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Surgical outcomes of pars plana vitrectomy with and without internal limiting membrane peeling for symptomatic vitreomacular traction

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Thesis

SURGICAL OUTCOMES OF PARS PLANA VITRECTOMY WITH AND WITHOUT INTERNAL LIMITING MEMBRANE PEELING FOR SYMPTOMATIC VITREOMACULAR TRACTION

by

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DEDICATION

I would like to dedicate this thesis to my friends, family, and all the teachers who have helped me to become the student and person I am today. I truly am grateful. I would also like to dedicate this thesis to the amazing patients, who inspire me every day with their spirit, kind words, and support. Thank you all.

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ABSTRACT

Purpose: To study the long-term anatomic and visual outcomes after pars plana vitrectomy (PPV) with and without internal limiting membrane (ILM) peeling in patients with symptomatic vitreomacular traction (VMT). This study assesses the frequency of complications, changes in visual acuity, and changes in anatomical central macular thickness after macular surgery.

Methods: This retrospective, single-site, single-surgeon study reviewed 40 medical records (45 eyes) of patients at the Beth Israel Deaconess Medical Center requiring PPV with ILM peeling (n=27) or without ILM peeling (n=18) for VMT between the years of 2003 and 2016. Successful surgery was defined as the relief of anatomical traction, and the absence of a second surgery, or any post-operative complications (n=42). Visual acuity was documented for each eye prior to surgery and post surgery.

Results: All 27 (100%) eyes that had ILM peeling had successfully resolved macular traction following a single surgery, and 15 of the 18 (83.3%) eyes without ILM peel were successful. None of 27 (0%) eyes that had ILM peeling required a second surgery, nor did they have complications. 3 of the 18 (16.7%) eyes without ILM peeling required a second surgery. Best corrected visual acuity (BCVA, logMAR) improved significantly in both groups: BCVA improved from 0.59 ± 0.29 preoperatively to 0.37 ± 0.25 postoperatively in eyes receiving ILM peeling and from 0.77 ± 0.37 to 0.53 ± 0.37 in eyes with PPV only. Mean change in CMT pre-operatively to post-operatively was found to be greater in eyes with PPV alone, but this difference was not statistically significant.

Conclusions: Our case series shows that PPV with ILM peeling for VMT relieved macular traction better than PPV alone, although there was no significant difference in visual acuity outcomes or central macular thickness between the two groups. Further research is required to validate these findings.

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LIST OF ABBREVIATIONS

BCVA .... Best corrected visual acuity

CMT .... Central macular thickness

ICG .... Indocyanine Green

ILM .... Internal limiting membrane

OCT .... Optical Coherence Tomography

PPV .... Pars plana vitrectomy

PVD .... Posterior vitreous detachment

VMA .... Vitreomacular adhesion

VMT .... Vitreomacular traction

INTRODUCTION

Basic Anatomy of the Human Eye

The human eye is a complex and intricate organ that is essential to providing the sense of sight. In order for humans to visualize the surrounding environment, light passes through different layers of the eye and is converted to neural impulses. The outermost layer of the eye includes the cornea, conjunctiva and the sclera. The cornea is a densely innervated tissue located on the anterior surface of the eye (25). Functions of the cornea include protecting the eye from structural damage and infection, and refracting light in combination with the lens of the eye, to focus light onto the retina (25). The sclera is a supportive, connective tissue layer that is responsible for maintaining the shape and intraocular pressure of the eye (13). It is also where extraocular muscles attach to the eye (13). The middle layer of the eye, also known as the uvea, is comprised of the choroid,

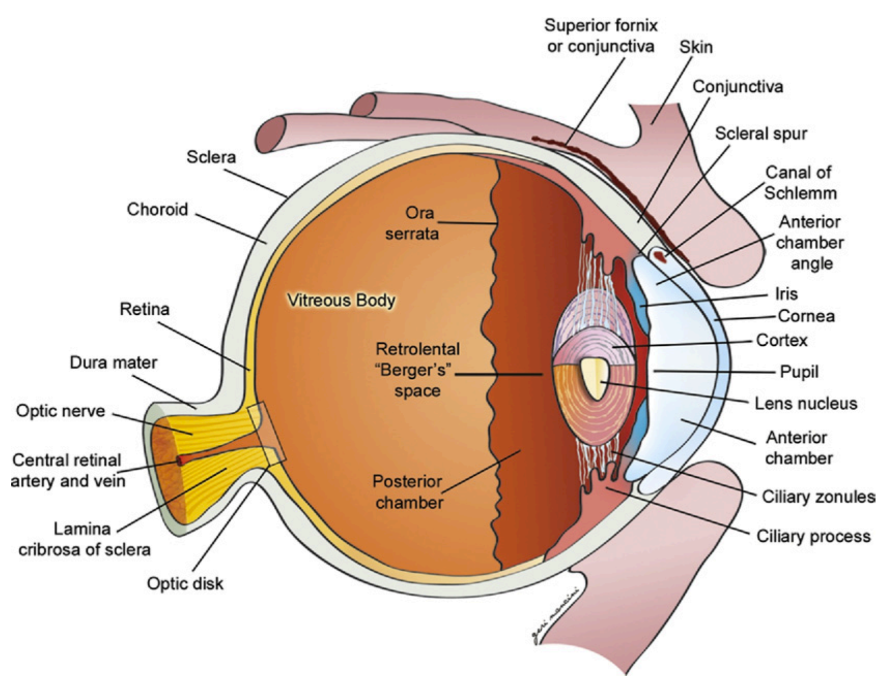

Figure 1: Anatomy of the eye. Figure taken from Malhotra et al., 2011 (13).

the ciliary body, and the iris (13). The choroid is a vascular tissue underlying the posterior sclera, while the ciliary body adjusts the power and shape of the lens, and secretes aqueous humor, which fills the anterior chamber of the eye. The iris is responsible for changing the size of the pupil (13, 25). Lastly, the inner layer of the eye is the neural sensory retina (13). There are also three addditional transparent components within the ocular layers, the lens, the vitreous, and the aqueous (25).

The retina is a tissue consisting of ten layers of cells (inner limiting membrane (ILM), nerve fiber layer (NFL), ganglion cell layer (GCL), inner plexiform layer (IPL), inner nuclear layer (INL), outer plexiform layer (OPL), outer nuclear layer (ONL), outer limiting membrane (OLM), rods and cones layer (R and CL), and retinal pigmented epithelium (RPE)). This tissue develops as two separate

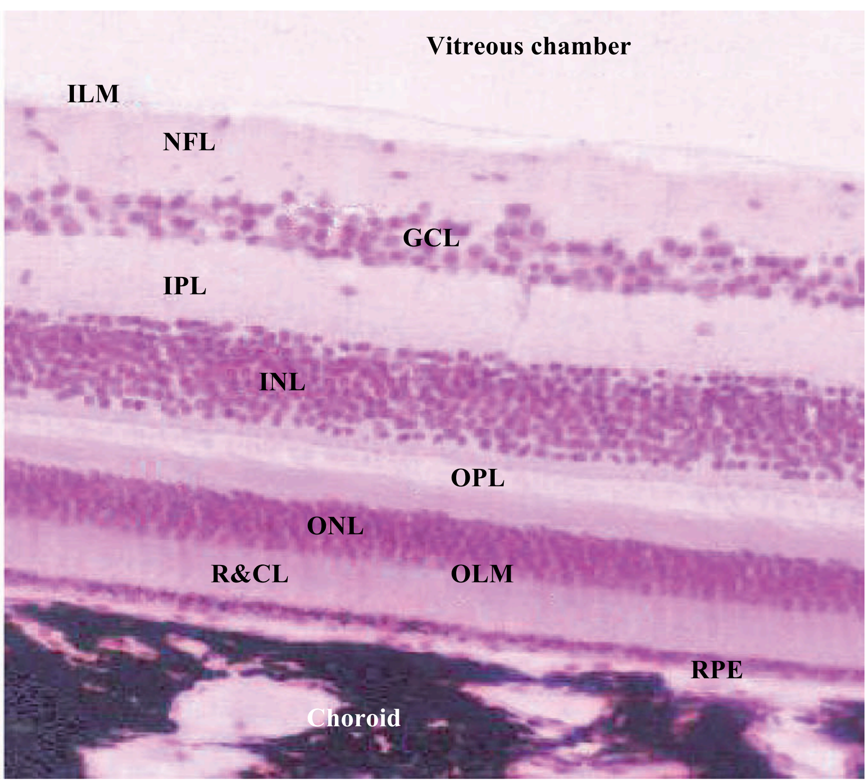

Figure 2: Layers of the retina. Figure taken from Willoughby et al., 2008 (25).

layers during embryogenesis; the neural retina is the inner sensory layer, and the retinal pigmented epithelium is the thin outer layer adjacent to the choroid (13). The neural retina consists of six different classes of neurons (photoreceptors, bipolar cells, horizontal cells, amacrine and ganglion cells, and the Müllerian glia) (25). These neurons help the retina perform its primary function, which is to capture and process visible light signals. The retinal pigment epithelium maintains photoreceptor function, stores and metabolizes vitamin A, and provides retinal adhesion (25). This pigmented epithelium is formed by a single layer of cells bound together by tight junctions, and which help to form the retinal blood barrier (13).

In the human eye the photoreceptor neurons are the rods and cones. These photoreceptors function by converting light into an electrical signal. The cones provide color vision, while the rods are only activated by low light conditions. Throughout the retina the density of the rods and cones differs depending on the region. In the center of

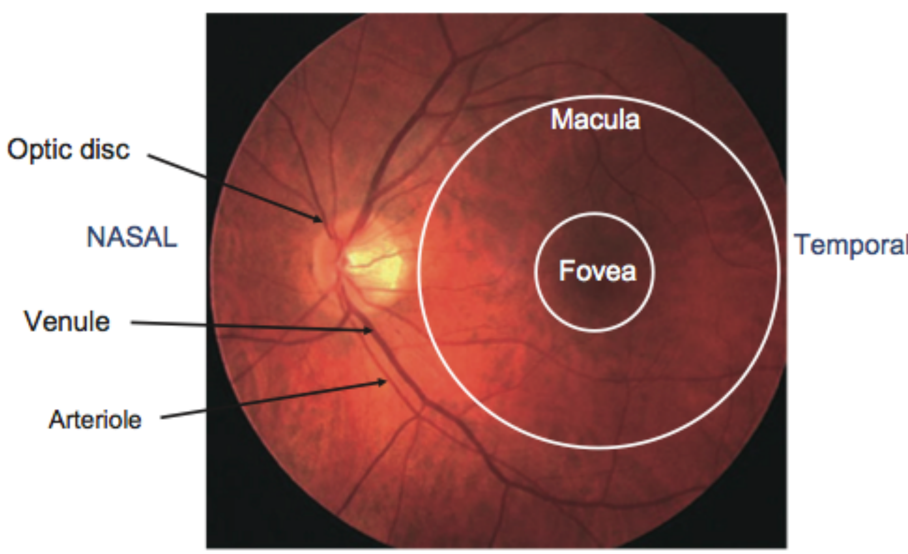

Figure 3: Fundus photo of the eye. Taken from Willoughby et al., 2008 (25).

the retina is the macula, which contains approximately fifty percent of all cones (25). At the center of the macula is the fovea. The fovea has the highest concentration of cones and provides central vision (25). In clinical practice, the fovea is defined by the annular light reflex off the internal limiting membrane (ILM) (12).

The ILM is the anterior basement membrane layer of the retina comprised of type IV collagen, glycoproteins, and Müller cells (12). The Müller cells of the ILM provide metabolic support, protection of the neurosensory retina, glutamate recycling, and exchange of waste products with the ganglion cells (14). The ILM is attached to the vitreous, which is a gel composed of a meshwork of collagen fibrils, soluble proteins, salts, and hyaluronic acid, and occupies the area between the retina and the lens (13). The strength of adhesion of the vitreous to the retina depends on age, and the location in the eye (12). The ILM varies in thickness over the retina, and the adhesion is strongest where the ILM is thinnest, which is over the fovea (12). The ILM is 400 nm thick at the peripheral retina, but can be up to 1,400 nm thick in the macular area (14). Adhesion of the vitreous to the ILM is due to a biochemical glue-like substance consisting of proteoglycans, such as laminin and fibronectin (21).

Background: Vitreomacular Traction Syndrome

The vitreous gel in the human eye gradually liquefies with age, and this natural process is usually accompanied by a weakening in adhesion of the posterior face of the vitreous to the ILM (20). Russel et al. (1995) used lectin probes to suggest that the weakening of adhesion is in part due to the lack of galactose β (1,3)-N-acetyl-glucosamine, a component of the extracellular matrix, in adults (7, 17). By the age of 70 approximately half of the vitreous gel will have liquefied (20). As the vitreous liquefies and the adhesion to the ILM weakens, the vitreous can separate from the ILM. This is known as a posterior vitreous detachment (PVD). The average age of a complete PVD is

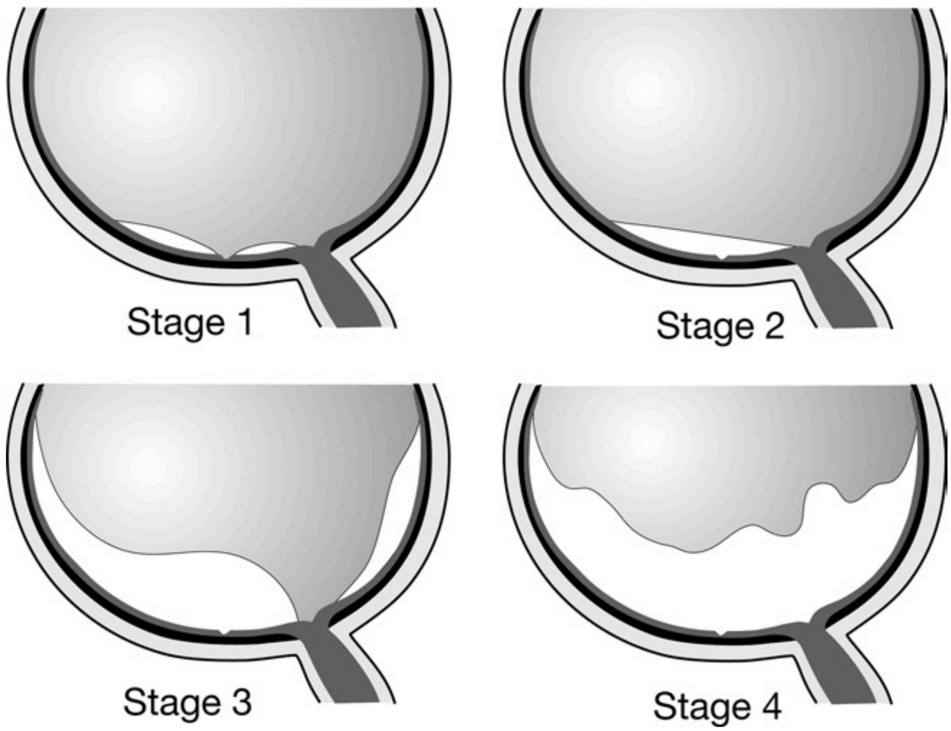

Figure 4: Drawing of the stages of PVD. Taken from Johnson, Mark W., 2010 (10).

around 60 years of age with an earlier onset found in patients with increasing severity of myopia (27). It has been shown that complete PVD often occurs gradually, and may begin focally in one quadrant of the perifoveal area with a superior predilection (20). Figure 4, taken from Johnson, Mark W. (2010), demonstrates stages of PVD. Attachment of the vitreous to the ILM usually persists to the optic nerve head and to the fovea (stage 3 of Figure 4) before the completion of the PVD occurs (20). As the vitreous continues to liquefy, and adhesion strength continues to weaken, the liquid is able to penetrate the retrohyaloid space and any microbreaks that are present (10). This liquid entry assists in the progression of the PVD (10). Eyes in which the vitreous liquefies quicker than normal, and before adequate weakening of adhesion may cause more complications due to PVD (19). PVD has been linked to a variety of pathologies such as epiretinal membranes, macular microholes, foveal red spot, and idiopathic macular holes (10).

Incomplete PVD from the ILM can persist, leaving some vitreous still firmly attached to the macula (10, 20). Clinically, when macular adhesion is present with surrounding separation of the hyaloid from the retina without anatomical distortion of the macula, it is known as vitreomacular adhesion (VMA) (20). VMA thus may be asymptomatic in terms of visual acuity (20). If the adhesion begins to exert a traction force on the retina and distorts the retinal anatomy, it is defined clinically as vitreomacular traction (VMT) syndrome (20). Symptoms of VMT syndrome are distortion or blurriness in the central vision, and it may cause decreased visual acuity, tractional retinal detachments, epiretinal membranes, and macular edema (20, 22). VMT syndrome has also been suggested to be involved in the progression of diabetic retinopathy, and age-related macular degeneration (22). Therefore, if VMT syndrome is left untreated chronic traction may lead to further complications, long-term damage to photoreceptors, and potentially irreversible decreases in visual acuity (4).

Diagnosis of VMT

Optical Coherence Tomography (OCT) has become an important tool in clinical practice for the diagnosis of various retinal pathologies. OCT is an imaging technique that uses the reflection of near-infrared light off tissues in order to create cross sectional images of morphological features on a micrometer scale (29). The OCT collects the

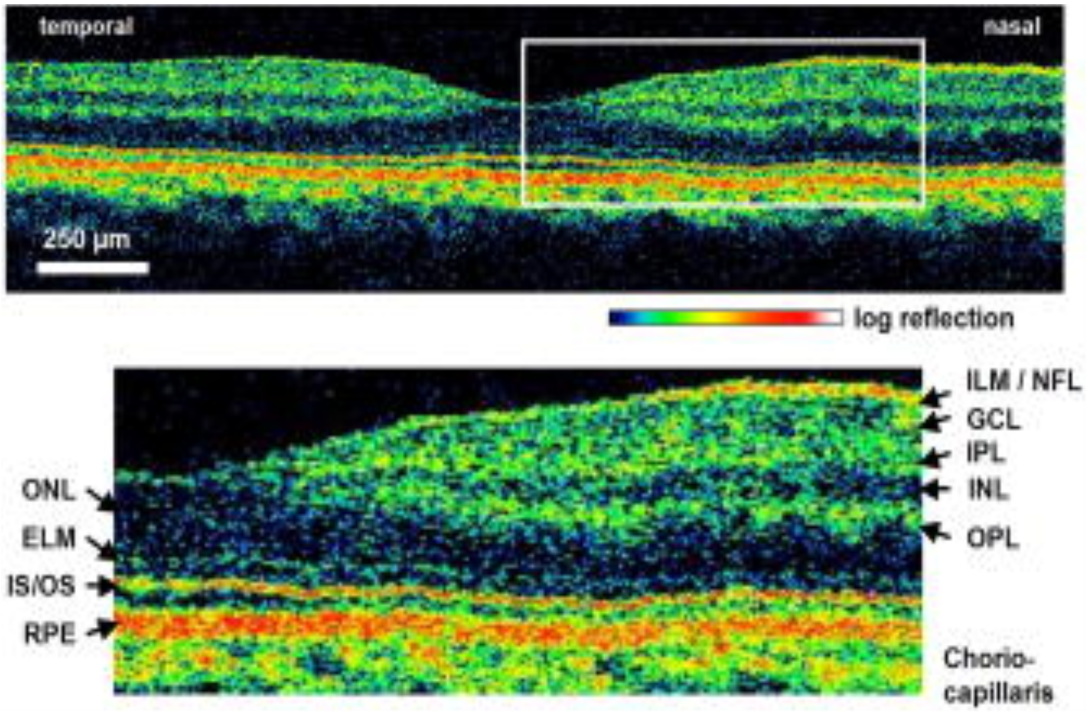

Figure 5: High-resolution OCT of the retina with labels. Taken from Zysk et al. 2007, (29)

reflected light and measures the differences in time of flight (5). The deeper the layer is, the longer the delay of the reflected light will be (5). OCT provides high-resolution images of different retinal features due to the contrasting structure, and therefore reflectivity of the layers of the retina (29). The layers that can be differentiated are the nerve fiber layer, the plexiform layers, the external limiting membrane, the retinal pigment epithelium, the photoreceptor layer, and the choriocapillaris (29).

The relatively recent implementation of OCT in clinical practice has significantly assisted in diagnosing VMA versus VMT. Before the invention of OCT there was no adequate method for visualizing and assessing the different attachments and adhesions between the vitreous and the ILM (7). Diagnosing VMT without OCT is difficult due to the translucent adhesions often being imperceptible to the human eye, even with lens

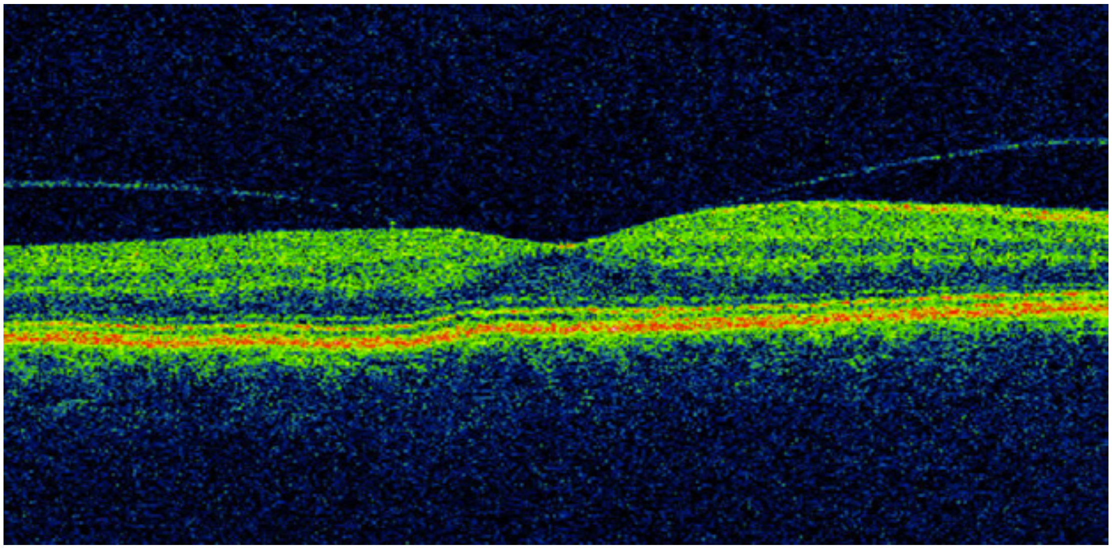

Figure 6: OCT image of VMA. Taken from Simpson et al. (2012) (20).

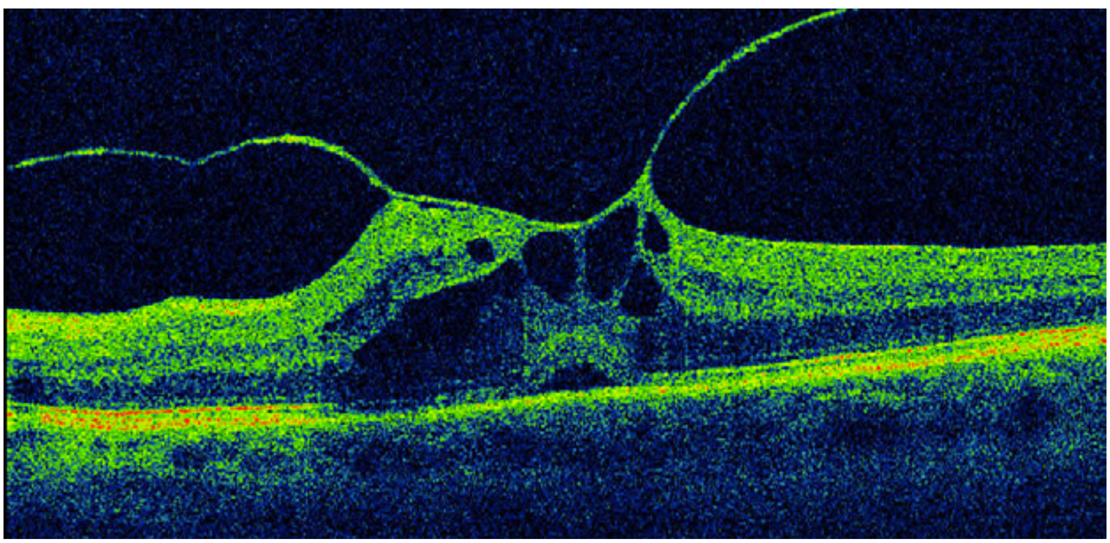

Figure 7: OCT image of VMT. Taken from Simpson et al., 2012, (20).

examination (4). VMA and VMT can now be distinguished from one another through the high-resolution imaging provided by OCT. The quality of imaging provided by OCT has created some basic classifications of VMT and VMA (4). Based on the size of the diameter of the vitreoretinal adhesion, VMT can either be classified as focal (≤1500 μm) or broad (>1500 μm) (4, 7). Eyes in which the VMA is associated with another macular problem such as diabetic macular edema, retinal vein occlusion or age-related macular degeneration are classified as concurrent VMA (7). The term isolated VMA is used when no ocular abnormalities are present (7). Figure 6 (taken from Simpson et al. 2012) depicts an excellent representation of isolated, focal VMA (20). In this image the posterior vitreous is attached to the fovea, but the surrounding hyaloid face is separated from the retina, and there is no distortion of the retinal anatomy (20). Figure 7 (taken from Simpson et al. 2012) demonstrates isolated, focal VMT syndrome because there are anatomical changes of the retina present due to tractional forces of the posterior vitreous surface on the ILM (20). A common anatomical change seen in the retina due to VMT syndrome is macular edema. Macular edema can be seen on OCT images, and this swelling due to the traction in the retina can be quantified by OCT. Central macular thickness is often used to quantify the severity of traction, edema, or other abnormalities in the retina. One limit to OCT is that the actual force from the traction on the fovea cannot yet be measured, however, it is expected that as the area of adhesion decreases the traction force on the fovea will increase (4).

Treatment of VMT

Patients with VMT syndrome often present with good visual acuity and minimal structural changes to the retina and thus do not require immediate treatment (4). In some instances, VMT syndrome can resolve spontaneously by natural PVD and can often have favorable anatomic and functional outcomes (4, 23). This spontaneous resolution of VMT has been reported to occur in 11% of eyes over a five-year period (9). Many cases, however, do manifest progressive macular traction and decreasing visual acuity and require surgical intervention (4).

The current standard for treatment of severe VMT syndrome is a surgical intervention with pars plana vitrectomy (PPV) (9). The PPV procedure was first developed by Robert Machemer in 1972 using a 14-gauge (2.1-mm diameter) instrument (9). A successful PPV separates the posterior surface of the vitreous from the ILM, thus creating a PVD. Today, small gauge vitrectomy using a 23-gauge, 25-gauge, or 27-gauge instrument is the preferred method. A survey conducted in 2007 indicated that eighty percent of retina surgeons used small gauge vitrectomy in most of their cases (15). Small gauge vitrectomy allows for the use of smaller instrumentation. This smaller instrumentation means that the incision made into the sclera, known as sclerotomies, do not require suturing post surgery. Smaller incisions and lack of sutures in modern PPV has led to reduced inflammation, patient discomfort, and recovery time (15). Smaller gauge vitrectomy also decreases the overall duration of the surgery (24).

Known as a three-port procedure, 23 and 27-gauge PPV require three sclerotomies. One port is for the infusion cannula, one is for instrumentation, and the third is for endoillumination, all of which are passed into the vitreous cavity via the pars plana (15, 24). Cannulas are used to facilitate the passing of instruments (15). These cannulas keep the conjunctival and scleral openings patent, and they are removed upon completion of the surgery (15). They are inserted at an oblique angle (longer path) because the sclerotomies seal better and leak less when the instruments are removed (24). A vitreous infusion suction cutter, which can make several thousand cuts per minute, is used to separate the posterior surface of the vitreous from the ILM during a PPV (15, 24). In a simple case of traction with no other macular abnormalities, a simple PPV will relieve the traction. A large-scale retrospective review of PPV for VMT syndrome by Jackson et al (2013) provided evidence for both the safety and the efficacy of using this procedure to treat VMT, as visual acuity improvement was observed in most eyes postoperatively, and the rate and types of complications were within expected values (9).

As with any surgery, there exists a potential for complications when performing a PPV. Complications of PPV include infection, retinal tears and detachments, cataract formation, and increased risk of developing glaucoma (28). Previously, the only treatment options for VMT were PPV or observation (28). However, new treatment options have become available for relieving VMT syndrome without requiring surgery. Enzymatic and non-enzymatic pneumatic vitreolysis are now being used in clinical practice often as a first attempt to resolve VMT syndrome. Enzymatic pneumatic vitreolysis works via an enzyme introduced to the vitreomacular interface by an intravitreal injection (22). One example is intravitreal Ocriplasmin. This treatment is an enzymatic form of a human serine protease plasmin with activity against fibronectin and laminin, and is another recently approved treatment option for VMT (22). Intravitreal Ocriplasmin has also resulted in a variety of complications such as retinal tears and detachments, retinal breaks, reduced visual acuity, and vitreous floaters (28). Non-enzymatic pneumatic vitreolysis is the introduction of a small gas bubble to the vitreomacular interface through an intravitreal injection. The introduction of the gas bubble forces separation of the remaining adhesion to the macula. Though pneumatic vitreolysis has been shown to relieve VMT in a less invasive way than PPV, it does not resolve VMT in all cases, and patients may still require PPV (22).

Peeling the Internal Limiting Membrane

While performing PPV for VMT, it may sometimes be necessary to peel the ILM. This step is especially necessary in cases where the traction has caused a macular hole, as the ILM can cause traction at the edges of the hole if it is not removed during surgery (14). Also, peeling the ILM during surgery for macular holes appears to stimulate the Müller cells, which stimulate wound healing through depolarization of underlying cells (14). In order to peel the ILM, complete removal of the posterior hyaloid is necessary (1). Since the ILM can act as a scaffold for cellular proliferation, removal of the ILM prevents subsequent traction on the retina from adhesion to the posterior hyaloid by newly proliferated cells (1, 14). An ultrastructural evaluation of epiretinal membrane tissue peeled during vitrectomy surgery for VMT discovered fibrocellular membranes made up of fragments of the ILM, fibrous astrocytes, fibrocytes, collagen, and myofibroblasts (8). However, studies have not yet clarified the pathology of the ILM in persistent VMT caused by fibrocellular proliferation (8).

In order to safely and effectively remove the ILM, many surgeons use dyes to stain, and thus visualize the ILM during surgery. A dye often used by surgeons for removal of the ILM is Indocyanine Green (ICG). ICG stains the extracellular matrix components of the ILM, such as type IV collagen, laminin, and fibronectin (16). Using ICG during PPV surgery selectively stains the ILM and assists in its complete removal, thus reducing the time of the operation and the potential for trauma to the retina (1). There are conflicting studies over the outcomes for visual acuity, recurrent epiretinal membrane, and macular edema when using ICG in idiopathic macular hole surgery, but more recent studies indicate better outcomes with use of ICG (16). ICG does have the potential for toxicity on the retina and may persist after surgery for up to 36 months (16). However, other complications may include retinal pigmented epithelium changes, visual field defects, and optic nerve atrophy (16).

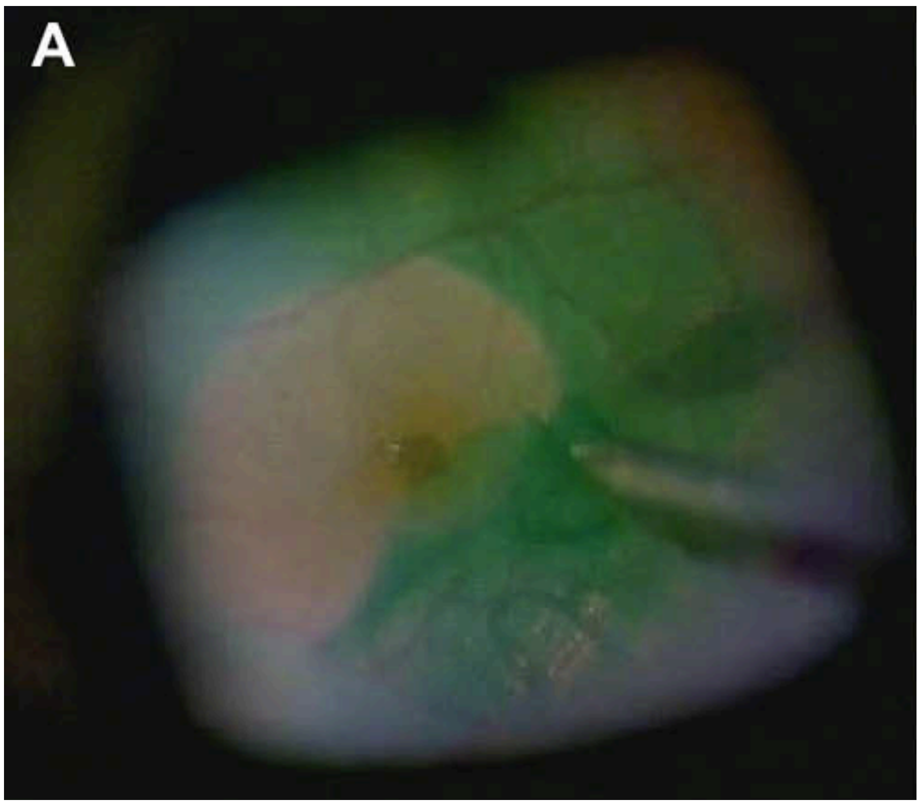

Figure 9: ICG dye stained ILM during surgery. Taken from Rodrigues et al. 2009, (16)

To peel the ILM there are several instruments and techniques available for a surgeon to use during PPV. Creating an initial flap is the first step in any ILM peel, which can be accomplished by using pick forceps, a bent MVR blade, or vitreoretinal forceps (1). There are a variety of methods for peeling the ILM once the ILM flap is created, including using ILM forceps, a blunt retinal pick, fluidic ILM separation, and passive aspiration through a tapered needle (1). There are conflicting clinical studies about the visual acuity results and the effect on the functionality of the retina when the ILM is peeled during surgery (14). One case series showed that the BCVA of 79.2% of eyes improved by 3 Snellen lines after macular hole surgery with ILM peeling, while BCVA improvement was found in just 44.8% of eyes that did not have the ILM peeled (2, 14). However, a different case series had results of comparable visual acuity after six months regardless of whether the ILM was peeled or not (14). Complications of peeling the ILM are similar to those when the ILM is not peeled (1). These complications are retinal tears and detachments, progression of cataracts, vitreous hemorrhage, and endophthalmitis (1).

PPV surgeries for treatment of macular holes, diabetic macular edema, complicated retinal detachments, and epiretinal membranes have been linked to epiretinal membrane (ERM) formation (3). Peeling of the ILM during PPV for macular holes has been shown to have a higher anatomical success rate compared to ERM dissection alone or no dissection (2). ERM development can cause decreased visual acuity, limit functionality of the retina, and require further surgery (3). ERM can develop due to VMT and progressing PVD when dehiscences in the ILM occur, allowing migration and proliferation of glial cells on the inner retinal surface (8). One study showed that peeling of the ILM during PPV for complicated retinal detachments prevented ERM formation and saw no negative effects in visual acuity outcomes (8). However, there is evidence that peeling of the ILM during PPV for macular holes results in initially better visual acuities, but the final visual results remain similar (2). Peeling of the ILM currently remains as a decision to be made by the surgeon on a case-by-case basis depending on each individual diagnosis. Studies for ILM peeling during the treatment of macular holes are mentioned throughout this research as a comparison because there are few investigations currently on the treatment of VMT with ILM peeling.

SPECIFIC AIMS

The objective of this single-site, single-surgeon investigation is to retrospectively assess the outcomes of pars plana vitrectomy surgery with and without internal limiting membrane peeling to resolve vitreomacular traction. The goal is to determine whether there is a statistically significant difference in surgical success between PPV with ILM peeling and PPV alone based on clinical examination of relief from traction, changes in central macular thickness, follow-up surgery due to complications, and visual acuity outcomes. The purpose of this research is to provide useful information for surgical treatment of vitreomacular traction in clinical practice by using over ten years (2003-2016) of data from a single vitreoretinal surgeon. Furthermore, this study may provide supplementary insight into the on-going discussion in medical literature of the clinical outcomes resulting from peeling the internal limiting membrane. This controlled, retrospective investigation and statistical analysis in context with related vitreoretinal surgery publications also aims to help guide future surgical technique decisions and research inquiries.

METHODS

After receiving International Review Board approval for this retrospective clinical case series 40 medical records were reviewed for a single surgeon's patients at the Beth Israel Deaconess Medical Center located in Boston, Massachusetts. A total of 45 eyes from these 40 patients were included in this study. These patient's charts were identified and included in this study based on pre-operative diagnosis. All patients that received PPV for VMT were included in this study. These 45 eyes underwent surgery between 2003 and 2016 for treatment of vitreomacular traction using two distinct surgical techniques. All surgical procedures were three-port 23 or 27-gauge pars plana vitrectomy with or without internal limiting membrane peeling. Some surgeries involved epiretinal membrane peeling. Prior to vitrectomy, eyes with a visually significant cataract underwent phacoemulsification and posterior chamber intraocular lens placement. Patients were examined in follow-up post-operative day 1 to determine if vitreomacular traction was anatomically relieved or persistent. Patients were then examined 3 months, and 12 months after surgery. For this clinical case series, the 12-month time point may range from 9 months to 10 years depending on available patient data in follow up. If patients had multiple follow up visits, the visit closest to 12 months after surgery was used. The Secondary operations were performed in some cases if complications arose postoperatively.

Pre-Operative Consult

Prior to any surgical procedures, patients were seen for a pre-operative consult to determine the diagnosis and discuss treatment options. All patients were examined, diagnosed, and given background information on vitreomacular traction by a board-certified, medically licensed ophthalmologist. Informed diagnosis was made through use of ophthalmoscopic examination and confirmed with OCT imaging. Information discussed with patients included but was not limited to mechanism for development of vitreomacular traction, typical age of onset, low occurrence rate of spontaneous anatomical relief from traction, and visual prognosis. Next the physician discussed the treatment options of observation versus pars plana vitrectomy surgery with the patient, weighing the benefits and risks of both treatment options. Patients were also informed of the high rate of success in relieving traction with a single surgery.

When surgical intervention was selected as the proper course of action, patients were informed that there is a one in one thousand risk of infection and bleeding with any ocular surgery, and these may lead to further complications, which can result in complete loss of vision. Patients were also informed of the one in one hundred risk for the development of retinal tears or detachments during surgery and that these complications can be fixed at the time of surgery and only in rare cases require a second surgery. Since many patients already had or were at risk for developing visually significant cataracts, the physician often recommended performing cataract removal and intraocular lens placement combined with PPV. Once the physician had presented the indications, risks, and benefits, patients signed consent forms and were scheduled for surgery. Patients were given instructions to fast after midnight prior to the day of surgery and to take any medications with a sip of water the morning of surgery.

Surgical Procedure

On the day of surgery, each patient was brought to the operating room, and monitors for oxygen and blood pressure, as well as an electrocardiogram were placed on the patient to monitor vitals during surgery. The operative eye was pharmacologically dilated, draped and then prepped, as is standard in ophthalmic surgery. A wire lid speculum was placed to keep the eyelids apart through the duration of the operation. The eye was anesthetized and akinesia was produced by a retrobulbar infusion behind the eye of a 50:50 mixture of 2% lidocaine and 0.75% Marcaine with epinephrine. Three sclerotomies were made 3.5 mm posterior to the limbus in the superonasal, superotemporal, and inferotemporal quadrants. The 4 mm inusion cannula was then inserted into the inferotemporal sclerotomy, and was inspected to ensure it was properly placed in the vitreous cavity before infusion took place.

Phacoemulsification and posterior chamber intraocular lens placement for cases requiring cataract extraction were performed and completed prior to vitrectomy (n=23). Kenalog dye was injected into the vitreous to stain the vitreous and the retina. Vitreomacular traction was identified, and was peeled using a soft tip aspirating cannula, followed by the vitreous cutter. Complete peripheral and central vitrectomy was then performed using the vitreous cutter and light pipe. If during vitrectomy the posterior hyaloid was noted to still be attached to the retina, the vitreous cutter was set to aspiration in order to peel the posterior hyaloid off the surface of the retina and macula to ensure a good peripheral vitrectomy could be performed.

If an epiretinal membrane was present, it was stained using kenalog and peeled off of the macula using ILM forceps. For cases in which the ILM was peeled, ICG was used to stain the ILM for 45 seconds to one minute. Next, the ILM was grasped using the ILM forceps, and an edge was created in the ILM. The ILM was then completely peeled off the macula and the fovea in a 360-degree circular fashion. After the ILM was peeled, a 360-degree scleral depressed examination was performed to check for evidence of retinal tears or detachments. If any tears or detachments were noted, they were fixed at this time. The sclerotomies were then closed and checked to ensure they were watertight. The intraocular pressure was checked, and a subconjunctival injection of Kefzol and dexamethasone was given. The operative eye was patched with a drop of scopolamine 0.25%, Bacitracin ointment, a soft eye pad, and a hard eye shield. The patient was then brought back to the recovery room. Patients followed up on postoperative day one to have the patch removed, and were given instructions for proper application of topical eye drops and ointment.

Successful Outcome Measures

In order to determine successful outcomes in this study, the three measures of anatomical relief of traction on the retina, requirement of further surgery, and postoperative best-corrected visual acuity were taken into consideration. Relief of traction on the retina was initially examined before the conclusion of surgery, and further assessed upon patient follow up with OCT image assistance. If the anatomical traction on the retina was relieved, and the eye did not require a second surgery due to complications arising from the first surgery, the surgery was deemed anatomically successful. When possible, best corrected visual acuities (BCVA) pre- and postoperatively were recorded and assessed based on medical records and notes made during visits to the eye clinic. Central macular thickness (CMT) was recorded pre- and postoperatively in order to provide an alternative to BCVA for comparing long-term success of cases that underwent ILM peeling and cases that did not. Surgical pre-and postoperative notes were used to record specific diagnosis and conditions of each procedure. Statistical methods used in this study were paired and unpaired t test, as well as chi squared test at $P<0.05$.

RESULTS

After the medical records were reviewed, the surgical VMT cases were placed into two separate groups: those who underwent PPV with ILM peeling (Group 1, 27 eyes) and those who underwent PPV alone (Group 2, 18 eyes). Table 1 displays a summary of the patient demographics for this study.

Table 1: Patient Demographics

	Total (n=45)	**Group 1 (n=27)**	**Group 2 (n=18)**
Sex (Male/Female)	14 / 28	9 / 18	8 / 10
Mean age ± SD (years)	71.6 ± 10.8	71.3 ± 11.6	72.1 ± 9.8
Age range (years)	40 - 92	40 - 92	55 - 89

This series consisted of 14 male and 28 female patients with an average age of 71.6 years at the time of the operation. Age at the time of operation ranged from 40 to 92 years. Preoperative and operative notes dictated by the surgeon were used to record indications for surgical intervention, and OCT images were reviewed to confirm these diagnosis. Cases were required to have a preoperative and operative diagnosis of VMT in order to be included in this study. The most common indications other than VMT were visually significant cataracts, epiretinal membranes, and macular holes. Table 2 provides information of the indications in this investigation.

Table 2: Indications for Surgical Intervention

	Total (n=45)	Group 1 (n=27)	Group 2 (n=18)
Vitreomacular traction	45	27	18
Visually-significant cataract	23	13	10
Epiretinal Membrane	15	9	6
Macular Hole	5	4	1

Anatomical relief of traction on the retina occurred in all 45 cases (100%), regardless of whether or not the ILM was peeled. Eyes were examined at the end of surgery, on postoperative day 1, and during further follow up for relief of traction. OCT imaging was used to further confirm relief of traction on the retina. All 27 eyes that underwent PPV with ILM peeling (100%) and 15 of 18 eyes that did not undergo ILM peeling (83.3%) had complete VMT resolution after a single surgery and did not require follow-up surgery due to complications. Three of the 18 eyes that did not have the ILM peeled required a follow-up PPV surgery due to the formation of an epiretinal membrane. These surgical success results are summarized in table 3.

Table 3: Surgical Success Rates

	Group 1 (n=27)	Group 2 (n=18)
Eyes not requiring a second surgery	27/27 (100%)	15/18 (83.3%)
Eyes requiring a second surgery	0/27 (0%)	3/18 (16.7%)
P Value: Difference Between Groups	0.028	

Best-corrected visual acuity (BCVA) was recorded for patients preoperatively and postoperatively at 3 months, 6 months, and 12 months when available. Of the 27 eyes in group 1, 17 had data for 12 months post operation, and of the 18 eyes in group 2, 10 had data available for 12 months post operation. In this case series 12 months may be anywhere from 9 months to 10 years, as needed, since long-term outcomes are the focus. The 3-month postoperative time point was included as it is an ongoing discussion in the current scientific literature regarding ILM peeling. Group 1 and group 2 had data for 16 and 11 eyes respectively at the 3-month post operation follow up. For the purposes of this study 3 month data ranges from 1 month to 5 months. There was not enough available data at the 6 month time point to perform statistical analysis. Visual acuity data was converted to LogMAR units and is listed in Tables 4 and 5 below. LogMAR units are used to convert Snellen line readings (for example 20/25) into statistically quantifiable numbers (0.1). The lower the LogMAR units, the better the visual acuity is.

Table 4: Mean BCVA preoperatively and 12 months postoperatively

	Group 1 (n=17)	**Group 2 (n=10)**	**P Value**
Preoperative BCVA ± SD	0.59 ± 0.29	0.77 ± 0.37	0.106
12 month BCVA ± SD	0.37 ± 0.25	0.53 ± 0.37	0.279
12 month BCVA change ± SD	0.22 ± 0.31	0.24 ± 0.25	0.56

Table 5: Mean BCVA preoperatively and 3 months postoperatively

	Group 1 (n=16)	**Group 2 (n=11)**	**P Value**
Preoperative BCVA ± SD	0.60 ± 0.33	0.92 ± 0.41	0.019
3 month BCVA ± SD	0.56 ± 0.38	0.72 ± 0.58	0.272
3 month BCVA change ± SD	0.04 ± 0.04	0.20 ± 0.17	0.195

For patients in Group 1 with available BCVA data at 12 months postoperatively, the weighted mean preoperative BCVA was 0.59 ± 0.29. Vision improved over 12 months by a weighted mean of 0.22 ± 0.31 to 0.37 ± 0.25 (approximately 2 Snellen lines). This difference between pre and postoperative vision was statistically significant (P = 0.0054). Patients in Group 2 with available BCVA data had a weighted mean preoperative BCVA of 0.77 ± 0.37, which was improved by a weighted mean of 0.24 ± 0.25 to 0.53 ± 0.37 (approximately 2 Snellen lines) at 12 months postoperatively. Thus, the difference between pre and postoperative BCVA in Group 2 was also found to be a statistically significant (P = 0.0065). However, there was no statistically significant difference between BCVA improvement of Group 1 and Group 2 at 12 months postoperatively (P = 0.56).

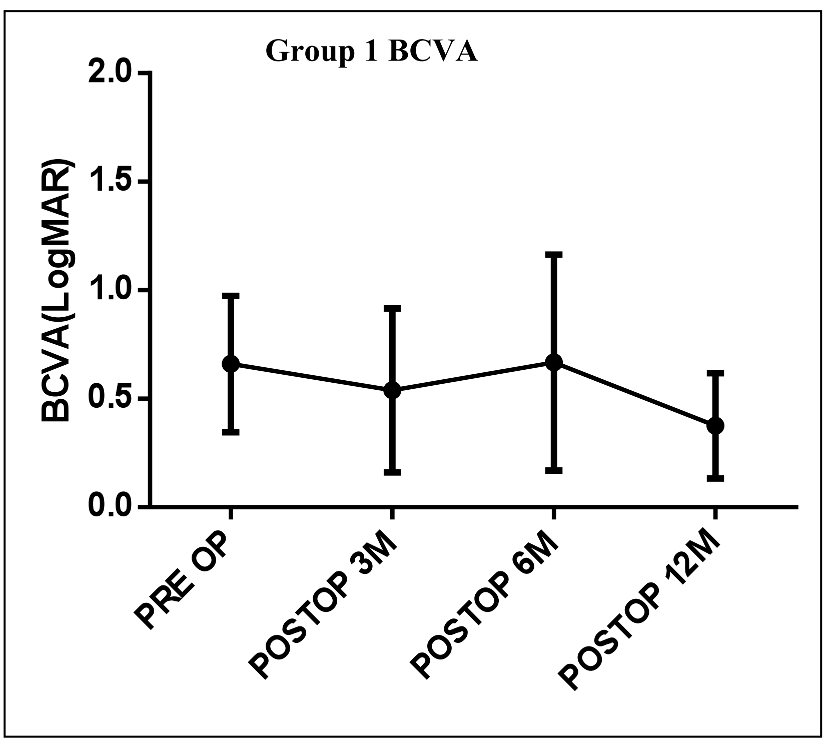

Figure 9: Group 1 LogMAR weighted BCVA over time

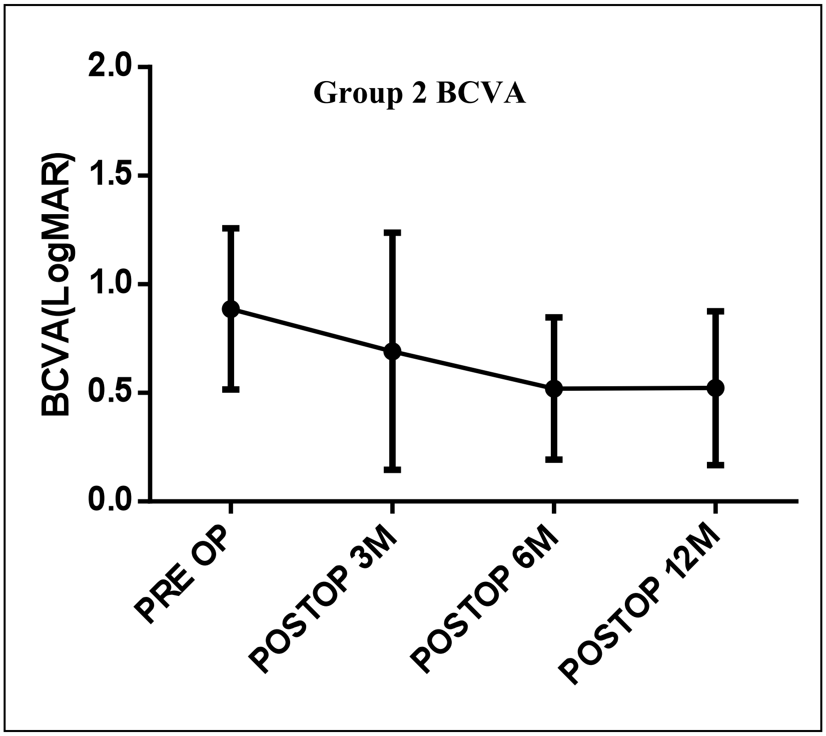

Figure 10: Group 2 logMAR weighted BCVA over time

The average BCVA improvement from the preoperative to 3 month postoperative time points was 0.04 ± 0.04 to 0.56 ± 0.38 for Group 1 and 0.20 ± 0.17 to 0.72 ± 0.58 for Group 2. Neither of these improvements was statistically significant (P >0.05). There was also no statistically significant difference in the BCVA improvement for this time period between the two groups (P = 0.195).

Data for central macular thickness (CMT) was gathered from 15 patients in Group 1 and 8 patients in Group 2. The average decrease in CMT was 119.6 ± 58.7 μm for Group 1 (416.4 ± 130.7 μm preoperatively to 296.8 ± 72.0 μm postoperatively) and 246.8 ± 182.4 μm for Group 2 (511.4 ± 254.0 μm preoperatively to 306.1 ± 71.6 μm postoperatively). Both groups had statistically significant decreases in CMT (P_1 = 0.0040 and P_2 = 0.045). While the average decrease in CMT was found to be greater for Group 2, this difference was not statistically significant (P = 0.118).

Table 6: Mean CMT pre- and postoperatively

	Group 1 (n=15)	Group 2 (n= 8)	P value
Preoperative mean CMT (μm)	416.4 ± 130.7	511.4 ± 254.0	0.131
Postoperative mean CMT (μm)	296.8 ± 72.0	306.1 ± 71.6	0.309
Change in CMT (μm)	119.6 ± 58.7	246.8 ± 182.4	0.118

DISCUSSION

Our retrospective case series demonstrates a similar surgical success rate, defined as complete VMT release after a single surgery with no follow-up surgery for complications, to that reported in the current scientific literature. As expected, initial traction relief was achieved after PPV in 100% of cases regardless of ILM peeling. Performing a PPV involves creating a posterior vitreous detachment, which relieves the traction on the retina. For cases in which the vitreous is difficult to separate from the ILM, posterior hyaloid peeling can be used to ensure relief of traction. Peeling of the ILM during PPV in Group 1 was 100% successful (27/27) in resolving VMT without requiring a second surgery due to the formation of an epiretinal membrane (ERM). PPV alone for Group 2 saw an 83.3% surgical success rate (15/18) in terms of requiring a second surgery with a 16.7% rate of postoperative formation of visually significant ERM requiring surgical intervention (3/18). Kiss et al. (2007) and Cox et al. (1995) report similar rates of postoperative ERM formation (20% of cases) when the ILM is not peeled during PPV (3, 6, 11). All 3 cases (100%) in this current study that required follow-up surgery for ERM underwent phacoemulsification and posterior chamber intraocular lens placement at the time of the original PPV for VMT, and ERM was diagnosed preoperatively in 2 of these 3 cases (66.7%). Therefore, 3 of the 6 eyes in Group 2 (50%) diagnosed with ERM prior to surgery had a recurrence, while none of the 9 eyes in Group 1 diagnosed with ERM preoperatively required follow-up surgical intervention. The difference in rate of follow-up surgery for postoperative ERM between the two groups was found to be statistically significant (P=0.028)

Previous studies have indicated a general trend in increased ERM recurrence in eyes that underwent combined ERM peeling and phacoemulsification without ILM peeling and have also shown decreased incidence of ERM recurrence in cases that received ILM peeling (26). Other studies indicate that ERM recurrence following combined ERM and ILM removal occurs in approximately 9% of ERM removal cases, whereas surgical removal of the ERM alone results in recurrent ERM in 7.5% to 56% of cases (1). The mechanism and pathogenesis of formation of ERM post PPV surgery has not been fully elucidated at this time. However, multiple studies in the current scientific literature present significant evidence that ILM peeling may prevent postoperative ERM formation.

Both groups of patients in our study had statistically significant increases in best-corrected visual acuity after 12 months, but there was no statistically significant difference in the changes in BCVA between the two surgical techniques. A meta analysis by Jackson et al. (2013) examined similar cases of PPV with and without ILM peel for VMT and found an average visual acuity improvement of 0.28 LogMAR units, from 0.72 ± 0.46 prior to surgery to 0.44 ± 0.37 after surgery, following PPV alone (9). They also reported an improvement from 0.64 ± 0.32 preoperatively to 0.41 ± 0.26 post-PPV for cases receiving PPV and ILM peeling, which was a change of 0.23 logMAR units (9). These results are consistent with the results from our current study, and are displayed in Table 7. Long-term visual acuity results for other retinal abnormalities treated with PPV and ILM peeling, such as diabetic macular edema, macular holes, and complicated retinal detachments, in most cases appear to show no statistically significant difference in visual acuity outcomes as compared to cases without ILM peeling (1, 2, 3).

Table 7: BCVA result comparison

	Mean Preoperative BCVA	Mean Postoperative BCVA	Mean change in BCVA
Current study: PPV/ILM peel	0.59 ± 0.29	0.37 ± 0.25	0.22
Jackson et al. (2013): PPV/ILM peel	0.64 ± 0.32	0.41 ± 0.26	0.23
Current study: PPV only	0.77 ± 0.37	0.53 ± 0.37	0.24
Jackson et al. (2013): PPV only	0.72 ± 0.46	0.44 ± 0.37	0.28

Neither group in our study had a statistically significant increase in BCVA within the short-term follow-up of 3 months. There was also no statistically significant difference between the change in BCVA for the two groups at this time point. Short-term visual acuity improvement was found with both surgical methods in this study, although it was not statistically significant with either technique. This result mostly agrees with results found in other studies for short-term visual acuity after PPV surgery with or without ILM peeling. Al-Abdulla et al. (2004) reported better visual acuity results at the 3 month postoperative follow-up for primary macular holes treated without ILM peel as compared to those treated with ILM peel (2). However,macular holes and VMT have inherent anatomical differences, and thus pre-operative BCVA and visual acuity improvement may not be comparable.

Our data for CMT indicates a statistically significant decrease in mean CMT for Group 1 (416.4 ± 130.7 μm preoperatively to 296.8 ± 72.0 postoperatively) and Group 2 (511.4 ± 254.0 μm preoperatively to 306.1 ± 71.6 μm postoperatively). There was no statistically significant difference in the CMT decrease when comparing the two surgical techniques, and this result is consistent with current scientific literature (18). Schecet et al. (2016) investigated CMT outcomes following PPV with and without ILM peeling for ERM. They found no significant difference in outcomes between the two techniques but reported a decreased change in average CMT for the group with ILM peeling, which is consistent with findings in our current study (18).

A study by Sonmez et al. (2008) provided evidence of a correlation between visual acuity outcomes with preoperative vitreomacular structure, duration of symptoms, and preoperative CMT (21). Their study indicated that eyes with greater CMT before surgery, as found by OCT, had greater visual acuity improvement after surgery (21). Our current study found similar results. Cases without ILM peeling had a greater mean CMT preoperatively, worse BCVA preoperatively, and a greater mean improvement in visual acuity postoperatively. This greater change in VA with ILM peeling may be due to the greater pre-operative CMT, as suggested by Sonmez et al. (2008). The CMT is related to the amount of macular abnormality found in VMT syndrome. Eyes with an increase in the CMT experience more tractional force applied to the macula and thus often have greater macular abnormalities (21). Therefore, relief of traction causing increased CMT and macular abnormalities may have the potential for better final visual acuity outcomes as compared to eyes with minimal increase in CMT and macular abnormalities due to traction. However, other factors such as duration of VMT may affect final visual acuity outcomes and should be considered in future studies.

As with many retrospective clinical case studies, this study has limitations due to patient compliance in follow up. Follow up dates used in this study were based on available data, which ranged from one month to five months for short-term follow-up and 9 months to 10 years for long-term follow-up. This range likely contributed to the inconclusiveness of the short-term visual acuity data and may have had an impact on long-term visual acuity data as well. This case series also did not take into account secondary diagnoses that may have resulted in poor, long-term visual outcomes, such as glaucoma, proliferative diabetic retinopathy, and hypertension. Larger studies should consider categorization of patients based on overall health factors and secondary diagnoses to limit these potential confounding factors. However, the results of this study regarding recurrent formation of epiretinal membranes in cases without internal limiting membrane peeling may be useful in context with other clinical studies and could help vitreoretinal specialists make decisions about surgical techniques. The significant increase in visual acuity for both groups regardless of ILM peeling may be useful for clinicians and future research as well.

Continued development of pneumatic vitreolysis may be significant in decreasing the number of patients requiring surgery for VMT, but PPV with internal limiting membrane peeling should be considered when pneumatic vitreolysis fails to relieve traction. Our retrospective case series provides further evidence that there is may be no significant difference in long-term visual acuity between VMT cases receiving PPV with

ILM peeling or those receiving PPV alone, but further and more extensive studies should be conducted to supplement these findings. If further research confirms the findings reported here, surgeons should consider using ILM peeling as a measure for preventing postoperative epiretinal membrane formation requiring follow-up surgery.

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