**Objectives:** To evaluate the surgical management of vitreoretinal pathology in patients with a permanent Boston Type 1 keratoprosthesis (hereafter referred to as a KPro) in the era of small-gauge vitrectomy techniques.

**Methods:** Retrospective review of 23 small-gauge vitreoretinal surgical procedures during or after Dohlman-Doane KPro placement in 14 eyes.

**Results:** Established and innovative techniques were used, including sutureless small-gauge vitrectomy, temporal positioning of surgeon, long-term tamponades, and exploratory endoscopy. Retro-KPro membranes formed less frequently when vitrectomy was performed during KPro placement. Anatomical goals were achieved, and no serious complications directly resulted from these techniques. Visual acuity, frequently limited by preexisting pathology, improved in most cases.

**Conclusions:** Modern posterior segment surgical techniques, including small-gauge sutureless vitrectomy, can be effectively used for patients with a permanent KPro. Vitrectomy and glaucoma tube revision by a team of subspecialists at the time of KPro placement may reduce subsequent complications.

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**Methods**

A retrospective review of 23 consecutive vitreoretinal procedures performed at Weill Cornell Medical College, New York, New York, in 14 eyes with a KPro was undertaken (Table and video, http://www.archneurol.com). Our study was performed in accordance with the Declaration of Helsinki and approved by our institutional review board.

**Video available online at www.archophthalmol.com**

Of 23 vitrectomies, 7 were performed at the time of KPro placement; 3 included a glaucoma procedure. Fifteen of the vitreoretinal procedures were in eyes with a preexisting KPro (including 1 KPro removal), 7 were performed at the time of KPro placement, and 1 was an exploratory endoscopy prior to KPro placement. Indications for KPro included corneal neovascularization, acid burn, corneal opacity, multiple graft failure, trauma, ulcers, and pseudophakic bullous keratopathy. Indications for vitrectomy included 8 cases with retro-KPro membranes (RPMs), with 7 of these cases occurring in eyes for which vitrectomy was not per-
formed at the time of KPro placement; 6 cases of retinal detachment; 6 cases of vitreous debris or opacity; and 5 cases with epiretinal membranes.

**PREOPERATIVE EVALUATION**

Prior to surgery, a patient underwent an evaluation of his or her retina by use of indirect ophthalmoscopy (if possible) and high-resolution B-scan ultrasonography. In one case, exploratory endoscopy was performed to determine visual potential. When RPMs were present, an assessment was made to determine whether YAG capsulotomy would be effective or whether surgical intervention was necessary.

**SURGICAL TECHNIQUES**

Of 23 cases, 22 underwent a 3-port small-gauge (23- or 25-gauge) vitrectomy (Figure, A); one case was via an open-sky approach. Excellent visualization of the posterior segment was routinely obtained using a 130° panoramic AVI contact lens (Figure, D and E); a Charles irrigating lens was used for macular maneuvers. The contact lens system provided a better visualization of the retina than did a noncontact lens system such as the BIOM 3 Non-Contact Panoramic Wide-Angle Viewing System (Oculus, Inc). Microcannulas were inserted from 1 to 3.5 mm posterior to

<table>
<thead>
<tr>
<th>Patient/ Age, y</th>
<th>Pre-KPro Diagnosis</th>
<th>Posterior Segment Complication(s)</th>
<th>Preoperative VA</th>
<th>Procedure</th>
<th>Best Postoperative VA</th>
<th>Preexisting KPro?</th>
<th>PPV at Time of KPro Placement?</th>
<th>Presence of Retro-KPro Membrane?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/76</td>
<td>1st operation</td>
<td>Corneal NV/pannus S/P multiple rejected grafts</td>
<td>Retained lens fragment</td>
<td>CF at 1 ft</td>
<td>KPro placement/PPV PPL^3</td>
<td>20/50 + 2</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>2nd operation</td>
<td>Corneal NV/pannus S/P multiple rejected grafts</td>
<td>Choroidal hemorrhage, RD, ERM</td>
<td>HM</td>
<td>PPV, AFE, ERM peel, drainage retinotomy, SO and drainage of choroidal hemorrhage</td>
<td>LP</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2/27</td>
<td>1st operation</td>
<td>Acid burn, corneal ulcer, opacity</td>
<td>None</td>
<td>HM</td>
<td>KPro placement/open sky lensectomy, vitrectomy^3</td>
<td>20/200 without correction, 20/80 PH</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2nd operation</td>
<td>Acid burn, corneal ulcer, opacity</td>
<td>Acute endophthalmitis</td>
<td>HM</td>
<td>Vitreous biopsy, antibiotic and antifungal injection</td>
<td>20/80 + 1 without correction, 20/50 PH</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>3/65</td>
<td>1st operation (OS)</td>
<td>Corneal opacity, graft failure</td>
<td>None</td>
<td>HM</td>
<td>PPV and partial open sky temporal approach, iridoplasty, synechialysis, removal of IOL and lens material, glaucoma shunt revision/KPro placement OS^A</td>
<td>20/30 + 2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2nd operation (OD)</td>
<td>PBK, and Hx of multiple failed PKs OS</td>
<td>None</td>
<td>HM</td>
<td>PPV, shunt revision, iridectomy/KPro placement OD</td>
<td>20/40</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>4/88</td>
<td>1st operation</td>
<td>Multiple graft failure</td>
<td>VH after permanent KPro</td>
<td>HM</td>
<td>PPV</td>
<td>CF</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2nd operation</td>
<td>Multiple graft failure</td>
<td>Uveitis flare, VH and vitreous opacity</td>
<td>HM</td>
<td>PPV</td>
<td>HM</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>3rd operation</td>
<td>Multiple graft failure</td>
<td>Vitreous opacity and pupillary membrane, retro-KPro membrane</td>
<td>HM</td>
<td>PPV, retro-KPro membrane peel</td>
<td>HM</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>5/79</td>
<td>Aniridia and associated limbal stem cell deficiency</td>
<td>Total RD with hypotony, retro-KPro membrane</td>
<td>HM</td>
<td>PPV, retro-KPro membrane removal, 270° relaxing retinotomy, PFO and tamponade, diode EL</td>
<td>HM</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>6/85</td>
<td>Recurrent sterile corneal ulcers, opacity with NV</td>
<td>Vitreous debris and cataract</td>
<td>20/500</td>
<td>Permanent KPro/vitreous biopsy/ICCE NV</td>
<td>20/20 – 2</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>7/36</td>
<td>Exposure keratopathy following trauma, multiple PK failure</td>
<td>RD with severe PVR, ERM, retro-KPro membrane</td>
<td>LP</td>
<td>PPV, retro-KPro membrane peel, ERM peeling, relaxing retinotomy, PFO, diode EL</td>
<td>HM</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2nd operation</td>
<td>Exposure keratopathy following trauma, multiple PK failure</td>
<td>RD with PVR, Rx with PFO tamponade for 3 wk, retro-KPro membrane</td>
<td>LP</td>
<td>PPV, removal of retro-KPro membrane, removal of PFO</td>
<td>LP</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>8/69</td>
<td>PBK, multiple graft failure</td>
<td>Recurrent macula-off RD, PVR secondary to hypotony, ERM</td>
<td>HM</td>
<td>PPV, ERM peel, AFE, focal EL, SO</td>
<td>CF at 1 ft</td>
<td>Yes, for 1 mo</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2nd operation</td>
<td>PBK, multiple graft failure</td>
<td>Retro-KPro membrane, after SO for RD repair</td>
<td>HM</td>
<td>PPV, SO removal, removal of retro-KPro membrane^5</td>
<td>CF at periphery</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

(continued)
the limbus. Infusion sites could then be changed, allowing conversion to a temporal surgical approach in one case (Figure, B). In conjunction with vitreectomy, an endolaser, silicone oil tamponades, perfluoro-octane (Figure, F), and intraocular steroids were used. Corticosteroids were removed using the small-gauge vitrectomy handpiece; intraocular lenses (IOLs) were taken out via an open-sky approach. Endoscopy was performed in one case (Figure, C). The majority of sclerotomy sites were not sutured: 13 of 15 cases of 25-gauge vitrectomy and 2 of 7 cases of 23-gauge vitrectomy were sutureless.

### RESULTS

Of 23 vitrectomies, 15 were for posterior segment complications in eyes with a preexisting KPro, 4 were performed at the time of KPro placement in eyes with vitreous debris and retained a lens fragment or a subluxated posterior chamber IOL, 3 occurred at the time of KPro placement without posterior segment complications, and 1 was performed as a prelude to KPro placement for retinal evaluation. The indications for vitrectomy in these cases included: (1) lensectomy at the time of KPro placement; (2) glaucoma shunt revision with IOL removal; and (3) glaucoma shunt revision. The most common indication for pars plana vitrectomy (PPV) with a preexisting KPro was the presence of RPMs in 7 cases, followed by retinal detachment, vitreous opacity or debris, and the presence of epiretinal membranes. The presence of a single RPM occurred in a patient who underwent a vitrectomy at the time of KPro placement. Other concurrent pathologies included choroidal hemorrhage and proliferative vitreoretinopathy. Additionally, patient 2 presented with acute endophthalmitis 16 months after KPro placement. The mean follow-up period for all eyes was 11.3 months (median, 7 months; range, 1 day to 40 months).

In all 8 cases, the RPMs were successfully removed. Visual acuity improved in 3 patients, and remained unchanged in 5 patients, with the unchanged visual acuities being attributable to preexisting retinal or optic nerve pathology.

Of the 6 cases of retinal detachment that underwent PPV, 4 cases attained a complete anatomical reattachment. In patient 2, owing to retinal holes and fibrosis, the retina was judged to be beyond meaningful repair during the PPV; thus, complete anatomical reattachment was not pursued. Patient 9 had a suspected retinal detachment that was found to be a shallow macular detachment on examination using exploratory endoscopy. Visual acuity improved in 2 patients. Visual acuity remained unchanged in patient 2 because the retina was not completely reattached. Patient 5 had a total retinal detachment. Patient 1 had concurrent choroidal hemorrhage that limited our determination of the patient’s final visual acuity.

Removal of vitreous opacities was successful in all 6 cases. Visual acuity improved from hand motions to 20/500 to 20/20 in patient 6, and from hand motions to 20/100 in patient 11.
For the cases in which PPV was performed at the time of KPro placement without posterior segment pathology, visual acuity improved from a range of light perception to 20/500 to counting fingers at 3 ft to 20/20. A significant amount of potentially proinflammatory anterior debris was removed along with the IOL.

In all 5 patients who underwent epiretinal membrane peeling, the membranes were successfully removed. In these patients, visual acuity changes, from a range of light perception to 20/200 before surgery to a range of light perception to 20/300 after surgery, were attributable to membrane peeling, the clearing of vitreous opacities, and KPro placement (Table).

COMMENT

Eyes with a KPro present a unique challenge for posterior segment surgery. Since the last report, indications for KPro placement have expanded, and vitreoretinal surgical techniques, including small-gauge vitrectomy, have advanced. We have successfully adapted these cutting-edge vitrectomy techniques to eyes that have undergone a KPro, with favorable outcomes. We describe the solutions to unique complications in these eyes and the strategies to prevent such complications.

SMALL-GAUGE VITRECTOMY IN A CLOSED SYSTEM

In the original report, a modified 2- and 3-port 20-gauge vitrectomy was described. Herein, we illustrate trocar-
based 23- and 25-gauge vitrectomy techniques in the setting of KPro. In our experience, vitrectomy in a closed globe, as opposed to a previously described open-sky approach, is most advantageous in minimizing the risk of choroidal hemorrhage during the surgery. The use of a trocar-based system permits effortless exchange of the infusion site, as exemplified with patient 3, for whom the temporal position was used for improved retinal visualization. Smaller incisions with 23- or 25-gauge systems may also be preferable given the extent of scarred conjunctiva and foreshortened fornices frequently found in these cases. Interestingly, even in these scarred eyes, the small-gauge incisions are oftentimes self-sealing and do not require a suture at the sclerotomy site. The use of this type of incision may also decrease the inflammatory response in an already inflamed eye.

MANAGEMENT OF POSTERIOR SEGMENT COMPLICATIONS

The most frequent posterior segment complication encountered was the presence of RPMs, the incidence of which is reported to be up to 40%. The energy required to perform a YAG capsulotomy on these thick membranes may lead to a retinal detachment, a giant retinal tear, or persistent ocular inflammation. Such complications were noted in patient 4, who ultimately required a vitrectomy. Of the 15 cases with a preexisting KPro, 7 (47%) had RPMs. In the 7 eyes for which a vitrectomy was performed at the time of KPro placement, only a single RPM formed (14%). Removal of potentially proinflammatory material during KPro placement may decrease the incidence of RPMs. With IOLs, however, the presence of RPMs presents a special challenge. Although RPMs can be successfully removed from between the IOL and the KPro (patient 10), there is a risk of displacing the IOL or damaging the prosthesis. We advocate vitrectomy at the time of KPro placement because removing the IOL and clearing the inflammatory material may decrease the incidence of RPM formation and post-KPro inflammation.

The second most frequent posterior segment complication requiring PPV was retinal detachment. In the previous series, the authors alluded to the need for a tamponade technique. We now report experience with both perfluoro-n-octane and a silicone oil tamponade. Although not routinely recommended as a prophylaxis for retinal detachment in all cases of KPro, a silicone oil tamponade can be successfully used with a KPro (eg, for patients 1, 8, and 9). Perfluoro-n-octane may also be left in place to temporarilily tamponade inferior retinal pathology (patient 5). However, given its inflammatory nature, short-term use of perfluoro-n-octane for 1 or 2 weeks requires concomitant topical and, at times, intravitreal steroid treatment.

EPIRETINAL MEMBRANE

Patients with a KPro may also develop epiretinal membranes that require peeling. As evidenced by patients 1, 7, 8, 10, and 12, anatomic and visual success can be achieved using small-gauge techniques and disposable instruments, even through a KPro. Standard visualization and surgical maneuvers can be applied in this setting without obvious complications related to a small-gauge PPV.

VITREOUS BIOPSY

Vitreous biopsies were performed to aid in the management of several cases. In patient 2, who developed endophthalmitis after being lost to follow-up for several months, a vitreous tap with the small-gauge infusion and vitrector provided a controlled means to enter a severely inflamed and scarred eye. In patient 4, who had recurrent uveitis after a YAG capsulotomy, and patient 6, who had recurrent non-Hodgkin lymphoma, a diagnostic small-gauge vitrectomy provided sufficient samples for treatment decisions. Small-gauge techniques are ideal in this setting because adequate specimen retrieval can be accomplished with minimal disruption to the eye.

EVALUATION PRIOR TO KPro PLACEMENT

By the nature of the disease process that results in the need for a KPro, the view of the fundus is typically extremely poor, and it may be difficult to evaluate visual potential. Although B-scan ultrasonography is useful, the best determination often comes with direct visualization. As such, an exploratory endoscopy (via a 20-gauge sclerotomy) was performed to evaluate whether visual potential would merit KPro placement in patient 9. The optic nerve, vessels, and macula were well visualized, and although a shallow macular detachment was noted, the tissues were judged to have adequate viability. This brief procedure allows for a more accurate assessment of potential visual recovery and of potential anatomical challenges prior to proceeding with KPro placement and may obviate the need for extensive surgery.

VITRECTOMY AT TIME OF KPro

In our series, a vitrectomy was frequently performed at the time of KPro placement. The advantages of combining these 2 procedures (ie, PPV and KPro) are that, together, they (1) provide valuable information on the patient’s visual potential (including a careful evaluation of retinal and optic nerve status), (2) remove potentially inflammatory material, and (3) prepare the eye for glaucoma drainage procedures during or subsequent to KPro placement.

For similar reasons, we also favor the removal of preexisting IOLs at the time of KPro placement. First, potential inflammatory material around the IOL can be removed, which may reduce the incidence of posterior segment complications and RPM formation. In all 3 cases in which the IOL was removed at the time of KPro placement, substantial potentially inflammatory material was noted in the remnant capsular bag. This may have previously contributed to the repeatedly failed penetrating keratoplasties and may have also contributed to post-KPro inflammation. Second, should RPMs appear, it is challenging to remove them from between the prosthesis and the IOL, as in patient 10. Third, in any subsequent surgery, there is a risk of displacing the IOL. The absence of an IOL in an eye that has...
Differing techniques and approaches to posterior segment surgery, such as small-gauge vitrectomy, membrane peeling, vitreous biopsy, and the use of tamponades, can be successfully applied to eyes with a KPro. As advances continue in the treatment of complications in eyes that have undergone a KPro, we must also consider the prevention of common complications such as retro-KPro membrane formation and treatment of glaucoma. We suggest that a PPV at the time of KPro placement has the potential to decrease the level of RPM formation by removing inflammatory material as well as the scaffolding on which these membranes may grow. Direct visualization of the retina by use of endoscopy or during PPV provides valuable information on the status of the retina. For the best long-term outcome in these eyes that have undergone a KPro, we advocate coordinated operations by retina, cornea, and glaucoma surgeons when appropriate and further follow-up by this multidisciplinary team. Continuing advances in vitreoretinal technology and in surgical techniques will further improve visual outcomes for the rapidly increasing number of patients receiving a KPro.

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REFERENCES