Effectiveness of 360-degree trabeculotomy in childhood glaucoma.

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Abstract

Purpose: To evaluate the effectiveness and safety of illuminated-microcatheter-assisted trabeculotomy in patients with childhood glaucoma.

Patients and methods: A retrospective chart review was conducted to identify all patients with childhood glaucoma who underwent ab externo illuminated microcatheter-assisted trabeculotomy by a single surgeon between October 2013 and June 2017. Baseline characteristics, pre- and post-operative intraocular pressures (IOP), medication use, surgical details and complications were recorded. Success was defined as an IOP>5 mmHg and<21 mmHg (with or without medications), without the need for additional glaucoma surgery.

Results: A total of 28 eyes of 22 patients were included with an average age of 3.90 ± 5.24 years (median 1 year). Mean IOP reduction after trabeculotomy was 14.0 ± 6.92 mmHg, representing a 43.7% overall reduction (p<0.001). IOP was successfully reduced by at least 20% from baseline in 24 of 28 eyes (85.7%). Medication usage decreased by 1.07 ± 1.18 medications (p<0.001). Patients with primary congenital glaucoma (PCG) had a higher success rate (92.3%) compared to patients with other types of glaucoma (53.3%) at their most recent follow up (average 21.8 months, range 6-53 months). Seven eyes (25%) required additional surgery for inadequate IOP control, all of which underwent placement of a glaucoma drainage implant.

Conclusion: Illuminated microcatheter-assisted trabeculotomy is an effective and safe option for the management of childhood glaucoma. Patients with PCG have significantly higher success rates compared to patients with other types of childhood glaucoma.

Keywords: Childhood Glaucoma, Trabeculotomy, Surgical outcomes.

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Introduction

Childhood glaucoma is an important cause of blindness worldwide and represents a heterogeneous group of diseases with variable treatment responses [1,2]. While surgery is the definitive treatment for childhood glaucoma, primary congenital glaucoma (PCG) patients typically show higher surgical success rates than either glaucoma following cataract surgery (GFCS) or juvenile open-angle glaucoma (JOAG) patients [3-5]. A 360-degree suture trabeculotomy was first described by Smith in 1960, [6] and later refined by Beck and Lynch through the use of a 6-0 polypropylene suture [7].

Although success rates for this procedure ranged from 87% to 93%, the surgery carried the risk of false passage and misdirection into the suprachorioidal space [8-10]. The use of an illuminated microcatheter (iTrack Microcatheter, Ellex, Adelaide, Australia) minimizes the risks traditionally associated with the procedure. Preliminary studies have reported success rates of up to 92% [11-15] for PCG patients, and more moderate success rates for GFCS patients (62-72%) [16,17].

This study evaluated the efficacy and safety of an ab externo trabeculotomy with the assistance of the iTrack 250A microcatheter in children with various types of childhood glaucoma at a single tertiary care center.

Patients and Methods

This study protocol was approved by the Institutional Review Board of Icahn School of Medicine at Mount Sinai and conformed to the requirements of the US Health Insurance Portability and Privacy Act of 1996. The medical records of all patients 0-18 years of age who underwent ab externo trabeculotomy at the New York Eye and Ear Infirmary of Mount Sinai hospital between 2013 and 2017 were identified and reviewed. Patients with less than 6 months of follow-up were excluded.

Preoperative intraocular pressure (IOP) was calculated as the mean of three IOP measurements (Tonopen, Reichert) recorded immediately after general anesthesia induction. A complete examination under anesthesia, including gonioscopic evaluation of the anterior chamber angle, was performed in all cases.

Data obtained from the medical record included demographic information, glaucoma diagnosis, pre- and post-operative IOP, number of pre- and post-operative glaucoma medications, cup-to-disc ratio, and intraoperative complications. Postoperative data were collected at postoperative day 1, week 1, month 1, and every three months thereafter. Patients with PCG were then separated from all other types of glaucoma in a subset analysis.

Surgical success was defined as an IOP>5 mm Hg and<21 mm Hg (with or without glaucoma medications), without the need for additional glaucoma surgery. Eyes were classified as failures if the IOP remained above 21 mm Hg at 2 consecutive follow-up visits or the patient required additional surgical intervention to control IOP. Eyes were classified as failures at the date upon which the second elevated IOP was recorded or the date upon which additional surgery was performed. Only patients with six months or longer follow-up were included in the calculation of surgical success.

Analysis was performed using R version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria). Kaplan-Meier survival analysis was used to calculate success over time. The log-rank test was used to compare success over time between PCG and other glaucoma groups. Two-tailed unpaired t-tests were used to compare IOP and other demographics between PCG and other glaucoma eyes. Statistical significance was set at 0.05.

Surgical procedure

All 360-trabeculotomy procedures were performed in a standard fashion by a single surgeon (JFP). A 4 mm temporal conjunctival peritomy was initially made, followed by creation of a 3.5 × 3.0 mm trapezoidal, partial-thickness scleral flap. Flap dissection was continued until clear cornea was reached.

A radial incision was made at the base of the flap with a #75 blade and deepened until the external wall of Schlemm's canal was incised (Figure 1A). Once the canal was identified, its location was confirmed by passing a 6-0 nylon suture into its lumen for several clock hours. The iTrack Microcatheter (Ellex, Adelaide, Australia) was then prepared and inserted through one side of the incision into the canal and gradually advanced circumferentially (Figure 1B). The illuminated tip confirmed proper positioning in the canal (Figure 1C).

The catheter tip was retrieved after passing though the opposite side of the incision site. Viscoelastic was injected into the anterior chamber through a paracentesis track. The 2 ends of the microcatheter were then grasped and pulled in a purse-string manner (Figure 1D). Once the majority of the canal was treated, one end of the catheter was released and the other end pulled through the incision site, leaving a small segment of tissue in place beneath the radial incision to prevent iris prolapse out of the wound. The incision was then closed with an interrupted 10-0 nylon suture.

The scleral flap was secured with 4 interrupted 8-0 polyglactin sutures. The conjunctival edge was re-approximated at the limbus and closed with a combination of interrupted and running 8-0 polyglactin sutures. Subconjunctival antibiotic and steroid were injected and the eye was patched after placement of antibiotic/steroid ointment.

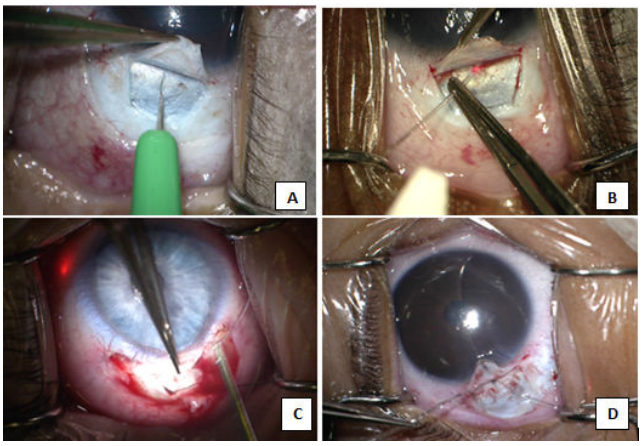

Figure 1. (A) After a trapezoidal scleral flap is made, a radial incision is made to identify Schlemm's canal, (B) The illuminated iTrack Microcatheter is prepared and inserted through one side of the incision into Schlemm's canal, (C) The iTrack Microcatheter is advanced circumferentially and the illuminated tip is visualized during its passage through the entire 360-degrees of the angle to ensure its proper position, (D) The catheter tip is retrieved on the opposite side of the incision and both sides of the catheter are pulled in a purse-string manner.

Results

A total of 28 eyes of 22 patients were included in the study. Thirteen eyes were diagnosed with PCG, 6 with glaucoma associated with acquired conditions, 5 with glaucoma following cataract surgery, and 4 with glaucoma associated with non-acquired systemic disease (2 with Sturge Weber, Phacomatosis pigmentovascularis, Persistent fetal vasculature).

As shown in Table 1, the majority of patients were male (53.6%), and the average age at time of surgery was 3.90 ± 5.24 years (median 1 year). Mean preoperative IOP was 31.0 ± 5.62 mm Hg using an average of 2.00 ± 1.39 medications. At postoperative month one, mean IOP was 14.82 ± 4.30, on an average of 0.58 ± 0.87 medications (Figure 2).

At most recent follow-up, mean IOP was 17.0 ± 5.01 mm Hg using an average of 0.93 ± 1.30 medications, representing a 45.2% overall reduction in IOP ($p<0.001$) and a 53.5% reduction in medications. The average time of follow-up was 21.8 months (range 6 - 53 months).

The IOP was successfully controlled at most recent follow up in 20 of the 28 eyes, representing an overall success rate of 71.4%. The average pre-operative cup-to-disc ratio was 0.67 ± 0.20, and the average pre-operative axial length was 22.11 ± 2.14 mm. At the most recent follow-up, the average cup-to disc ratio was 0.61 ± 0.26, and the average axial length was 23.77 ± 2.94 mm.

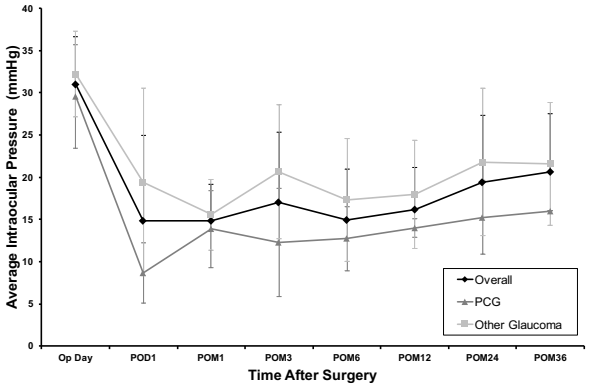

Figure 2. Plot of average IOP over time following trabeculotomy for overall, primary congenital glaucoma (PCG), and other glaucoma eyes. POD signifies post-operative day, and POM signifies post-operative month.

Table 1. Comparison of demographics, intraocular pressure, number of medications, and percent success for overall, primary congenital glaucoma, and other glaucoma eyes.

Value (mean ± standard deviation or %)	Overall (n=28)	Primary Congenital Glaucoma (n=13)	Other Glaucoma (n=15)
Age at Surgery (years)	3.9 ± 5.24	1.1 ± 1.44	6.12 ± 6.31
Length of Follow-Up (months)	21.84 ± 13.36	22.5 ± 14.3	21.3 ± 13
Pre-op IOP (mm Hg)	31 ± 5.62	29.42 ± 6.01	32.23 ± 5.06
Last Follow-Up IOP (mm Hg)	17 ± 5.01	15.54 ± 4.93	18.07 ± 5.3
IOP Reduction (mm Hg)	14 ± 6.92	13.88 ± 6.48	14.17 ± 8.03
% IOP Reduction	43.68 ± 18.59	45.97 ± 17.03	41.93 ± 21.49
# Medications Pre-Op	2 ± 1.39	-	2.87 ± 1.19
# Medications at Last Follow-Up	0.93 ± 1.3	0.31 ± 0.85	1.47 ± 1.41
# Medications Decreased	1.07 ± 1.18	0.92 ± 0.76	1.4 ± 1.45
% Success	71.40%	92.30%	53.30%

Complications occurred in 14 eyes (50.0%), the most common of which was early post-operative hyphema (11 eyes; 39.3%). Seven eyes (25%) required additional surgery for inadequate IOP control – all of which underwent subsequent placement of a glaucoma drainage implant (GDI). GDI placement was performed at an average of 11 months after trabeculotomy (range 2-36 months).

A separate analysis was performed using data from only one eye (first operated eye) of patients who underwent bilateral trabeculotomy (Table 2). 22 eyes of 22 patients were included. Mean preoperative IOP was 31.63 ± 5.87 mm Hg, using an average of 2.08 ± 1.28 medications. At most recent follow-up, mean IOP was 16.54 ± 5.18 mm Hg using an average of 0.75 ± 1.15 medications, representing a 47.7% overall reduction in IOP ($p<0.001$). The success rate of the ab externo 360-degree trabeculotomy was found to 86.4% at 6 months, 68.8% at 12 months, and 53.8% at 24 months as shown in Table 3 and on the Kaplan-Meier survival plot (Figure 3). When success rates from only the first operated eye were compared to success rates of all eyes, no significant difference was found ($p=0.825$).

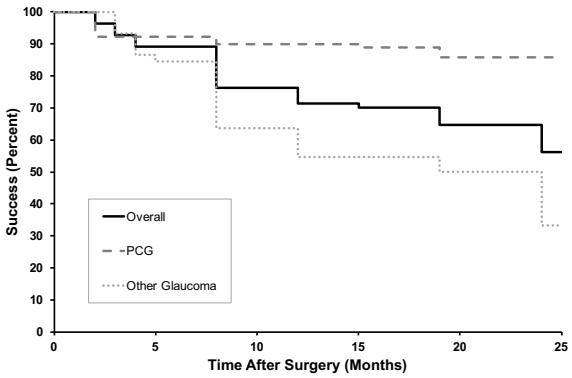

Figure 3. Kaplan-Meier survival curve for trabeculotomy success for overall, primary congenital glaucoma (PCG), and other glaucoma eyes.

Table 2. Success of first operated eye for overall, primary congenital glaucoma (PCG), and other glaucoma (OG) patients, over various post-operative time periods.

Post-Operative Time	Overall:% Successful	Primary Congenital Glaucoma (PCG): % Successful	Other Glaucoma (OG): % Successful
6 months (n=10 PCG; n=12 OG)	86.40%	90%	83.30%
12 months (n=6 PCG; n=9 OG)	68.80%	85.70%	55.60%
24 months (n=4 PCG; n=8 OG)	53.80%	80%	37.50%
Log-rank test for primary congenital glaucoma and other glaucoma: P<0.001, X2 27.25, df 1			

In 26 of 28 (82%) eyes Schlemm's canal was successfully cannulated with the catheter through the entire 360 degrees of the angle. In one of the eyes with glaucoma following cataract surgery in which the catheter was unable to be threaded through the entire circumference of the canal, a cut down was made and the distal end of the catheter was retrieved to allow for treatment of 90 degrees of the canal in one direction; a standard trabeculotomy using a Harm's trabeculotome was performed to treat the opposite side. In one patient with glaucoma associated with non-acquired systemic disease, the catheter repeatedly veered off outside the canal away from the limbus and the decision was made to perform a standard trabeculotomy. Both of these cases in which less than 360

degrees were cannulated eventually required placement of GDI for IOP control.

Table 3. Success of all operated eyes for overall, primary congenital glaucoma (PCG) and other glaucoma (OG) eyes, over various post-operative time periods.

Post-Op Time	Overall: % Successful	Primary Congenital Glaucoma (PCG): % Successful	Other Glaucoma (OG): % Successful
6 months (n=13 PCG; n=15 OG)	89.30%	92.30%	86.70%
12 months (n=9 PCG: n=11 OG)	71.40%	90%	54.50%
24 months (n=6 PCG; n=9 OG)	56.30%	85.70%	33.30%
Log-rank test for primary congenital glaucoma and other glaucoma: P<0.001, X2 37.63, df 1			

Additional analysis was performed on the subset of eyes with PCG (n=13). When compared with the sub-group of eyes with all other glaucoma diagnoses (n=15), the PCG group had a significantly lower age at the time of surgery (p=0.009) and significantly fewer preoperative glaucoma medications (p<0.001). Other demographic data were not significantly different between the two groups (Table 1). Overall, success rates were significantly higher in the PCG group (92.3%) when compared to the group with all other glaucoma diagnoses (53.3%, p=0.019). This remained true when comparing these groups at each time point as demonstrated by the Kaplan-Meier survival curves (log-rank test, p<0.001) (Figure 3). The eyes with PCG had lower average IOP than other glaucoma patients at each post-operative time point as shown in Figure 3. Only one eye in the PCG group compared to 6 eyes in the other glaucoma group required subsequent GDI placement for IOP control.

Discussion

PCG is the most common type of childhood glaucoma and treatment is primarily surgical [18]. Goniotomy and trabeculotomy have high success rates and a low risk of complications [3-5]. Conventional goniotomy is performed *via* an ab interno approach under direct gonioscopic view with a variety of instruments used to incise the trabecular meshwork and inner wall of Schlemm's canal (23-g needle, microvitreoretinal blade, or goniotomy knife). A trabeculotome is used to cannulate and disrupt the inner wall of Schlemm's canal and trabecular meshwork *via* an ab externo approach in standard trabeculotomy. Only a portion of the anterior chamber angle can be treated with either of these procedures. More recently, 360-degree suture trabeculotomy has been described and allows treatment of the entire circumference of the angle *via* an ab externo approach, regardless of corneal clarity. This approach avoids multiple surgeries to treat the entire angle and has demonstrated good outcomes [8-10]. The introduction of an illuminated microcatheter to cannulate Schlemm's canal has the benefit of reducing misdirection of the suture into the anterior chamber, suprachoroidal, or subretinal space, as the location of the catheter tip can be visually tracked as it is passed through Schlemm's canal. This approach allows for more consistent treatment of 360 degrees of the angle with good control and visualization of the catheter's position throughout the procedure. Additionally, injection of a viscoelastic substance through the distal tip of the catheter during the procedure allows for expansion of the canal and easier passage of the catheter tip in some patients.

Prior retrospective studies of the illuminated microcatheter technique for trabeculotomy [19-21] have shown the procedure to be successful in lowering IOP without severe complications. When compared to goniotomy [22] or conventional trabeculotomy [23] in PCG patients, the 360-degree microcatheter technique has been found to have a higher success rate and produce a greater decrease in IOP. Reported success rates for the procedure in PCG patients have ranged from 81% to 93%, after follow-up periods of 6 months to 2 years [11-15, 22]. Neustein and Beck reported a success rate of 74.8% for the procedure in PCG patients with a follow-up of ten years [23]. Significantly higher success rates and better visual acuity compared with conventional trabeculotomy were noted. While all surgeries in this study were performed ab-externo, Grover et al. [24] reported adequate IOP control and minimal complications for an ab-interno gonioscopy-assisted transluminal trabeculotomy (GATT) procedure in adult patients [24] as well as pediatric patients with PCG and JOAG [25]. A major advantage of the external approach is the ability to perform the procedure in the setting of poor corneal clarity which is often encountered in children with PCG and other forms of glaucoma.

Overall, success rates for angle surgery have been shown to be higher for PCG than other childhood glaucomas [3-5]. Our results (92.3% success for PCG vs. 53.3% success for other glaucoma) are consistent with this. The reason for the higher success rates in PCG is likely explained by its pathogenesis. In children with PCG, the primary pathology is at the level of the trabecular meshwork, whereas in other forms of childhood glaucoma, the downstream collector channels and/or episcleral venous pressure may contribute more significantly to the overall resistance to outflow. Many children with GFCS as well as glaucoma associated with non-acquired systemic disease eventually require either trabeculectomy with miotmycin-C or GDI placement. Despite the lower rate of successful IOP control in children with glaucoma diagnoses other than PCG, the lower incidence of severe postoperative complications with 360-degree trabeculotomy relative to trabeculectomy and GDI surgery, may still make this procedure the preferred initial surgical intervention in this patient group. The success rate of trabeculectomy with mitomycin-C has been reported to range from 50-87% [4,5] in congenital glaucoma and JOAG patients and is associated with a significant risk of bleb-related infection and hypotony. The widely variable outcomes with trabeculectomy are likely related to the aggressive wound healing response in children as well as difficulty with postoperative management. Successful control of IOP following GDI placement for childhood glaucoma has been reported to vary between 33%-93% beyond 1 year of

follow-up. Tube-related complications such as malposition, migration/retraction, and obstruction are more common in the pediatric population than in adults and result in significant morbidity.

This study is limited by its retrospective nature, small sample size, and limited follow-up time. Additionally, this study reports the outcomes from a single surgeon and thus may not be representative of surgeons with variable levels of experience. The study does not include data on visual acuity or amblyopia, which might strengthen the analysis.

Conclusion

In conclusion, this study demonstrates that illuminated-microcatheter-assisted trabeculotomy is an effective and safe option for the management of childhood glaucoma. Patients with PCG have higher success rates compared to patients with all other types of childhood glaucoma. Further studies with larger sample size, longer follow-up period, and more comprehensive visual function evaluation are warranted to investigate the long-term efficacy of this intervention.

References

1. Beck A, Chang TCP, Freedman S (2013) Childhood Glaucoma: Definition, classification, differential diagnosis. In: Weinreb RN, Grajewski AL, Papadopoulos M, Grigg J, Freedman S, eds. The 9th Consensus Report of the World Glaucoma Association, Kugler Publications, Amsterdam, Netherlands, pp: 3-14.
2. Kong L, Fry M, Al-Samarraie M, et al. An update on progress and the changing epidemiology of causes of childhood blindness worldwide. J AAPOS. 2012;16:501–7.
3. Biglan AW. Glaucoma in children: are we making progress? J AAPOS. 2006;10:7–21.
4. Chen TC, Chen PP, Francis BA, et al. Pediatric glaucoma surgery: a report by the American Academy of Ophthalmology. Ophthalmology. 2014;121:2107–15.
5. Chang I, Caprioli J, Ou Y. Surgical management of pediatric glaucoma. Dev Ophthalmol. 2017;59:165-78.
6. Smith R. A new technique for opening the canal of schlemm: preliminary report. Br J Ophthalmol. 1960;44:370-3.
7. Beck AD, Lynn MJ, Crandall J, et al. Surgical outcomes with 360-degree suture trabeculotomy in poor-prognosis primary congenital glaucoma and glaucoma associated with congenital anomalies or cataract surgery. J AAPOS. 2011;15:54–8.
8. Neely DE. False passage: a complication of 360 degrees suture trabeculotomy. J AAPOS. 2005;9:396-7.
9. Mendicino ME, Lynch MG, Drack A, et al. Long-term surgical and visual outcomes in primary congenital glaucoma: 360 degrees trabeculotomy versus goniotomy. J AAPOS. 2000;4:205-10.
10. Verner-Cole EA, Ortiz S, Bell NP, et al. Subretinal suture misdirection during 360 degrees suture trabeculotomy. Am J Ophthalmol. 2006;141:391-2.
11. Lim ME, Neely DE, Wang J, et al. Comparison of 360-degree versus traditional trabeculotomy in pediatric glaucoma. J AAPOS. 2015;19:145-9.
12. Shi Y, Wang H, Yin J, et al. Microcatheter-assisted trabeculotomy versus rigid probe trabeculotomy in childhood glaucoma. Br J Ophthalmol. 2016;100:1257-62.
13. Temkar S, Gupta S, Sihota R, et al. Illuminated microcatheter circumferential trabeculotomy versus combined trabeculotomy-trabeculectomy for primary congenital glaucoma: a randomized controlled trial. Am J Ophthalmol. 2015;159:490-7.
14. Celea C, Dragosloveanu S, Pop M, et al. Comparison of 360-degree circumferential trabeculotomy and conventional trabeculotomy in primary pediatric glaucoma surgery: Part 1. J Pediatr Ophthalmol. Strabismus 2016;53:357-64.
15. El Sayed Y, Gawdat G. Two-year results of microcatheter-assisted trabeculotomy in paediatric glaucoma: a randomized controlled study. Acta Ophthalmol. 2017;95:713-9.
16. Dao JB, Sarkisian SR, Freedman SF. Illuminated microcatheter-facilitated 360-degree trabeculotomy for refractory aphakic and juvenile open-angle glaucoma. J Glaucoma. 2014;23:449-54.
17. Lim ME, Dao JB, Freedman SF. 360-Degree Trabeculotomy for Medically Refractory Glaucoma Following Cataract Surgery and Juvenile Open-Angle Glaucoma. Am J Ophthalmol. 2017:175:1-7.
18. Hoguet A, Grajewski A, Hodapp E, Chang TCP. A retrospective survey of childhood glaucoma prevalence according to Childhood Glaucoma Research Network classification. Indian J Ophthalmol. 2016;64:118–23.
19. Sarkisian SR. An illuminated microcatheter for 360-degree trabeculotomy in congenital glaucoma: a retrospective case series. J AAPOS. 2010;14:412-6.
20. Girkin CA, Marchase N, Cogen MS. Circumferential trabeculotomy with an illuminated microcatheter in congenital glaucomas. J Glaucoma. 2012;21:160-3.
21. Saheb H, Ahmed II. Micro-invasive glaucoma surgery: current perspectives and future directions. Curr Opin Ophthalmol. 2012;23:96–104.
22. Girkin CA, Rhodes L, McGwin G, et al. Goniotomy versus circumferential trabeculotomy with an illuminated microcatheter in congenital glaucoma. J AAPOS. 2012;16:424-7.
23. Neustein RF, Beck AD. Circumferential trabeculotomy versus conventional angle surgery: comparing long-term surgical success and clinical outcomes in children with primary congenital glaucoma. Am J Ophthalmol. 2017;183:17-24.
24. Grover DS, Godfrey DG, Smith O, et al. Gonioscopy-assisted transluminal trabeculotomy, ab interno trabeculotomy: technique report and preliminary results. Ophthalmology. 2014;121:855-61.
25. Grover DS, Smith O, Fellman RL, et al. Gonioscopy assisted transluminal trabeculotomy: an ab interno circumferential trabeculotomy for the treatment of primary

congenital glaucoma and juvenile open angle glaucoma. Br J Ophthalmol. 2015;99:1092–6.

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