OPEN

Transconjunctival XEN45 Implantation for Glaucoma Performed at the Slit Lamp: A Pilot Study

Sébastien Gagné, MD, FRCSC, Darana Yuen, MD,† and Shawn Cohen, MD‡*

Précis: This pilot study of ab externo implantation of a gel microstent is a novel, minimally invasive glaucoma surgery performed at the slit lamp that is effective for lowering intraocular pressure in patients with uncontrolled glaucoma.

Purpose: To evaluate the intraocular pressure (IOP)–lowering effect of gel microstent (XEN Gel Stent, Allergan, Irvine, CA) implantation using an ab externo approach in an office setting.

Patients and Methods: This retrospective, multicenter chart review examined outcomes in patients with uncontrolled glaucoma receiving maximally tolerated medical therapy, who underwent slit lamp ab externo gel stent implantation. At postoperative visit, the IOP, the number of glaucoma medications, the final position of the stent, and the needling rate were analyzed. Assessments were conducted 1 day, 1 week and 1, 3, 6, and 12 months after the implantation. Treatment success was defined as IOP ≥ 6 mm Hg and ≤ 18 mm Hg with $\geq 20\%$ reduction from presurgical IOP, with or without medications.

Results: Thirty-four eyes from 28 patients were included. Mean preoperative IOP was 24.1 ± 8.0 mm Hg on 3.2 ± 0.9 glaucoma medications. At 12 months postoperative, IOP was reduced to 15.4 ± 4.7 mm Hg on 0.6 ± 1.0 medications; 46.9% and 81.3% of eyes achieved complete and partial success, respectively. The gel stent was properly positioned in 94.1% of eyes after 1 attempt at implantation and in 100% of eyes after a second attempt. In addition to malpositioning, observed complications included occlusion, erosion, and endophthalmitis following anterior chamber reformation. Adjunctive needling was required in 21% of implanted eyes.

Conclusion: Slit-lamp-based transconjunctival XEN45 implantation reduced intraocular pressure in glaucoma patients in the first year of this pilot study and was most commonly associated with wound leak and hypotony among other adverse events.

Key Words: glaucoma, XEN gel stent, microstent, minimally invasive glaucoma surgery, MIGS, slit lamp

Received for publication February 18, 2021; accepted June 12, 2022.

From the *Département d'ophtalmologie, Université de Montréal; ‡Department of Ophthalmology, McGill University, Montréal, Quebec; and †Department of Ophthalmology & Vision Sciences, University of Toronto, Toronto, Ontario, Canada.

Disclosure: Drs. S.G., D.Y. and S.C. are consultants for Allergan. This work received financial support from Allergan, Irvine, CA. The remaining authors declare no conflict of interest.

Reprints: Sébastien Gagné, MD, FRCSC, Institut de l'Oeil des Laurentides 6110 Doris-Lussier, Boisbriand, Quebec, Canada, J7H 0E8 (e-mail: Sebastien.gagne@institutdeloeil.com).

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.glaucomajournal.com.

DOI: 10.1097/IJG.0000000000002070

(*J Glaucoma* 2022;31:675–681)

Glaucoma affects more than 64 million adults aged 40-80 years[1] and is a leading cause of blindness worldwide.[2] Trabeculectomy effectively lowers intraocular pressure in patients with glaucoma and is considered the gold-standard glaucoma-filtering surgery.[3] In an effort to mitigate bleb-related and perioperative hypotony-related complications, newer bleb forming stent-based surgical approaches designed to minimize scleral dissection and conjunctival tissue disruption have emerged.[4,5] The XEN Gel Stent (XEN45; Allergan, Irvine, CA) can reduce intraocular pressure (IOP) by filtering aqueous humor from the anterior chamber (AC) to the subconjunctival space.[6–9]

The gel stent is typically implanted ab interno, through the peripheral cornea and across the AC toward the targeted quadrant, through a small corneal incision.[9] The surgery is traditionally performed in an operating room with the patient supine, either in an outpatient surgery center or in a hospital setting.[10]

The ab externo approach is the off-label use of the XEN device. However, the ab externo approach has potential advantages over the ab interno technique, as follows: it is less invasive and does not require tissue dissection or sutures; there is no need for specialized surgical equipment; it can be performed in an office setting with the patient seated at the slit lamp; the approach allows supra-Tenons access; it does not require the use of viscoelastic and AC washout; it expands the area for treatment into the supero-temporal quadrant, which is less invasive than traditional surgery; and the surgeon can avoid crossing over a crystalline lens. All of this translates into a potentially safer and less time-consuming in-office procedure than the ab interno approach. Furthermore, preclinical ex vivo work in rabbit eyes suggests that, compared to the ab interno approach, ab externo stent implantation provides less outflow resistance and a more predictable bleb formation.[11]

Despite the potential advantages of an ab externo approach, the effectiveness of lowering the IOP and reducing reliance on topical medication have not been assessed for a stent that is implanted using this novel slit lamp technique. Thus, this retrospective pilot study assessed IOP for the first 12 months after the ab externo implantation of a gel stent. The success rate of the stent and the postoperative needling rate were evaluated, along with the number of glaucoma medications needed postoperatively and the final position of the stent.

PATIENTS AND METHODS

Study Design

This retrospective, consecutive chart review examined outcomes in patients with uncontrolled glaucoma and receiving maximally tolerated medical therapy who

underwent slit lamp ab externo implantation of a gel stent at 3 centers (located in Boisbrand and Montréal, Quebec, Canada, and Toronto, Ontario, Canada) by the 3 authors of this report. Charts of all patients, including each surgeon's initial cases, undergoing slit lamp gel stent implantation between May and November 2018 were reviewed to collect baseline and preoperative ocular characteristics, details of the procedure, and outcome data from 1 day, 1 week (±2 d), 1 month (±7 d), 3 months (±14 d), 6 months (±30 d), and 12 months (±60 d) postoperatively.

Participants

Patients' charts were included if the patient underwent slit lamp ab externo implantation of a XEN45 gel stent by one of the investigators. Patients were required to be in good general health and at least 18 years of age at the preoperative exam. Eyes with prior incisional surgery to the conjunctiva were excluded, but those with other forms of glaucoma surgery could be included. The study protocol was reviewed and approved by an independent review board (Veritas IRB Inc., Montréal, Quebec, Canada). All patients provided informed consent for the surgery using a nonstandard and experimental approach. The requirement for informed consent for data collection was waived due to the retrospective design of the study.

Ab Externo Implantation Technique

The transconjunctival ab externo technique is a modification of the ab interno procedure, as previously described[12] and shown in Figure 1. Topical treatments were discontinued on the night before the surgery. Topical anesthesia with tetracaine 0.5% eye drops was performed before the ocular surface was disinfected with 5% povidone iodine drops. Cycloplegia was not used. A full blade speculum was used to retract the patient's eyelid, and the patient was positioned at the slit lamp. While the patient gazed down toward the nose, a mixture of an antimetabolite, lidocaine, and epinephrine was injected into the exposed surgical site of the superotemporal quadrant. The antimetabolite was either mitomycin C (MMC) or fluorouracil (5-FU), chosen based on the surgeon's preference. The mixture contained either 0.1 cm^3 of MMC (0.2 mg/mL) or 5-FU (50 mg/mL), and 0.05 cm^3 of 2% lidocaine with epinephrine, for a total volume of 0.15 cm^3. The speculum was then removed. After 5 to 7 minutes, topical anesthesia and disinfection were repeated, and the speculum was secured again. An inserter with a preloaded gel stent was directed to enter the conjunctiva approximately 2 to 3 mm lateral to the intended scleral entry point, and 6 to 7 mm from the limbus, using an aseptic no-touch technique. The inserter was then directed downward to enter the sclera 2.5 mm posterior to the limbus. Once the tip of the inserter needle was visualized in the AC, the plunger of the inserter was advanced while the inserter needle was slowly and simultaneously withdrawn until the gel stent was fully released. The ideal target position of the stent is approximately 3 mm within the subconjunctiva, 2 mm within the sclera, and 1 mm within the AC (see Supplemental Content 1, http://links.lww.com/IJG/A630).[13] The positioning of the stent was considered successful if a connection was made by the stent between the subconjunctival space and the AC, and a bleb was formed. Gonioscopy was performed to confirm proper seating of the gel microstent and a slit lamp biomicroscopy was performed to confirm a formed bleb. Postoperative needling in the subconjunctival space was performed if deemed necessary by the surgeon once the conjunctival bleb showed signs of decreased filtration, early fibrosis, or hypervascularization. Postsurgical regimens included moxifloxacin QID for 1 week and topical bromfenac die for 1 month. Topical steroidal medications (prednisolone acetate 1%, dexamethasone 0.1%, or difluprednate 0.05%) were applied q2h for the first week and maintained over 1 to 2 months, with dose tapering depending on the bleb morphology. Patients were instructed to limit physical activity for the first week and, depending on the surgeon's preference, to wear a protective shield at bedtime. Glaucoma drops were reintroduced only if the IOP was above target.

Assessments

Demographics, medical history, and clinical characteristics were collected from patients' charts, along with IOP, measured via Goldmann applanation tonometry, and pre-surgical slit lamp and gonioscopy findings.

Outcomes

The primary efficacy outcome was 12-month postoperative IOP. Complete success was defined as postoperative IOP $\geq$6 mm Hg and $\leq$18 mm Hg with $\geq$20% reduction from presurgical IOP without medications, no loss of light perception, and no additional glaucoma procedures with the exception of needling. Partial success was defined similarly but with the allowance of medications, comparable to other studies.[6,7,14] A more stringent success criterion (postoperative IOP $\leq$15 mm Hg with an IOP reduction $\geq$30%, without medication) was also applied. The total number of postoperative glaucoma medications used and the needling rate during the 12 months after surgery were explored as secondary outcomes. The position of the stent and any surgical complications were recorded on the day of the surgery. IOP, the number of glaucoma medications used, adverse events, and any adjunct procedures were recorded at baseline and postoperatively.

Statistical Analysis

SAS version 9.4 (SAS Institute Inc, Cary, NC) and Stata version 14.2 (StataCorp LLC, College Station, TX) were used for data analyses. Descriptive statistics are reported as mean ± standard deviation for continuous variables and percentages for categorical variables. Missing data were not imputed. A P-value of <0.05 was considered statistically significant.

RESULTS

Baseline and Clinical Characteristics

In all, 34 eyes from 28 patients were included. Baseline demographics and clinical characteristics are listed in Table 1. Most patients were Caucasian (n = 25; 89.3%), had primary open angle glaucoma (n = 21; 61.8%), and had undergone previous selective laser trabeculoplasty (n = 21; 61.8%). Two eyes in 2 individuals were lost to follow-up, 1 due to the patient leaving the country, and 1 due to the patient not being observed at 12 months post surgery.

Intraocular Pressure (IOP)

The mean preoperative and postoperative IOP and the mean percent reduction in IOP from baseline are shown in Figure 2. Immediately after implantation and up to 12 months postoperatively, the mean IOP remained $\leq$18 mm Hg and was significantly lower than the mean preoperative

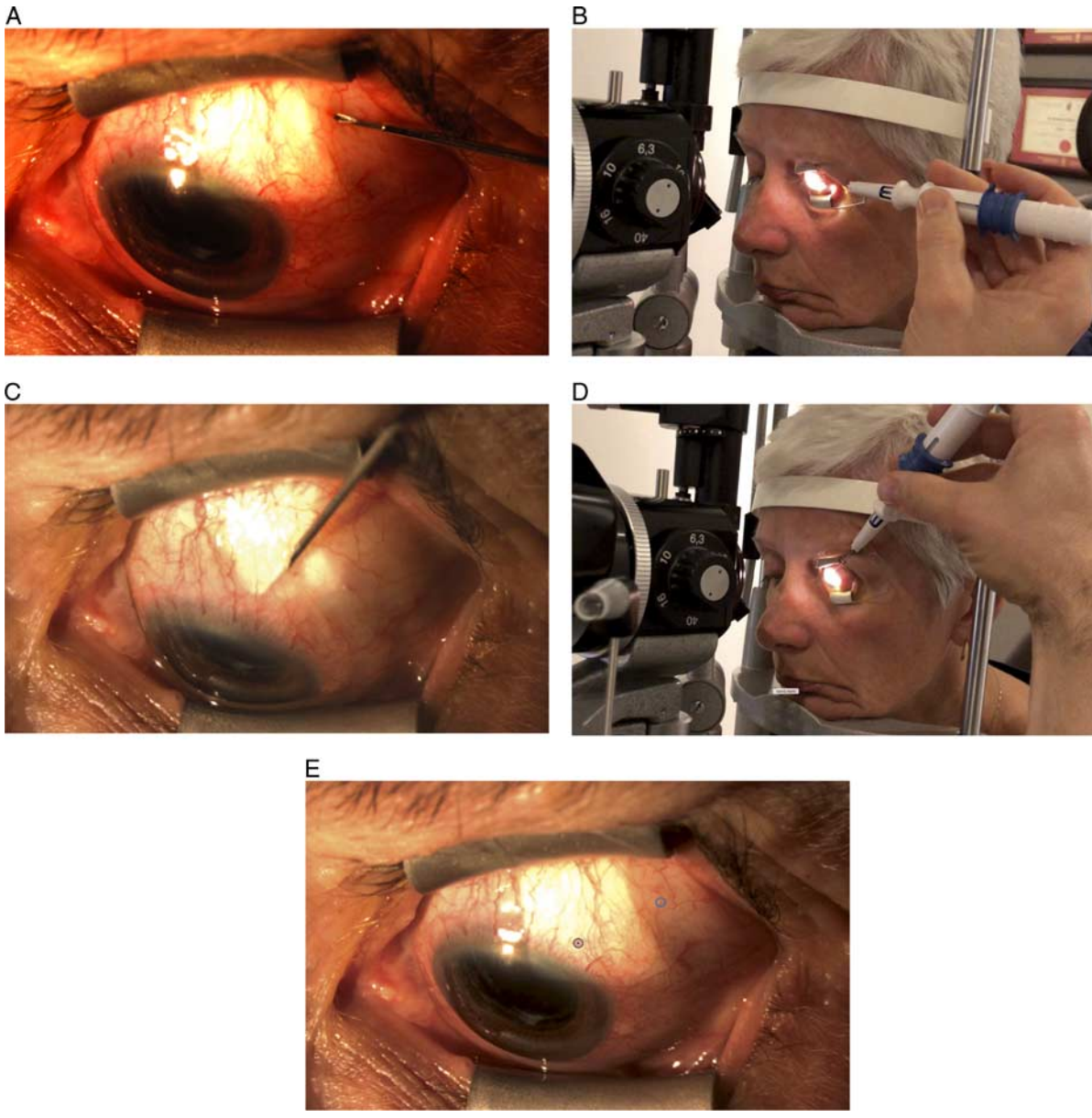

FIGURE 1. Transconjunctival ab externo implantation of a gel microstent. A, The conjunctival entry point of the needle is 6 to 7 mm from the limbus. B, At this stage the inserter is held in a horizontal orientation to prevent dropping the gel microstent. C, The scleral entry point is 2 to 2.5 mm from the limbus. D, At this stage the inserter is held in a vertical orientation. E, The conjunctival entry point is depicted by the blue circle and the scleral entry point is depicted by the black circle. Note the conjunctival entry point at 1 o'clock from scleral entry point.

IOP ($P < 0.001$). After 12 months, the mean IOP was 15.4 ± 4.7 mm Hg and the mean reduction was 30.5%.

Success Rate

At 12 months postoperatively, 15 eyes achieved complete success with an IOP ≤ 18 mm Hg and a reduction of >20%, without medication, corresponding to an overall complete success rate of 46.9% (15/32), with 2 patients (2 eyes) being lost to follow-up. Partial success was achieved by 81.3% of eyes. Moreover, 34.4% of eyes achieved a postoperative IOP ≤ 15 mm Hg with a reduction of $\geq 30\%$ without medication. Maintenance of treatment success over 1 year, using standard and stringent criteria for complete success, as well as partial treatment success, is shown in Figure 3.

During the surgery, 5-FU was used in 16 eyes and MMC was used in 18 eyes. Of these, data were available for 15 eyes treated with 5-FU and 17 eyes treated with MMC at 12 months post surgery. There was no difference in the mean change in IOP from preoperative baseline between these subgroups (-8.8 ± 7.0 and -8.5 ± 8.7 mm Hg for 5-FU and MMC, respectively; $P = 0.89$).

Medication Use and Visual Acuity Change

The mean number of glaucoma medications used decreased on postoperative day 1 and remained significantly

TABLE 1. Baseline Demographics of the Patients and Clinical Characteristics of the Operated Eyes

Demographics, n = 28	Mean ± SD or n (%)
Age	66.3 ± 16.2
Sex, male	11 (39.3)
Ethnicity	
Caucasian	25 (89.3)
Afro-American	2 (7.1)
Asian	1 (3.6)
Clinical Characteristic, n = 34	Mean ± SD or n (%)
Operated eye	
OD (right eye)	15 (44.1)
OS (left eye)	19 (55.9)
Glaucoma diagnosis	
Primary open angle glaucoma	21 (61.8)
Primary angle closure glaucoma	2 (5.9)
Pseudoexfoliative glaucoma	1 (2.9)
Pigment dispersion syndrome glaucoma	2 (5.9)
Uveitic glaucoma	1 (2.9)
Other*	7 (20.6)
Previous glaucoma surgeries	7 (20.6)
Previous selective laser trabeculoplasty	21 (61.8)
Preoperative IOP, mm Hg	24.2 ± 8.0
Number of preoperative medications (n = 33)	3.2 ± 0.9
IOP at Tmax, mm Hg	35.4 ± 11.2
Number of preoperative medications at Tmax	2.5 ± 1.5
Central corneal thickness, μm (n = 30)	541.2 ± 39.6
Visual field mean defect, dB (n = 33)	11.6 ± 9.1
Preoperative visual acuity, logMAR	0.5 ± 1.0
Lens status	
Phakic	12 (35.3)
Pseudophakic	22 (64.7)

*1 neovascular, 2 steroid-induced, 1 secondary to penetrating keratoplasty, 1 angle recession, 2 juvenile open-angle.

IOP indicates intraocular pressure; OD, oculus dexter; OS, oculus sinister; SD, standard deviation; Tmax, maximum recorded intraocular pressure.

lower than the preoperative number of medications used ($P < 0.001$) at every follow-up over 12 months (Fig. 4). At 12 months postoperatively, 24 of the 34 (70.6%) eyes were medication-free, and there was no difference ($P = 0.54$) in the change in the number of medications needed in the group that was treated with 5-FU (−2.5 ± −1.0 [n = 15]) intraoperatively compared with the group that was treated with MMC intraoperatively (−2.8 ± −1.3 [n = 16]).

Visual acuity was unchanged from preoperative values to 12 months postoperative (0.5 ± 0.87 vs. 0.5 ± 0.84 logMAR; 0.71).

Final Gel Stent Position

The target position for the implant is described in Supplemental Figure 1, http://links.lww.com/IJG/A630. On the first implantation attempt, 32 out of 34 stents (94.1%) were positioned appropriately. Two eyes required a second implantation attempt: 1 was performed immediately, and the other was performed 1 day following the first attempt. Proper positioning was achieved in 100% of the eyes after the second attempt. The final mean length of the stent was 1.4 ± 0.6 mm in the anterior chamber, 2.2 ± 0.3 mm in the sclera, and 2.4 ± 0.5 mm in the subconjunctival space. In 1 case, the first implantation failed because the gel stent prematurely exited the inserter when it was under the conjunctiva, before entering the scleral wall. In the other case, the first implantation failed because the inserter was not angled sufficiently for the approach; as such, the tip of the needle did not enter the AC. In both the cases, a second device was used to complete the procedure.

Adjunctive Procedures

All adjunctive procedures used are listed in Table 2. Needling, the most common adjunct procedure performed, was required in 21% of implanted eyes. The next most common adjunct procedure was AC reformation, for which 2 were performed due to clinically significant hypotony and 3 were performed as safety precautions.

Adverse Events

Adverse events (AEs) that occurred postoperatively are reported in Table 3. In all, 27 AEs occurred in 15 patients. Wound leak on the day of the surgery and transient hypotony lasting less than 1 week were the most common adverse events. A late leak that occurred in one eye required a conjunctival suture. Endophthalmitis due to a secondary procedure occurred 1 month postoperatively in 1 eye, when a doctor from another clinic performed an AC reformation. One case was reported in which the device was malpositioned. The patient had a functioning bleb, and the gel stent was seen under the conjunctiva, although the stent was not evident under gonioscopy. Ultrasound biomicroscopy imaging showed the final position of the stent localized in the sulcus (see Figure, Supplemental Digital Content 2, http://links.lww.com/IJG/A631, showing the malpositioned stent and a photograph of the bleb formation). In another case, the stent became occluded post hyphema (see Figure, Supplemental Digital Content 3, showing the occlusion and resulting pigment seen within the stent, http://links.lww.com/IJG/A632). There were two cases in which the stent became exposed; 1 case was due to severe dry eye, and the other case was iatrogenic and occurred during a needling procedure. There were no occurrences of persistent hypotony (IOP < 6 mm Hg lasting longer than 4 wk duration) or hemorrhagic choroidal detachment. No association of adverse events with preoperative IOP was observed.

DISCUSSION

This retrospective chart review explored the outcomes of a novel slit lamp transconjunctival ab externo implantation of a gel stent for reducing IOP, observed over 12 months. The XEN gel stent used here was a 6 mm nondegradable, hydrophilic tube with a 45 μm lumen composed of glutaraldehyde cross-linked with porcine-derived gelatin.[9]

Mean IOP decreased to ≤18 mm Hg after slit lamp ab externo implantation, and the decrease was sustained throughout the follow-up period in 81.3% of the eyes. The 12-month postoperative IOP of 15.4 ± 4.7 mm Hg was consistent with the previously reported IOP following ab interno implantation of a gel stent microstent (12 ± 3 to 15.5 ± 1.9 mm Hg)[6–8,14] but different from trabeculectomy (12.7 ± 5.8).[15] Rates of complete and partial success in this patient population were within the ranges of success rates observed in the previous studies of ab interno stent implantation.[6,7,14] Complete success rates in those studies ranged from 40%[14] to 55%,[7] whereas partial success rates ranged from 67%[6] to 89%.[14] These studies used nonidentical definitions of complete and partial success, which may account for the differences in the results.

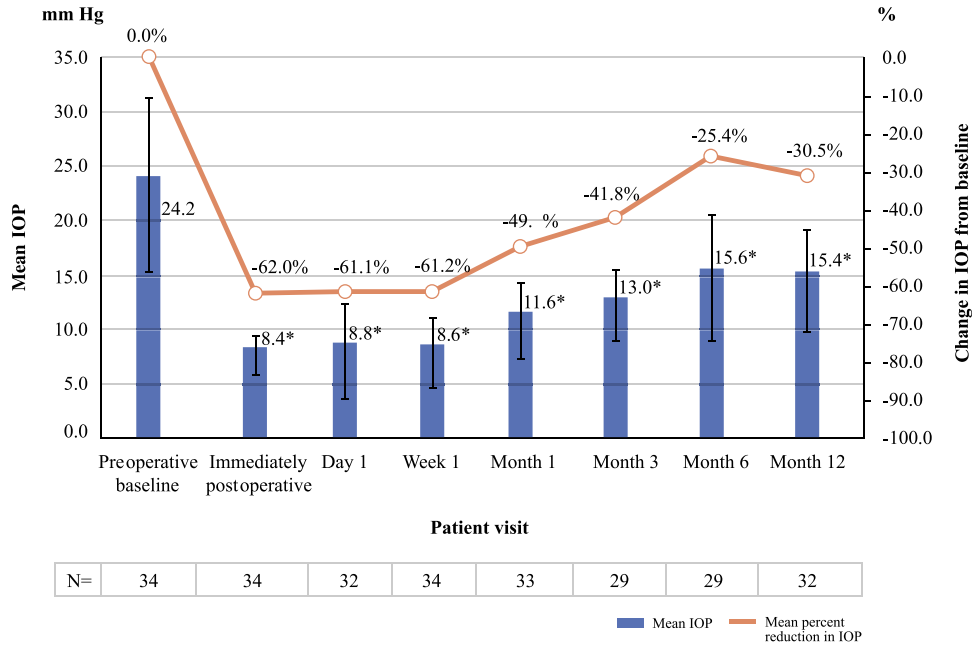

FIGURE 2. Mean intraocular pressure (±standard deviation) and mean percent reduction in intraocular pressure pre-ab externo and post-ab externo implantation of a gel stent. *$P < 0.001$ different from preoperative baseline. IOP indicates intraocular pressure.

The number of glaucoma medications was significantly reduced after the transconjunctival ab externo implantation of the gel stent and 70.6% of eyes off all glaucoma medications 12 months postoperatively. This proportion is much greater than that reported by Sheybani et al (42%),[14] but similar to other reports (81.1%[7] and 90%[8]). The mean number of medications used was similar to that observed after the ab interno implantation of a stent (range: 0.17 ± 0.65 to 1.3[6–8,14]). Given the negative impact that topical medication can have on the patient's quality of life,[16] the substantial reduction in the use of glaucoma medication achieved in this pilot study may contribute to improved quality of life for patients.

Proper placement of the gel stent reduces the chance that the stent will extrude or contact the corneal endothelium and ensures enough resistance through the sclera to prevent excessive drainage.[13] In this patient population, proper placement of the stent was achieved in all but 2 eyes on the first attempt at implantation. Proper placement was achieved in the remaining 2 eyes after a second implantation.

The needling rate required in our patient population was lower than the rates reported for postoperative needling after the ab interno implantation,[6,7,14] likely due to supra-Tenons' placement of the external stent tip, but higher than the needling rate of 13% reported after trabeculectomy.[17] A high needling rate (47%) was reported for eyes that received ab interno implantation of the XEN140 stent,[14] although antimetabolites were not used during those surgeries, complicating the comparison to the current study, in which all the surgeries were performed using either 5-FU or MMC. Nevertheless, the needling rate here was lower than the 27.7%[7] and 30.7%[6] reported in studies where MMC was applied intraoperatively. This lower needling rate suggests that the novel ab externo approach, with the use of an antimetabolite, can reduce the need for postoperative care. Similarly, stent exposure occurred in two patients, one in the course of post-treatment needling.

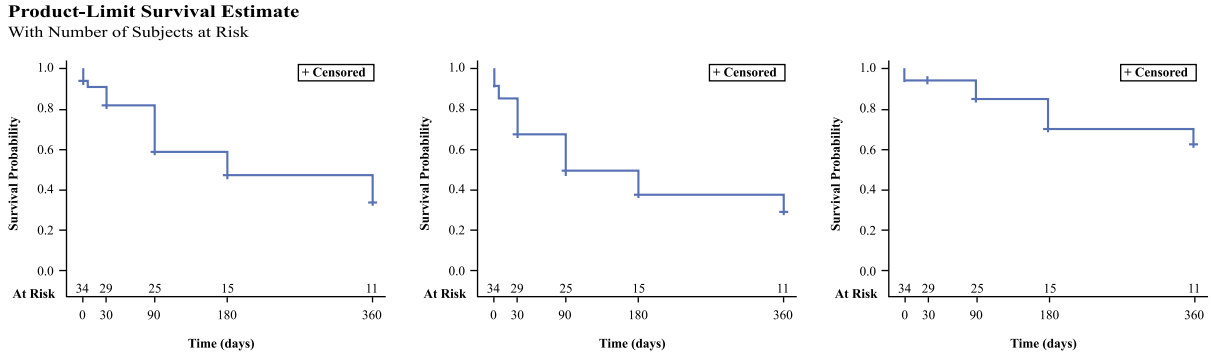

FIGURE 3. Maintenance of treatment success over 1 year. Left panel: complete treatment success (IOP ≤18 mmHg and ≥20% IOP reduction without medication); middle panel: stringent criteria for treatment success (IOP ≤15 mmHg and ≥30% IOP reduction without medication); right panel: partial treatment success (IOP ≤18 mmHg, irrespective of medication use). IOP indicates intraocular pressure.

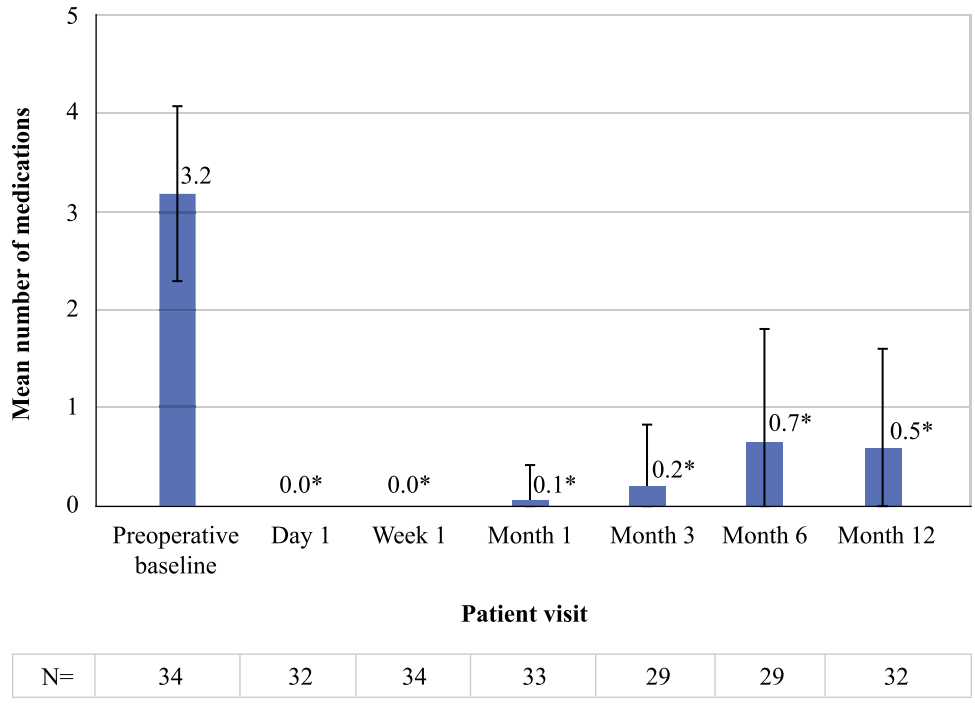

FIGURE 4. Mean number of glaucoma medications (±standard deviation) used pre-ab externo and post-ab externo implantation of a gel stent. *$P < 0.001$ different from preoperative baseline.

The exposure of XEN stents has also been reported in isolated cases following ab interno placement.[6,18]

The slit lamp ab externo approach offers several advantages over the more invasive ab interno approach. It can be performed safely and effectively in the ophthalmologist's office, rather than in an operating room, using techniques that are similar to needling at the slit lamp. Indeed, comparing the first 5 eyes versus the latest 5 eyes treated by each surgeon identified no significant difference in clinical outcome (not shown). Combined with the high overall success rate of this procedure, this finding suggests a minimal learning curve for surgeons already accustomed to slit lamp-based procedures. Office-based surgery may reduce the carbon footprint of the surgery, as has been suggested, and can be done in other ophthalmologic procedures.[19] Furthermore, the slit lamp method may be used as an adjunct to provide access to the super-temporal quadrant for a gel stent implant when the ab interno implantation of a stent in the nasal quadrant has failed. Additionally, the temporal bleb is less likely to cause bleb dysesthesia than a superonasal bleb.[20] It remains unclear whether the ab externo approach can be used to implant a second gel stent[21] for patients requiring a further reduction in IOP.

This pilot study was limited by its nonrandomized, retrospective design and by the reliance on historical comparisons to evaluate clinical outcomes. Given that this report captures data from all eyes treated with the slit lamp approach, the inclusion of both eyes of the 6 patients might have biased our success rate estimates. Furthermore, because the XEN45 stent was used in all cases, it remains unclear whether the ab externo approach could be used with equal success with stents of different dimensions or compositions. Prospective, randomized studies will be required to evaluate the efficacy and safety of transconjunctival

TABLE 2. Adjunct Procedures

Procedure, n = 34	n (%)
Needling	
Total	7 (20.6)
MMC	3 (8.8)
5-FU	4 (11.8)
AC reformation	5 (14.7)
Conjunctival suture closure (for wound leak)	1 (2.9)
Digital ocular compression	1 (2.9)
Gel stent revision	2 (5.9)
Reoperation for glaucoma	2 (5.9)

AC indicates anterior chamber; MMC, mitomycin C.

TABLE 3. Adverse Events

Adverse Event, n = 28	n (%)
Early wound leak, day of surgery	6 (21.4)
Early wound leak, Seidel test positive, <24 h	1 (3.6)
Late wound leak, Seidel test positive >24 h	1 (3.6)
Transient hypotony, IOP < 6 mm Hg lasting less than 1 wk	6 (21.4)
Transient hypotony, IOP < 6 mm Hg lasting more than 1 wk to less than 4 wk	1 (3.6)
Hyphema	2 (7.1)
Shallow AC	2 (7.1)
Serous choroidal detachment	2 (7.1)
Encapsulation	1 (3.6)
Device malposition	1 (3.6)
Stent occlusion	1 (3.6)
Stent exposure	2 (7.1)
Endophthalmitis (AC reform 1-month postoperative)	1 (3.6)

AC indicates anterior chamber; MMC, mitomycin C.

ab externo stent implantation, relative to ab interno implantation or trabeculectomy.

CONCLUSION

This pilot study demonstrated that the slit lamp transconjunctival ab externo implantation of the gel microstent, the first minimally invasive glaucoma surgery performed in an office-based setting, is an effective treatment strategy for reducing IOP in patients with uncontrolled glaucoma.

ACKNOWLEDGMENTS

The authors thank John Ashkenas, PhD, and Celeste Lavallee, MSc (imc North America, Toronto) for writing and editorial contributions and Mahwesh Saleem, PhD (imc North America, Toronto) and Miguel Chagnon, MSc, PStat (Université de Montréal) for consultation on statistical analysis.

REFERENCES

1. Tham Y-C, Li X, Wong TY, et al. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. *Ophthalmology*. 2014; 121:2081–2090.
2. Bourne RR, Stevens GA, White RA, et al. Causes of vision loss worldwide, 1990-2010: a systematic analysis. *Lancet Glob Health*. 2013;1:e339–e349.
3. Jampel HD, Musch DC, Gillespie BW, et al. Perioperative complications of trabeculectomy in the Collaborative Initial Glaucoma Treatment Study (CIGTS). *Am J Ophthalmol*. 2005; 140:16–22.
4. Saheb H, Ahmed II. Micro-invasive glaucoma surgery: current perspectives and future directions. *Curr Opin Ophthalmol*. 2012; 23:96–104.
5. US Department of Health and Human Services Food and Drug Administration. Premarket studies of implantable minimally invasive glaucoma surgical (MIGS) devices: guidance for industry and Food and Drug Administration staff: US Department of Health and Human Services Food and Drug Administration; 2015. Available at: https://www.fda.gov/media/90950/download. Accessed July 16, 2020.
6. Galal A, Bilgic A, Eltanamly R, et al. XEN glaucoma implant with mitomycin C 1-year follow-up: result and complications. *J Ophthalmol*. 2017;2017:5457246.
7. Hengerer FH, Kohnen T, Mueller M, et al. Ab interno gel implant for the treatment of glaucoma patients with or without prior glaucoma surgery: 1-year results. *J Glaucoma*. 2017;26: 1130–1136.
8. Pérez-Torregrosa VT, Olate-Pérez Á, Cerdà-Ibáñez M, et al. Combined phacoemulsification and XEN45 surgery from a temporal approach and 2 incisions. *Arch Soc Esp Oftalmol*. 2016;91:415–421.
9. AqueSys Inc. *Directions for Use for the XEN•45 Glaucoma Treatment System*. Aliso Viejo, CA: AqueSys Inc; 2020. Available at: https://allergan-web-cdn-prod.azureedge.net/allergancanadaspecialty/allergancanadaspecialty/media/actavis-canada-specialty/en/products/pms/xen-45-dfu-english-3037-004-rev-a.pdf. Accessed July 16, 2020.
10. American Academy of Ophthalmology. What is a glaucoma drainage implant? *American Academy of Ophthalmology*. 2020. Available at: https://www.aao.org/eye-health/diseases/glaucoma-drainage-implants. Accessed July 16, 2020.
11. Lee RMH, Bouremel Y, Eames I, et al. The implications of an ab interno versus ab externo surgical approach on outflow resistance of a subconjunctival drainage device for intraocular pressure control. *Transl Vis Sci Technol*. 2019;8:58.
12. Vera V, Gagne S, Myers JS, et al. Surgical approaches for implanting XEN gel stent without conjunctival dissection. *Clin Ophthalmol*. 2020;14:2361–71.
13. Chaudhary A, Salinas L, Guidotti J, et al. XEN gel implant: a new surgical approach in glaucoma. *Expert Rev Med Devices*. 2018;15:47–59.
14. Sheybani A, Dick HB, Ahmed II. Early clinical results of a novel ab interno gel stent for the surgical treatment of open-angle glaucoma. *J Glaucoma*. 2016;25:e691–e696.
15. Gedde SJ, Schiffman JC, Feuer WJ, et al. Treatment outcomes in the Tube Versus Trabeculectomy (TVT) study after five years of follow-up. *Am J Ophthalmol*. 2012;153:789–803.e2.
16. Nordmann J-P, Auzanneau N, Ricard S, et al. Vision related quality of life and topical glaucoma treatment side effects. *Health Qual Life Outcomes*. 2003;1:75.
17. Gedde SJ, Herndon LW, Brandt JD, et al. Postoperative complications in the Tube Versus Trabeculectomy (TVT) study during five years of follow-up. *Am J Ophthalmol*. 2012;153: 804–814.e1.
18. Widder RA, Dietlein TS, Dinslage S, et al. The XEN45 gel stent as a minimally invasive procedure in glaucoma surgery: success rates, risk profile, and rates of re-surgery after 261 surgeries. *Graefes Arch Clin Exp Ophthalmol*. 2018;256:765–71.
19. Morris DS, Wright T, Somner JE, et al. The carbon footprint of cataract surgery. *Eye (Lond)*. 2013;27:495–501.
20. Budenz DL, Hoffman K, Zacchei A. Glaucoma filtering bleb dysesthesia. *Am J Ophthalmol*. 2001;131:626–630.
21. Hu WD, Moster MR, Zheng CX, et al. Outcomes of sequential glaucoma drainage implants in refractory glaucoma. *J Glaucoma*. 2016;25:e340–e345.

