Trabecular Aspiration
A New Mode to Treat Pseudoexfoliation Glaucoma

Philipp C. Jacobi and Günter K. Krieglstein

Purpose. The primary cause of intraocular pressure (IOP) elevation in pseudoexfoliation glaucoma is obstruction of the intertrabecular spaces by exfoliation material. The aim of the current study was to evaluate the efficacy of a novel surgical approach—trabecular aspiration—for the management of pseudoexfoliation glaucoma.

Methods. Twelve patients characterized by medically uncontrolled IOP level in pseudoexfoliation glaucoma underwent trabecular aspiration as a primary antiglaucomatous procedure. Aspiration treatment of the meshwork was performed in the inferior circumference of the chamber angle using a specially designed irrigation-aspiration device to fit the chamber angle. Trabecular debris and pigment were cleared with a suction force of 100 to 200 mm Hg.

Results. Before surgery, IOP ranged from 24 mm Hg to 52 mm Hg (mean, 37.4 mm Hg). Fifteen months after surgery, IOP ranged from 15 mm Hg to 23 mm Hg (mean, 18.3 mm Hg), which is equivalent to an absolute decrease of 18.7 mm Hg (50%). After surgery, the IOP of 10 eyes was less than 21 mm Hg, although 6 of these eyes still required topical medication. Two eyes attained a final IOP of 24 mm Hg. All treated eyes were aspirated once. Mean antiglaucomatous medication decreased from 4.3 medications daily before surgery to 1.39 medications daily at 15 months after surgery.

Conclusions. This new surgical modality, removing intertrabecular and pretrabecular debris of the trabecular meshwork, can be effective in the management of pseudoexfoliation glaucoma. However, long-term follow-up and extended sample size must be prospected for further clinical evaluation.

Pseudoexfoliation syndrome is clinically relevant because of its association with open-angle glaucoma and cataract formation. Glaucoma associated with pseudoexfoliation syndrome has a more serious clinical course than primary open-angle glaucoma (POAG). Various studies suggest that optic nerve damage, visual field defects, and levels of intraocular pressure (IOP) are more severe in glaucomatous eyes complicated with pseudoexfoliation (PEX) than in glaucomatous eyes without PEX. Pseudoexfoliation glaucoma shows less response to adrenergic and cholinergic drugs; thus, many of these eyes require early drainage surgery. The reason for this is not fully understood. Pseudoexfoliation glaucoma is characterized by the deposition of fibrillogranular PEX material and dispersed pigment granules on various structures of the anterior segment of the eye proximating the aqueous humor pathways and, recently, the skin of the eyelids. The origin of PEX material is thought to be multifocal and secondary to an abnormal basement membrane produced by degenerated epithelial cells. Pseudoexfoliating fibrils and pigment granules have been detected in the intratrabecular and intertrabecular spaces of the uveal meshwork by light microscopy and electronmicroscopy. The worse prognosis in pseudoexfoliation glaucoma could be related to increased resistance to aqueous outflow because of clogging of the trabecular meshwork by exfoliative debris. Assuming that the main pathogenetic factor in pseudoexfoliation glaucoma is obstruction of filtering pores of the trabecular meshwork, which become increasingly clogged by deposits of pigment and exfoliation material, a surgical procedure relieving the uveal meshwork of its debris should be effective.

Recently, we described a new concept of glaucoma surgery—trabecular aspiration (Fig. 1)—designed to...
FIGURE 1. Schematic drawing of the trabecular aspirator inserted into the anterior chamber and directed against the trabecular meshwork at the 6 o'clock position. The tip of the instrument was angulated at 45° to comply with the anatomic configuration of the chamber angle. With an applied suction pressure of 100 to 200 mm Hg, trabecular aspiration was performed in sweeping motions in the inferior circumference for 2 to 3 minutes.

increase trabecular outflow facility in pseudoexfoliation glaucoma. The morphologic analysis of the trabecular aspirate (Fig. 2) clearly indicated the efficacy of trabecular aspiration for removing pretrabecular and intratraquecular debris. In combination with extracapsular cataract extraction, removal of pretrabecular and intertrabecular debris by using trabecular aspiration substantially lowered the intraocular pressure (42% from baseline) in 12 pseudoexfoliative eyes over 6 months after surgery.

The aim of the current study was to examine the IOP-lowering efficacy of trabecular aspiration as a primary therapeutic modality in the management of pseudoexfoliation glaucoma designed as an alternative to fistulating surgery.

MATERIALS AND METHODS

Patient Selection

All patients included in this study had medically uncontrolled intraocular pressure, progressive visual field loss, and glaucomatous optic nerve head damage from pseudoexfoliation glaucoma. Exclusion criteria were a history of uveitis, herpetic keratitis, ocular trauma, cataract, diabetic retinopathy, previous laser or intraocular surgery, and glaucoma other than pseudoexfoliation glaucoma. Preoperative evaluation included measurement of visual acuity, quantitative visual field testing, if possible, measurement of IOP, gonioscopy, anterior and posterior segment slit-lamp biomicroscopy, indirect ophthalmoscopy of the retina, and ultrasonography when required. The tenets of the Declaration of Helsinki were followed, and informed consent was obtained from all patients after they had been fully informed of the experimental nature of the procedure. All patients had an open angle with heavy pigmentation and deposits of amorphous debris.

Treatment before surgery included oral acetazolamide (500 mg, intravenously), mannite infusion (osmofundin, 125 ml, intravenously), ocuulopression for 10 to 15 minutes, and prophylactic antibiotic drops and ointment. Statistical evaluation was based on non-parametric two-tailed paired t-test (Wilcoxon signed rank test).

Procedure

Surgery was performed according to our previously described technique (Fig. 1). The handheld instrument used had three outlets, one for aspiration (400 μm wide and horizontally angulated at 45°) and two (650 μm wide) for irrigation to maintain a deep anterior chamber and to ensure that the iris was not subjected to suction.

Trabecular aspiration was performed in all patients under the operating microscope using retrobul-
bar anesthesia. After injection of viscoelastic, the aspirator was inserted into the anterior chamber through a clear corneal incision and directed against the trabecular meshwork in the 6 o'clock position. Suction pressure between 100 and 200 mm Hg was applied over 5 to 6 clock-hours of the inferior circumference of the chamber angle for 2 to 3 minutes (Fig. 1). The wound was closed with a single 10-0 monofilament nylon suture after the remaining viscoelastic was evacuated by gentle irrigation with balanced salt solution, which also served to reform the anterior chamber.

Immediately after surgery, 50 mg of mezlocillin (Baypen; Bayer, Leverkusen, Germany) and 2 mg of dexamethason (Fortecortin, Merck) were injected subconjunctivally, and 500 mg of acetazolamide was injected parenterally. During postoperative recovery, each patient was given topical steroid drops and a combination of steroid and antibiotic ointment at night, which was rapidly tapered off depending on the degree of postoperative inflammation.

**Pressure Measurements**

Two to 4 days before surgery, IOP was measured five times a day over a period of 15 hours, and the mean was taken as baseline pressure. Goldmann applanation tonometry was performed at the slit lamp in a double-masked fashion by the same examiner. After surgery, regular pressure readings were taken during the period extending to the 17th month. The same time intervals were used in all patients (see Fig. 3). The number of postoperative pressure determinations at a specific visit varied from three to as many as five individual determinations for some patients. Analogous mean IOP was taken as the baseline value.

Before considering patients for glaucoma surgery and admitting them to the current study, great care was taken to seek the most effective and tolerable medical treatment for IOP reduction 1 to 3 months before surgery (i.e., medications used before surgery were discontinued to find out if they were superfluous). After surgery, pressure-reducing medication was discontinued in all patients for at least 5 days. Thereafter, recommencement of medical treatment was titrated according to the postoperative pressure measurements. However, no change in type of medication was performed. The amount of antiglaucomatous medications used was encoded by an antiglaucomatous medication score (Table 1).
Table 1. Intraocular Pressure-Reducing Medication Score

<table>
<thead>
<tr>
<th>Medication Group</th>
<th>Score</th>
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<tbody>
<tr>
<td>Timolol 0.5%</td>
<td>1</td>
</tr>
<tr>
<td>Pilocarpine 1%</td>
<td>1</td>
</tr>
<tr>
<td>Pilocarpine 2%−4%</td>
<td>2</td>
</tr>
<tr>
<td>Clonidine</td>
<td>2</td>
</tr>
<tr>
<td>Carbachol 0.75%−3%</td>
<td>2</td>
</tr>
<tr>
<td>D'epinephrine + pilocarpine 1%</td>
<td>2</td>
</tr>
<tr>
<td>Timolol 0.5% + pilocarpine 1%</td>
<td>3</td>
</tr>
<tr>
<td>Acetazolamide (&lt;750 mg/die)</td>
<td>3</td>
</tr>
<tr>
<td>Acetazolamide (750−1500 mg/die)</td>
<td>4</td>
</tr>
</tbody>
</table>

Surgical success was assumed when IOP was below 21 mm Hg and the patient required no further topical medication, and qualified success was assumed when IOP was below 21 mm Hg and one topical agent was allowed at 14 months after surgery.

RESULTS

Twelve eyes of 12 patients were treated (four men, eight women). Ages at the time of treatment ranged between 62 and 79 years (mean, 71.5 ± 5.8 years). Follow-up averaged 15.9 ± 1.3 months (range, 14 to 17 months). The mean pretreatment IOP was 37.4 ± 9.4 mm Hg (range, 24 to 52 mm Hg) (Table 2). Trabecular aspiration resulted in a consistent pressure reduction from the fifth postoperative day on, and it remained at a stable level for 17 months (Fig. 3). In one patient, a transient IOP elevation (5 mm Hg) in the immediate postoperative period was observed, probably because of residual viscoelastic in the anterior chamber. The IOP started to decrease on the second postoperative day. Considering all treated patients, the mean pressure reduction after surgery was 18.7 ± 1.5 mm Hg (range, 8 to 24 mm Hg) at 15 months after surgery (Table 2). This represents a percentage decrease from baseline (Δ%) of 50%, which is statistically highly significant (P < 0.05).

Preoperative and postoperative medication was classified as shown in Table 1. After 1 week of treatment, all patients required less or no antiglaucomatous medication for IOP control. None of the patients required more medication than they did before surgery. Table 3 shows the average antiglaucomatous medication used before surgery, and this was significantly reduced after surgery. Before surgery, the mean antiglaucoma medication score was 4.3 ± 1.9. Fifteen months after surgery, therapy dropped to 1.39 ± 0.42 (P < 0.05), representing a percentage of reduction (Δ%) of 67.7% (Table 3).

Preoperative visual acuity ranged from 20/200 to 20/20 within the patient group and did not change more than one line throughout the postoperative period. No serious complications or longlasting side effects in the treated eyes were noted. In three eyes, minor inadvertent descemetoysis of the treatment site occurred. No corneal haze was associated with it.

The success rate, defined as IOP below 21 mm Hg without therapy, was 33%. The qualified success, IOP below 21 mm Hg with one topical agent allowed, was 75%. In one eye, pressure control was achieved with two topical medications. Two eyes attained a final IOP of 24 mm Hg and required continued carbonic anhydrase inhibitor therapy.

DISCUSSION

The association of open-angle glaucoma and pseudoexfoliation is well established.3,5,16 As early as 1930, Vogt17 noted that pseudoexfoliation glaucoma did not respond to therapy as well as did POAG. Others have confirmed this observation, including Lindblom and Thorburn18 who, as recently as 1982, reported a higher incidence of advanced glaucoma among patients with pseudoexfoliation when compared to comparable patients with POAG. Various studies suggest that optic nerve damage, visual field defects, IOP levels, and reduced IOP tolerance22 are more severe in glaucomatous eyes complicated by pseudoexfoliation than in those without PEX. Davanger and...

Table 2. Preoperative and Postoperative Intraocular Pressure After Trabecular Aspiration

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>Diff</th>
<th>P-value</th>
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<td>37.40</td>
<td>9.40</td>
<td>24−52</td>
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<tr>
<td>1</td>
<td>12</td>
<td>25.80</td>
<td>6.70</td>
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<td>5</td>
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<td>90</td>
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<td>12−18</td>
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<td>12</td>
<td>17.90</td>
<td>2.60</td>
<td>14−24</td>
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<td>16−24</td>
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SD = standard deviation; diff = difference.
greater risk of visual loss than patients with POAG. To obtain IOP control, surgical intervention is more often
from basement membrane-secreting cells, including
with pseudoexfoliation probably results from deposi-
ted a major risk factor for the development of
indicated in PEX eyes.24 Pseudoexfoliation is consid-
ered a major risk factor for the development of chronic open-angle glaucoma.23 252b
The pseudoexfoliative material likely originates from basement membrane-secreting cells, including epithelial cells of the anterior lens equator, iris pig-
ment epithelium, and ciliary body; consequently, it is deposited on the surface of the entire anterior segment of the eye.78 27 28 Electron microscopy studies have shown that the presence of the crystalline lens is not necessary for this condition to be manifested clini-
cally.9 10 However, the exact origin of the material is still uncertain; its composition is suggested to be amyloid, elastin, or glycosaminoglycans because of a metabolic disorder related to aging.7 8 30 In one study, scanning electromicroscopy of the trabecular meshwork in pseudoexfoliation syndrome revealed that it may be similar to the meshwork in chronic open-angle glau-
coma except that it appeared “dirtier.”10 Distinct characteristics in pseudoexfoliation were: gray appearance of the trabecular meshwork with white PEX-de-
positions; pigment granules remaining on the chamber aspect of the trabeculum; and collar arrangements of the pigment granules around the trabeculum.10 Ap-
parently, because of its size, the pigment granule pseudoexfoliation complex is obstructed in its filtra-
tion process through the entire meshwork and re-
 mains on its superficial layers. Glaucoma associated with pseudoexfoliation probably results from deposi-
tion of pigment and pseudoexfoliative material within the endothelial cells of the trabecular beams. Jern-
dal31,32 proposed the presence of a dysgenetic cellular membrane, as seen in congenital goniodysgenesis, to contribute to outflow disturbances, whereas others speculate that pseudoexfoliation glaucoma results from an overload of pigment and exfoliative material in an already impaired outflow system and that eyes that develop glaucoma with pseudoexfoliation already have an underlying predisposition to POAG.7

Assuming that the main pathogenetic factor in pseudoexfoliation glaucoma is that the filtering pores of the trabecular meshwork are increasingly clogged by deposits of pigment and exfoliative material, a sur-
urgical procedure relieving the uveal meshwork of its debris could be effective. In this study, we describe a new technique for glaucoma surgery aimed at increas-
ting trabecular outflow facility. In a previous study,15 in a limited number of patients (12) with pseudoexfo-
liation glaucoma and cataract, trabecular aspiration performed in combination with extracapsular cataract extraction (ECCE) resulted in significant IOP reduc-
tion after surgery. Removal of intertrabecular and pre-
 trabecular debris by means of ab interno “vacuum cleaning” before ECCE decreased IOP by 42% from baseline, which indicates clinical relevance. However, if trabecular aspiration with ECCE and posterior chamber lens implantation (PC-IOL) are combined, other possible mechanisms may account for the ob-
erved IOP reduction that has been considered when evaluating the efficacy of this new concept. In a 12-
month follow-up study of IOP changes after uncompli-
cated ECCE/PC-IOL of 33 patients with glaucoma (in-
cluding pseudoexfoliation glaucoma), Steuhl and as-
ociates33 reported a significant IOP decrease from 18.9 ± 3.6 mm Hg before surgery to 16.5 ± 2.6 mm Hg after surgery. Another retrospective study observed a statistically significant average pressure decrease of 1.95 mm Hg, or 12.8%, after 1 year compared with its preoperative IOP in 97 eyes after ECCE/PC-IOL. Longer observation periods (2 years) revealed a tendency of IOP levels after surgery to revert to increasing levels.22 Nonetheless, these reported pressure drops were far below the amount of IOP reduction observed in our pilot study.15 Using trabecular aspiration, we observed an average decrease of 14 ± 5.6 mm Hg (42.2% ± 18.1%) at 9 months after surgery, indicating functional efficacy.

These preliminary results encouraged us to use trabecular aspiration as a primary therapeutic mod-
ality in the management of patients with pseudoexfoli-

<table>
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<th>Difference</th>
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<td>9</td>
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</table>
Trabecular Aspiration in Glaucoma Surgery

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(n under maximum IOP) a limited number of patients with pseudoexfoliation glaucoma generally considered to be resistant to medical or laser management. Fifteen months after surgery, the mean IOP reduction averaged 18.7 mm Hg, representing a significant drop of 50% from baseline. Antiglaucoma medication could be reduced in all eyes and suspended in four eyes, and none of the treated patients required more pressure-lowering medication after surgery. With a success rate of 33% (qualified success rate of 75%), these results are superior to those of argon laser trabeculoplasty and challenge those of traditional filtering surgery. In a retrospective study on 68 patients with pseudoexfoliation glaucoma, Hetherington states that success is markedly higher in pseudoexfoliative eyes in the early period after laser surgery but that, at 1 year, the success rate approaches that of chronic open-angle glaucoma. The success rate of argon laser trabeculoplasty in pseudoexfoliation glaucoma is approximately 50%, and most patients require maximum medical therapy for IOP control. Searle and associates reported a 39% success rate in eyes treated with argon laser trabeculoplasty as a primary therapeutic procedure after a follow-up ranging from 2 to 4 years (IOP < 21 mm Hg) without additional medical therapy. Moulin et al, after long-term follow-up of 159 eyes with chronic open-angle glaucoma in phakic eyes of patients treated with argon laser trabeculoplasty, reported failure rates of 19% at 1 year, 30% at 2 years, 41% at 3 years, 48% at 4 years, and 52% at 5 years. Comparison of long-term results of laser treatment with our data, with a maximum follow-up of only 17 months, is admitted in light of the experience that most eyes in which laser treatment failed required surgical therapy for IOP control during the 2nd year of follow-up. The effectiveness of filtering surgery on pseudoexfoliation glaucoma has been reported recently to have a success rate (IOP < 21 mm Hg, no further medical therapy) of 81% at 1-year follow-up and associated with complications such as hyphema (10%), flat anterior chamber (12%), choroidal detachment (5%), and ciliary block glaucoma (4%). In our small group treated with trabecular aspiration, no major complications were noted during or after surgery. However, as reported previously, in three patients we observed a small desemetolysis at the area treated, indicating localized corneo-endothelial stripping. Thus far, no corneal hazes or edema has occurred.

The surgical modality described here—using a single-handed, irrigation-aspiration device for trabecular aspiration in the phakic pseudoexfoliative eye—demands an intraoperative deep anterior chamber during surgery in order not to touch the anterior surface of the crystalline lens (compare to the combined intervention [aspiration and ECCE] described before). As a refinement of the single-handed aspiration, which works fine with ECCE for primary surgical intervention, we now propose a bimanual technique by which irrigation and aspiration are separated and better control of manipulation within the chamber angle is feasible. A study to prove this has been initiated. Irrespective of these encouraging midterm results using trabecular aspiration as the primary therapeutic surgical intervention for pseudoexfoliation glaucoma, longer observation periods including more patients are warranted. Moreover, trabecular aspiration might be applicable in treating other types of secondary obstructing open-angle glaucoma, such as pigmentary, ghost-cell, and phacoelastic glaucoma. However, secondary intracellular changes of the trabecular endothelium—as in pigmentary glaucoma, in which pigment released is phagocytized by the trabecular endothelium—also may impair outflow facility, and these may not be affected by trabecular aspiration.

Key Words

glaucoma surgery, intraocular pressure, pseudoexfoliation syndrome, trabecular aspiration

References

11. Jerndal T. Open-angle glaucoma and the pseudoexfo-