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Comparison of the Ahmed Glaucoma Valve, the Krupin Eye Valve with Disk, and the Double-plate Molteno Implant

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Objective: To compare the efficacy of the nonvalved double-plate Molteno implant with two valved implants, the Krupin Eye Valve with Disc and the Ahmed Glaucoma Valve, in the treatment of recalcitrant glaucoma.

Patients and Methods: The authors performed a nonrandomized retrospective review of patients who received the Molteno implant (n = 27), Krupin Eye Valve with Disc (n = 13), or Ahmed Glaucoma Valve (n = 13), with adjunctive mitomycin C.

Results: Kaplan-Meier life-table analysis showed that the Molteno implant patients were more likely to maintain an intraocular pressure between 5 and 15 mm Hg than Ahmed Glaucoma Valve patients ($P = 0.03$). Success rates at 1 year were 80% (95% CI, 66–97%) for the Molteno implant, 39% (19–77%) for the Krupin Eye Valve with Disc, and 35% (15–82%) for the Ahmed Glaucoma Valve. However, Ahmed Glaucoma Valve patients were less likely to experience complications requiring reoperation or loss of two or more lines of visual acuity ($P < 0.01$) than Molteno implant or Krupin Eye Valve with Disc patients.

Conclusions: This nonrandomized study suggests that the Molteno implant with mitomycin C is more likely to result in intraocular pressures in the lower teens than the Ahmed Glaucoma Valve with mitomycin C. The findings suggest that the Ahmed implant is less likely to create problems leading to reoperations or visual acuity loss than the Molteno or Krupin implants.

Key Words: Ahmed—Glaucoma implant—Krupin—Mitomycin—Molteno—Shunt.

Glaucoma drainage implants have become an important method of controlling intraocular pressure (IOP). The double-plate Molteno implant (Molteno) has a surface area of 268 mm^2 and consists of a silicone tube that runs from the anterior chamber to two plates sutured to the equatorial sclera. During placement of the device, the tube leading from the anterior chamber is temporarily ligated to prevent hypotony until a fibrous capsule forms around the plates and creates resistance to fluid flow.[1–4]

To obviate the need to temporarily ligate the glaucoma implant, several valved devices have been developed. Krupin[5] described the first commercially available valved implant, which was later attached to a plate with a planar surface area of 184 mm^2 and called the Krupin Eye Valve with Disk (Krupin).[6] The Ahmed Glaucoma Valve implant (Ahmed) also has a valve that is attached to a plate with a surface area of 185 mm^2.[7]

To date no study has directly compared the efficacy and complication rates of nonvalved and valved implants. This study provides a retrospective chart review

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with long-term follow-up data comparing a series of the double-plate Molteno implant with two valved implants, the Krupin disk and the Ahmed valve, all used with mitomycin C (MMC).

MATERIALS AND METHODS

The medical records of all patients in our practice who had undergone placement of a Molteno, Krupin, or an Ahmed between June 1, 1991 and October 1, 1997 were reviewed. The Krupin implant was used prior to November 1995, after which date the Ahmed was used instead; Molteno implants were used throughout the period. During the study period, a total of 36 Molteno, 21 Krupin, and 17 Ahmed implantations were performed. Procedures were excluded if they were the second implant in an eye (8 Molteno, 2 Krupin, and 1 Ahmed), if they were the second implant in a patient (1 Molteno, 2 Krupin, 1 Ahmed; i.e., only one eye per patient was studied), or if MMC was not used (0 Molteno, 4 Krupin, and 2 Ahmed). Therefore, a total of 27 Molteno, 13 Krupin, and 13 Ahmed implantations were studied. All surgeries were performed by, or under the direction of, one of three surgeons (T.W.P., n = 36; G.A.H., n = 9; P.L.K., n = 8)

Surgical Technique

The double-plate Molteno implant was placed either superiorly or inferiorly with the interplate tube underneath the respective rectus muscle. The anterior edge of each plate was sutured 10 to 12 mm posterior to the limbus. A cellulose surgical eye spear soaked in 0.5 mg/mL MMC was applied for 5 minutes in each quadrant before plate placement. The proximal tube was ligated with an intracameral 9–0 polypropylene suture, an external 9–0 polyglactone suture, or an external 9–0 nylon combined with a luminal 4–0 polypropylene rip-cord suture. After ligation, the tube was irrigated with a 27-gauge cannula to prove that no aqueous could flow past the ligature. Venting slits were used for some patients. After ligation, the tube was trimmed and inserted into the anterior chamber through a 23-gauge needle track at the limbus, usually under a limbal-based scleral flap. Banked, alcohol-preserved human sclera was sewn over the tube at the limbal edge. In one of the eyes, early IOP control in absence of a venting slit was obtained by performing a fornix-based trabeculectomy, which was expected to and did fail with loss of the bleb within 3 to 4 weeks. In addition to the intraoperative exposure to MMC, 5 of the 27 eyes received one to 10 subconjunctival injections of 5 mg fluorouracil at the surgeon's discretion during the first 2 postoperative weeks. (This practice was abandoned after an internal review revealed that the supplemental fluorouracil was not beneficial.) After 4 to 8 weeks, the 9–0 polypropylene ligature suture was cut with a laser in the anterior chamber or the 4–0 polypropylene suture was removed. The polyglactone suture typically opened 3 to 5 weeks postoperatively.

The surgical technique for the Krupin and Ahmed implants involved creation of a fornix-based or limbal-based conjunctival flap between two adjacent rectus muscles. The anterior edge of the plate was sutured 10 to 12 mm posterior to the limbus. A cellulose surgical eye spear soaked in 0.5 mg/mL MMC was applied for 5 minutes in the quadrant before plate placement, except for four Ahmed eyes that received a 3-minute application. The tube was trimmed and inserted into the anterior chamber through a 23-gauge needle track at the limbus, usually under a limbal-based scleral flap. Banked, alcohol-preserved human sclera was sewn over the proximal tube at the limbal edge.

Postoperative Management

Postoperative management for all implants consisted of topical corticosteroid (prednisolone acetate 1% or dexamethasone phosphate 0.1%) drops every 2 hours while awake, dexamethasone 0.1% ointment at bedtime, topical atropine sulfate 1% every 6 to 24 hours, and a topical antibiotic. The steroids were tapered over 3 months. Antiglaucoma medications were used if needed with the Molteno implants until tube ligature release and later with all of the implants if the IOP increased above target levels.

Data Analysis

Results were analyzed using a Kaplan-Meier life-table analysis to calculate survival curves.[8] This method takes into account variable follow-up times and patient dropout. The Kaplan-Meier analysis supplies the probability that a given operation will succeed beyond discrete postoperative time points, excludes patients from further analysis once they have failed, and assumes that patients who drop out have approximately the same probability of success as those who have remained in the study.

Success was defined as avoiding an IOP <6 mm Hg or >15 mm Hg after 90 days follow-up (with or without glaucoma medications) on two consecutive occasions 1 month apart, additional filtration surgery, or tube removal. This criterion was selected because IOPs in the lower teens are probably required to prevent further damage in cases of advanced glaucoma. A second, more

traditional definition of success was chosen: avoiding an IOP <6 mm Hg or >21 mm Hg after 90 days follow-up on two consecutive occasions 1 month apart, the addition of glaucoma medication, additional filtration surgery, or the removal of the implant. Kaplan-Meier life table analysis was also used to determine the rate of visual acuity loss, defined as loss of two or more Snellen lines on two consecutive occasions one month apart after 90 days follow-up.

Many studies have used a more traditional cross-sectional analysis despite the disadvantages of this method.[3,9] Therefore, for comparison, we performed cross-sectional analysis at 1 year (nearest visit, at least 0.5 years, but no more than 1.5 years) of patients with at least 6 months of follow-up data and who avoided additional glaucoma filtration surgery or tube removal.

Information was collected on age, race, diagnosis, preoperative IOP, and preoperative medication use. Differences in baseline characteristics between the three treatment groups were examined using Fisher exact test for categorical variables and an ANOVA F test for continuous variables. Univariate Cox proportional hazards models were used to examine the effects of these preoperative characteristics on success. Cox models were also used to assess the effect of the three different implants on success. Results were expressed in terms of the hazard ratio (or instantaneous relative risk), which is the relative risk of an event occurring during a short period. Under the Cox model, this ratio is assumed to be constant over time.

RESULTS

Patient Characteristics

Preoperative demographics are shown in Table 1. No statistically significant difference was detected in age, diagnosis, IOP, or number of glaucoma medications used at the time of surgery, although the Ahmed patients had higher mean IOPs and number of medications. No aphakic or pseudophakic patients received Krupin implants, but this finding was not statistically significant.

TABLE 1. *Demographic and preoperative characteristics*

Variable	Molteno	Krupin	Ahmed	*P*
Number of patients	27	13	13	
Age (%)				>0.10
<40 y	19	31	23	
40–70 y	52	38	54	
>70 y	30	31	23	
Diagnosis (%)				>0.10
Aphakia/pseudophakia	19	0	23	
Neovascular	30	38	38	
Failed filter/other	52	62	38	
IOP*	33 (13)	31 (11)	38 (16)	>0.10
Medication*	2.9 (1.3)	3.1 (1.0)	3.7 (0.9)	>0.10

Groups were compared with ANOVA F test for continuous variables and Fisher exact test for categorical variables, testing the hypothesis that the groups were the same.

IOP, intraocular pressure.

* Data are mean (SD).

Univariate Cox models for the four preoperative characteristics are presented in Table 2. Patients 40 years and older were more likely to succeed ($P = 0.044$) the criterion of 15 mm Hg. Eyes requiring fewer preoperative glaucoma medications were significantly more likely to succeed both the 15-mm Hg criterion ($P = 0.037$) and the 21-mm Hg criterion ($P = 0.036$).

Incomplete follow-up data were obtained for two Ahmed patients (both of whom died), one Krupin patient (who was lost to follow-up), and eight Molteno patients (two of whom moved, four of whom died, one who refused further care, and one who lives in India and was lost to follow-up). Two Molteno eyes failed the 21-mm Hg criterion when the patient started oral acetazolamide or neptazane for inadequately controlled glaucoma in the other eye.

Implant Success Rates

Univariate Cox models revealed that the type of implant significantly affected the success rates for the 15-mm Hg criterion ($P = 0.029$) (Table 3). The Molteno implant had the highest chance of success, followed by the Krupin and the Ahmed, respectively. Using the 21-mm Hg criterion, the Molteno implant similarly had the highest probability of success, followed by the Krupin, and lastly the Ahmed, although this difference was not statistically significant ($P = 0.079$).

Analyses using Cox models showed that the Molteno group was significantly more likely to meet the 15-mm Hg criterion than the Ahmed group ($P = 0.003$, log-rank test) (Fig. 1), and there was a similar but statistically insignificant relationship using the 21-mm Hg criterion ($P = 0.06$) (Fig. 2). The Molteno group also appeared to have a higher, but not statistically significant, probability of success than the Krupin group using the 15-mm Hg criterion ($P > 0.08$). Similarly, the Krupin group appeared to have a higher, but not statistically significant, chance of success than the Ahmed group using the 15-mm Hg criterion ($P > 0.10$)

Success rates with the 15-mm Hg criterion at 1 year were 80% (95% CI, 66–97%) for the Molteno, 39% (95% CI, 19–77%) for the Krupin, and 35% (95% CI, 15–82%) for the Ahmed implant (Fig. 1). Success rates with the 21-mm Hg criterion at 1 year were 57% (95% CI, 40–80%) for the Molteno, 46% (95% CI, 26–83%) for the Krupin, and 25% (95% CI, 9–67%) for the Ahmed implant (Fig. 2).

TABLE 2. *Cox models: effects of baseline covariates on success*

Variable	15 ≥ IOP ≥ 6 with medications*		21 ≥ IOP ≥ 6 without medications†	
	Hazard ratio‡ (95% CI)§	*P* (Wald test)	Hazard ratio‡ (95% CI)§	*P* (Wald test)
Age (y)		0.044		0.22
<40	1.00		1.00	
40–70	0.38 (0.17–0.87)		0.50 (0.22–1.10)	
>70	0.37 (0.14–0.95)		0.56 (0.23–1.37)	
Diagnosis		0.51		0.065
Aphakia/pseudophakia	1.00		1.00	
Neovascular	2.11 (0.59–7.47)		0.38 (0.13–1.09)	
Failed filter, other	1.85 (0.51–5.91)		0.95 (0.38–2.35)	
Preoperative IOP (per 10 mm Hg)	1.02 (0.77–1.35)	0.89	0.77 (0.56–1.04)	0.09
Preoperative medications	1.40 (1.02–1.91)	0.037	1.38 (1.02–1.87)	0.036

IOP, intraocular pressure.

* Failure defined as IOP <6 or >15 mm Hg on two consecutive observations at least 30 days apart after 90 days of follow-up, or the addition of glaucoma medication, further surgery, or implant removal.

† Failure defined as IOP <6 or >21 mm Hg on two consecutive observations at least 30 days apart after 90 days of follow-up, further surgery, or implant removal.

‡ Estimated hazard ratio (instantaneous relative risk) from Cox proportional hazards model. For categorical variables, reference category is listed with a hazard ratio of 1.00.

§ 95% confidence interval for log hazard ratio transformed back to hazard ratio score.

Cross-sectional Analysis: Intraocular Pressure

Cross-sectional analysis at 1 year of patients who avoided additional glaucoma filtration surgery or tube removal revealed that the average IOP for the Molteno and Krupin groups was below 15 mm Hg (Table 4). On average, the Molteno implant required the fewest medications, followed by the Krupin and the Ahmed, respectively, although the difference was not statistically significant ($P = 0.079$).

Loss of Two or More Lines of Visual Acuity

The Kaplan-Meier life-table estimates revealed that the Ahmed group was significantly less likely to lose two or more lines of visual acuity than the Molteno group ($P = 0.0029$, log-rank test) or the Krupin group ($P = 0.0014$, log-rank test) (Table 5). None of the eyes in the Ahmed group showed a loss of two or more lines of visual acuity throughout their course. Two of the Molteno eyes and one of the Krupin eyes lost visual acuity due to worsening corneal decompensation after tube-corneal touch, which was caused by a hypotony-related flat anterior chamber in the early postoperative period. Four of the Molteno eyes lost more than one line of visual acuity due to worsening diabetic retinopathy, two eyes to worsening cataracts, one eye to a retinal detachment, and one eye for unknown reasons. One of the Krupin eyes lost more than one line of visual acuity due to worsening diabetic retinopathy, one to glaucoma, one to cataract, one to age-related macular degeneration, one to endophthalmitis, and two for unknown reasons.

TABLE 3. *Effect of implant on success with two failure criteria*

Implant	15 ≥ IOP ≥ 6 with medications*		21 ≥ IOP ≥ 6 without medications†	
	Hazard ratio‡ (95% CI)§	*P* (Wald test)	Hazard ratio‡ (95% CI)§	*P* (Wald test)
Molteno	1.0	0.029	1.0	0.079
Krupin	2.04 (0.90–4.61)		1.65 (0.78–3.50)	
Ahmed	3.34 (1.32–8.48)		2.68 (1.12–6.44)	

IOP, intraocular pressure.

* Failure defined as IOP <6 mm Hg or >15 mm Hg on two consecutive observations at least 30 days apart after 90 days of follow-up, or the addition of glaucoma medication, further surgery, or implant removal.

† Failure defined as IOP <6 mm Hg or >21 mm Hg on two consecutive observations at least 30 days apart after 90 days of follow-up, further surgery, or implant removal.

‡ Estimated hazard ratio from Cox proportional hazards model. Reference category is patients receiving Molteno implant. This is the risk of failure for patients receiving the Ahmed or Krupin valve relative to patients receiving a Molteno implant.

§ 95% confidence interval for log hazard ratio transformed back to ratio scale.

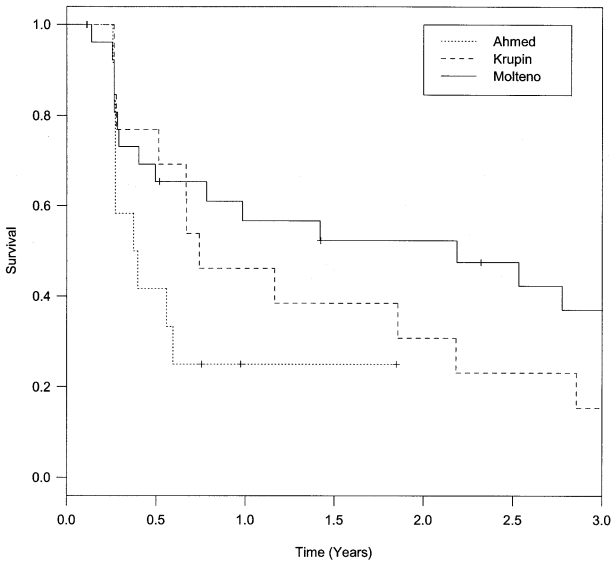

FIG. 1. Life-table success rate versus postoperative follow-up time. Failure was defined as an IOP >15 mm Hg or <6 mm Hg on two consecutive occasions 1 month apart after 90 days follow-up, reoperation for glaucoma, or implant removal. Log-rank tests: Molteno versus Ahmed ($P = 0.003$), Molteno versus Krupin ($P > 0.08$), and Ahmed versus Krupin ($P > 0.10$).

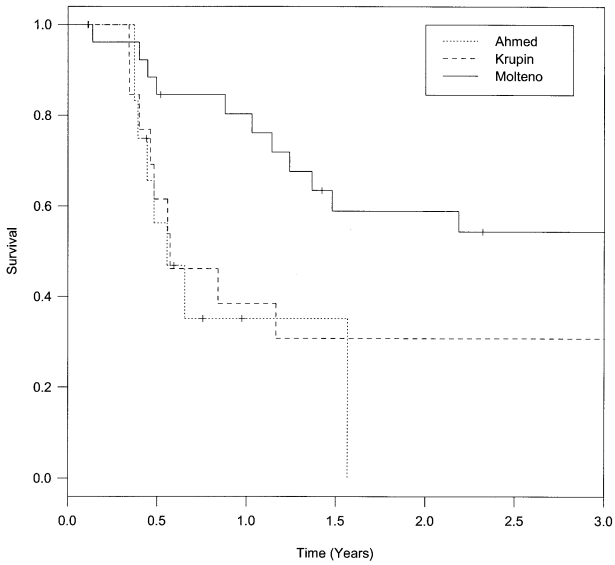

FIG. 2. Life-table success rate vs postoperative follow-up time. Failure defined as an IOP >21 or <6 mm Hg on two consecutive occasions 1 month apart after 90 days follow-up, the addition of glaucoma medication, reoperation for glaucoma, or implant removal. Log rank tests: Molteno versus Ahmed ($P = 0.06$), Molteno versus Krupin ($P > 0.10$), and Ahmed versus Krupin ($P > 0.10$).

Complications

None of the Ahmed patients suffered a complication requiring reoperation with incisional or laser surgery (Table 6). However, 13 of the 27 (48%) Molteno patients had complications requiring reoperation, 11 of which occurred during the first 3 months after surgery. The most common causes for reoperation (5 of 13) were hypotony-related complications, notwithstanding temporary ligature of the tube. All hypotony-related complications occurred in the first 3 months, in some patients prior to ligature release and in others only after the ligature release. When hypotony-related complications occurred prior to ligature release, they occurred within the first week and appeared to be caused by an overly large venting slit or flow of aqueous around the tube at its passage into the anterior chamber. Reoperations for hypotony-related complications included various combinations of drainage of suprachoroidal effusions, anterior chamber reformation, and repeat ligation of the tube. Complications occurring more than 3 months after surgery included a vitrectomy to remove a dense anterior vitreal membrane, and a penetrating keratoplasty for worsened corneal decompensation. One tube was removed as part of the treatment of endophthalmitis.

Seven of the thirteen Krupin patients (54%) had complications requiring surgical intervention, all of which occurred in the first 90 days after surgery, and five of which were hypotony related. Reoperations for hypotony-related complications included combinations of anterior chamber reformation, ligation of the tube, and drainage of suprachoroidal effusions. The two other re-

TABLE 4. *Cross-sectional analysis at 1 year**

	Molteno	Krupin	Ahmed	*P*
Number of patients	21	13	10	
IOP†	13.8 (4.8)	13.6 (5.7)	17.4 (4.5)	>0.10
Medication use (%)	29	31	60	>0.10
Number of medications†	0.48 (0.87)	0.77 (1.24)	1.50 (1.51)	0.079

Groups were compared with ANOVA, F test, or χ^2 test.
IOP, intraocular pressure.
* Cohort of patients with at least one follow-up visit after 0.5 years, analyzing the nearest observation to 1.0 years, within 6 months.
† Data are mean (SD).

TABLE 5. *Loss of visual acuity at 1 year**

	Number at risk	Loss of ≥2 lines (95% CI)
Molteno	10	52.4 (26.4, 69.2)
Krupin	5	58.3 (18.6, 78.7)
Ahmed	8	0.0

Log rank tests (*P*): Molteno versus Ahmed, 0.0029; Molteno versus Krupin, 0.24; Ahmed versus Krupin, 0.0014.

* Kaplan-Meier estimates of loss of ≥2 lines of acuity on two consecutive occasions 1 month apart after 90-day follow-up visit.

operations were performed to repair a wound dehiscence and to replace a melting scleral graft with a fresh corneal graft.

The total number of hypotony-related complications, including those not requiring surgical intervention, was also calculated. Four of the thirteen patients in the Ahmed group (31%), 10 of 13 patients in the Krupin group (77%), and 14 of the 27 patients in the Molteno group (52%) suffered from these complications, which included serous suprachoroidal effusions, hypotony maculopathy, and flat anterior chamber.

The total number of eyes with an IOP <5 mm Hg, a traditional definition of hypotony, during the first 3 months postoperatively was calculated. Hypotony, by this definition, occurred in none of the 13 Ahmed patients, 6 (46%) of the 13 Krupin patients, and 13 (48%) of the 27 Molteno patients.

DISCUSSION

Results of this retrospective study suggest that patients who receive a double-plate Molteno implant with MMC are more likely to maintain an IOP between 5 and 15 mm Hg than those who receive an Ahmed implant with MMC. The Ahmed implant with MMC, however, produced fewer complications and less vision loss than the Molteno or Krupin implants with MMC.

Prior studies have shown that patients who receive an Ahmed implant have a 77% to 78% chance of maintaining an IOP <22 mm Hg with or without medications at 1 year,[7,10] and patients who received a Krupin implant have a 66% chance of maintaining an IOP between 5 and 22 mm Hg.[11] However, comparison of the current study with prior studies is difficult because the criteria used for success (IOP <15 mm Hg or <21 mm Hg without medication) in this study are more stringent. These criteria were chosen because they better reflect the current practice of selecting IOP targets in the lower teens for patients with advanced glaucoma. Differences in the performance of implant devices tend to be masked when success criteria incorporate higher targets and allow use of glaucoma medications.[3] In addition, the present analysis used patient data from all visits rather than just data at 1 year, which provided more opportunity for failure to occur.

The double-plate Molteno was able to maintain a low IOP more often than the Ahmed implant, most likely because the double-plate Molteno has greater surface area than the Ahmed implant. The Ahmed implant and the Krupin have a planar surface area of 185 and 184 mm^2, respectively, compared with 270 mm^2 for the double-plate Molteno implant. A number of studies of glaucoma implants in humans, rabbits, and monkeys, have observed that more surface area available for filtration results in more filtration of aqueous and lower IOP.[12,13] Furthermore, in a prospective, randomized trial, it has been observed that single-plate Molteno implants

TABLE 6. *Complications requiring reoperation*

	Molteno % (N)	Krupin % (N)	Ahmed % (N)
Hypotony related*	19 (5/27)	38 (5/13)	0 (0/13)
Endophthalmitis	4 (1/27)	0 (0/13)	0 (0/13)
Tube exposure	0 (0/27)	8 (1/13)	0 (0/13)
Wound dehiscence	4 (1/27)	8 (1/13)	0 (0/13)
Suprachoroidal hemorrhage	4 (1/27)	0 (0/13)	0 (0/13)
Tenon tube block	4 (1/27)	0 (0/13)	0 (0/13)
Tube malposition	4 (1/27)	0 (0.13)	0 (0/13)
Blocked sclerostomy†	4 (1/27)	0 (0.13)	0 (0/13)
Vitreal membrane‡	4 (1/27)	0 (0/13)	0 (0/13)
Corneal decompensation‡	4 (1/27)	0 (0/13)	0 (0/13)
Total	48 (13/27)	54 (7/13)	0 (0/13)

* Flat anterior chamber, suprachoroidal effusions.

† Blocked sclerostomy in two-stage procedure.

‡ Complications that occurred late (more than 3 months after surgery); all other complications occurred early (within the first 3 months after surgery).

result in higher intraocular pressures and fewer hypotony-related complications than double-plate Molteno implants.[14]

Despite having the same surface area, the Krupin implant appeared to lower intraocular pressure better than the Ahmed valve. Thus, using the criterion of 15 mm Hg with or without medications, the Krupin implant was more likely to succeed than the Ahmed, although this difference was not statistically significant ($P > 0.10$). The Molteno implant, however, was more likely to succeed than the Krupin at the 15-mm Hg criterion, although again this finding was statistically insignificant ($P > 0.08$).

One explanation for this result is that the Krupin implant has a less restrictive valve, resulting in greater initial flow of aqueous than the Ahmed or the ligated Molteno. The aqueous flow may modify the formation of the fibrous capsule by inhibiting fibroblast proliferation and function,[14] or by physically stretching the tissue, resulting in increased filtration of aqueous per unit of surface area. It is also possible that the lower exposure time of four Ahmed eyes to MMC (3 vs. 5 minutes) could have had an effect. In addition, the small size of this series also could have resulted in a selection bias.

Although the Ahmed implant may be less effective in lowering IOP than the other two implants, results of this study suggest that the Ahmed implant may cause fewer serious complications than the other two implants and may result in better retention of visual acuity. None of the Ahmed eyes required reoperation because of complications, and none lost two or more lines of acuity. Approximately half of the Molteno and Krupin patients required reoperations because of complications, and half lost two or more lines of acuity. These results differ from those of prior studies that have found rates of visual acuity loss ranging between 20% and 30% for Ahmed, Krupin, and Molteno implants.[6,7,10,11,14]

The increased safety of the Ahmed implant found in this study may relate in part to the restrictiveness of its valve,[15] which prevented complications of hypotony even when MMC was used. In contrast, most of the complications in the Krupin group (71%) were related to hypotony, which may be attributable to the use of MMC, and a less restrictive valve. This observation suggests caution in the use of MMC with the Krupin implant. Another reason for the safety of the Ahmed implant compared with the Molteno may be the relative simplicity of placement. Only one quadrant of dissection is required, and no ligature, venting slits, or rip-cord sutures are needed.

Use of MMC with implants is controversial. Our prior work has suggested better long-term performance with MMC in double-plate Molteno implants.[3,4] However, many of the complications in this study related to early hypotony may have been due to use of MMC.

This study is limited by its retrospective, nonrandomized nature, relatively short-term follow-up data for the Ahmed valves, and by relatively small numbers. Within these limitations, this study indicates that the double-plate Molteno implant with MMC may provide a better chance for patients to maintain an IOP between 5 and 15 mm Hg when compared with the Ahmed implant with MMC. However, this study also found that the Ahmed implant produced fewer complications and less vision loss than the Molteno or Krupin implants. Our observations underscore a need for prospective, randomized studies directly comparing the most popular glaucoma implants.

REFERENCES

1. Suner IJ, Greenfield DS, Miller MP, et al. Hypotony maculopathy after filtering surgery with mitomycin C: incidence and treatment. *Ophthalmology* 1997;104:207–15.
2. Rosenberg LF, Krupin T. Implants in glaucoma surgery. In: Ritch R, Shields MB, Krupin T, eds. *The Glaucomas*, 2nd ed. St. Louis: CV Mosby; 1996:1783–807.
3. Perkins TW, Çardakli UF, Eisele JR, et al. Adjunctive mitomycin C in Molteno implant surgery. *Ophthalmology* 1995;102:91–7.
4. Perkins TW, Gangnon R, Ladd W, Kaufman PL, Libby CM. Molteno implant with mitomycin C: intermediate-term results. *J Glaucoma* 1998;7:86–92.
5. Krupin T, Podos SM, Becker B, Newkirk JB. Valve implants in filtering surgery. *Am J Ophthalmol* 1980;89:338.
6. The Krupin Eye Valve Filtering Surgery Study Group. Krupin eye valve with disk for filtration surgery. *Ophthalmology* 1994;101: 651–8.
7. Coleman AL, Hill R, Wilson RM, Choplin N, et al. Initial clinical experience with the Ahmed Glaucoma Valve Implant. *Am J Ophthalmol* 1995;120:23–31.
8. Fisher LD, Van Belle G. *Biostatistics: A Methodology for the Health Sciences.* New York: John Wiley and Sons; 1996:801–22.
9. Perkins TW, Fisher M. When is "final"? *Ophthalmology* 1998;105: 395–6.
10. Ayyala RS, Zurakoxski D, Smith JA, Monshizadeh R, et al. A clinical study of the Ahmed Glaucoma Valve Implant in advanced glaucoma. *Ophthalmology* 1998;105:1968–76.
11. Fellenbaum PS, Almeida AR, Minckler DS, Sidoti PA, et al. Krupin disk implantation for complicated glaucomas. *Ophthalmology* 1994;101:1178–82.
12. Prata JA, Santos RCR, LaBree L, Minckler DS. Surface area of glaucoma implants and perfusion flow rates in rabbit eyes. *J Glaucoma* 1995;4:274–80.
13. Wilcox M, Minckler DS, Ogden TE. Pathophysiology of artificial aqueous drainage in primate eyes with Molteno implants. *J Glaucoma* 1994;3:140–51.
14. Heuer DK, Lloyd MA, Abrams DA, et al. Which is better? One or two? A randomized clinical trial of single-plate versus double-plate Molteno implantation for glaucomas in aphakia and pseudophakia. *Ophthalmology* 1992;99:1512–9.
15. Francis BA, Cortes A, Chen J, Alvarado JA. Characteristics of glaucoma drainage implants during dynamic and steady-state flow conditions. *Ophthalmology* 1998;105:1708–14.