BACKGROUND AND OBJECTIVE: To examine the outcomes of vitrectomy in ocular trauma with opaque cornea.

PATIENTS AND METHODS: This retrospective study included 17 eyes of 16 patients who underwent vitrectomy with temporary keratoprosthesis or endoscopy at Walter Reed Army Medical Center, Washington, DC, from March 2003 to October 2010.

RESULTS: A temporary keratoprosthesis was used in 8 eyes (47%) and endoscopy in 9 eyes (53%). Overall, the number of eyes with visual acuity of 20/200 or better improved from 0 at baseline to 5 (29%) at 6 months. The number of eyes with retinal detachment also improved from 10 (59%) at baseline to 3 (18%) at 6 months.

CONCLUSION: Vitrectomy may be safely performed in ocular trauma with opaque cornea using a temporary keratoprosthesis or endoscopy with comparable outcomes. Endoscopy allows earlier diagnosis and treatment of occult pathology and requires less time and fewer procedures to implement than the temporary keratoprosthesis.

Ocular trauma is often complicated by corneal opacities that may interfere with the diagnosis and management of posterior segment pathology. Faulborn et al. 1 reported that the cornea was involved in 57% of severe perforating injuries in a civilian population. The leading cause of blindness was retinal detachment occurring either at the time of injury or during the postoperative period. Among
the injuries sustained in military combat treated at Walter Reed Army Medical Center (WRAMC) from February 2003 to November 2005, 46% of the 79 eyes with perforating injuries had entrance wounds in the cornea. Most corneas retain adequate clarity to perform retinal surgery, but some have severe opacities that preclude the diagnosis and repair of posterior segment pathology. Corneal clarity may be affected by severe stromal edema, sutures, glue, foreign bodies, and distortion caused by large oversewn defects. Computed tomography and ultrasonography may yield clues to the presence of pathology such as retinal detachment, intraocular foreign bodies (IOFBs), or occult rupture, but retinal tears and detachments may still be missed. Early intervention may prevent some late complications, but an alternative intraoperative viewing system may be desirable due to the increased risk of iatrogenic injury in an eye with opaque cornea. Options include the “open-sky” technique, temporary keratoprosthesis, penetrating keratoplasty without temporary keratoprosthesis, or endoscopy.

The use of temporary keratoprosthesis for vitreectomy in ocular trauma was described by Landers et al. in 1981. These keratoprosthesis were composed of a polymethylmethacrylate cylinder with a threaded shaft to secure it to the recipient cornea and a minus optic to permit posterior segment surgery without the use of additional lenses. The silicone temporary keratoprosthesis, described by Eckardt in 1987, is sutured to host corneal tissue and allows improved access to the periphery of the posterior segment due to its shorter shaft length. In the same year that Landers et al. reported on their temporary keratoprosthesis, a 1.7-mm small-diameter rigid endoscope was described for use in vitrectomy. In 1990, Volkov et al. reported using a flexible ophthalmic endoscope on 23 eyes for posterior segment surgery. Later that year, Eguchi et al. described using a 20-gauge video endoscope to view the far periphery of the posterior segment and to examine the subretinal space in an eye with a proliferative vitreoretinopathy (PVR) retinal detachment. In 1994, the laser ophthalmic endoscope was reported for the treatment of PVR. Several studies have examined various temporary keratoprosthesis for vitrectomy following ocular trauma (Table 1), but the ophthalmic endoscope has not been widely adopted for this purpose despite its introduction more than 20 years ago. The current study reports on the functional and anatomic outcomes of vitrectomy with either a temporary keratoprosthesis or endoscopy in ocular trauma with opaque cornea.

**TABLE 1**

<table>
<thead>
<tr>
<th>Author</th>
<th>No. of Eyes</th>
<th>Mean (Median) Follow-Up (Mo)</th>
<th>Clear Graft at Final Visit</th>
<th>Retina Attached at Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmadieh</td>
<td>6</td>
<td>–</td>
<td>33%</td>
<td>67%</td>
</tr>
<tr>
<td>Dong</td>
<td>107</td>
<td>25</td>
<td>75%</td>
<td>88%</td>
</tr>
<tr>
<td>Gallemore</td>
<td>11</td>
<td>(9)</td>
<td>73%</td>
<td>91%</td>
</tr>
<tr>
<td>Garcia-Valenzuela</td>
<td>22</td>
<td>–</td>
<td>59%</td>
<td>55%</td>
</tr>
<tr>
<td>Gelender</td>
<td>7</td>
<td>(6)</td>
<td>43%</td>
<td>43%</td>
</tr>
<tr>
<td>Roters et al.</td>
<td>34</td>
<td>30</td>
<td>15%</td>
<td>88%</td>
</tr>
<tr>
<td>Yan</td>
<td>7</td>
<td>28</td>
<td>43%</td>
<td>71%</td>
</tr>
</tbody>
</table>

**PATIENTS AND METHODS**

This retrospective interventional case series was conducted under a research protocol approved by the Institutional Review Board of the WRAMC Department of Clinical Investigation by reviewing all of the vitrectomies performed at WRAMC from March 2003 to October 2010. Inclusion criteria were age 18 years or older, ocular trauma requiring vitrectomy, and opaque cornea with no intraocular view. Exclusion criteria were baseline “no light perception” (NLP) status, the use of standard viewing techniques for any part of vitrectomy, and incomplete data. Either a 7.0-mm Eckardt temporary keratoprosthesis (Dutch Ophthalmic USA, Exeter, NH) or the Endo Optiks E2 Endoscopy System (Endo...
Optiks, Little Silver, NJ) was used as the sole means of intraocular visualization during vitrectomy in all of the study eyes. All of the eyes in the keratoprosthesis group were managed conservatively to allow for corneal clearing until an urgent indication for vitrectomy such as retinal detachment was diagnosed ultrasonographically or if vitrectomy was required for a less urgent condition in the presence of a nonclearing cornea. The endoscopic procedures were performed when any indication for vitrectomy was identified without waiting for corneal clearing. All of the corneal procedures were performed by one of two corneal surgeons and all of the retinal procedures were performed by one of three retinal surgeons. The conventional viewing systems available at WRAMC that failed to provide an intraocular view in all of the study eyes included the Oculus BIOM 2 (Oculus, Inc., Lynnwood, WA) with disposable and autoclavable reduction lenses and the Volk Mini Quad XL (Volk Optical, Inc., Mentor, OH) wide-angle indirect contact lens viewing system.

Data Collection
Data obtained from transfer summaries, inpatient and outpatient medical records, operative reports, and slit-lamp photographs and surgical videos were collected in a Microsoft Excel 2007 spreadsheet (Microsoft Corp., Redmond, WA). Ocular trauma data included the mechanism and type of injury classified according to the Ocular Trauma Classification.23,24 The Ocular Trauma Score was also calculated for each eye.25 Baseline data were collected from the last clinical examination before vitrectomy and from intraoperative findings. Snellen best-corrected visual acuity (BCVA) was converted to logarithm of the minimum angle of resolution (LogMAR) visual acuity scores for statistical analysis. Eyes for which Snellen visual acuity could not be measured were assigned LogMAR scores according to a scale adapted from Holladay in which “counting fingers” = 2.0, “hand motions” = 3.0, and “light perception” = 4.0.26 No baseline NLP eyes were included in the study, but NLP in the postoperative setting was assigned a score of 5.0. Overall corneal opacification was sufficient to preclude conventional intraocular visualization in all study eyes, but the causes of opacification in the central 4 mm of the cornea were examined to compare the degree of injury between the two groups. Dense vitreous hemorrhage was defined as vitreous hemorrhage obscuring the posterior pole. The macula was considered to be involved if any part of the macula was affected by a condition or procedure. PVR was graded according to the updated Retina Society classification.27

Statistical Analysis
The data collection spreadsheet was exported to the IBM Statistical Package for the Social Sciences version 18 (IBM Corp., Chicago, IL) for analysis. Continuous variables were compared using the Wilcoxon rank sum test. The Fisher exact test was used to compare categorical variables. All reported P values are two sided.

RESULTS
Ocular Trauma Data and Baseline Characteristics
From March 2003 to October 2010, there were 679 cases of military and civilian ocular trauma treated at WRAMC. A total of 194 eyes required vitreoretinal surgery, of which 98.5% were due to combat injuries from Operation Iraqi Freedom and Operation Enduring Freedom. Sixty-four (33.5%) of the 191 eyes injured during Operation Iraqi Freedom and Operation Enduring Freedom also had some degree of corneal injury. Seventeen eyes of 16 patients met the criteria for inclusion in this study. Eight eyes of eight patients underwent vitrectomy with a temporary keratoprosthesis and nine eyes of eight patients underwent endoscopy. All of the retinal tears in both groups were subclinical and were diagnosed intraoperatively. Five of the seven retinal detachments (71%) in the keratoprosth-
thesis group were diagnosed preoperatively using ultrasonography. The remaining two retinal detachments (29%) were discovered intraoperatively; the indications for vitrectomy in these eyes were traumatic cataract and nonclearing vitreous hemorrhage in one eye and IOFB in a second eye. One eye in the keratoprosthesis group underwent vitrectomy for IOFB without retinal detachment. Only one of the three retinal detachments (33%) in the endoscopy group was diagnosed preoperatively. The remaining two retinal detachments (66%) were diagnosed intraoperatively during removal of traumatic cataract and dense vitreous hemorrhage. The indications for vitrectomy in the remaining eyes in the endoscopy group were IOFB in two eyes and traumatic cataract with IOFB or dense vitreous hemorrhage in four eyes. Grade C PVR occurred at similar rates in both groups but extended posterior to the equator in all of the affected eyes in the keratoprosthesis group. In the endoscopy group, grade C PVR was found only anterior to the equator.

Surgical Data

Both the median number of days from injury to vitrectomy and the median surgical time were significantly shorter in the endoscopy group (Table 4). There were no differences in the surgical procedures performed between the two groups except for macular membrane stripping \( (P = .029) \) and perfluoro-n-octane use \( (P < .0005) \), which were more common in the keratoprosthesis group. All of the eyes in the keratoprosthesis group received a corneal allograft at the conclusion of vitrectomy.

3- and 6-Month Postoperative Outcomes

The visual and anatomic outcomes were similar for the two groups at 3 and 6 months (Tables 5 and 6, respectively). Six of the 17 eyes (35%) had 20/200 or better BCVA at 6 months due to recurrent retinal detachment in one eye and corneal graft failure in another. One eye

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n =17)</th>
<th>Keratoprosthesis (n = 8)</th>
<th>Endoscopy (n = 9)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)(^a)</td>
<td>27 ± 10</td>
<td>25 ± 7</td>
<td>28 ± 13</td>
<td></td>
</tr>
<tr>
<td>Right/left eyes</td>
<td>8/9</td>
<td>5/3</td>
<td>3/6</td>
<td></td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td>|</td>
<td>|</td>
<td>|</td>
<td>|</td>
</tr>
<tr>
<td>Combat</td>
<td>16 (94%)</td>
<td>8 (100%)</td>
<td>8 (89%)</td>
<td>.58</td>
</tr>
<tr>
<td>Non-combat</td>
<td>1 (6%)</td>
<td>0 (0%)</td>
<td>1 (11%)</td>
<td>.99</td>
</tr>
<tr>
<td>Type of injury</td>
<td>|</td>
<td>|</td>
<td>|</td>
<td>|</td>
</tr>
<tr>
<td>Penetrating</td>
<td>1 (6%)</td>
<td>1 (13%)</td>
<td>0 (0%)</td>
<td>.47</td>
</tr>
<tr>
<td>IOFB</td>
<td>10 (59%)</td>
<td>5 (63%)</td>
<td>5 (56%)</td>
<td>.99</td>
</tr>
<tr>
<td>Perforating</td>
<td>2 (12%)</td>
<td>1 (13%)</td>
<td>1 (11%)</td>
<td>.99</td>
</tr>
<tr>
<td>Rupture</td>
<td>4 (24%)</td>
<td>1 (13%)</td>
<td>3 (33%)</td>
<td>.58</td>
</tr>
<tr>
<td>Zone of injury(^b)</td>
<td>|</td>
<td>|</td>
<td>|</td>
<td>|</td>
</tr>
<tr>
<td>Zone 1</td>
<td>9 (53%)</td>
<td>5 (63%)</td>
<td>4 (44%)</td>
<td>.64</td>
</tr>
<tr>
<td>Zone 2</td>
<td>3 (18%)</td>
<td>1 (13%)</td>
<td>2 (22%)</td>
<td>.99</td>
</tr>
<tr>
<td>Zone 3</td>
<td>5 (29%)</td>
<td>2 (25%)</td>
<td>3 (33%)</td>
<td>.99</td>
</tr>
<tr>
<td>Laceration &gt; 10 mm</td>
<td>6 (35%)</td>
<td>3 (38%)</td>
<td>3 (33%)</td>
<td>.99</td>
</tr>
<tr>
<td>Uveal prolapse</td>
<td>12 (71%)</td>
<td>5 (63%)</td>
<td>7 (78%)</td>
<td>.62</td>
</tr>
<tr>
<td>Ocular trauma score(^c)</td>
<td>70 (37–80)</td>
<td>65 (47–80)</td>
<td>70 (37–80)</td>
<td>.82</td>
</tr>
</tbody>
</table>

\( \text{IOFB} = \text{intraocular foreign body.} \)
\( \text{\(^a\)Mean ± standard deviation.} \)
\( \text{\(^b\)Zone 1: cornea; Zone 2: sclera up to 5 mm posterior to limbus; Zone 3: posterior to Zone 2.} \)
\( \text{\(^c\)Median (range).} \)
in the keratoprosthesis group improved from 20/400 at 3 months to 20/60 at 6 months with the removal of a dense lens capsular membrane. All of the eyes in the endoscopy group with 20/200 or better BCVA at 3 months maintained this level of vision at 6 months. The causes of visual acuity worse than 20/200 at 3 months in the keratoprosthesis group were failed graft with recurrent retinal detachment in two eyes and unrelated to the cornea in four eyes (maculopathy, recurrent retinal detachment, or lens capsule opacity). In the endoscopy group, visual acuity worse than 20/200 at 3 months was accounted for by corneal opacities alone in one eye and corneal opacities with maculopathy or neuropathy in four eyes.

Only one repeat penetrating keratoplasty was performed during the study period and this occurred before the 3-month visit. A total of four eyes underwent repeat retinal detachment repair. In the keratoprosthesis group, this level of vision was accounted for by corneal opacities in one eye and corneal opacities with maculopathy or neuropathy in four eyes.

TABLE 3
Baseline Preoperative Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n = 17)</th>
<th>Keratoprosthesis (n = 8)</th>
<th>Endoscopy (n = 9)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>LogMARa</td>
<td>4.0 (2.0–4.0)</td>
<td>4.0 (2.0–4.0)</td>
<td>4.0 (2.0–4.0)</td>
<td>.57</td>
</tr>
<tr>
<td>20/200 or better BCVA</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>.99</td>
</tr>
<tr>
<td>Corneal opacitiesb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–4+ stromal edema</td>
<td>17 (100%)</td>
<td>8 (100%)</td>
<td>9 (100%)</td>
<td>.99</td>
</tr>
<tr>
<td>3–4+ blood staining</td>
<td>5 (29%)</td>
<td>2 (25%)</td>
<td>3 (33%)</td>
<td>.99</td>
</tr>
<tr>
<td>Haze or scarring</td>
<td>8 (47%)</td>
<td>3 (38%)</td>
<td>5 (56%)</td>
<td>.64</td>
</tr>
<tr>
<td>Foreign bodies</td>
<td>7 (41%)</td>
<td>1 (13%)</td>
<td>6 (67%)</td>
<td>.05</td>
</tr>
<tr>
<td>Total hyphema</td>
<td>3 (18%)</td>
<td>1 (13%)</td>
<td>2 (22%)</td>
<td>.99</td>
</tr>
<tr>
<td>Traumatic cataract</td>
<td>11 (65%)</td>
<td>5 (63%)</td>
<td>6 (67%)</td>
<td>.99</td>
</tr>
<tr>
<td>Traumatic aphakia</td>
<td>4 (24%)</td>
<td>2 (25%)</td>
<td>2 (22%)</td>
<td>.99</td>
</tr>
<tr>
<td>Dense vitreous hemorrhage</td>
<td>10 (59%)</td>
<td>4 (50%)</td>
<td>6 (67%)</td>
<td>.64</td>
</tr>
<tr>
<td>Vitreous foreign bodies</td>
<td>7 (41%)</td>
<td>2 (25%)</td>
<td>5 (56%)</td>
<td>.34</td>
</tr>
<tr>
<td>Retinal foreign body damage</td>
<td>6 (35%)</td>
<td>3 (38%)</td>
<td>3 (33%)</td>
<td>.99</td>
</tr>
<tr>
<td>Traumatic maculopathy</td>
<td>7 (41%)</td>
<td>4 (50%)</td>
<td>3 (33%)</td>
<td>.64</td>
</tr>
<tr>
<td>Traumatic optic neuropathy</td>
<td>4 (24%)</td>
<td>1 (13%)</td>
<td>3 (33%)</td>
<td>.58</td>
</tr>
<tr>
<td>Retinal tears</td>
<td>13 (76%)</td>
<td>7 (88%)</td>
<td>6 (67%)</td>
<td>.58</td>
</tr>
<tr>
<td>Retinal detachment</td>
<td>10 (59%)</td>
<td>7 (88%)</td>
<td>3 (33%)</td>
<td>.15</td>
</tr>
<tr>
<td>Involving macula</td>
<td>7 (41%)</td>
<td>6 (75%)</td>
<td>1 (11%)</td>
<td>.015</td>
</tr>
<tr>
<td>Grade C PVR</td>
<td>9 (53%)</td>
<td>5 (63%)</td>
<td>4 (44%)</td>
<td>.64</td>
</tr>
<tr>
<td>Suprachoroidal hemorrhage</td>
<td>5 (29%)</td>
<td>3 (38%)</td>
<td>2 (22%)</td>
<td>.62</td>
</tr>
</tbody>
</table>

LogMAR = logarithm of the minimum angle of resolution; BCVA = best-corrected visual acuity; PVR = proliferative vitreoretinopathy.

*Median (range).

**Central 4 mm.**
### TABLE 4
**Surgical Data**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (n = 17)</th>
<th>Keratoprosthesis (n = 8)</th>
<th>Endoscopy (n = 9)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days from injury</td>
<td>18 (7–96)</td>
<td>38 (11–87)</td>
<td>14 (7–96)</td>
<td>.034</td>
</tr>
<tr>
<td>Surgical time in hours</td>
<td>3.8 (1.8–10.5)</td>
<td>8.4 (5.8–10.5)</td>
<td>2.8 (1.8–3.8)</td>
<td>&lt; .0005</td>
</tr>
<tr>
<td>Pars plana lensectomy</td>
<td>11 (65%)</td>
<td>5 (63%)</td>
<td>6 (67%)</td>
<td>.99</td>
</tr>
<tr>
<td>Membrane stripping</td>
<td>9 (53%)</td>
<td>4 (50%)</td>
<td>5 (56%)</td>
<td>.99</td>
</tr>
<tr>
<td>Involving macula</td>
<td>4 (24%)</td>
<td>4 (50%)</td>
<td>0 (0%)</td>
<td>.029</td>
</tr>
<tr>
<td>IOFB removal</td>
<td>10 (59%)</td>
<td>3 (38%)</td>
<td>7 (78%)</td>
<td>.15</td>
</tr>
<tr>
<td>Relaxing retinectomy</td>
<td>4 (24%)</td>
<td>2 (25%)</td>
<td>2 (22%)</td>
<td>.99</td>
</tr>
<tr>
<td>Perfluoro-n-octane</td>
<td>9 (53%)</td>
<td>8 (100%)</td>
<td>1 (11%)</td>
<td>&lt; .0005</td>
</tr>
<tr>
<td>Laser or cryoretinopexy</td>
<td>15 (88%)</td>
<td>7 (88%)</td>
<td>8 (89%)</td>
<td>.99</td>
</tr>
<tr>
<td>Endotamponade</td>
<td>15 (88%)</td>
<td>8 (100%)</td>
<td>7 (78%)</td>
<td>.47</td>
</tr>
<tr>
<td>Air</td>
<td>2 (12%)</td>
<td>1 (13%)</td>
<td>1 (11%)</td>
<td>.99</td>
</tr>
<tr>
<td>SF₆</td>
<td>2 (12%)</td>
<td>0 (0%)</td>
<td>2 (22%)</td>
<td>.47</td>
</tr>
<tr>
<td>C₃F₈</td>
<td>8 (47%)</td>
<td>6 (75%)</td>
<td>2 (22%)</td>
<td>.057</td>
</tr>
<tr>
<td>Silicone oil</td>
<td>3 (18%)</td>
<td>1 (13%)</td>
<td>2 (22%)</td>
<td>.99</td>
</tr>
<tr>
<td>Encircling buckle</td>
<td>5 (29%)</td>
<td>3 (38%)</td>
<td>2 (22%)</td>
<td>.62</td>
</tr>
<tr>
<td><strong>IOFB</strong> = intraocular foreign body; <strong>SF₆</strong> = sulfur hexafluoride; <strong>C₃F₈</strong> = perfluoropropane.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>aMedian (range).</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 5
**3–Month Postoperative Outcomes**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall (n = 17)</th>
<th>Keratoprosthesis (n = 8)</th>
<th>Endoscopy (n = 9)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>LogMARa</td>
<td>3.0 (0.2–4.0)</td>
<td>3.0 (1.0–4.0)</td>
<td>2.0 (0.20–4.0)</td>
<td>.34</td>
</tr>
<tr>
<td>20/200 or better BCVA</td>
<td>6 (35%)</td>
<td>2 (25%)</td>
<td>4 (44%)</td>
<td>.62</td>
</tr>
<tr>
<td>Corneal graft failure</td>
<td>–</td>
<td>2 (25%)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Retinal detachment</td>
<td>5 (29%)</td>
<td>4 (50%)</td>
<td>1 (11%)</td>
<td>.13</td>
</tr>
<tr>
<td>Involving macula</td>
<td>4 (24%)</td>
<td>3 (38%)</td>
<td>1 (11%)</td>
<td>.29</td>
</tr>
<tr>
<td><strong>LogMAR = logarithm of the minimum angle of resolution; BCVA = best-corrected visual acuity.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>aMedian (range).</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 6
**6-Month Postoperative Outcomes**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall (n = 17)</th>
<th>Keratoprosthesis (n = 8)</th>
<th>Endoscopy (n = 9)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>LogMARa</td>
<td>2.0 (0.2–5.0)</td>
<td>3.0 (1.0–5.0)</td>
<td>1.3 (0.20–3.0)</td>
<td>.093</td>
</tr>
<tr>
<td>20/200 or better BCVA</td>
<td>5 (29%)</td>
<td>1 (13%)</td>
<td>4 (44%)</td>
<td>.29</td>
</tr>
<tr>
<td>Corneal graft failure</td>
<td>–</td>
<td>3 (38%)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Retinal detachment</td>
<td>3 (18%)</td>
<td>3 (38%)</td>
<td>0 (0%)</td>
<td>.082</td>
</tr>
<tr>
<td>Involving macula</td>
<td>3 (18%)</td>
<td>3 (38%)</td>
<td>0 (0%)</td>
<td>.082</td>
</tr>
<tr>
<td><strong>LogMAR = logarithm of the minimum angle of resolution; BCVA = best-corrected visual acuity.</strong></td>
<td></td>
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<td><strong>aMedian (range).</strong></td>
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The results of this study suggest that vitrectomy may be safely performed with either a temporary keratoprosthesis or endoscopy in eyes with opaque cornea following ocular trauma with comparable visual and anatomic outcomes. Both techniques can be used to view intraocular contents while maintaining a closed system, which should reduce the risks associated with “open sky” vitrectomy including intraocular hemorrhage, prolapse of intraocular tissues, and difficulty of globe manipulation.9,11,28 The major differences observed between the two techniques are that endoscopy allows earlier intervention and shorter surgical times than does the temporary keratoprosthesis.

Earlier vitrectomy in the endoscopy group can be attributed to differences in the management options available with each technique. Although the eyes in each group sustained similar degrees of injury and shared similar baseline characteristics, the decision to perform vitrectomy in the endoscopy group was made at the discretion of the surgeon when an indication for vitrectomy was identified. The eyes in the keratoprosthesis group preceded the arrival of the endoscope at WRAMC and were thus managed conservatively with serial ultrasonography. The decision to perform vitrectomy was made only after ultrasonographic evidence of a retinal detachment developed or if another indication for vitrectomy was present in an eye with a nonclearing cornea. Conservative management of eyes without clinical evidence of a retinal detachment is generally preferred over exploratory vitrectomy with a keratoprosthesis because opaque corneas often gradually clear with time and the risk of corneal graft failure is increased if penetrating keratoplasty is performed during the first 2 months of ocular trauma.21 Severely injured eyes are also more likely to require additional procedures or silicone oil, which may stress the donor endothelium and ultimately result in decompensation or failure of the graft.21,29,30 In our study, corneal graft failure was observed in two eyes (25%) at 3 months and three eyes (38%) at 6 months. These eyes may have been able to retain their native corneas if endoscopy had been available at the time of their vitrectomy. If their corneas failed to clear sufficiently with time, delayed allografting could have then been performed several months later when the eye was quiet and the risk of graft failure was lower.

A major limitation of conservative management of severe eye injuries is the difficulty of accurately diagnosing retinal tears and detachments ultrasonographically, particularly in the presence of significant vitreous hemorrhage and organizing membranes. Latent retinal breaks and detachments may be missed due to the presence of media opacities and frequent anterior location of retinal pathology.31,32 Many of the eyes in the endoscopy group were found to have occult retinal tears and detachments that would certainly have progressed to more extensive pathology if the eyes had been managed conservatively. Conversely, the pathology in the keratoprosthesis group would have been less extensive if prompt vitrectomy could have been performed before a retinal detachment became evident ultrasonographically.

The benefit of early intervention is reflected in the lower rates of macular involvement by retinal tears and detachments and posterior grade C PVR in the endoscopy group. Preretinal traction and PVR are the leading cause of surgical failure in penetrating and perforating injuries and their early removal is known to reduce late complications such as retinal tears and detachments.33-38 There is no consensus regarding the timing of vitrectomy following ocular trauma, but several studies have reported better outcomes when surgery is performed within the first 2 weeks.35,38-40 In our opinion, high-risk conditions predisposing to vitreoretinal traction should undergo prompt vitrectomy even in the absence of a frank retinal detachment. Conditions for which early vitrectomy has been advocated include perforating injuries, lens disruption, ciliary body epithelial damage, dense vitreous hemorrhage, significant vitreous loss, tractional complications, and endophthalmitis.1,28,41 IOFBs should also be removed promptly to reduce the risk of retinal toxicity when their composition is unknown.36 Early IOFB removal also prevents encapsulation, which may otherwise complicate their safe removal.36,42

An indirect benefit of the early treatment of occult pathology and the prevention of its progression is shorter surgical time. The management of more extensive retinal detachments and PVR in the keratoprosthesis group required additional procedures such as macular membrane stripping and the instillation and removal of perfluorocarbon liquids for intraoperative tamponade and countertraction during membrane dissection. The shorter surgical times in the endoscopy group are also directly related to differences in the pro-
cedures required to implement each viewing system. Whereas endoscopy was performed through standard 20-gauge sclerotomies and required no additional time or invasive procedures to implement, the temporary keratoprosthesis required additional time to remove glue, revise sutures, trephinate the cornea, suture and remove the keratoprosthesis, and graft corneal tissue at the conclusion of vitrectomy. Although such data were not available for this study, additional time may have been incurred waiting for the corneal and retinal surgeons to prepare for their respective procedures. Prolonged surgery and additional invasive procedures may be associated with higher operating costs and increased risk of surgical and anesthetic complications.

The ease of creating surgical access for endoscopy and its ability to be employed shortly after ocular trauma also allows it to be used for diagnostic purposes in cases where the viability of the retina or optic nerve are uncertain. With endoscopy, these structures may be examined directly and help guide decisions for additional intervention. Direct examination of anterior structures also allows the treatment of far peripheral pathology such as cyclitic membranes and anterior loop traction without requiring scleral depression or globe manipulation. This is particularly helpful in severe ocular trauma where closed but friable wounds and suprachoroidal hemorrhage may be exacerbated by excessive globe manipulation. The smaller incisions required for endoscopy should also further reduce the risk of hemorrhagic complications and prolapse of intraocular contents compared to those of the temporary keratoprosthesis.

The limitations of endoscopy are related to its inferior image quality, changing intraocular perspective, and steep initial learning curve. Video images obtained through small-gauge endoscopy probes are inherently of low resolution. The absence of stereopsis and the dynamic intraocular perspective and field of view may be disorienting, particularly in an eye with dense vitreous hemorrhage or disorganized intraocular contents. Complex bimanual surgery, which may be required in cases of extensive PVR, is also difficult to perform with endoscopy. Other factors include the cost of the endoscopy system and its probes, which have a limited lifespan.

In summary, vitrectomy may be performed safely in eyes with opaque cornea following ocular trauma either with a temporary keratoprosthesis or endoscopy with similar visual and anatomic outcomes. Endoscopic vitrectomy requires less surgical time to use and facilitates the early diagnosis and treatment of occult retinal tears and detachments. For these reasons, endoscopy should be considered for use in most cases of ocular trauma with opaque cornea and the temporary keratoprosthesis should be reserved for use in cases requiring extensive bimanual surgery or for delayed vitrectomy when the risk of graft failure is lower in eyes at low risk of harboring occult retinal tears or detachments. The limitations of this study are its small sample size, its retrospective nature, and the difficulty of controlling for the complexities of ocular trauma. Additional investigation comparing both techniques is required to validate the findings of this study. A randomized, prospective, multicenter trial comparing the two viewing systems may provide additional insight into the relative strengths and weaknesses of each and whether the findings of this study can also be generalized to non-traumatic cases.

REFERENCES