Comparison of the Efficacy and Longevity of Nonpenetrating Glaucoma Surgery With and Without a New, Nonabsorbable Hydrophilic Implant

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■ **BACKGROUND AND OBJECTIVE:** To compare the efficacy and longevity of nonpenetrating glaucoma surgery with and without the use of a nonabsorbable hydrophilic implant at the Oxford Eye Centre, Johannesburg, South Africa, and the Glaucoma Unit, Jules Gonin Ophthalmic Hospital, Lausanne, Switzerland.

■ **PATIENTS AND METHODS:** In a nonrandomized, prospective study between March 1997 and December 2001, 48 eyes of 32 patients aged 18 to 86 years with primary open-angle glaucoma underwent nonpenetrating glaucoma surgery; 25 eyes with the implant and 23 eyes without it. Intraocular pressure (IOP) was recorded preoperatively and postoperatively at 1, 7, and 14 days, at 1, 3, and 6 months, and thereafter every 6 months.

■ **RESULTS:** The mean preoperative IOP was 27.5 ± 11.8 mm Hg (range, 20 to 64 mm Hg) in the implant group and 24.8 ± 7.1 mm Hg (range, 16 to 38 mm Hg) in the control group. During the first 18 months of follow-up, both groups showed identical IOP progression and the mean IOP remained less than 14 mm Hg. After 2 years of follow-up, the IOP started to rise in the control group but remained stable in the implant group. After 30 months, the mean IOP was 12.4 ± 2 mm Hg and the IOP decrease in percentage was 62% ± 6% in the implant group (n = 13) versus 16.1 ± 3 mm Hg and 34% ± 13% in the control group (n = 15) (mean IOP, $P = .0022$; mean IOP decrease in percentage, $P = .01$).

■ **CONCLUSIONS:** During the first 18 months, there was no difference in the outcomes between the two groups. After 2 years of follow-up, the mean IOP was lower and the IOP decrease in percentage was greater in the implant group compared with the control group.

[Ophthalmic Surg Lasers Imaging 2003;34:457-463.]

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Accepted for publication September 24, 2003.
The T Flux implants used in this study were supplied to the surgeons by IOLTECH Laboratoires, free of charge. IOLTECH Laboratoires sponsored, in part, animal studies done on rabbits at the research laboratories of the Glaucoma Unit of the Jules Gonin Eye Hospital in Lausanne, Switzerland.
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INTRODUCTION

The evolution of nonpenetrating glaucoma surgery started relatively slowly with the original works of Epstein[1] and Krasnov[2] in the late 1950s and early 1960s. Both authors suggested unroofing Schlemm's canal as a means to reduce intraocular pressure (IOP). The longevity of effective filtration with these early methods was relatively short. The conjunc-

tiva scarred over the bare trabecular meshwork, thus blocking effective filtration within a few months. High quality surgical microscopes were not yet available and few surgeons could perform these filtration operations. The classic trabeculectomy was introduced by Sugar[3] and Cairns[4] almost concurrently. The relative ease of performing a trabeculectomy and its efficacy overshadowed and held back the development of nonpenetrating glaucoma surgery.

In the early 1980s, the Russian school led by Fyodorov et al.[5] and Koslov et al.[6] and the North American school led by Zimmerman et al.[7] returned to nonpenetrating glaucoma surgery and performed it under a scleral flap following the trabeculectomy model. Fyodorov et al.[5] and Koslov et al.[6] proposed a portion of deep sclerectomy adjacent to Schlemm's canal under the superficial scleral flap. The deep sclerectomy was supposed to enhance intrascleral and uveal aqueous humor absorption. The scleral flap added some protection to the bare trabecular meshwork and somewhat improved the results of nonpenetrating glaucoma surgery.

Currently, nonpenetrating glaucoma surgery is still an evolving surgical technique that has evoked a growing interest in the past decade because of its lower rate of complications compared with trabeculectomy.[5-27] Proponents and opponents argue about the efficacy and longevity of nonpenetrating glaucoma surgery versus the classic trabeculectomy. The opponents of nonpenetrating glaucoma surgery claim that classic trabeculectomy yields lower IOP and has longer longevity.[28-31] The proponents of nonpenetrating glaucoma surgery still prefer it to the classic trabeculectomy because of its superior safety profile.[5-28]

One of the main goals in any glaucoma surgery is the longevity of successful filtration. Currently, nonpenetrating glaucoma surgery has proved to be safer than trabeculectomy, but not necessarily more effective in the long-term. Koslov et al.[6] proposed a porcine collagen implant to keep a filtration space under the superficial scleral flap. Stegmann et al.[20] proposed to enlarge the lumen of Schlemm's canal adjacent to the site of filtration by injecting viscoelastic material therein. Sourdille et al.[21] developed an absorbable implant made of reticulated hyaluronic acid. This absorbable implant is left under the superficial scleral flap to create a space for aqueous humor reabsorption.

Until recently, all of the proposed implants were absorbable and have shown certain value in improving the outcomes of nonpenetrating glaucoma surgery.[6,10-13,15-21,24-26] This study compared the outcomes of nonpenetrating glaucoma surgery with and without the use of a nonabsorbable hydrophilic implant (T-Flux; IOLTECH Laboratoires, La Rochelle, France). The T-Flux implant is made of a biocompatible hydrophilic acrylic material with 38% water content.

PATIENTS AND METHODS

Patients older than 18 years with primary open-angle glaucoma who needed glaucoma surgery because of inadequate medical IOP control were enrolled prospectively in the study. In patients who needed bilateral nonpenetrating glaucoma surgery, the eye with the higher IOP received the implant, whereas the eye with the lower IOP underwent nonpenetrating glaucoma surgery without the implant. This partial selection was done to disfavor the group that received the T-Flux implant. The excluding criteria were glaucoma secondary to uveitis or trauma and congenital and infantile glaucoma. Patients with primary open-angle glaucoma who needed combined glaucoma and cataract surgery were not included in this study.

Forty-eight eyes of 32 patients were included in the study; 25 eyes underwent nonpenetrating glaucoma surgery with the T-Flux implant and 23 eyes underwent the same surgery without the implant. All of the patients had elevated IOP, glaucomatous visual field defects, and optic nerve cupping. None had had an argon laser trabeculoplasty in the 6 months prior to the operation.

The operations were performed by three surgeons (ED, ER, AM) between March 1997 and December 2001. All three surgeons were well trained in nonpenetrating glaucoma surgery and together performed several hundred nonpenetrating glaucoma operations before the commencement of the study. The three surgeons agreed on a basically identical technique for this study.

Surgical Technique

Nonpenetrating glaucoma surgery began with a 7-mm fornix- or limbal-based conjunctival flap in the upper quadrant. A 5 × 5 × 1.5 mm trapezoidal or a 5 × 5 mm square scleral flap of 40% to 50% depth was dissected into clear cornea. This first scleral flap was everted over the cornea and pulled down with an 8-0 virgin silk suture that was fixed to the lower limbus at the 6-o'clock position. This temporary flap fixation improved the exposure during the next phase of

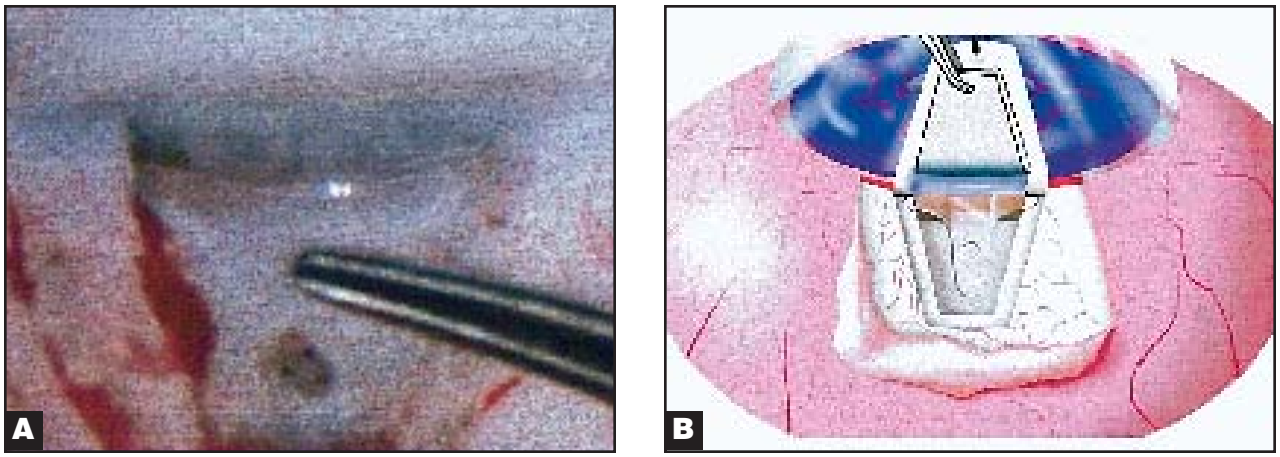

Figure 1. The nonabsorbable hydrophilic glaucoma implant is placed in the deep sclerectomy and its arms are tucked into Schlemm's canal. (A) In vivo image. (B) Artistic illustration.

the operation, which was performed under the highest magnification.

A second 3 × 3 × 1 mm trapezoidal flap or a 3 × 3 mm square scleral flap was dissected to a depth of 90%, creating a deep sclerectomy and leaving only a thin layer of scleral tissue over the underlying uvea. At the level of the scleral spur, Schlemm's canal was deroofed, creating a 3-mm long fenestration in its lumen. The posterior aspect of the trabecular meshwork and the adjacent Descemet's membrane were exposed. A dry cellulose sponge was used to assess the amount of aqueous oozing from the trabecular meshwork and from the adjacent Descemet's membrane.

To thin out and render the trabecular meshwork more permeable, trabecular forceps (HUCO 4.4475; HUCO Vision SA, Saint Blaise, Switzerland) were used to peel off Schlemm's canal endothelium and the juxtacanalicular trabeculum. In some cases, these structures were first loosened using a trabecular meshwork scraper with a carbide-impregnated metal tip (Katena K3-1120, Katena Products, Inc., Denville, NJ, or HUCO 4.6030, HUCO Vision SA).

The internal scleral flap was excised along its base, 0.5 mm anterior to Schwalbe's line. At this stage, the T-Flux implant was placed in the deep sclerectomy space in those patients who were selected for it (Fig. 1). The extremities of its arms were tucked into the Schlemm's canal openings and its trunk was fixated with a 10-0 nylon suture. The superficial scleral flap was reflected back in place and sutured with at least one loose suture. For a fornix-based approach, the conjunctival flap was sutured back into place with one or two 10-0 nylon sutures. For a limbal-based approach, the conjunctival flap was sutured with a continuous 8-0 polyglactin 910 suture.

Postoperative treatment consisted of topical dexamethasone, neomycin, polymyxin B sulfates, or dexamethasone and chloramphenicol instilled 4 times a day for 2 weeks or until the IOP was 12 mm Hg or greater. The steroids were replaced with a nonsteroidal anti-inflammatory agent such as diclofenac when the IOP was 12 mm Hg or greater and continued for 4 to 8 weeks. Postoperatively, IOP was recorded at 1, 7, and 14 days, at 1, 3, and 6 months, and then every 6 months. Anterior chamber depth and the presence of hyphema, choroidal detachment, macular edema, and bleb appearance were recorded at these visits.

When successful filtration ceased (IOP > 18 mm Hg without medical therapy), goniopunctures were performed at the level of Descemet's membrane in the site of filtration with a YAG laser. When the IOP remained greater than 18 mm Hg despite the goniopunctures, the patient was given medical antiglaucoma therapy to keep the IOP below 18 mm Hg.

RESULTS

Twenty-five patients underwent nonpenetrating glaucoma surgery with the T-Flux implant, whereas 23 underwent nonpenetrating glaucoma surgery without the implant. Preoperative data are summarized in Table 1. The mean follow-up was 29.5 ± 7.9 months (range, 12 to 42 months) in the implant group, and 32.9 ± 8.1 months (range, 18 to 32 months) in the control group. Nonpenetrating glaucoma surgery yielded good results in both groups

TABLE 1
Demographics and Preoperative Data of the Study Population

Characteristic	NPGS + Implant	NPGS
No. (male/female)	25 (10/15)	23 (13/10)
Mean age, y (range)	59 ± 19 (20 to 86)	65 ± 17 (20 to 84)
Mean preoperative VA, logMAR (range)	0.89 ± 0.17 (0.5 to 1.25)	0.92 ± 0.11 (0.6 to 1)
Mean preoperative IOP, mm Hg (range)	27.5 ± 11.8 (14 to 64)	24.8 ± 7.1 (16 to 43)
Optic nerve cupping, % (range)	74 ± 21 (20 to 100)	73 ± 20 (25 to 100)
Mean no. of medications (range)	2.3 ± 1 (1 to 4)	2.3 ± 0.9 (0 to 4)

NPGS = nonpenetrating glaucoma surgery; VA = visual acuity; IOP = intraocular pressure.

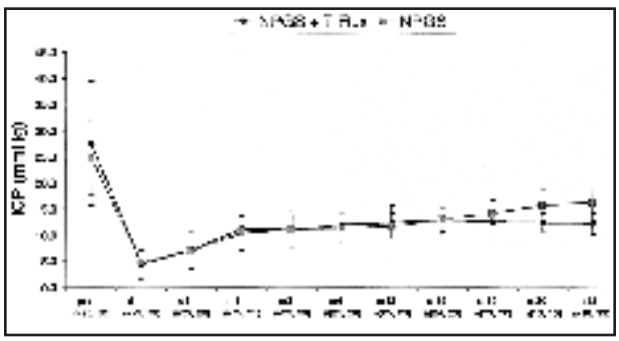

Figure 2. Mean intraocular pressure (± standard deviation) progression over time.

with significantly lower postoperative IOP (P = .003).

Figure 2 illustrates the IOP progression over time in the two groups for the first 36 months postoperatively. During the first 18 months of follow-up, the trend was identical. On the first postoperative day, the mean IOP was 4.4 ± 2.9 mm Hg in the implant group and 4.8 ± 2.8 mm Hg in the control group. The relative hypotony on day 1 was a positive prognostic sign because it demonstrated the augmented permeability of the freshly manipulated trabecular meshwork. From day 7 on, the IOP normalized in the two groups. From the 18th month on, the IOP started to rise in the control group but remained stable in the implant group.

Eight patients, all belonging to the control group, needed medications to keep the IOP at 18 mm Hg or less. This difference between the groups was statistically significant (P = .03). Complete success (IOP ⩽ 18 mm Hg without medications) was achieved in 25 of 25 eyes (100%) in the implant group. Complete success was achieved in 15 of 23 eyes (65%) in the control group, whereas 8 eyes (35%) were defined as having qualified success (IOP ± 18 mm Hg with medications). Six patients in the implant group (24%) and 6 patients in the control group (26.1%) underwent YAG laser goniopunctures to keep the IOP below 18 mm Hg without medications.

Table 2 summarizes the postoperative data in those patients who reached 30 months of follow-up to offset the difference in follow-up time in the two groups. In the implant group (n = 13), the mean postoperative IOP (12.4 mm Hg) was significantly lower than the postoperative IOP (16.9 mm Hg) in the control group after 30 months (P = .003). In addition, the IOP decrease in percentage in the implant group (62%) was significantly lower than the IOP decrease in percentage in the control group (34%) after 30 months of follow-up (P = .01).

The preoperative visual acuity (implant group = 0.89 ± 0.17 [range, 0.5 to 1.25] and control group = 0.92 ± 0.11 [range, 0.6 to 1]) remained unchanged postoperatively in both groups (implant group = 0.88 ± 0.21 [range, 0.5 to 1.25] and control group = 0.93 ± 0.14 [range, 0.7 to 1.25]).

Complications

In the implant group, the T-Flux implant migrated into the anterior chamber in one patient (4%). This patient suffered from severe obstructive lung disease and reported coughing or rubbing of the eye that was operated on a week after the operation. The implant was not fixated with a suture in this case, because it was one of the first operations. The implant was retrieved from the anterior chamber without sequelae. Since this occurrence, all T-Flux implants have been fixated with a 10-0 nylon suture under the superficial scleral flap.

In the control group, iris incarceration in the fil-

TABLE 2
Preoperative and Postoperative Data in the Two Groups at 30 Months of Follow-up

Characteristic	NPGS + Implant (n = 13)	NPGS (n = 15)	*P*
Mean preoperative IOP ± SD (range)	33 ± 13.6 (20 to 64)	24.4 ± 6.8 (16 to 38)	.093*
Mean IOP ± SD at 30 months (range)	12.4 ± 2.1 (9 to 16)	16.1 ± 3.1 (12 to 21)	.003†
Postoperative medications ± SD (range)	0 ± 0	0.3 ± 0.6 (0 to 2)	.03‡
IOP decrease in % ± SD	62 ± 6 (52 to 73)	34 ± 13 (14 to 51)	.01‡

NPGS = nonpenetrating glaucoma surgery; IOP = intraocular pressure; SD = standard deviation.
**Not significant.*
†P < .005.
‡P < .05.

tration site was identified in two patients (8.7%) who reported severe coughing.

DISCUSSION

This study tested the role and the value of a nonabsorbable, biocompatible, hydrophilic implant in nonpenetrating glaucoma surgery. The rationale behind this implant is to maintain a permanent space under the superficial scleral flap. The intrascleral implant is situated in the deep sclerectomy and rests against the lower part of the trabecular meshwork. The previously proposed implants were hydrophilic and absorbable, whereas the T-Flux implant is highly hydrophilic but nonabsorbable.

During the first 18 months of follow-up, there were no marked differences in the mean IOP between the two groups. After the 23rd month, the mean IOP in the control group started to rise but remained stable in the implant group (Fig. 2). This phenomenon indicates a beneficial effect of the presence of the nonabsorbable implant in the filtration site. The ultrabiomicroscopic studies confirm a permanent intrascleral space surrounding the T-Flux implant (Fig. 3).

Nonpenetrating glaucoma surgery can be offered earlier because it has a lower risk rate than trabeculectomy.[5-28,32,33] The benefits of early surgery have been well demonstrated, especially in severe forms of open-angle glaucoma.[34,35] The adverse effects of antiglaucoma therapy on the outcome of glaucoma surgery are well documented.[36-40] In their series on nonpenetrating glaucoma surgery, Dahan and Drusedau[22] found that treated patients had 4.7 times more failures than untreated patients. The differences in outcomes between Stegmann et al.'s

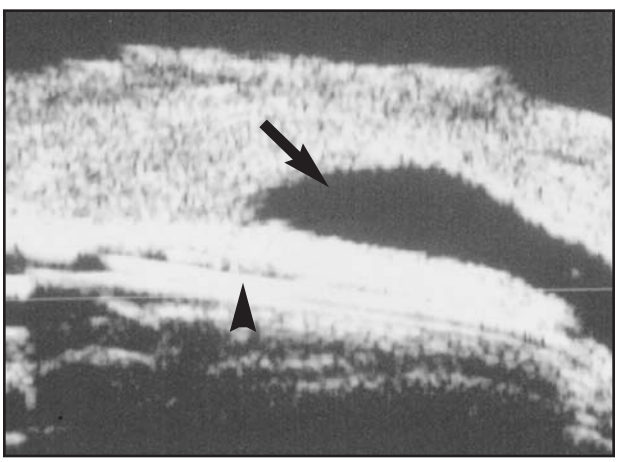

Figure 3. The nonabsorbable hydrophilic implant (arrowhead) in place 3 months postoperatively. Note the subconjunctival bleb (arrow).

results and other reported viscocanalostomy series may be partly due to the fact that the black African patients were not exposed to long medical treatment,[20] whereas in the other series most of the patients were medically treated.[23,30,31] Therefore, it appears logical to consider nonpenetrating glaucoma surgery earlier than it is presently done to optimize its outcomes.

Our study demonstrates a beneficial effect of the T-Flux nonabsorbable hydrophilic implant in terms of nonpenetrating glaucoma surgery longevity. There was no significant difference in the immediate outcomes in the two groups because both groups yielded good results in the short-term. Because the weak spot in nonpenetrating glaucoma surgery is the long-term outcome, the use of an implant, absorbable or nonabsorbable, is recommended to prolong its longevity. The patients in this study will continue to be monitored to provide further infor-

mation on the role of the T-Flux nonabsorbable hydrophilic implant in nonpenetrating glaucoma surgery.

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