Intra-operative gonioscopy: a key to successful angle surgery

Since its inception, gonioscopy has been primarily utilized for angle assessment, laser trabeculoplasty and surgery limited to the pediatric age group. Three-fourths of a century would pass since Barkan’s description of goniotomy before intra-operative gonioscopy would come into vogue with the advent of micro-invasive glaucoma surgery. Over the last decade, several clinical trials have been conducted or are currently underway in evaluating devices and instruments targeting different surgical spaces within the angle. However, a rate-limiting step of successful angle surgery requires good gonioscopy and has led to a renewed interest among ophthalmologists to master this skill. During this same time period, several goniosurgical lens prototypes have been introduced in the market with the goal of optimizing angle viewing including clarity, globe stability, accessibility and simultaneous surgical manipulation of angle structures. Several non-gonioscopic methods have also been recently introduced to facilitate angle surgery.

**Historical background**

‘Gonioscopy’ is a term coined by Trantas [1] to describe a technique to visualize the irido-corneal angle structures [2]. Salzmann was the first to utilize a lens to directly view the angle [3]. Koepe and Goldmann introduced direct and indirect goniolenses in 1919 and 1938, respectively [4]. With the introduction of the modern Zeiss slit lamp microscope in 1920, significant advances in gonioscopy took place including angle evaluation in an upright position, accurate assessment of angle closure [5], indentation gonioscopy to differentiate appositional angle closure versus peripheral anterior synchiae (PAS) by Forbes [6] and angle grading [7-9] including extent of trabecular meshwork (TM) pigmentation [7]. Building on Tornquist’s [10] clinical description of plateau iris, Ritch [11] showed anterior chamber (AC) deepening confined to the central iris with indentation versus peripherally as seen in relative pupillary block. This was confirmed with imaging [12] showing anteriorly displaced ciliary processes at the iris root as the etiology. These discoveries spanning a century (FIGURE 1) have laid the foundation for our current understanding and approach to angle surgery.

In 1936, Barkan [13] first described goniotomy using a special contact lens to directly visualize the angle. However, gonioscopic angle surgery was limited primarily to congenital glaucoma [14] until the US FDA approved the Trabectome (Neomedix) 70 years later in 2006 [15] with a resultant expansion of angle surgery beyond the pediatric age group. Although the ‘gold standard’ trabeculectomy has shown successful long-term intraocular pressure (IOP) lowering [16] among Medicare beneficiaries from 1995 to 2004, Ramulu et al. [17] showed a decline in filtration surgery in eyes without prior surgery by >50% from 1995 to 2001. From 2001 to 2004, laser trabeculoplasty increased by the same magnitude with a parallel trend noted globally [18]. This increased utilization may reflect the trend to intervene earlier in glaucoma and avoid potential short- and long-term complications related to filtration and aqueous shunt surgery [19].

**Micro-invasive glaucoma surgery**

Indeed, with the introduction of micro-invasive glaucoma surgery (MIGS) [20-24] in the last decade, there has been a major shift in thinking from an ab externo surgical approach to an ab interno one focusing on the natural
drainage system instead of abandoning it and creating a new conduit with filtration or tube shunt surgery [25]. The definition of MIGS [22] includes an *ab interno* microincision, minimal trauma, efficacy, high safety profile and rapid recovery. Since FDA approval of the iStent (Glaukos) in June 2012 [26], over 20,000 trabecular micro-bypass stents have been sold for implantation [27] with 4000 devices used in over 30 studies spanning 10 years [28]. Additionally, with the prospect of taking anti-glaucoma medications indefinitely, a recent Canadian study suggests that there may be a long-term cost savings to undergo angle surgery versus medications reflecting a trend toward earlier surgical intervention and less dependence on medications for those diagnosed with early to moderate glaucoma [29].

At present, there are a number of publications and videos that describe surgical techniques for a variety of MIGS procedures including optimal hand positioning, instrument handling and incision or device insertion in the angle [28,30–40]. This anatomically confined space houses the semi-transparent TM measuring approximately 700 microns [41] and provides access to three surgical target drainage routes within the angle (Figure 2): Schlemm’s canal (SC) via TM, uveoscleral and sub-conjunctival space. There has been considerable investment in these surgical spaces to develop new MIGS devices (Table 1). However, the rate-limiting step in achieving successful surgical outcomes requires good *intra-operative* gonioscopy [42], the only means of viewing the proximal anatomy of the conventional outflow system and the uveoscleral pathway. A technology assessment report by the American Academy of Ophthalmology noted that although anterior segment imaging can provide quantitative measurements of the AC angle, it is not a substitute for gonioscopy [43] not only in assessing angle structures, including degree of pigmentation, presence of blood or PAS, but also its 3D relationship with the cornea and iris plane. Despite recommendations by the American Academy of Ophthalmology Preferred Practice Patterns in performing gonioscopy [44], only 49% of Medicare beneficiaries underwent this procedure 5 years prior to glaucoma surgery in 1999. Resources to train physicians in gonioscopy through videography [45] and online teaching modules to obtain certification for surgical implantation have become available. Glaukos Corp. recently reported 572 physicians as being ‘fully trained’ to implant their device [46].

Over the last decade, there has been an exponential growth in several different MIGS devices and procedures that have been FDA approved or authorized to conduct clinical trials. Such a growth demands good visualization in a surgically confined space for introducing surgical instruments to precisely manipulate the delicate angle structures in order to optimize outcomes. During this same time period, a number of surgical goniolenses with varying properties have become commercially available to meet surgeon preference (Figure 3).

### Intra-operative gonioscopy

Pre-operative gonioscopy needs to be performed in the office to ascertain adequate viewing of the anatomic target routes for planning purposes. In the presence of extensive PAS, surgical manipulation may not be possible. With appositional closure, however, angle surgery may still be possible following cataract surgery.

For successful angle surgery, attention needs to be first directed toward external factors, which include patient cooperation, head positioning and rotation, surgical microscope adjustment and surgeon hand positioning. If a patient is anxious or has involuntary eye movements, tolerability of topical versus alternate routes of anesthesia need to be taken into consideration. From a temporal approach, the head is rotated approximately 30–40 degrees away and the microscope is tilted 30 degrees toward the surgeon. The goal is to find the right combination of head and microscope adjustments to optimize direct viewing of the angle parallel to the iris plane and facilitate proper entry of instruments for surgical manipulation [28]. Use of a coaxial light source with either xenon or halogen, high magnification, increased light intensity and a smaller diameter of light to reduce reflections provides for adequate illumination of the angle.

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The surgical goniolens is held in the non-dominant hand resting either on the forehead or cheek depending upon the eye being operated on. The lens is coupled to the corneal surface with a viscoelastic agent to eliminate any air bubbles. This allows the dominant hand to have access to the temporal incision 180 degrees away from the nasal angle structures (Figure 4).

Second, for intra-operative gonioscopy, a number of factors are desirable in a surgical goniolens [42] (Figure 5). These include clarity in viewing the angle structures; absence of Descemet’s folds; globe stability, particularly when using topical anesthesia; accessibility of instruments via the peripheral cornea; simultaneous viewing and surgical manipulation of the angle structures and fine tuning and positioning of the eye to optimize angle visualization. Table 2 outlines the physical properties of commercially available surgical lenses for intra-operative gonioscopy [47,48] including corneal contact, static field of view (FOV), magnification, handle length and notable pros and cons for each lens. All lenses can be steam sterilized. With exception of the Ahmed and Osher lens, all are direct gonio lenses. The variability in handle length (72–88.5 mm) takes into consideration the engineering of each goniolens prototype encompassing optical performance, functionality and ergonomics including surgeon hand size, comfort and fatigue [RAYMOND GRAHAM, PERS. COMM.].

The preferred ophthalmic viscosurgical devices (OVD) for angle surgery are the viscohesive OVD as they are best for creating and maintaining space, visualization and adequate access of instruments. During TM surgery where blood reflex can occur upon entering SC, unlike a viscodispersive agent where heme can admix within the OVD, a cohesive forms a barrier and can serve to push aside the heme with additional OVD injection.

In phakic eyes undergoing angle surgery, unlike SC micro-stents, the use of agents to induce pupillary constriction is important when implanting suprachoroidal micro-stents to place tension and draw the iris away from the iris root facilitating access to the target surgical site. In combined procedures involving dense cataracts. Additionally, loss of globe rigidity following cataract surgery can decrease visibility during surgical manipulation of the angle [38,49]. However, for suprachoroidal and sub-conjunctival devices, we prefer to implant them after lens implantation in order to prevent irrigating into these spaces during phacoemulsification.

Intra-operative gonioscopy can be used for both therapeutic and diagnostic purposes. In patients undergoing lensectomy for angle closure glaucoma, one can assess the angle before and after lens removal to ascertain angle opening, identify presence of PAS and consider performing goniosynechialysis. During trabecular bypass surgery, gentle depression of the corneal wound with subsequent lowering of the IOP will result in blood refluxing into SC. This will allow for easy identification of collector channels and targeted SC stenting during gonioscopy. This can also be achieved with diagnostic provocative gonioscopy by increasing the episcleral venous pressure externally with the goniolens resulting in focal reflex of blood into SC facilitating stenting (Figure 5).

Barkan, the prototypical surgical goniolens [2,42], is a modification of the Koepe lens, the latter primarily used for diagnostic purposes in children. The angle is viewed as an upright image in the absence of a mirror with no distortion [4]. The Swan-Jacob (SJ) goniolens is a further modification with a handle enabling lens manipulation during angle surgery. A 9.5 mm contact, 90 degree FOV with a 1.2× image magnification enables adequate visualization to perform goniotomy and MIGS surgery. A variant of the SJ has a relieved anterior face with an 8.0 mm contact increasing access to clear cornea for introducing surgical instruments. It should be noted that over

**Table 1. Surgical procedures/devices categorized by anatomic surgical space in the angle.**

<table>
<thead>
<tr>
<th>Micro-invasive glaucoma surgery</th>
<th>Targeted angle surgical space</th>
<th>Trabecular meshwork</th>
<th>Hydrus iStent/iStent Inject</th>
<th>Trabectome</th>
<th>Excimer laser trabeculostomy</th>
<th>Gonioscopy-assisted transluminal trabeculotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprachoroid</td>
<td>CyPass</td>
<td>iStent supra</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-conjunctiva</td>
<td>Xen</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Future micro-invasive glaucoma surgery in clinical trials or yet to be conceptualized.
half a century earlier, Barkan modified the Koeppen lens for the same purpose by flattening one side to allow passage of a knife from a temporal corneal approach [2]. With topical anesthesia, these lenses pose a potential risk for sudden involuntary ocular excursions during surgical manipulation placing the patient at increased risk for intra-operative complications including iridodalysis or bleeding. Furthermore, excessive indentation during angle surgery can lead to Descemet’s folds compromising angle clarity. Using the tip of a surgical glove to create a skirt around the SJ lens, Nakasato-Sonn et al. [50] have used this design to elevate the lens 1–2 mm without touching the cornea and perfused saline into this space via a 20-gauge cannula mounted to the handle, eliminating air space, need for viscoelastic, Descemet’s folds and rinsing away any blood, thereby achieving a clear view in all cases when performing iridocorneal angle surgery.

The debut of the Hill, Khaw and Ritch surgical goniolenses (FIGURE 3) represent additional alterations of the SJ lens [42]. The Hill Gonioprism has unique features that include a left and right hand version with the handle held in the non-dominant hand and an extended peripheral flange to help stabilize the globe providing some back resistance to the eye tissue being pushed away from the surgeon during surgical manipulation [28,47]. Ridges on the metal surface holding the optics provide further eye stabilization. These specifications enable the surgeon to optimally view the filtering angle parallel to the iris plane and not the peripheral corneal plane.

Unlike the SJ and Hill lens with a 90 degree FOV, both the Khaw and Ritch goniolenses provide 120 and 160 degree panoramic FOV, respectively suitable for performing goniosynechialysis from one sitting position. The Khaw lens has a posteriorly attached fixation ring providing globe stabilization whereas with the Ritch, half the cornea closest to the surgeon is uncovered enhancing access to corneal incisions with instruments and permits placement of corneal sutures [47]. The Khaw lens

![Figure 3. Timeline overlap of marketed surgical goniolenses with the US FDA-approved MIGS devices or ongoing clinical trials. With exception of Transcend goniolens (Transcend Medical Inc.), Ocular Instruments, Inc., provided launch year for each lens indicated. Select clinical trials with start dates accessed from ](76). Trabectome (NeoMedix Inc.); CyPass (Transcend Medical Inc.); iStent Supra, iStent inject and iStent (Glaukos Corp.); Hydrus (Ivantis Inc.); XEN implant (AqueSys). Note: Swan Jacob lens debuted prior to ’76; Osher lens debut ’96; Timeline not inclusive of all MIGS clinical trials. CE: Cataract extraction; OAG: Open angle glaucoma; COMPASS trial [77].

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- Alward, W.
- Crandall, A.
- Vold, A.
- Ahmed, A.

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lens provides a 1.4× image magnification making it more suitable for MIGS versus Ritch with a 0.73× magnification.

Ocular surgery is performed using coaxial illumination from an operating microscope. However, the SJ-style gonioscopic lenses require head and microscope repositioning resulting in a coaxial view from an oblique angle in addition to an increased working distance during angle surgery. Based upon principles of the double mirror peripheral vitrectomy lens [51], a prototype double mirror gonioscopic lens was designed with two internal mirrors to allow coaxial illumination with upright image viewing of angle structures [52] eliminating the need for head tilt or microscope adjustment. With a desire to monitor the 3D location of surgical instruments in the AC during surgery, Mori et al. [53] combined the two internal mirrors with a central direct path creating a ‘dual viewing system’ during goni-surgery [54] (Figure 6). This provides not only clear visualization of the angle with a wider 110 degrees FOV, but also the AC via the central view. They randomized 20 patients undergoing angle surgery to either the modified lens or the SJ noting no complication in either group. However, the former eliminated the need to tilt either the microscope or the head >30 degrees during surgical manipulation of the angle. They proposed use of their lens for all types of angle surgery including placement of trabecular micro-bypass stents.

The Ocular Ahmed Surgical Goniolens (Figure 7) is unique in that it is an indirect surgical goniolens that can be rotated on a handle enabling full view with a 1.5× magnification of the angle [42]. It is ideal for conducting goniosynechialysis from one sitting position. However, the inverted image requires surgical dexterity in introducing and manipulating instruments in the angle 180 degrees away from the viewing mirror [55].

The Transcend Vold Gonio Lens (TVG) [48,56], distributed by Volk Optical Inc. (Table 2), has a unique ergonomic design featuring several characteristics desirable in a lens during angle surgery [57]. Unlike other goniolenses that form a continuum with the handle, a free-floating lens is suspended from a hinge on the main handle offering multiple pivot points. This minimizes pressure on the cornea eliminating Descemet’s folds, thereby providing an unimpeded clear view of angle structures without AC distortion. Additionally, a 14 mm cleat ring at the base of the handle enables globe stabilization and control countering any involuntary ocular movements under topical anesthesia during surgical manipulation reducing risk of intraocular injury. It provides additional rotation in the axis of the patient’s head turn to fine tune viewing of angle structures reducing the amount of head tilt and microscope adjustments. Patient discomfort under topical anesthesia and subconjunctival heme from the cleat ring are potential adverse effects.

**Non-gonioscopic methods**

A number of non-gonioscopic approaches to angle visualization and surgery have been introduced. This may reflect alternatives for novice surgeons or those not comfortable in performing gonioscopy. For those adept at performing gonioscopy, this emerging technology may supplement their surgical skills in optimizing patient outcomes post-operatively.

Several ophthalmic endoscope systems have been designed for use in both anterior and posterior segment surgeries. Endooptiks, Inc. (Little Silver, NJ, USA) is FDA approved and was introduced in 1991 [58]. The E2 endoscope model combines a light source, diode laser, aiming beam and a fiberoptic video camera [59]. It has the advantage of eliminating head and microscope tilt, though it requires viewing on a monitor during intra-operative surgery. Although frequently used for ab interno cyclophotocoagulation to decrease aqueous production, the endoscope can be utilized in a variety of anterior segment intraocular procedures [60] including assessment of angle structures in presence of opaque media or during goniosynechialysis [61]. It has been used in identifying the exact extent and localization of cyclodialysis clefts with subsequent lasering [62], endoscopically guided goniotomy [63], excimer laser trabeculotomy [64]...
<table>
<thead>
<tr>
<th>Lens</th>
<th>Image Contact (mm)</th>
<th>Static FOV (degrees)</th>
<th>Gonio Magnification</th>
<th>Handle length (mm)</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Hoskins-Barkan | 9.0 – premature infant  
10.0 – infant  
11.5 – adult | 360 Panoramic view of entire circumference | 1.30×               | None               | Direct, upright image; no mirror; angle viewed in natural state; no distortion; examine eyes simultaneously [4]  
Designed for transverse goniotomy surgery | Need for examiner to tilt head or scope; difficult to learn; less magnification vs indirect techniques |
| Ahmed        | 10.0               | 90                   | 1.5×                | 72 mm (lens with handle design) | Large mirror provides magnified view  
Eliminates need for head/scope tilt  
Optical design corrects corneal astigmatism  
Ample access to cornea  
With 360-degree rotation, goniosynechiolysis can be performed from one sitting position | Inverted image requires surgical dexterity to view and perform angle surgery  
180 degrees away [55] |
| Mori         | 11.5               | 110                  | 0.80×               | 21.6 (lens height) | Properly oriented upright image of angle  
Central view enables viewing of instruments crossing across AC  
2 mirror design redirects oblique gonio-image to coaxial ‘cataract’ surgical position; allows 360-degree viewing  
Large limbal aperture gives access to cornea  
Eliminates head/scope tilt | Minification of images; reduction of light transmission; rotation of lens may not be ergonomic; absence of globe stability under topical anesthesia |

Lenses are listed here in no particular order with specifications obtained from Ocular Instruments, Inc. [47], except the Transcend Vold Gonio Lens from Transcend Medical, Inc. [48].

AC: Anterior chamber; FOV: Field of view; MIGS: MicrInvasive glaucoma surgery.

Photos used with permission from Ocular Instruments, Inc. and Transcend Medical Inc.
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<tr>
<th>Lens</th>
<th>Image</th>
<th>Contact (mm)</th>
<th>Static FOV (degrees)</th>
<th>Gonio Magnification</th>
<th>Handle length (mm)</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Mirror</td>
<td></td>
<td>9.0</td>
<td>90</td>
<td>1.20 ×</td>
<td>49.0 (lens height)</td>
<td>Similar features as Mori lens with absence of a central viewing system. In addition, larger image magnification (1.20 ×) Holding ring – ergonomic ambidextrous hand control of goniolens during surgery</td>
<td>Reduction of light transmission; light reflections; absence of globe stability under topical anesthesia</td>
</tr>
<tr>
<td>Ritch</td>
<td></td>
<td>10.8</td>
<td>160</td>
<td>0.73 ×</td>
<td>77.5 4.56 (lens height)</td>
<td>Half of cornea closest to surgeon is exposed for ease of accessing corneal incisions, introducing instruments and placing corneal sutures. Provides direct panoramic view for 160 degrees; useful for goniotomy</td>
<td>Minification of images; need for head and scope rotation; absence of globe stability under topical anesthesia</td>
</tr>
<tr>
<td>Hill - Right and Left</td>
<td></td>
<td>9.0</td>
<td>90</td>
<td>1.20 ×</td>
<td>77.5</td>
<td>Peripheral flange helps stabilize globe during surgical manipulation. Right/left handed (RLH) handles facilitate lens handling. Useful for goniotomy and angle surgeries</td>
<td>Need for head and scope rotation; RLH handles not optimal for goniosynechiolysis; requires surgeon repositioning/reseating</td>
</tr>
</tbody>
</table>

Lenses are listed here in no particular order with specifications obtained from Ocular Instruments, Inc. [47], except the Transcend Vold Gonio Lens from Transcend Medical, Inc. [48].

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<tr>
<th>Lens</th>
<th>Image</th>
<th>Contact (mm)</th>
<th>Static FOV (degrees)</th>
<th>Gonio Magnification</th>
<th>Handle length (mm)</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swan Jacob</td>
<td><img src="image1.png" alt="Image" /></td>
<td>9.5</td>
<td>90</td>
<td>1.20×</td>
<td>88.17</td>
<td>Direct view goniolens; designed for goniotomy</td>
<td>Need for head and scope rotation; potential for globe movement under topical anesthesia during surgical manipulation</td>
</tr>
<tr>
<td></td>
<td><img src="image2.png" alt="Image" /></td>
<td>8.0</td>
<td>90</td>
<td>1.50×</td>
<td>88.17</td>
<td>Direct view goniolens; relieved anterior increases accessibility to limbus/clear cornea for surgical instruments</td>
<td></td>
</tr>
<tr>
<td>Osher Gonio and Post Pole</td>
<td><img src="image3.png" alt="Image" /></td>
<td>14.0</td>
<td>38</td>
<td>0.84×</td>
<td>72</td>
<td>Provides both angle and posterior pole view Two 60-degree gonio mirrors provide (i) wide-view; (ii) confirmation of proper haptic placement of AC lens Can rotate lens while holding handle</td>
<td>Minification of images; narrow FOV; inverted image requires surgical dexterity to view and perform angle surgery 180 degrees away; large contact diameter limits access to clear cornea with instruments</td>
</tr>
</tbody>
</table>

Lenses are listed here in no particular order with specifications obtained from Ocular Instruments, Inc. [47], except the Transcend Vold Gonio Lens from Transcend Medical, Inc. [48].

AC: Anterior chamber; FOV: Field of view; MIGS: Microinvasive glaucoma surgery.

Photos used with permission from Ocular Instruments, Inc. and Transcend Medical Inc.
### Table 2. Surgical goniolenses (cont.)

<table>
<thead>
<tr>
<th>Lens</th>
<th>Contact (mm)</th>
<th>Static FOV (degrees)</th>
<th>Gonio Magnification</th>
<th>Handle length (mm)</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khaw</td>
<td>11.5</td>
<td>120</td>
<td>1.40 ×</td>
<td>88.5</td>
<td>Posteriorly attached fixation ring stabilizes globe during surgical procedures. Wide-field view lens provides clear AC viewing. Useful for goniotomy; high magnification may be ideal for MIGS procedures.</td>
<td>Need for head and scope rotation; potential discomfort from ring under topical anesthesia.</td>
</tr>
<tr>
<td>Transcend Vold Gonio Lens</td>
<td>9.0</td>
<td>90</td>
<td>1.20 ×</td>
<td>84 mm</td>
<td>Free floating lens - suspended from a hinge on main handle eliminates corneal folds. Multiple pivot points provide undistorted view with no AC distortion. Cleat ring provides globe control and fixation. Allows fine positioning with rotation.</td>
<td>Need for head and scope rotation; potential for subconjunctival heme from ring and discomfort during globe fixation/rotation with topical anesthesia.</td>
</tr>
</tbody>
</table>

Lenses are listed here in no particular order with specifications obtained from Ocular Instruments, Inc. [47], except the Transcend Vold Gonio Lens from Transcend Medical, Inc. [48].

AC: Anterior chamber; FOV: Field of view; MIGS: Microinvasive glaucoma surgery.

Photos used with permission from Ocular Instruments, Inc. and Transcend Medical Inc.
and endocycloplasty to open the angle in plateau iris syndrome by laserig the ciliary body and its processes [65]. The expanded use of endoscopy has also been demonstrated in iStent implantation (Figure 8; [66]).

In contrast to the endoscope, angle structure viewing can also be achieved with the RetCam (Clarity Medical Systems, Inc., Pleasanton, CA, USA), an external fiber optic video camera system with a coupling gel placed on the cornea [42,67]. Surgeons can document the angle with photography and video. Placement of an iStent is demonstrated using this technology (Figure 9).

Ianchulev [68–70] has demonstrated a gonio-free technique in implanting the CyPass suprachoroidal micro-stent intra-operatively with ‘direct goniometry’. Via a <1.5 mm clear corneal incision, a tactile gonioprobe is introduced into the AC and advanced until it comes into contact with the ciliary body insertion 180 degrees away. The angle depth is then measured to the limbus using a measurement scale built into the probe. Subsequently, during implantation, the CyPass micro-stent is introduced via an inserter into the AC and advanced into the suprachoroidal space. The stent is then disinserted from the inserter when the corresponding measurement scale on the inserter matches that of the probe. This ensures that the device is precisely advanced with the proximal collar remaining in the AC. However, currently this technique requires follow-up gonioscopic assessment to confirm proper collar placement (Figure 10).

An emerging technology is intra-operative optical coherence tomography for the anterior segment. The optical coherence tomography is integrated into the operating microscope enabling scanning during live surgery. Non-contact, non-invasive cross-sectional imaging of the eye is obtained in ‘real time’ before, during and after microsurgery [71,72]. It has the potential to provide instant feedback enabling the surgeon to evaluate implantation of a device in relation to surrounding tissues and assess proper placement with the option to reposition or re-insert the device if necessary in order to optimize surgical outcomes.

Expert commentary
A pre-requisite in caring for glaucoma patients is to become proficient in performing gonioscopy starting in the office setting. An excellent resource for learning angle anatomy and familiarity in both health and disease including videography is available [45]. Indirect goniolenses such as the four mirror are an ideal starting point due to their convenience and lack of need for viscous coupling agents [73]. Additionally, performing argon laser trabeculoplasty requires not only proper handling of a goniolens in order to clearly view the iridocorneal angle, but also delivering laser burns at the junction of the pigmented and non-pigmented TM [74], the same anatomic surgical site for introduction and implantation of the SC micro-stents. Performing direct gonioscopy prior to or following routine cataract surgery in the operating room suite or on volunteers in the minor procedure room with the microscope are initial steps
one can take in attaining proficiency in intra-operative gonioscopy. Webinars, workshops and online training modules leading to certification for implanting devices provide additional resources in learning to perform gonioscopy prior to embarking on angle surgery.

Intra-operatively, the use of any commercially available surgical goniolens in the setting of a peri- or retrobulbar block or general anesthesia would suffice. However, under topical anesthesia, we prefer a goniolens such as the Hill or TVG that provides added globe stability from involuntary eye movements during angle surgery, thereby reducing potential risk of intraocular complications. Both lenses provide fine-tuning to bring the angle into view by rotating the globe further in the same axis and direction as the patient’s head turn. Given that areas of greater TM pigmentation have been suggested to occur in close proximity to collector channels, the TVG cleat ring enables globe rotation in the z axis 30 degrees in either a clockwise or counter clockwise direction bringing such areas into the surgeon’s view to precisely place a SC implant to achieve optimal IOP lowering.

In combined procedures with SC implantation, we prefer to perform angle surgery prior to phacoemulsification for a number of reasons: the patient is maximally anesthetized at the start of the surgery both topically and with i.v. sedation to tolerate any discomfort that may arise from placement of the peripheral flange or cleat ring on the globe at the start of the surgery, the surgeon has a ‘bird’s eye’ view of angle structures through a pristine cornea and unaltered keratome incision prior to introduction of the phaco handpiece. This is especially important when one is operating in a surgically confined space along the iris plane limited by the anterior chamber depth of 2–3 mm. Any alteration would compromise visibility and introduction of instrumentation to safely perform angle surgery. Contrast this with the ‘full’ view of the cornea in the supine position during cataract surgery. We prefer a soft shell technique that allows to not only coat and protect the corneal endothelium with a dispersive OVD, but also to take advantage of the cohesive OVD properties by injecting it to create space in the angle for reasons already mentioned to safely perform surgery in a controlled manner.

The demand on ophthalmologists caring for adults with glaucoma to acquire this skill set is unprecedented, especially in light of merger of angle surgery combined with small incision phacoemulsification using micro-instrumentation and topical anesthesia. Gonioscopy, at present, is here to stay. Gonioscopic-assisted angle surgery will enable surgeons to intervene much earlier in the glaucoma disease spectrum, decreasing dependence upon medications with associated non-compliance and adherence issues. Glaucoma is transitioning into becoming a surgically treatable disease improving a patient’s quality of life and potentially averting more invasive surgical procedures.

**Five-year view**

As several goniolasurgical lenses have become commercially available in the last decade, it is anticipated that this trend will continue into the future with further modification of existing prototypes to meet the specific needs of novel MIGS procedures yet to be conceptualized as well as those currently seeking FDA approval. Novel methods to anatomically delineate SC and the distal outflow pathway either via imaging or with a dye akin to fluorescein angiography (i.e., canalography) will enable precise gonioscopically targeted angle surgery in areas with the largest cross-sectional area of collector channels, thereby customizing optimal IOP lowering in a given patient. In addition, the introduction of non-gonioscopic methods may reflect a parallel trend of growth that one may anticipate in the next several years to meet the growing needs of surgeons performing angle surgery. Given the dynamic nature of gonioscopy in providing 3D information, rather than being replaced by technology, an integration of these two approaches may perhaps provide the ideal medium in precisely performing angle surgery with the goal of optimizing outcomes in helping glaucoma patients lead productive lives by preserving visual function.

**Financial & competing interests disclosure**

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Key issues

- Historically, gonioscopy has been utilized primarily for angle assessment, trabeculoplasty and goniotomy.
- With the advent of micro-invasive glaucoma surgery (MIGS), more than three-fourths of a century after Barkan’s description of goniotomy, intra-operative gonioscopy has come into vogue expanding beyond the pediatric age group with a renewed interest among ophthalmologists to master this technique.
- Several MIGS clinical trials have been introduced in the last decade focusing on different target surgical spaces within the angle.
- The key to successful MIGS surgery requires good gonioscopy. This has led to a parallel introduction and commercialization of several surgical goniolenses to optimize angle visualization with a focus on clarity, globe stability, instrument accessibility and simultaneous surgical manipulation of delicate angle structures.
- Non-gonioscopic methods have recently been introduced to facilitate angle surgery.

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• Outlines trends in glaucoma filtration, tube shunt and laser surgery, a decade preceding the micro-invasive glaucoma surgery (MIGS) era.
• Provides a nice overview of the various MIGS devices and procedures.
• Discusses the importance of understanding the outflow pathway beyond the trabecular meshwork from a basic science perspective and its clinical assessment.


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