;2:14-19.
53. Johnson MW. Myopic traction maculopathy: Pathogenic mechanisms and surgical treatment. Retina (Philadelphia, Pa.) 2012;32(Suppl 2):S205-10.
54. Sasoh M, Yoshida S, Ito Y, Matsui K, Osawa S, Uji Y. Macular buckling for retinal detachment due to macular hole in highly myopic eyes with posterior staphyloma. Retina (Philadelphia, Pa.) 2000;20:445-9.