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REVIEW

INTRAOPERATIVE GONIOSCOPY – A NECESSITY FOR MINIMALLY INVASIVE GLAUCOMA SURGERY

N. Velikova^{1,2}, B. Kutchoukov^{1,2}

¹University Hospital “Tsaritsa Yoanna – ISUL” – Sofia, Bulgaria

²Department of Emergency Medicine, Faculty of Medicine, Medical University – Sofia, Bulgaria,

Abstract. *Minimally invasive glaucoma surgery (MIGS) has transformed the surgical management of mild-to-moderate glaucoma by lowering intraocular pressure (IOP) with a favorable safety profile. Accurate intraoperative visualization of the anterior chamber angle (ACA) via gonioscopy is fundamental to the success of ab-interno angle procedures. This review synthesizes the optical principles underpinning gonioscopy, compares contemporary surgical lenses (direct, indirect, and upright designs), and outlines practical recommendations for intraoperative setup, patient selection, and troubleshooting. We highlight critical landmarks (e.g., scleral spur, trabecular meshwork pigmentation, Schlemm’s canal reflux) and discuss adjuvants, such as trypan blue for trabecular meshwork staining. By aligning lens selection with the intended procedure and optimizing the operative ergonomics, surgeons can enhance visualization, reduce complications, and improve outcomes.*

Key words: *gonioscopy, minimally invasive glaucoma surgery, anterior chamber angle, intraoperative visualization, goniolens, trabecular meshwork*

Corresponding author: *Nora Velikova-Pavlova, University Hospital “Tsaritsa Yoanna-ISUL” – Sofia, Bulgaria, email: norito_83@abv.bg*

ORCID: 0009-0002-5865-1618

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INTRODUCTION

Glaucoma remains the leading cause of irreversible blindness worldwide [1]. Reducing intraocular pressure (IOP) is the only proven strategy for preventing disease progression. This is traditionally achieved with topical therapy or laser trabeculoplasty, while surgical intervention is reserved for refractory cases.

The options for the surgical treatment of glaucoma have expanded significantly over the past two decades. The introduction of the latest trend in glaucoma surgery – the minimally invasive glaucoma sur-

gery – has fundamentally transformed the surgical management of glaucoma, offering surgeons a safer and more effective approach to control the mild and moderate stages of the disease [2-9, 10].

Minimally invasive glaucoma surgery (MIGS) and intraoperative gonioscopy are inseparably linked, as the accurate anterior chamber angle (ACA) examination – known as gonioscopy – is a key element of their successful performance. Gonioscopy remains one of the “gold standard” techniques to differentiate the type of glaucoma. It determines whether the glaucoma is open-angle or closed-angle (Figure 1). Examination and grading of the “degree of opening”

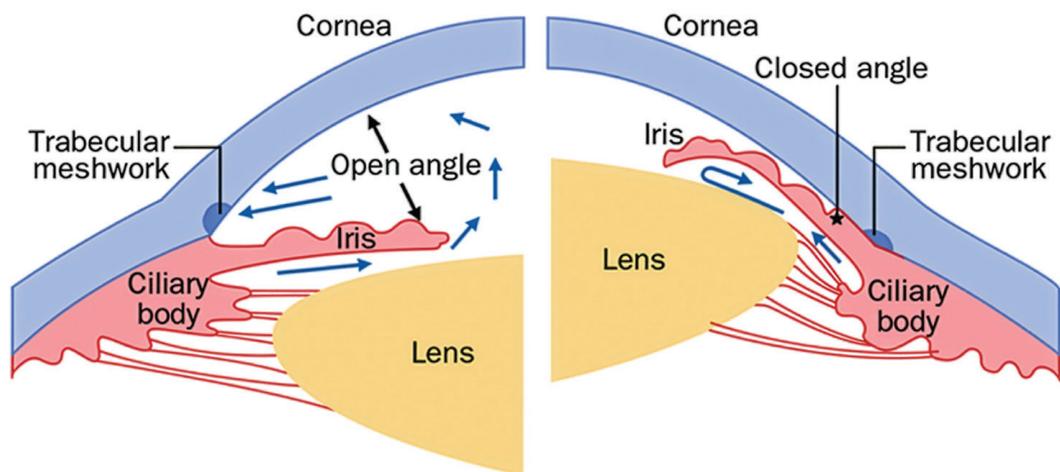


Fig. 1. Schematic diagram of the ocular anterior segment in open-angle and closed-angle glaucoma. Under normal conditions (open angle), the aqueous humor formed by the ciliary body flows around the lens and iris (blue arrows) and exits the eye through the trabecular meshwork, through Schlemm's canal, and empties into aqueous veins and the episcleral venous system. In the closed angle, the iris and lens are positioned anteriorly, causing an obstruction of aqueous flow through the trabecular meshwork. Reproduced from Wiggs and Pasquale, 2017, *Genetics of glaucoma Hum Mol Genet.* 2017 May 16;26(R1):R21–R27. by permission of Oxford University Press: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6074793/figure/ddx184-F1/>

of the anterior chamber angle defines the further therapeutic management of the established type of glaucoma [11-15, 16].

For almost 70 years, gonioscopy has served primarily as a diagnostic procedure. Its intraoperative use was limited to the pediatric age group. In 2006, the United States Food and Drug Administration (U.S. FDA) approved the Trabectome (Neomedix), marking the beginning of the wider use of intraoperative gonioscopy.

The increasing number of MIGS procedures performed in the practice of glaucoma surgeons has led to a greater variety of tools for visualizing ACA structures – the primary target area of surgical manipulation. Therefore, a comprehensive understanding of all commercially available lenses for intraoperative gonioscopy, including their advantages, limitations, and complete characteristics, is crucial in the practice of ophthalmologists performing surgical procedures in this area [17-24].

In Bulgaria, the first attempts at ACA surgery were made in the early 1960s by Prof. Konstantinov, who introduced goniotomy for the treatment of congenital glaucoma. However, he reported that no gonioscopic lenses were used during these early procedures [25]. Nearly 60 years later, with the introduction of goniotomy with the Kahook Dual Blade in adult patients, Velikova and Kutchoukov began to use various go-

nioscopic lenses and described their specific optical characteristics, advantages, and limitations [26, 27].

PRINCIPLES OF GONIOSCOPY

Visualization of the natural aqueous drainage structures within the ACA – a procedure known as gonioscopy – cannot be achieved without using a gonioscopic lens applied to the cornea. When light emerging from the iridocorneal junction strikes the tear film–air interface at a shallow angle, it undergoes total internal reflection, making the angle structures invisible. However, if the light meets the cornea at a steeper angle – greater than approximately 46° , known as the critical angle – the light is able to pass through the cornea and exit the eye instead of being reflected back (Figure 2).

Gonioscopy eliminates the barrier of the critical angle by placing a contact lens on the cornea with a refractive index similar to that of the cornea, thereby allowing light to be refracted (direct lenses) or redirected via mirrors (indirect lenses) so that the angle structures become visible. Two fundamental categories exist: (1) direct lenses, which present an upright, non-inverted view; and (2) indirect lenses, which use mirrored optics and produce an inverted image. Key performance characteristics include static field of view (SFOV), image magnification, contact diameter, presence of a fixation ring, and handle ergonomics

(right/left, ambidextrous designs) [13-15, 19-21, 24, 28-32].

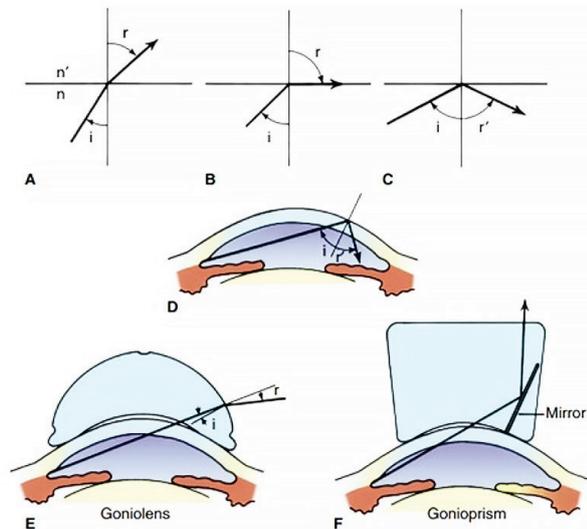


Fig. 2. Principle of gonioscopy. **A:** A light ray is refracted when the angle of incidence (i) at the interface between two media with different refractive indices (n and n') is smaller than the critical angle. **B:** Angle of refraction (r) is 90 degrees when i equals the critical angle. **C:** Light is reflected when i exceeds the critical angle. **D:** Light from the anterior chamber angle exceeds the critical angle at the cornea-air interface and is reflected back into the eye. **E-F:** Contact lenses have an index of refraction (n) similar to that of the cornea, allowing light to enter the lens and then be refracted (goniolens) or reflected (gonioprism) beyond the contact lens-air interface. Reproduced with permission of Wolters Kluwer Health, Inc., from Shields MB, Textbook of Glaucoma, Allingham R., Rand, 7th ed., 2020.

GONIOLENSES

A wide variety of surgical goniolenses are currently available on the market. Some have been in use for decades, while others have been introduced within the past 10 to 12 years as modified versions of earlier models, adapted for right- or left-hand configuration, or providing an expanded field of view. Those modifications facilitate easier placement in eyes with narrow palpebral fissures and enhance intraoperative visualization owing to improved optical performance, thereby reducing surgical difficulty [28].

INDIRECT GONIOLENSES

Indirect goniolenses use mirrors that redirect light at approximately right angles, effectively eliminating total internal reflection. A major disadvantage of indirect lenses is the inverted image of ACA. Very few indirect lenses are used for surgical procedures, mainly for goniosynechialysis [13, 28, 29, 30].

Zeiss and Posner

Four-mirror goniolenses, such as the Posner lens, a modernized version of the classic Zeiss lens (Ocular Instruments, Inc., Bellevue, WA), allow rapid 360° assessment with minimal rotation. The Zeiss lens is no longer commercially available and has been replaced by a Posner model (Fig. 3). The Posner lens incorporates four mirrors inclined at 64°, providing 0.80x magnification and an 80° static field of view (SFOV). It is available with 3 handle designs: round, hexagonal, and ergonomic, to accommodate individual surgeon preferences. This type of lens does not require a contact gel, which allows the physician to easily recognize whether the angle closure results from apposition or from goniosynechia. Both of these lenses can be used effectively for angle surgery (eg, goniosynechialysis). It is important to keep in mind, however, that they must be disinfectant in glutaraldehyde or bleach and cannot be sterilized in an autoclave or heat disinfectant system [28, 29].

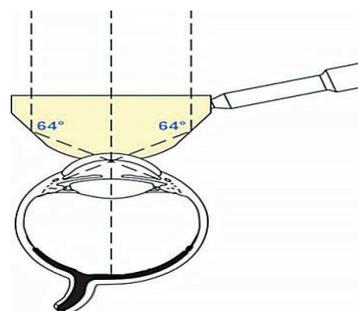


Fig. 3. Posner gonioscopes

Reproduced with permission from Ocular Instruments, Inc. (Bellevue, WA, USA)

(<https://ocularinc.com/ocular-posner-diagnostic-and-surgical-gonioprism-with-ergonomic-handle-black.html#>)

Ahmed 1.5X

The Ocular Ahmed Surgical Gonioscope is an indirect surgical gonioscope designed with a rotatable handle that enables a complete view of the ACA, offering a unique 1.5x image magnification [18].

It combines high magnification with advanced optical engineering. It is made of low-dispersion glass, which minimizes chromatic aberrations, and features an anti-reflective coating, as well as correction of corneal astigmatism (Figures 4, 5). These optical enhancements provide a sharper and more detailed image of the ACA structures, making this lens particularly suitable for the most precise and minimalistic minimally invasive angle procedures. Compared to the Upright 1.3X, it incorporates a larger reflective mirror, which expands its field of view by 90° [28, 33].



Fig. 4. The Ocular Ahmed 1.5X

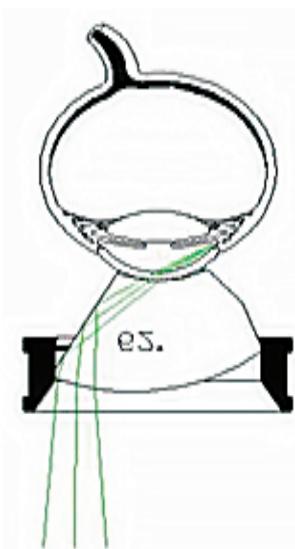


Fig. 5. Line drawing of Ahmed 1.5X

Reproduced with permission from Ocular Instruments, Inc. (Bellevue, WA, USA)

(<https://ocularinc.com/ocular-ahmed-1-5x-surgical-gonio-w-handle.html>)

DIRECT GONIOLENSES

The radius of curvature of direct goniolenses is steeper than that of the cornea; therefore, the critical angle is not reached, and the light rays are refracted

at the contact lens-air interface. This optical principle permits direct visualization of the anterior chamber angle. [22, 28, 30].

Hoskins-Barkan/Koepple Goniolens

The Barkan goniolens (Ocular Instruments, Inc.) has long served as the prototypical surgical goniolens [28]. It is designed for transverse goniotomy surgery with the operating microscope, but can also be used as a diagnostic lens (Figure 6). There are several diameters and posterior curvature radii, which are applied depending on the patient's age: 9 mm for premature infants, 10 mm for infants, and 11.5 mm for adults.

The Koepple lens (Ocular Instruments, Inc.) is the standard diagnostic goniolens used for children (Figure 7). It rests on the scleral flange, forming a corneal vault that leaves the anterior chamber undisturbed. The Koepple lens provides 1.53x magnification, a contact diameter of 17-19 mm, and a 160° static field of view (SFOV). Three sizes are available to accommodate different eye anatomies. To ensure an adequate view of the angle, one needs a hand-held biomicroscope or to tilt the surgical microscope. Neither lens has a rod [13, 18, 22, 28, 29, 33].



Fig. 6. Hoskins-Barkan goniolens



Fig. 7. Koepple goniolens

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(<https://ocularinc.com/products/gonio-lenses/ocular-hoskins-barkan-goniotomy-infant-10mm-lens.html>)
(<https://www.accutome.com/koepple-diagnostic-gonio-lens-medium>)

Swan-Jacob

The most commonly used gonioscope for minimally invasive glaucoma surgery is the Swan-Jacob gonioscope (Ocular Instruments, Bellevue, Washington). It is a modified version of Barkan's lens with an added supporting rod. Its main advantages include reusability, the availability of right- and left-hand configurations to accommodate surgeon preference, and excellent optical clarity that provides superior visualization of the structures [18]. The lens offers a magnification of 1.20x and is made of glass. In a static position, the SJ provides visualization of the ACA of 90° (Figures 8, 9). To achieve an optimal view of the angle, the patient's head should be tilted 30-45° away from the surgeon, while the operating microscope is simultaneously tilted at the same degree toward the surgeon [34-39].

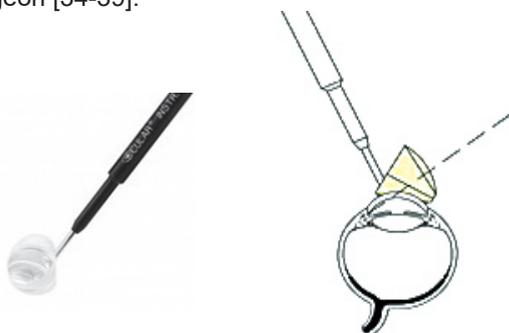


Fig. 8. Swan-Jacob gonioscope **Fig. 9.** Line drawing

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(<https://ocularinc.com/ocular-swian-jacob-autoclavable-gonioscope.html>)

Hill, Khaw, Ritch

All three lenses are modifications of the Swan-Jacob model [18, 28]. The Hill Open Access represents an improvement on the classic Hill design. It is specifically adapted for minimally invasive surgical procedures and goniotomy, providing improved access to the cornea because of its optimized design – especially in smaller eyes, where the classic lens is more likely to cover corneal incisions and complicate instrument maneuvering. The magnification is 1.2x and, similar to classic lenses, it includes a peripheral fixation ring, which allows stabilization of the globe. Available for left and right hands [33]. Unlike the SJ and Hill lenses, which allow a stationary 90° observation, the Khaw and Ritch lenses provide a 120° and 160° panoramic view of the angle, which makes them suitable for performing goniosynechiolysis in a sitting position. With minimal rotation of the lens, up to 180° can be visualized.

The Khaw lens is equipped with a fixation ring, while the Ritch lens (Fig. 10) features a distinctive design that leaves half the cornea exposed, facilitating access for instruments, incisions, and corneal retraction sutures. The Khaw lens has a magnification of 1.4x, which makes it more suitable for minimally invasive glaucoma surgery, compared to the Ritch lens, which has a magnification of 0.73x [18, 30].



Fig. 10. Ritch surgical gonioscope

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(<https://ocularinc.com/ocular-ritch-panoramic-surgical-gonioscope.html#>)

Katena

Katena Products, Inc. (currently part of Corza Medical) offers on the market the advantages of disposable instruments (unused clear optics – without any dust, scratches, or prints) and is focused mainly on the production of single-use ophthalmic surgery instruments [40]. Katena's single-use lenses provide direct observation of the ACA while performing minimally invasive glaucoma procedures (Figure 11). These lenses do not have an anti-reflective coating. The standard model provides a magnification of 1.2x and is available for right- and left-hand use. Additionally, the manufacturers offer a wide-field, single-mirror model with 0.42x magnification, an anti-reflective coating, and an extended 155° field of view [40].



Fig. 11. Katena single-use surgical gonioscope and Katena Wide Field

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(<https://corzaeye.com/surgical-gonio-prism-k30-1405>)
(<https://corzaeye.com/surgical-wide-field-with-handle>)

Volk Vold Gonio

The Volk Vold Gonio Lens has a unique ergonomic design that allows the surgeon to maintain optimal control and achieve superior visualization during surgery. Unlike other gonioscopes that form a continuum with the handle, this model incorporates a free-floating lens suspended from a hinge on the main handle, thus offering several advantages. This design minimizes pressure on the cornea, eliminating Descemet's folds and providing an unobstructed, clear view of angle structures without AC distortion.

In addition, the base of the handle includes a fixation ring, which enhances stability and reduces the risk of intraocular injury during surgery (Figure 12).

The lens has a ring diameter of 14 mm, image magnification of 1.2x, and a static FOV of 90°. It also allows rotational adjustment along the axis of the patient's head, facilitating fine-tuned visualization of the ACA structures, while reducing the amount of head tilt and minimizing microscope repositioning. The ambidextrous handle enables all surgeons to use a single gonioscope [18, 41, 42].



Fig. 12. Volk Vold Gonio Lens

Reproduced with permission from Volk Optical, Inc.
Source:

www.volk.com. Surgical Gonio Lenses

INDIRECT LENSES WITH DIRECT/UPRIGHT VIEW

These lenses have a completely different design from the previously described ones, allowing the surgeon to work without tilting the patient's head or the operating microscope. The two-mirror configuration redirects the oblique gonioscopic image to the coaxial "cataract" surgical position, providing a complete 360° view of the anterior chamber. The two internal mirrors, together with the central direct path, create a 'dual viewing system' during goniosurgery, allowing the position of the instruments to be observed through the central view while the procedure is being performed [33].

OCULAR MORI UPRIGHT AND UPRIGHT 1.3X

The Ocular Mori Upright lens has mirrored surfaces silvered with an exclusive double-layer protective coating, which prevents peeling and damage during routine use. Its magnification is 0.80x (Figure 13, left), and the field of view in a static position is 110°. This lens is recommended for glaucoma surgery, including goniosynechialysis. However, it should be noted that this lens is not steam-sterilizable.

The Ocular Upright 1.3x lens is made of glass and specially adapted for minimally invasive glaucoma surgery, goniotomy, and direct intraoperative gonioscopy, due to its superior image resolution and higher magnification (Figure 13, middle). The static field of view is 45°. It is considered an excellent choice for anterior chamber inspection during vitrectomy surgery or for delicate ab-interno glaucoma procedures, such as stenting of the trabecular meshwork. Unlike the aforementioned model, it is steam-sterilizable and equipped with a handle. [18, 33, 43, 44].



Fig. 13. Mori Upright Gonio Lens and Ocular Upright 1.3X Surgical Gonioprism

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http://www.ocularinc.com/_featured/mori/index.html;
<https://ocularinc.com/ocular-upright-1-3x-surgical-gonioprism.html#>

Ahmed DVX

Ocular's latest surgical gonioscope offers an exceptionally wide field of view of 120°, which surpasses that of other lenses with a similar design that do not require tilting the surgical microscope. It provides 1.31x magnification and delivers an extremely clear image of ACA structures. The lens has a rotatable ring, resulting in a 360° view of the angle. It incorporates 3 viewing windows (Fig. 14, middle photo): anterior chamber window, a central window, and an alignment window that ensures correct lens positioning [45].

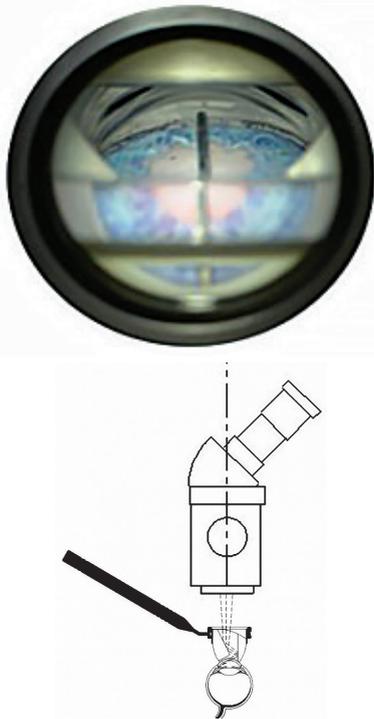


Fig. 14. Ahmed DVX Gonio Lens/Line drawing

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(<https://ocularinc.com/ocular-ahmed-direct-view-dvx-surgical-gonio.html#>)

DISCUSSION

Intraoperative gonioscopy features and recommendations

Over the last decade, an increasing number of ophthalmologists have begun performing minimally invasive glaucoma surgery as a method of IOP control, especially in patients with glaucoma and cataract, encountering both the specific advantages and challenges of its application. There are several essential steps that any surgeon can follow to improve their surgical technique and outcomes.

Proper patient selection is the first step toward successful angle surgery. Intraoperative gonioscopy usually requires rotation of the patient's head; therefore, assessment of neck mobility and the absence of significant head tremor should be taken into account [36, 38, 46]. The type of anaesthesia used is also of great importance.

The patient must be cooperative enough for local anaesthesia. If the surgeon needs to change the method, alternatives such as a peri- and retrobulbar block or sub-Tenon's block should be considered to ensure a safe and effective procedure.

Preoperatively, the surgeon should possess substantial experience with gonioscopy in the outpatient setting to be able to identify all the important landmarks, to ensure the intended procedure is possible, and to modify the chosen technique if required [38].

Such a valuable surgical landmark is the scleral spur, which separates the canal-based surgery performed anteriorly – through the trabecular meshwork – and the suprachoroidal-based surgery, which proceeds posteriorly via the ciliary body face [36].

Other equally important characteristics are the pigmentation of the trabecular meshwork and the presence of blood in Schlemm's canal, both of which are key target areas in MIGS. To obtain a clear view of the trabecular meshwork (TM) during a canal-based procedure, most MIGS surgeons recommend the use of a dye for coloring the TM, usually Trypan Blue. Ts-aousis K et al. [47] investigated the time-dependent toxicity of Trypan Blue at a concentration of 0.06% in cultured human trabecular meshwork cells and concluded that, in this concentration, the dye is non-toxic for exposure times of up to 60 seconds. However, prolonged exposure results in a gradual increase in cellular damage of cultured human trabecular meshwork.

Regarding the biocompatibility of Trypan Blue with corneal cells, van Dooren reported experience with concentrations ranging from 0.0001% to 0.1% in cultured human corneal fibroblast and endothelial cells. They found that, at concentrations commonly used for lens capsule staining (0.06%) and donor corneal endothelial staining (0.3-0.5%) for durations of a few to 60 seconds, Trypan Blue is sufficiently safe. Nevertheless, at higher concentrations or longer exposures, caution is warranted [48-50].

The selection of an appropriate goniolens is the next crucial step before initiating surgery. The gonioscopy lenses review reveals their main characteristics:

- Type (direct or indirect): indicates the method of observing the ACA structures, producing either a straight (direct) or inverted (indirect) image. Most often, lenses providing a straight (direct) image are used for surgery.
- Static Field of View (SFOV): defines the visual range achieved when the lens remains in a static position, with no rotation.
- Magnification (x): represents the ratio between the magnified image produced by the lens and the actual size of the observed object.
- Contact diameter: indicates the area of contact between the lens and the cornea

- Handle availability: specifies whether the lens is designed for right- or left- hand use
- Presence of a fixation ring: assists in stabilizing the eyeball during surgical manipulations
- Tilt and number of mirrors in indirect lenses: determine the optical configuration and influence the field of view [33-43].

Based on our experience, the most important feature of a surgical gonio lens is the presence of a fixation ring and the ability to provide a direct image.

Regarding corneal wound construction, several technical points should be considered: avoiding the limbal vessels to minimize bleeding that could interfere with angle visualization; directing the incision toward the targeted working area; and performing the smallest workable incision.

Once the surgeon has selected the gonio lens and made the corneal incision, it is important to consider the substantial differences between the cataract surgical position and the positioning required for intraoperative gonioscopy during MIGS. The working distance between the oculars and the surgical field is increased by approximately 20 centimeters, resulting in a more extended position of the surgeon's elbows and at a greater distance from the patient than usual [33, 36, 43].

Morgan MG recommends performing intraoperative gonioscopy multiple times during cataract surgery in patients, even without undertaking actual angle surgery. He advises that, prior to removing the viscoelastic and after inserting the IOL, the ophthalmologist should rotate the patient's head, tilt the microscope, apply the gonio lens, and attempt to visualize the angle. After approximately five training cases, they consider the surgeon would be ready to proceed with actual surgery. Morgan further emphasizes that the position of the patient's head and the maintenance of a clear view are critical for successful angle surgeries. He notes that the degree of head rotation and microscope tilt may vary between patients, and that the most common mistake is insufficient rotation of the patient's head [9].

Once the surgeon has positioned the patient correctly, selected a lens that is comfortable to use, and followed all the recommendations, they must be prepared for the challenges that may arise during the procedure and develop the ability to troubleshoot.

For instance, corneal folds are a common factor that can impair the angle view. They typically occur when the IOP is either too low or too high, or when excessive pressure is applied with the gonio lens on the cornea or at the corneal incisions. In the first scenario, the surgeon may add an ophthalmic viscosurgical

device (OVD) to the anterior chamber, given that the cohesive OVD creates space but easily comes out of the eye. A dispersive OVD can be used additionally as a stopper within the wound to help retain the cohesive OVD. In the second scenario, the surgeon may need to adjust his technique and try to be more gentle. Under-rotation of the eye or microscope is another common issue that can lead to blockage of the view by the posterior cornea, increasing the risk of misjudging the anatomy of the anterior chamber angle and causing surgical failure. In such cases, Descemet's membrane may be easily damaged, and the rotation of the patient's head and the microscope must be carefully coordinated.

During goniosurgery, the surgeon will also often have to deal with the presence of blood, which may interfere with angle visualization. Mild bleeding is common and often signifies successful access to the trabecular meshwork during MIGS; therefore, it is considered almost unavoidable. The surgeon may attempt to minimize blood reflux from Schlemm's canal by adding OVD or by washing the anterior chamber. Avoiding the limbal vessels when creating corneal incisions is also critical, as this can help prevent intraoperative bleeding. It is worth noting that the point of incision chosen by the surgeon significantly influences bleeding control. Additionally, excessive magnification through the microscope and fluctuations in the surgeon's accommodation can blur the visual field, reducing the precision of intraoperative manipulations [33-36].

CONCLUSIONS

The first minimally invasive glaucoma surgery is considered to be goniotomy. More than a century ago, De Vicentis (1893) introduced this evolutionary concept for glaucoma treatment. He performed the procedure without a gonio lens and consequently, without direct visualization of the surgical field. This limitation resulted in a lack of precision, and goniotomy was therefore abandoned and considered unsuccessful for many years.

More than 40 years later, in 1936, Otto Barkan succeeded in reviving De Vicentis' concept, improving the original technique and adapting it to contemporary surgical practice. He enhanced the accuracy of angle visualization by introducing the use of a gonioscopic lens with direct observation of the ACA during surgery. Through these advancements, Barkan laid the foundation of modern goniotomy and contributed significantly to the angle-based glaucoma surgery [51, 52].

For this reason, the intraoperative observation of the anterior chamber angle during surgery is not only

recommended, but also represents a mandatory component of these manipulations.

Nowadays, gonioscopy lenses are considered to be the surgeon's "window" when performing minimally invasive glaucoma surgery. Some MIGS procedures, such as Schlemm's canal stenting, require a more detailed image and higher magnification, while others, e.g., goniosynechiolysis and excisional goniotomy, necessitate a wider field of view. Therefore, comprehensive knowledge of all commercially available surgical lenses – their magnification, optical advantages/disadvantages, fixation, the field they provide for viewing, etc. – is strategically important for optimal execution of each procedure.

Intraoperative gonioscopy requires that, before performing a MIGS procedure, the surgeon consider multiple factors and gain substantial experience with gonioscopy in the clinical setting to ensure safe and effective surgical performance. Therefore, having a thorough understanding of the surgical field and mastering its visualization techniques are essential prerequisites for successful outcomes.

In conclusion, the selection of a tool for observation of MIGS is just as important as the surgeon's expertise and the choice of the surgical procedure itself.

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