It’s hard to believe that we are closing in on 50 years of performing pars plana vitrectomy using the tools and techniques developed by Robert Machemer, MD, and Jean-Marie Parel, PhD, in the early 1970s. Along the way, countless advances have been made by the likes of Steve Charles, MD; Jay Federman, MD; Conor O’Malley, MD; Gary W. Abrams, MD; Stanley Chang, MD; and many others. These innovators shaped current microincisional vitrectomy systems (MIVS) and the surgical tools and techniques that enable modern day vitreoretinal surgery. The advances have enabled vitreoretinal surgeons to more effectively address multiple sight-threatening retinal diseases and conditions, including retinal detachments, macular pucks, and macular holes, plus complications associated with diabetic retinopathy and intraocular lenses (IOLs). This article takes a closer look at these latest developments that we rely on today to achieve improved surgical outcomes.

REPAIRING RETINAL DETACHMENTS
The surgical repair of retinal detachments can be achieved with vitrectomy and/or scleral buckling, which are discussed below. Laser retinopexy and pneumatic retinopexy are other options that will not be covered in this article.

**Vitrectomy**
Vitrectomy for retinal detachment has advanced over the decades to include vitreous removal, subretinal fluid drainage, retinopexy, and air-fluid exchange followed by gas exchange or silicone oil. Although there are variations in the techniques and tools used in these surgical steps, together they have resulted in reports of retinal reattachment in approximately 85% to 90% of patients. Proliferative vitreoretinopathy (PVR) continues to be our nemesis, as effective prevention eludes us.

Current vitrectomy techniques rely on advanced MIVS platforms. The benchmark Constellation Vision System (Alcon), released in 2008, has been joined by advanced vitrectomy systems from other companies, including Dutch Ophthalmic USA and Bausch + Lomb. The technology of these platforms improves efficiency.

**AT A GLANCE**
- Valved trocars result in less risk of retinal incarceration and more stable IOP control, which in turn decreases the risk of suprachoroidal hemorrhage.
- Small-gauge instrumentation allows many advanced diabetic TRD surgeries to be performed with only the vitreous cutter and ILM forceps.
- Arcuate retinotomy and perifoveal radial incisions are surgical techniques that have recently been described to address previously failed macular hole repair.
and safety in the OR. Use of an integrated platform allows each step of retinal detachment repair to be performed without a break in concentration. There are fewer instrument exchanges, and the surgeon can keep his or her eyes on the surgical field at all times, thanks to footpedal integration of most, if not all, critical steps in the procedure. As a result, MIVS leads to shorter operating times and lower risk of complications.

Valved trocars have also had a tremendous influence on retinal detachment surgery. By maintaining a closed system with minimal fluid leak during instrument exchange, these devices reduce the risk of vitreous or retinal incarceration, and stable control of intraocular pressure (IOP) decreases the risk of suprachoroidal hemorrhage. Additionally, with less turbulent flow of fluid, use of perfluorocarbon liquid is better controlled and there is less risk of fish eggs.

Most manufacturers now produce instruments for vitreoretinal surgery in 23-, 25-, and 27-gauge. Faster cut rates (5,000 to 12,000 cpm) improve fluidics and reduce traction on the vitreous. Combined with duty cycle control, these advances have led to improved safety and efficacy. During surgical repair of retinal detachments, surgeons can vary the cut rate and duty cycle as needed for different steps of the procedure. With a high cut rate and a port-closed bias, shaving vitreous over detached retina is safer with significantly less risk of iatrogenic breaks. The retina remains almost motionless, despite close shaving over the detached and freely mobile retina.

Visualization during retinal detachment surgery has also improved. With advanced widefield systems such as the A.V.I. Panoramic Viewing System (Advanced Visual Instruments), Oculus BIOM S (Oculus Surgical), and Resight 500 and 700 Fundus Viewing Systems (Carl Zeiss Meditec), the surgeon has unobstructed, panoramic views of more than 100°. Widefield viewing systems allow adequate viewing despite small pupils and media opacities.

Visualization has also been enhanced by newer light sources in small-gauge instrumentation with filters to reduce phototoxicity. Chandelier light sources are available to allow peripheral shaving with scleral depression with no need for an assistant. This can also be accomplished with retroillumination, using the light pipe as a scleral depressor. Several manufacturers offer a special cap to insert over the light pipe to aid in this maneuver.

Curved, illuminated laser probes improve visualization for laser retinopexy. With these probes, the surgeon can easily visualize and apply laser up to the ora serrata with scleral depression without the aid of an assistant. This maneuver can even be performed in a phakic patient without risk of damaging the lens.

As one of us (Dr. Houston) was recently operating on four advanced diabetic tractional retinal detachments (TRDs) using the Ngenuity 3D Visualization System (Alcon), he was reminded of the enhanced depth of focus provided by this system. At high magnification under the BIOM, the Ngenuity allowed him to dissect membranes from the nerve out to the periphery without the use of a macular contact lens. Visualization was superior to the operating microscope in these situations, allowing him to easily differentiate tissue planes, efficiently segmenting and delaminating preretinal membranes.

Scleral Buckling

Use of chandelier endoillumination for scleral buckling with a widefield viewing system has gained popularity as an alternative to use of indirect ophthalmoscopy in selected cases of retinal detachment repair. Since the original description of the procedure, authors from around the world have reported excellent overall outcomes comparable with traditional scleral buckling without increased incidence of adverse events. This modified technique may have several advantages over traditional buckling methods.

First, the higher magnification of the wide-angle viewing system, together with the oblique, dynamic endoillumination from the chandelier, may permit better localization and treatment of small peripheral retinal defects. Second, when applicable, endolaser can be introduced through the transscleral cannula to treat pathology in areas of attached retina (ie, lattice degeneration), which may be less inflammatory compared with cryotherapy. Third, and most advantageous, in teaching environments, all portions of the surgery can be directly visualized simultaneously by the attending surgeon and the trainee.

Managing the Macula

Over the past several years, a variety of new techniques for the management of macular diseases, in particular macular holes, have emerged. The success rate for macular hole surgery is approximately 90%. For larger macular holes, however (ie, those >400 µm

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in diameter), the success rate is not so optimistic. New techniques have emerged for the repair of large macular holes in an attempt to improve closure rates and visual outcomes. Many of these new techniques focus on internal limiting membrane (ILM) free-flap variations, but other novel surgical techniques have also been described.

The inverted ILM flap technique, initially described in 2010, has been successful for myopic and large idiopathic macular hole repairs. Modifications of this procedure have been described, such as autologous ILM transplantation and the temporal inverted ILM flap technique. In the latter, the ILM is peeled only on the temporal side of the fovea and remains attached at the margin of the macular hole. The ILM flap is then used to cover the macular hole. Results with these techniques, both in anatomic closure rate and visual acuity, have been comparable.

For autologous ILM flap transplantation, a potential complication is dislocation of the flap. The edges of the flap can often be tucked under the macular hole to prevent this from occurring. Anterior and posterior lens capsules have also been used as adjuvants for macular hole repair. In 2016, Chen and Yang reported macular hole closure in all eyes that received anterior capsular flap transplantation. This technique may be considered in eyes that have minimal ILM remaining after previous macular hole surgery.

For refractory myopic macular hole repair, Grewal and Mahmoud described a technique involving the harvesting of an autologous neurosensory retinal free flap. This procedure is assisted by the use of perfluoro-n-octane heavy liquid and then silicone oil exchange. These authors reported improvements in vision and macular hole closure.

Arcuate retinotomy and perifoveal radial incisions are two additional surgical techniques that have recently been described to address previously failed macular hole repair. Charles et al described use of arcuate retinotomy in six patients, with closure achieved in five patients and improved visual acuity in three. Reis et al used full thickness radial incisions in seven patients, sparing the papillomacular bundle, and reported hole closure in all patients.

**COMBATTING COMPLICATIONS**

**Complications of Diabetes**

Advances have enhanced the surgical treatment of patients with complications of diabetes, including vitreous hemorrhage, TRD, and refractory diabetic macular edema, with or without epiretinal membrane. Small-gauge instrumentation, especially 25- and 27-gauge, allows many surgeries for advanced diabetic TRDs to be performed with only the vitreous cutter and ILM forceps. On small-gauge vitreous cutters, the ports are closer to the tip of the cutter, allowing precise dissection of preretinal membranes.

Another option for surgeons who prefer 23- and 25-gauge instrumentation is to open only a 27-gauge cutter and perform combination-gauge
surgery. This provides the benefits that many surgeons find with the larger instruments (stability, efficiency, and better end-grasping forceps) plus the utility of the smaller-gauge cutter for fine membrane dissection.

As noted above, valved trocars allow IOP control in a closed system. As a result, intraoperative bleeding is minimized and easily controlled. To reduce intraoperative hemorrhage and facilitate membrane dissection, anti-VEGF therapy can be given preoperatively. Chandelier illumination can be used to facilitate binocular surgical maneuvers, such as the use of forceps to elevate membranes combined with a pick to dissect between tissue planes.

Complications Related to IOLs
Some surgeons are working to expand methods for placing IOLs in aphakic patients. Although many surgeons rely on anterior chamber IOLs, aphakic patients with contraindications to these lenses (ie, shallow anterior chamber, glaucoma, iris trauma, aniridia, etc.) require an alternative solution. Scleral suspension is increasingly the preferred surgical option over iris fixation. Techniques for scleral suspension are manifold, but many recent innovations involve externalizing the haptic tips of a three-piece IOL through counterpoised sclerotomies and securing them externally.

One of the first techniques popularizing this approach involved bringing the haptic tips through partial thickness scleral pockets and then securing them within the sclera using needle tunnels. With sufficient practice, this technique can reliably hold an IOL in place. However, the scleral dissection and tunneling can often be unwieldy and may not be necessary to secure the lens. Recent publications report good results by simply pulling the haptics through a standard trocar (or a large bore needle) and leaving them subconjunctival. 13 Cauterizing the PMMA tip creates a distal bulb that can prevent the haptic from falling back through the sclerotomy.

Concerns remain as to whether this technique is stable enough, although early series report extremely low dislocation rates. Rather than relying on standard three-piece IOLs, a recently published technique uses a four-flanged lens (Akreos Advanced Optics; Bausch + Lomb) secured to the sclera using PTFE (Gore-Tex) suture to hold the optic centrally with four-point fixation. 12 This requires two additional sclerotomies, made with a microvitreoretinal blade through limited peritomies, through which the suture is passed and tied. This allows the surgeon to fine-tune the position of the lens by adjusting the relative tensions of the suture before the end of the case.

This technique is not without difficulties and complications, and concerns about late lens opacification after vitrectomy with intraocular gas further complicates an already complex surgical selection. Lens opacification can rarely occur after the use of intraocular gas, and it is poorly understood why some lenses exhibit this rare complication. As a result, some surgeons who perform PTFE suture fixation techniques are exploring the use of a hydrophobic lens (envista; Bausch + Lomb) that does not have the potential for opacification. 13

Other surgeons have advocated the use of iris-claw IOLs, which can be implanted safely in either the anterior chamber or a retropupillary position, and recent analysis suggests that these techniques achieve similar visual outcomes to scleral-fixating techniques with a quicker learning curve. 14

IT’S GOOD TO HAVE OPTIONS
To determine the best surgical option in situations in which multiple pathologies are present, a wide selection of techniques is called for. As retina surgeons push the envelope on the development of new surgical techniques, these options will continue to expand. We look forward to seeing what new developments lie in store for the surgical retina community.