REVIEW ARTICLE

A Review of Canaloplasty in the Treatment and Management of Glaucoma

Isabella V Wagner[1], Caleb Towne[2], Marie C Saade[3], P Connor Lentz[4], Arianna Rashedi[5], Pranav Vasu[6], Nithya Boopathiraj[7], Leticia Checo[8], Chelsey Krambeer[9], Darby D Miller[10], Syril Dorairaj[11]

Received on: 01 June 2024; *Accepted on:* 25 June 2024; *Published on:* 10 July 2024

Abstract

Aim: To review the published literature evaluating the safety and efficacy outcomes of canaloplasty performed in the treatment of glaucoma.

Background: Canaloplasty is a nonpenetrating glaucoma procedure involving combined 360° circumnavigation and viscodilation of Schlemm's canal. The procedure may be performed under an ab externo (with tensioning suture) or ab-interno (conjunctiva-sparing) approach. Given the wide variety of glaucoma procedure types and approaches, further investigation into the role of canaloplasty in ophthalmological practice is warranted. The objectives of this narrative review are to synthesize the existing literature in order to investigate indications, safety and efficacy outcomes, and the optimal place of canaloplasty in glaucoma treatment and management.

Review of results: A total of 60 articles were included in this review. Both ab externo and ab-interno canaloplasty (ABiC) were found to be significantly effective at reducing intraocular pressure (IOP) and glaucoma medication burdens in patients with mild-to-moderate open-angle glaucoma (OAG). These findings remained consistent regardless of phacoemulsification status. ABiC was found to exhibit a safety profile favorable compared to trabeculectomy and comparable to minimally invasive trabecular bypass implants.

Conclusion: Canaloplasty is a nonpenetrating surgical intervention that is highly effective in treating patients with mild-to-moderate OAG across a large variety of clinical scenarios.

Clinical significance: These findings support the clinical use of canaloplasty in ophthalmological practice, clarify its patient profile, and compare procedural outcomes to other minimally invasive glaucoma surgery (MIGS) devices on the market.

Keywords: Canaloplasty, Glaucoma, Glaucoma surgery, iTrack, OMNI surgical system.

Journal of Current Glaucoma Practice (2024): 10.5005/jp-journals-10078-1442

Background

History of Canaloplasty

Minimally invasive glaucoma surgeries (MIGS) defined a new era in the history of glaucoma. One of the most common methods described in this group of procedures is canaloplasty. This technique has evolved over time and continues to accumulate evidence regarding its long-term efficacy and safety, making it a viable option for the majority of patients with open-angle glaucoma (OAG).[1–4]

For many years, the "gold standard" for treating glaucoma surgically was trabeculectomy, a technique first described by Dr Cairns in 1968.[5] However, it has been associated with severe complications, including bleb leaks and hypotony.[6] Attempts to create a safer procedure with an acceptable risk-to-benefit balance resulted in a technique called viscocanalostomy, described by Dr Robert Stegmann in South Africa in 1999.[7] It is a procedure in which the Schlemm's canal is identified under a scleral flap and then dilated using high viscosity sodium hyaluronate, thereby creating microperforations in its wall.[8] In the context of the viscocanalostomy procedure, the iTrack™ microcatheter (Nova Eye Medical) was first introduced to the glaucoma surgical armamentarium in 2005.[9] With the realization that the intraocular pressure (IOP)-lowering effect in viscocanalostomy is mostly due to the viscodilation of Schlemm's canal and consequent disruption of its inner structure, Dr Stegmann improved his initial technique to a nonincisional, bleb-independent version, based on permanently distending Schlemm's canal with the iTrack microcatheter. This new method was entitled canaloplasty.[10–12] On 18th July 2008, the iTrack microcatheter received clearance from the Food and Drug Administration (FDA) for catheterization and viscodilation of Schlemm's canal to reduce IOP in adult patients with OAG.[13] Early after its invention and application, canaloplasty enabled surgeons to achieve postoperative pressures comparable to those obtained with traditional invasive surgeries

[1,2,4,7–11]Department of Ophthalmology, Mayo Clinic, Jacksonville, Florida, United States of America

[3]Department of Nephrology, University of Texas Southwestern Medical Center, Dallas, Texas, United States of America

[5]Department of Medicine, Lake Erie College of Osteopathic Medicine, Bradenton, Florida, United States of America

[6]Department of Medicine, Creighton School of Medicine, Phoenix, Arizona, United States of America

Corresponding Author: Syril Dorairaj, Department of Ophthalmology, Mayo Clinic, Jacksonville, Florida, United States of America, Phone: +19049532377, e-mail: syrildorairaj@gmail.com

How to cite this article: Wagner IV, Towne C, Saade MC, *et al.* A Review of Canaloplasty in the Treatment and Management of Glaucoma. J Curr Glaucoma Pract 2024;18(2):79–85.

Source of support: Nil

Conflict of interest: Dr Syril Dorairaj is associated as the Associate Managing Editor of this journal and this manuscript was subjected to this journal's standard review procedures, with this peer review handled independently of this editorial board member and his research group.

but with a superior safety profile.[2] Moreover, canaloplasty demonstrated its advantage over trabeculectomy in terms of postoperative quality of life and patient satisfaction.[14]

In brief, for the past 15 years, canaloplasty was not only established as a reliable and safe modality in glaucoma but also as a procedure that would decrease the heavy burden of postoperative care on both the patient and the physician.

Materials and Methods

Literature Search

A PubMed search for all literature from 1st January 1990 to 30th September 2023, was carried out using the following keywords—"canaloplasty" or "ab-externo canaloplasty" or "ab-interno canaloplasty" or "iTrack microcatheter" or "VISCO360" or "OMNI surgical system" or "trabeculotomy and canaloplasty" or "trabecular bypass and canaloplasty." All article types [including case reports, case series, review articles, clinical articles, and randomized controlled trials (RCT)] were included. This search yielded a total of 462 articles. All articles and their references were scrutinized, and 402 articles were deemed not relevant for the purpose of this review. A total of 60 articles were included in this review.

Review of Results

Safety and Efficacy

Ab-externo Canaloplasty

Canaloplasty first started as an ab-externo procedure. This technique aims to enhance aqueous outflow by inserting a microcatheter inside the circumference of Schlemm's canal, injecting a viscoelastic material, and finally closing with a suture that applies tension to the inner wall of Schlemm's canal, producing distention within the trabecular meshwork.[15]

The first study investigating the efficacy and safety of this procedure was published in 2009 by Lewis et al.[16] This multicenter prospective study included 127 patients with a postsurgical follow-up of 2 years. Canaloplasty was demonstrated as effective and safe in treating patients with OAG. The IOP and medication use were significantly reduced compared to baseline at all time points, with no serious complications reported.[16] Numerous studies followed, all aiming to evaluate the clinical efficacy profile of this procedure. In fact, based on the available literature, the percentage IOP reduction resulting from canaloplasty ranges between 25 and 56%, with a medication reduction of 53–88% (Table 1).[17–23] This variability in the success rate of this procedure is due to several external factors, including the duration of follow-up, the number of subjects, the competency of the surgeons, variability between patients, and patient comorbidities. Few studies have compared the efficacy of phacoemulsification alone to both ab-externo canaloplasty and phacoemulsification. In a study by Arthur et al., the IOP lowering effect was significantly more profound in the group combining both procedures.[24] The ab-externo canaloplasty is a challenging procedure, and the learning curve is associated with the procedure's performance. A recent study by Zhang et al. investigated the clinical application of the carbon dioxide (CO_2) laser as a knife in ab externo canaloplasty and compared this technique to the conventional procedure method.[25] The CO2 laser-assisted ablation of the outer wall of Schlemm's canal resulted in fewer postsurgical complications and was shown to be less technically challenging than the conventional technique.

As for classic nonpenetrating glaucoma surgeries, ab-externo canaloplasty is best performed in patients with OAG and contraindicated in eyes with angle-closure glaucoma (ACG), chronic angle closure, posttraumatic glaucoma, neovascular glaucoma, and in patients with previous ocular surgeries that would prevent circumferential catheterization of Schlemm's canal (Table 2).[26,27] The safety of this technique has been steadily investigated for patients with OAG over the past decade. However, the incidence of these post-surgical adverse outcomes is minimal. The most commonly reported side effects are the occurrence of microhyphema on the first postoperative day (1.6–6.1%), IOP spikes >30 mm Hg (1.6–8.7%), Descemet's membrane detachment (1.6–6.1%), and other adverse outcomes including hypotony, choroidal effusion, exposed closure suture with epiphora, eyelid edema, and erythema.[18,28] Canaloplasty offers significantly fewer postsurgical complications and simplified follow-up compared to classical trabeculectomy.[29,30]

Throughout the years, this procedure has been shown to be safe and effective. Based on the available data in the literature, ab-externo canaloplasty has been successful in reducing IOP as well as the use of hypotensive medications. It is associated with a low rate of surgical complications, which in most cases resolve on their own without requiring medical intervention.[31]

Table 1: Intraocular pressure and medication reductions from standalone to combined (with phacoemulsification) ab-externo canaloplasty in eyes with mild-to-moderate OAG

Ab-externo canaloplasty	*IOP reductions*	*Medication reductions*
Standalone[16–19,22]	30–34%	53–76%
Canaloplasty with phacoemulsification[16–18,22,23]	41–56%	64–88%
All eyes combined regardless of phacoemulsification status[16,18,20,21]	25–36%	56–74%

Table 2: Contraindications to canaloplasty surgery

Contraindications
Eyes with an extensive surgical history precluding circumferential catheterization of Schlemm's canal
Angle-closure (narrow angle) glaucoma or chronic angle closure
Posttraumatic glaucoma (with recession of angle)
Neovascular glaucoma

Ab-interno Canaloplasty and Viscocanalostomy

In recent years, ab-interno canaloplasty (ABiC) with iTrack, the VISCO360® ViscoSurgical System (Sight Sciences), or the OMNI® Surgical System (Sight Sciences) has become favored over ab-externo canaloplasty due to its comparable safety profile and efficacy achieved with a minimally invasive, conjunctiva-sparing approach.[21]

iTrack Microcatheter

ABiC with iTrack is a popular canaloplasty procedure targeting Schlemm's canal. It involves passing a lit catheter 360° through Schlemm's canal, dilating it. Then, during removal, ophthalmic viscoelastic device (OVD) is injected into the canal, preserving the dilation. Due to its relative simplicity, ABiC is considered one of the better options in canaloplasty treatment.[32] In regard to its efficacy, when comparing iTrack standalone and iTrack with phacoemulsification, the standalone procedure shows significant capability. With a starting IOP of 20.9 mm Hg for the standalone cohort and 20.0 mm Hg for the combined cohort, Gallardo recorded a mean IOP decrease of 7.7 mm Hg (–36.8%) and 6.5 mm Hg (–32.5%),

respectively, at 36 months.[33] Additionally, no serious postoperative complications were observed, with 95.5% of patients maintaining an IOP below 17 mm Hg.[33] Köerber and Ondrejka investigated iTrack's efficacy with or without phacoemulsification over a 4-year period and noted an IOP decrease of 5.2 mm Hg (–26.2%) at 48 months, as well as a decrease in glaucoma medication dependency from 1.9 at baseline to 0.9 medications (–52.6%), across all eyes.[34] When evaluated separately, there were no significant differences between groups.[34] Khaimi evaluated 36-month outcomes of iTrack ABiC with or without phacoemulsification in patients with well-controlled baseline IOPs (mean: 14.42 + 2.2 mm Hg) and reported mean percent decreases in IOP and number of antiglaucoma medications of 1.6% and 61% in all eyes, respectively.[35] Similarly to Koerber and Ondrejka, no significant differences were seen when the study groups were analyzed separately. Additional studies have reported percent IOP reductions from 1 to 40% and decrease in medication burdens from 30 to 97% under a time period of 12–48-months (Table 3).[36–41] Under these datasets, iTrack appears to be a strong canaloplasty option both in combination with phacoemulsification and as a standalone procedure. The iTrack™ Advance (Nova Eye Medical) is a recent advancement of the microcatheter and received FDA clearance in 2023. The new device features a spatulated cannula tip and a handheld injector that employs an actuator mechanism, eliminating the need for forceps required in the original procedure (Fig. 1). An intraoperative image of the iTrack Advance can be seen in Figure 2.

VISCO360 Visocosurgical System

VISCO360 (Sight Sciences) is similar to iTrack in that it involves dilation of Schlemm's canal utilizing OVD but differs in the manner of catheter insertion. It is inserted 180° from its point of insertion and OVD is injected. The catheter is then retracted and flipped over to penetrate the other 180°, completing a full 360° procedure.[32] Results of clinical use are relatively uncommon for this device, but those published show promising results. In a 12-month study by Ondrejka and Koerber, an initial mean IOP of 24.6 ± 7.1 mm Hg was reduced to 14.6 ± 2.8 mm Hg (–41.0%), with a decrease in glaucoma medication dependence by 1.9 ± 1.1 medications (–90.5%), and 85% of eyes became medication-free.[42] Very few patients involved demonstrated adverse effects past the 1 week mark, though one patient had IOP levels >10 mm Hg higher than baseline following the procedure.[42] In a later study (2020), less significant results were found. At 12 months, Tracer et al. reported a mean IOP decrease from 22 to 17.2 mm Hg (–21.8%), but an increase in medication use from 0.9 to 1.0 (+11.1%) in eyes with a baseline IOP >18 mm Hg.[43] The study also evaluated eyes with a baseline IOP <18 mm Hg (mean: 14.3 mm Hg) and observed an increase in mean IOP by 1.1 mm Hg (+7.7%), but a decrease in the number of glaucoma medications from 1.1 to 0.6 (–45.5%).[43] As the two studies report conflicting results and there are few other reports of the VISCO360 in clinical use, it would be prudent to wait for additional research on the device before drawing conclusions regarding its effectiveness. However, the use of VISCO360 has been largely replaced by the OMNI surgical system due to its higher potential to reduce IOP.

Table 3: Intraocular pressure and medication reductions of standalone and combined (with phacoemulsification) ABiC using the iTrack microcatheter in eyes with mild-to-moderate OAG

iTrack ABiC	*IOP reductions*	*Medication reductions*
Standalone[33–37]	1*–37%	30–62%
Canaloplasty with phacoemulsification[33–37,41]	1*–40%	48–80%
All eyes combined regardless of phacoemulsification status[33–40]	2*–35%	53–97%

*Khaimi[35] analyzed eyes with well-controlled baseline IOPs (mean: 14.4 mm Hg)

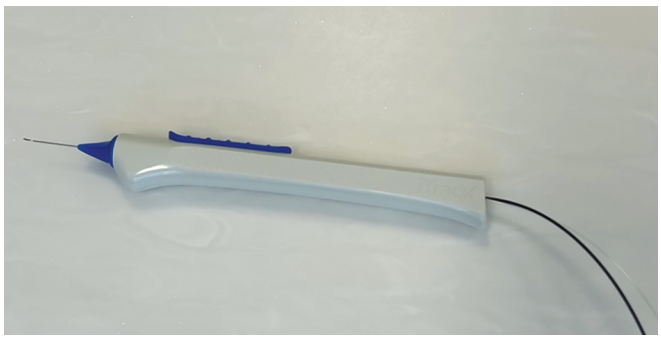

Fig. 1: Image of iTrack advance device

OMNI Surgical System

The OMNI surgical system is a combined canaloplasty and trabeculotomy device indicated for the treatment of OAG. Essentially combining the TRAB360 (Sight Sciences) and VISCO360 approaches, OMNI involves passing a microcatheter through Schlemm's canal in 180° segments with concurrent OVD delivery, then tearing through the trabecular meshwork to perform a trabeculotomy. The extent to which canaloplasty and trabeculotomy are performed is adjustable and dependent upon the surgeon's preferences. The OMNI system received FDA clearance in 2017, and studies have shown it is highly effective in reducing IOP and glaucoma medication dependence, with a good safety profile. The ROMEO and GEMINI studies are the most well-known multicenter reports on OMNI and are frequently cited as strong evidence supporting the use of the device. The ROMEO study retrospectively assessed 72 patients with mild-to-moderate-stage OAG and a baseline IOP of >18 mm Hg (group I) or <18 mm Hg (group II).[44–46] At 12 months, phacoemulsification with OMNI surgery was found to decrease mean IOP from 21.9 ± 3.7 mm Hg to 15.1 ± 3.7 mm Hg (–31.1%) in group I, and from 14.1 ± 2.5 mm Hg to 13.4 ± 3.1 mm Hg (–5.0%) in group II, with 5% of eyes experiencing IOP spikes immediately following surgery.[44] Decreases in medication dependency by 23.5 and 35.0% were seen in group I and group II, respectively.[44] Adverse events were

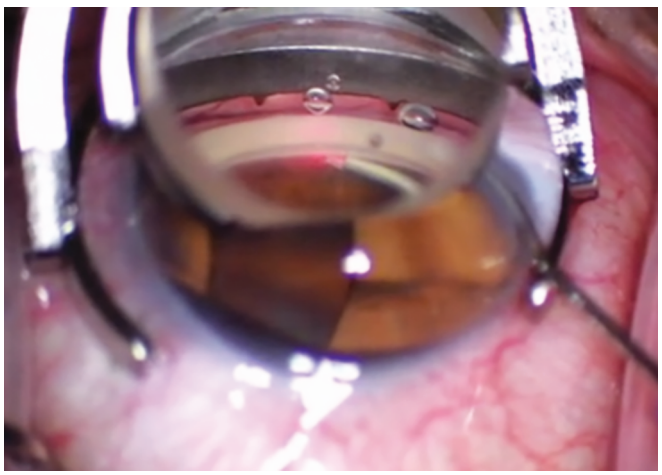

Fig. 2: Intraoperative image of iTrack advance device

kept to a minimum among all patients, with mild inflammation occurring in 11% of eyes.[44] At 24 months, IOP was 15.6 mm Hg (–28% from baseline) and 13.7 mm Hg (–4.2% from baseline) in groups I and II, with respective medication decreases of 15.0 and 14.7%.[45] No device-related complications were observed, although 8.3% of eyes required a glaucoma surgical reintervention.[45] These findings remained consistent in pseudophakic eyes.[46] The GEMINI study is a prospective trial evaluating 120 patients receiving combined phacoemulsification and OMNI surgery.[47] At 12 months, the mean IOP and number of antiglaucoma medications were reduced from 23.8 ± 3.1 mm Hg to 15.6 ± 4.0 mm Hg (–35%) and from 1.8 ± 0.9 to 0.4 ± 0.9 (–80%), respectively. The safety profile was excellent, with no eyes requiring secondary surgical reinterventions.[47]

Other studies have reported similar efficacy outcomes in eyes receiving combined OMNI with phacoemulsification and standalone OMNI surgery. Toneatto et al. retrospectively analyzed eyes with mild-to-moderate OAG that underwent OMNI surgery with or without combined phacoemulsification. In the standalone group, mean IOP decreased from 23.0 to 15.6 mm Hg (–32.2%) after 12 months, with a reduction in glaucoma medication dependency from 3.0 to 2.0 medications (–33.3%).[48] Likewise, in the phacoemulsification-OMNI group, mean IOP decreased from 21.5 to 14.1 mm Hg (–34.4%) at 12 months, with a decrease in IOP lowering medications from 3.4 to 1.9 medications (–44.1%).[48] There was no significant difference in IOP reduction between groups, and OMNI surgery was found to be safe and effective, regardless of phacoemulsification status.[48] Additional OMNI studies within the literature report IOP reductions between 4 and 40% and medication reductions of 15–80% over 12–24-months (Table 4).[49–51] The OMNI® Ergo-Series (Sight Sciences) represents the latest advancement of the device, featuring an improved cannula tip profile and a removable viscoelastic luer connector (Fig. 3). An intraoperative image of the OMNI Ergo-Series can be seen in Figure 4.

Table 4: Intraocular pressure and medication reductions of standalone and combined (with phacoemulsification) ABiC using the OMNI surgical system in eyes with mild-to-moderate OAG

OMNI ABiC	*IOP reductions*	*Medication reductions*
Standalone[45,46,48–51]	15–40%	15–74%
Canaloplasty with phacoemulsification[44,45,47,48,50,51]	4*–40%	24–80%
All eyes combined, regardless of phacoemulsification status[50,51]	29–36%	32–75%

*Hirsch et al.[44] analyzed eyes with well-controlled baseline IOPs (mean: 14.1 mm Hg)

Fig. 3: Image of OMNI Ergo-Series device

In Comparison to Other Procedures Targeting Schlemm's Canal

Trabeculectomy

Studies comparing canaloplasty to the "gold standard" of glaucoma surgery are abundant within the literature. Liu et al. performed a meta-analysis of eight studies (437 eyes) and found that trabeculectomy led to a more substantial decrease in IOP by 12 months, with a lower success rate and higher complication rate compared to canaloplasty (e.g., hypotony, choroidal detachment, bleb leaks, hemorrhaging).[5] Klink et al. distributed a satisfaction questionnaire to 327 patients (trabeculectomy: 152; canaloplasty: 175) and found that canaloplasty patients reported a higher quality of life in relation to postoperative mood, with comparably lower rates of stress and visual/nonvisual symptoms.[14] In a retrospective comparative case series of 79 eyes, Ayyala et al. determined that trabeculectomy produced a more marked reduction in IOP ($p < 0.05$) and higher rates of choroidal effusions (trabeculectomy: 17%, canaloplasty: 0%; $p = 0.02$), although hyphema was more common in canaloplasty patients (trabeculectomy: 2%, canaloplasty: 21%; $p < 0.01$).[19] Matlach et al. performed a retrospective trial (39 eyes) comparing eyes undergoing trabeculectomy or canaloplasty with concomitant phacoemulsification and found that phaco-canaloplasty patients required more medications but less intensive postoperative care.[23] In a longitudinal cohort study (68 eyes), Garris et al. found that patients who received trabeculectomy (with mitomycin C) achieved a significantly lower IOP at 24 months (trabeculectomy: 12.2 mm Hg, canaloplasty: 14.9 mm Hg; $p = 0.03$), with comparable failure rates and preservation of visual acuity in both groups.[30] A prospective RCT performed by Matlach et al. (62 eyes) supported all aforementioned findings and noted significantly higher rates of corneal erosion (trabeculectomy: 43.8%, canaloplasty: 3.3%; $p < 0.001$) and late (>90 days postsurgery) hypotony (trabeculectomy: 18.8%, canaloplasty: 0%; $p = 0.03$) in trabeculectomy patients through 24 months.[52] The authors concluded that canaloplasty should be considered for patients requiring moderate IOP reduction due to its lower complication rates and less stringent postoperative care compared to trabeculectomy.[52]

Trabecular Bypass Implants

Canaloplasty has been compared to various trabecular bypass implants, such as the iStent (Glaukos Corporation) and Hydrus

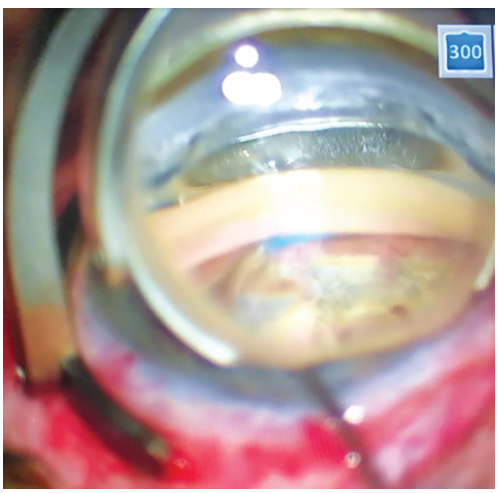

Fig. 4: Intraoperative image of OMNI Ergo-Series device

Microstent (Ivantis). In a meta-analysis of 10 RCTs, Golaszewska et al. determined that both iStent implantation and canaloplasty have similar safety profiles and achieve comparable reductions in IOP and glaucoma medication usage. However, additional high-quality RCTs are needed to confirm these findings.[31] In accordance with this conclusion, these same authors performed a prospective RCT involving 92 eyes, comparing first-generation phaco-iStent implantation to ab-externo phaco-canaloplasty.[53] Around 6-month outcomes showed no significant differences in the hypotensive effect between both procedures, but there was significantly higher endothelial cell loss in eyes receiving phaco-iStent bypass implantation, suggesting a favorable safety profile for phaco-canaloplasty surgery.[53] In a retrospective comparative case series, Gandolfi et al. compared Hydrus implantation to ab-externo canaloplasty and determined that both procedures were comparably safe, with slightly increased clinical success in the canaloplasty group at 24 months, though not statistically significant.[54] Studies have also shown canaloplasty to be effective when combined with Hydrus Microstent implantation.[55,56] Dickinson et al. reported that combined phacoemulsification, Hydrus implantation, and canaloplasty surgery resulted in greater reduction in medication use and similar lowering of IOP compared to phacoemulsification and Hydrus implantation alone for up to 6 months.[55] Creagmile et al. investigated the clinical outcomes of combined Hydrus implantation and ABiC with OMNI and found the procedure to be well tolerated in a heterogeneous group of 8 phakic patients, through 12 months.[56] There is a need for additional randomized trials comparing canaloplasty to trabecular bypass implants and other MIGS devices.

Discussion

Comparison of Different Surgical Approaches

Given the option of different surgical approaches (ab-externo vs ab-interno) that can be applied and the variety of devices that can be used (iTrack, VISCO360, OMNI) when performing a canaloplasty, there is a need to discuss which method is best for both the surgeon and patient. Gallardo et al. retrospectively compared ab-externo canaloplasty to ABiC (with iTrack) in 12 subjects over 12 months and did not find significant differences in IOP reduction (ab-externo: −25.4%, ab-interno: −25.4%; $p > 0.05$) or glaucoma medication reduction (ab-externo: −62.5%, ab-interno: −66.7%; $p > 0.05$) between groups, suggesting both procedures have similar efficacy profiles.[21] Conversely, in their 12-month study of eyes undergoing ABiC (with OMNI), Toneatto et al. compared their surgical success outcomes (>25% IOP reduction from baseline to <18 mm Hg on no IOP-lowering medications and without surgical reinterventions) to an ab-externo canaloplasty study conducted by Lewis et al.[18] and found their results to be inferior to those achieved with ab-externo canaloplasty (Standalone group: 40 vs 68.1%; combined group: 67.9 vs 77.8%).[48] The authors concluded that this was likely due to the tensioning suture during ab-externo canaloplasty, which provides a more substantial distension.[48] However, the inherent disadvantages associated with ab-externo canaloplasty (e.g., longer operation time, conjunctival suturing, placement of tensioning suture, intrascleral lake formation, higher complication rate) would potentially negate its slight increase in efficacy when compared to ABiC.

Considerations for Patient Selection

Canaloplasty is indicated for patients with mild-to-moderate OAG and without a history of narrow angles and/or any secondary glaucoma types. The procedure is particularly suitable in eyes requiring moderate pressure reduction to an achievable IOP,[52] as canaloplasty avoids significant complications and the strict postoperative regimen seen following bleb-based procedures. However, exceptions have been found within the literature, suggesting canaloplasty can be considered across a broad range of glaucoma types and severities. For instance, promising results have been shown in the treatment of patients with severe/advanced glaucoma[37,57,58] and in eyes with extensive surgical histories.[59,60] Gallardo compared 24-month outcomes of iTrack canaloplasty in eyes with mild-to-moderate glaucoma to eyes with severe glaucoma and reported comparable reductions in IOP (mild-to-moderate: 32.7%; severe: 33%).[37] Likewise, Patel and Reiss compared the safety and efficacy of iTrack canaloplasty in 24 eyes with severe glaucoma to 48 eyes with mild-to-moderate glaucoma and reported similar outcomes, with a comparable percentage in each group achieving >20% IOP reduction (mild-to-moderate: 53%; severe: 60%) but inferior medication reduction observed in the severe cohort (mild-to-moderate: 40%; severe: 16%).[57] Yadgarov et al. retrospectively analyzed 24-month clinical outcomes of OMNI canaloplasty in 63 eyes with advanced glaucoma of various subtypes and reported IOP and glaucoma medications reductions of 26.9 and 7.5%, respectively.[58] In accordance with the aforementioned studies, eyes with advanced glaucoma achieved a comparable IOP value but required a higher number of glaucoma medications than mild-to-moderate eyes.[58] Under these results, ABiC appears to be an effective surgical option for patients with all stages of glaucoma due to its ability to significantly lower IOP and delay the need for invasive bleb-based procedures, regardless of its slight compromise in medication burden-reducing efficacy. iTrack and OMNI canaloplasty has also been shown to be safe and effective in postkeratoplasty patients[59] and eyes with prior trabecular micro-bypass stenting,[60] respectively. These findings can have several implications on the use of canaloplasty in patients with severe/advanced glaucoma or in eyes that are not surgically naive, but additional RCTs are required to confirm these findings.

Conclusion

Canaloplasty has indeed emerged as a minimally invasive procedure that has largely supplanted traditional incisional surgeries in treating mild-to-moderate OAG. Current literature supports its safety and effectiveness, demonstrating its capability to reduce IOP and the dependency on glaucoma medications significantly. Importantly, canaloplasty offers a safety profile that is favorable compared to bleb-based procedures like trabeculectomy and is comparable to other MIGS devices. These characteristics highlight canaloplasty as a valuable option in the management of OAG, providing patients and surgeons with an effective treatment alternative.

Acknowledgments

We would like to thank Ms Joyce Baker for her many contributions to the Department of Ophthalmology, Mayo Clinic, Jacksonville, Florida, United States of America. Without her, the publication of this article would not be possible.

References

1. Brusini P. Canaloplasty in open-angle glaucoma surgery: a four-year follow-up. Sci World J 2014;2014:469609. DOI: 10.1155/2014/469609
2. Harvey BJ, Khaimi MA. A review of canaloplasty. Saudi J Ophthalmol 2011;25(4):329–336. DOI: 10.1016/j.sjopt.2011.08.003
3. Bull H, von Wolff K, Körber N, et al. Three-year canaloplasty outcomes for the treatment of open-angle glaucoma: European study results. Graefes Arch Clin Exp Ophthalmol 2011;249(10):1537–1545. DOI: 10.1007/s00417-011-1728-3
4. Grieshaber MC, Fraenkl S, Schoetzau A, et al. Circumferential viscocanalostomy and suture canal distension (canaloplasty) for whites with open-angle glaucoma. J Glaucoma 2011;20(5):298–302. DOI: 10.1097/IJG.0b013e3181e3d46e
5. Liu H, Zhang H, Li Y, et al. Safety and efficacy of canaloplasty versus trabeculectomy in treatment of glaucoma. Oncotarget 2017;8(27):44811–44818. DOI: 10.18632/oncotarget.14757
6. 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(5):804.e1–814.e1. DOI: 10.1016/j.ajo.2011.10.024
7. Stegmann R, Pienaar A, Miller D. Viscocanalostomy for open-angle glaucoma in black African patients. J Cataract Refract Surg 1999;25(3):316–322. DOI: 10.1016/s0886-3350(99)80078-9
8. Wagdy FM. Canaloplasty versus viscocanalostomy in primary open angle glaucoma. Electron Physician 2017;9(1):3665–3671. DOI: 10.19082/3665
9. Konopińska J, Mariak Z, Rękas M. Improvement of the safety profile of canaloplasty and phacocanaloplasty: a review of complications and their management. J Ophthalmol 2020;2020:8352827. DOI: 10.1155/2020/8352827
10. Byszewska A, Konopińska J, Kicińska AK, et al. Canaloplasty in the treatment of primary open-angle glaucoma: patient selection and perspectives. Clin Ophthalmol 2019;13:2617–2629. DOI: 10.2147/OPTH.S155057
11. Xie MS, Zheng YZ, Huang LB, et al. Experimental circumferential canaloplasty with a new Schlemm canal microcatheter. Int J Ophthalmol 2018;11(1):1–5. DOI: 10.18240/ijo.2018.01.01
12. Smit BA, Johnstone MA. Effects of viscoelastic injection into Schlemm's canal in primate and human eyes: potential relevance to viscocanalostomy. Ophthalmology 2002;109(4):786–792. DOI: 10.1016/s0161-6420(01)01006-5
13. Iscience Interventional Ophthalmic Microcatheter 510(k) FDA Premarket Notification K080067 ISCIENCE INTERVENTIONAL [Internet]. [cited 2022 Aug 18]. Available from: https://fda.report/PMN/K080067
14. Klink T, Sauer J, Körber NJ, et al. Quality of life following glaucoma surgery: canaloplasty versus trabeculectomy. Clin Ophthalmol 2014;9:7–16. DOI: 10.2147/OPTH.S72357
15. Lewis RA, von Wolff K, Tetz M, et al. Canaloplasty: circumferential viscodilation and tensioning of Schlemm's canal using a flexible microcatheter for the treatment of open-angle glaucoma in adults: interim clinical study analysis. J Cataract Refract Surg 2007;33(7):1217–1226. DOI: 10.1016/j.jcrs.2007.03.051
16. Lewis RA, von Wolff K, Tetz M, et al. Canaloplasty: circumferential viscodilation and tensioning of Schlemm canal using a flexible microcatheter for the treatment of open-angle glaucoma in adults: two-year interim clinical study results. J Cataract Refract Surg 2009;35(5):814–824. DOI: 10.1016/j.jcrs.2009.01.010
17. Mansouri K, Shaarawy T. Update on Schlemm's canal based procedures. Middle East Afr J Ophthalmol 2015;22(1):38–44. DOI: 10.4103/0974-9233.148347
18. Lewis RA, von Wolff K, Tetz M, et al. Canaloplasty: three-year results of circumferential viscodilation and tensioning of Schlemm canal using a microcatheter to treat open-angle glaucoma. J Cataract Refract Surg 2011;37(4):682–690. DOI: 10.1016/j.jcrs.2010.10.055
19. Ayyala RS, Chaudhry AL, Okogbaa CB, et al. Comparison of surgical outcomes between canaloplasty and trabeculectomy at 12 months' follow-up. Ophthalmology 2011;118(12):2427–2433. DOI: 10.1016/j.ophtha.2011.05.021
20. Fujita K, Kitagawa K, Ueta Y, et al. Short-term results of canaloplasty surgery for primary open-angle glaucoma in Japanese patients. Case Rep Ophthalmol 2011;2(1):65–68. DOI: 10.1159/000324808
21. Gallardo MJ, Supnet RA, Ahmed IIK. Circumferential viscodilation of Schlemm's canal for open-angle glaucoma: ab-interno vs ab-externo canaloplasty with tensioning suture. Clin Ophthalmol 2018;12:2493–2498. DOI: 10.2147/OPTH.S178962
22. Vastardis I, Fili S, Gatzioufas Z, et al. Ab externo canaloplasty results and efficacy: a retrospective cohort study with a 12-month follow-up. Eye Vis (Lond) 2019;6:9. DOI: 10.1186/s40662-019-0134-5
23. Matlach J, Freiberg FJ, Leippi S, et al. Comparison of phacotrabeculectomy versus phacocanaloplasty in the treatment of patients with concomitant cataract and glaucoma. BMC Ophthalmol 2013;13:1. DOI: 10.1186/1471-2415-13-1
24. Arthur SN, Cantor LB, WuDunn D, et al. Efficacy, safety, and survival rates of IOP-lowering effect of phacoemulsification alone or combined with canaloplasty in glaucoma patients. J Glaucoma 2014;23(5):316–320. DOI: 10.1097/IJG.0b013e3182741ca9
25. Zhang L, Yao Y, Lin Q, et al. Clinical application of the CO2 laser in Ab externo Schlemm's canal surgery. Front Med 2022;9:974056. DOI: 10.3389/fmed.2022.974056
26. Godfrey DG, Fellman RL, Neelakantan A. Canal surgery in adult glaucomas. Curr Opin Ophthalmol 2009;20(2):116–121. DOI: 10.1097/ICU.0b013e32831eef65
27. Riva I, Brusini P, Oddone F, et al. Canaloplasty in the treatment of open-angle glaucoma: a review of patient selection and outcomes. Adv Ther 2019;36(1):31–43. DOI: 10.1007/s12325-018-0842-6
28. Brandão LM, Grieshaber MC. Update on minimally invasive glaucoma surgery (MIGS) and new implants. J Ophthalmol 2013;2013:705915. DOI: 10.1155/2013/705915
29. Khaimi MA. Canaloplasty: a minimally invasive and maximally effective glaucoma treatment. J Ophthalmol 2015;2015:485065. DOI: 10.1155/2015/485065
30. Garris WJ, Le C, Zurakowski D, et al. Comparison of surgical outcomes between canaloplasty and trabeculectomy with mitomycin C at 2-year follow-up: a longitudinal cohort study. Indian J Ophthalmol 2018;66(1):66–70. DOI: 10.4103/ijo.IJO_543_17
31. Gołaszewska K, Konopińska J, Obuchowska I. Evaluation of the efficacy and safety of canaloplasty and iStent bypass implantation in patients with open-angle glaucoma: a review of the literature. J Clin Med 2021;10(21):4881. DOI: 10.3390/jcm10214881
32. Francis BA, Akil H, Bert BB. Ab interno Schlemm's canal surgery. Develop Ophthalmol 2017;59:127–146. DOI: 10.1159/000458492
33. Gallardo MJ. 36-month effectiveness of ab-interno canaloplasty standalone versus combined with cataract surgery for the treatment of open-angle glaucoma. Ophthalmol Glaucoma 2022;5(5):476–482. DOI: 10.1016/j.ogla.2022.02.007
34. Koerber N, Ondrejka S. Four-year efficacy and safety of iTrack ab-interno canaloplasty as a standalone procedure and combined with cataract surgery in open-angle glaucoma. Klin Monbl Augenheilkd 2023;240(12):1394–1404. DOI: 10.1055/a-1737-4149
35. Khaimi MA. Long-term medication reduction in controlled glaucoma with iTrack ab-interno canaloplasty as a standalone procedure and combined with cataract surgery. Ther Adv Ophthalmol 2021;13:25158414211045751. DOI: 10.1177/25158414211045751
36. Gallardo MJ, Supnet RA, Ahmed IIK. Viscodilation of Schlemm's canal for the reduction of IOP via an ab-interno approach. Clin Ophthalmol 2018;12:2149–2155. DOI: 10.2147/OPTH.S177597
37. Gallardo MJ. 24-month efficacy of viscodilation of Schlemm's canal and the distal outflow system with iTrack ab-interno canaloplasty for the treatment of primary open-angle glaucoma. Clin Ophthalmol 2021;15:1591–1599. DOI: 10.2147/OPTH.S272506
38. Körber N. Ab interno canaloplasty for the treatment of glaucoma: a case series study. Spektrum Augenheilkd 2018;32(6):223–227. DOI: 10.1007/s00717-018-0416-7

39. Kazerounian S, Zimbelmann M, Lörtscher M, et al. Canaloplasty ab interno (AbiC) - 2-year-results of a novel minimally invasive glaucoma surgery (MIGS) technique. Klin Monbl Augenheilkd 2021;238(10):1113–1119. DOI: 10.1055/a-1250-8431
40. Körber N. [Canaloplasty ab interno - a minimally invasive alternative]. Klin Monbl Augenheilkd 2017;234(8):991–995. DOI: 10.1055/s-0042-123829
41. Gillmann K, Aref A, Niegowski LJ, et al. Combined ab interno viscocanaloplasty (ABiC) in open-angle glaucoma: 12-month outcomes. Int Ophthalmol 2021;41(10):3295–3301. DOI: 10.1007/s10792-021-01891-1
42. Ondrejka S, Körber N. 360° ab-interno Schlemm's canal viscodilation in primary open-angle glaucoma. Clin Ophthalmol 2019;13:1235–1246. DOI: 10.2147/OPTH.S203917
43. Tracer N, Dickerson JE Jr, Radcliffe NM. Circumferential viscodilation ab interno combined with phacoemulsification for treatment of open-angle glaucoma: 12-month outcomes. Clin Ophthalmol 2020;14:1357–1364. DOI: 10.2147/OPTH.S252965
44. Hirsch L, Cotliar J, Vold S, et al. Canaloplasty and trabeculotomy ab interno with the OMNI system combined with cataract surgery in open-angle glaucoma: 12-month outcomes from the ROMEO study. J Cataract Refract Surg 2021;47(7):907–915. DOI: 10.1097/j.jcrs.0000000000000552
45. Williamson BK, Vold SD, Campbell A, et al. Canaloplasty and trabeculotomy with the OMNI system in patients with open-angle glaucoma: two-year results from the ROMEO study. Clin Ophthalmol. 2023;17:1057–1066. DOI: 10.2147/OPTH.S407918
46. Vold SD, Williamson BK, Hirsch L, et al. Canaloplasty and trabeculotomy with the OMNI system in pseudophakic patients with open-angle glaucoma: the ROMEO study. Ophthalmol Glaucoma 2021;4(2):173–181. DOI: 10.1016/j.ogla.2020.10.001
47. Gallardo MJ, Pyfer MF, Vold SD, et al. Canaloplasty and trabeculotomy combined with phacoemulsification for glaucoma: 12-month results of the GEMINI study. Clin Ophthalmol 2022;16:1225–1234. DOI: 10.2147/OPTH.S362932
48. Toneatto G, Zeppieri M, Papa V, et al. 360° ab-interno schlemm's canal viscodilation with OMNI viscosurgical systems for open-angle glaucoma-midterm results. J Clin Med 2022;11(1):259. DOI: 10.3390/jcm11010259
49. Klabe K, Kaymak H. Standalone trabeculotomy and viscodilation of Schlemm's canal and collector channels in open-angle glaucoma using the OMNI surgical system: 24-month outcomes. Clin Ophthalmol 2021;15:3121–3129. DOI: 10.2147/OPTH.S325394
50. Grabska-Liberek I, Duda P, Rogowska M, et al. 12-month interim results of a prospective study of patients with mild to moderate open-angle glaucoma undergoing combined viscodilation of Schlemm's canal and collector channels and 360° trabeculotomy as a standalone procedure or combined with cataract surgery. Eur J Ophthalmol 2022;32(1):309–315. DOI: 10.1177/1120672121998234
51. Murphy Iii JT, Terveen DC, Aminlari AE, et al. ROMEO study group. a multicenter 12-month retrospective evaluation of canaloplasty and trabeculotomy in patients with open-angle glaucoma: the ROMEO 2 study. Clin Ophthalmol 2022;16:3043–3052. DOI: 10.2147/OPTH.S384105
52. Matlach J, Dhillon C, Hain J, et al. Trabeculectomy versus canaloplasty (TVC study) in the treatment of patients with open-angle glaucoma: a prospective randomized clinical trial. Acta Ophthalmol 2015;93(8):753–761. DOI: 10.1111/aos.12722
53. Gołaszewska K, Obuchowska I, Konopińska J. Efficacy and safety of ab externo phaco-canaloplasty versus first-generation iStent bypass implantation combined with phacoemulsification in patients with primary open angle glaucoma-early results. Int J Environ Res Public Health 2023;20(2):1365. DOI: 10.3390/ijerph20021365
54. Gandolfi SA, Ungaro N, Ghirardini S, et al. Comparison of surgical outcomes between canaloplasty and Schlemm's canal scaffold at 24 months' follow-up. J Ophthalmol 2016;2016:3410469. DOI: 10.1155/2016/3410469
55. Dickinson A, Leidy L, Nusair O, et al. Short-term outcomes of hydrus microstent with and without additional canaloplasty during cataract surgery. J Glaucoma 2023;32(9):769–776. DOI: 10.1097/IJG.0000000000002245
56. Creagmile J, Kim WI, Scouarnec C. Hydrus microstent implantation with OMNI surgical system ab interno canaloplasty for the management of open-angle glaucoma in phakic patients refractory to medical therapy. Am J Ophthalmol Case Rep 2022;29:101749. DOI: 10.1016/j.ajoc.2022.101749
57. Patel S, Reiss G. Long-term clinical and safety outcomes of canaloplasty performed across all grades of glaucoma severity. J Ophthalmol 2023;2023:5625990. DOI: 10.1155/2023/5625990
58. Yadgarov A, Dentice K, Aljabi Q. Real-world outcomes of canaloplasty and trabeculotomy combined with cataract surgery in eyes with all stages of open-angle glaucoma. Clin Ophthalmol 2023;17:2609–2617. DOI: 10.2147/OPTH.S422132
59. Riaz KM, Gill MS, Murphy DA, et al. Surgical management of intraocular pressure with ab interno canaloplasty in postkeratoplasty patients: 12-month results. Cornea 2023;42(1):52–59. DOI: 10.1097/ICO.0000000000003009
60. Terveen DC, Sarkisian SR Jr, Vold SD, et al. Canaloplasty and trabeculotomy with the OMNI® surgical system in OAG with prior trabecular microbypass stenting. Int Ophthalmol 2023;43(5):1647–1656. DOI: 10.1007/s10792-022-02553-6