The 21st Century Gonioscopy: A Technical Paper

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Abstract

Objective The aim of this paper was to create a Portable Gonioscopy System (PGS) that is efficient and cost-effective in documenting iridocorneal angles.
Methods A 4-mirror gonioscopy prism lens was attached to a portable USB microscope with a built-in camera. The microscope was then connected to a laptop for viewing of the images. A lubricant was instilled and the portable gonioscope was placed parallel to the cornea for viewing and recording of iridocorneal angles. Images were filed and stored in a laptop.
Results The portable gonioscopy system allowed sufficient viewing and recording of the iridocorneal angles. The total cost of producing the portable gonioscopy system was PHP 25,000.00.
Conclusion Iridocorneal angles can be visualized and recorded using the portable gonioscopy system. This device requires skill and expertise from professional prototypist to create. Like gonioscopy, this system also has a steep learning curve. The researchers are continuously improving the device adding more features and making it more affordable and easier to use.

Key words: Gonioscopy, portable gonioscopy, gonioscopy video system, gonioscopy imaging, gonioscopy lenses, portable gonioscope

Gonioscopy or "observation of the angle" was coined by Alexios Transtas in 1907. He used a direct ophthalmoscope in viewing the angles, while indenting the sclera of the eye with his finger.[1] A few years later, Maximilian Salzmann performed gonioscopy by using a contact lens with angled lighting to view the iridocorneal angles.[1] Both are considered fathers of gonioscopy.

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Gonioscopy is part of a complete eye examination. Under normal conditions, light from the angles undergoes total internal reflection at the tear-air interface and prevents viewing of the angle structures. Hence, several gonio lenses and techniques were developed in eliminating total internal refraction.[2] There are two methods in performing gonioscopy: direct and indirect. A direct gonioscopy allows direct and erect view of the angle structures. This technique requires a direct gonioscopy lens (Koeppe, Barkan, Wurst, Swan-Jacob, or Richardson lenses), a binocular microendoscope, a light source and is performed comfortably when a patient is in the supine position. The main disadvantage of direct gonioscopy is inconvenience; it is currently done in examining eyes under anesthesia or when performing certain filtration surgery.[2]

Indirect gonioscopy, the most widely used technique in the clinics was introduced by Hans Goldmann in 1938. It utilizes mirrors to redirect light from the iridocorneal angle to examine the angle structure. This technique uses an indirect goniolens (Goldmann, Zeiss, Posner, Sussman, Allen-Thorpe prism lenses) with or

without a coupling agent and a slit lamp. Although images of the angle structures are seen inverted and are reflections of the opposite angle, it can be performed comfortably with the patient in an upright position. Some of the indirect gonioscopy lenses allow dynamic and indentation gonioscopy, which is another technique in examining iridocorneal angles.[2]

Capturing images and video recording are now an integral part of the patient examination. Images and videos aid an examiner keep track of and may be used to communicate more effectively to explain to a patient his or her condition. These materials may also be used, with proper patient consent, as teaching tools for training physicians and medical students. Newer slit lamps have built-in cameras but cost more than twice as much as a regular slit-lamp microscope. Some older slit-lamp microscopes have options for camera module upgrades but are costly as well. In the Philippines, smartphones and portable cameras are widely used for recording purposes due to their availability and affordability. These smartphones are manually focused or attached to the slit-lamp eyepiece to take images, requiring time and effort to set up, and are oftentimes counter-productive due to its instability. Additionally, manual adjustments of the smartphones are needed to get a better view of the angles.

Based on the researchers' review, there is no modern method of viewing and recording iridocorneal angles similar to the researchers'. This study presents a modern, portable and affordable alternative in viewing and recording iridocorneal angles.

Methods

Selection of Participants

Participants of the study were adult patients and personnel from a tertiary hospital in Quezon City, Philippines. Five healthy volunteers with no ocular problems were included. An informed consent was secured prior to the examination. Patients who were not able to sign and those who did not give their consent were excluded from the study. Personal information was limited to informed consent and was not used in the study. A code assignment was given to participants for organizing images and videos captured during the study that would not be part of their medical record.

Device Specification

The portable gonioscopy system is composed of a gonioscopy lens, a light source with a light diffuser, a microscope lens housed in an adapter and a viewing lens or device capable of recording images. The gonioscopy lens is used to overcome the total internal reflection in order to view the iridocorneal angles. A microscope with a light source imitates the slit-lamp microscope capabilities. Despite the numerous types of gonioscopy lenses, iridocorneal angles can be viewed by focusing the microscope at the center of the gonio prism or mirror of interest. An adapter is used to fixate the gonio lens and the microscope in place and allow fine adjustments in aligning the lenses. Images of the iridocorneal angles can be viewed directly using a magnifying glass or camera connected to a computer or a portable device. Any material that effectively limits lux intensity to 200-600 lumen/m^2, softens and distributes the intensity of a light source evenly can be used as a light diffuser. (Figures 1-4)

The investigators used the following to create the Portable Gonioscopy System (PGS). A four-mirror gonioscopy lens (Volk Optical Inc. Ohio, USA) for viewing angles was used in this study (Figure 5).

Figure 1A and 1B. Volk single use 4-mirror gonio lens.

Figure 2. USB microscope.

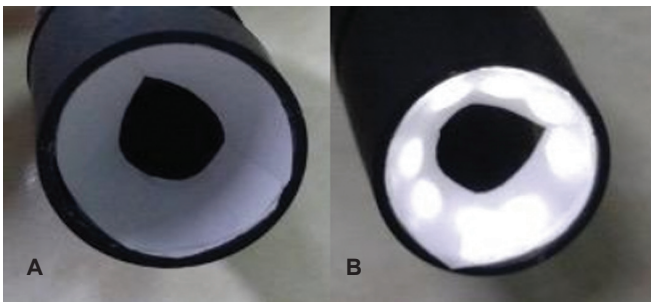

Figure 3. Microscope lights with light diffuser; light off (A) and light on (B).

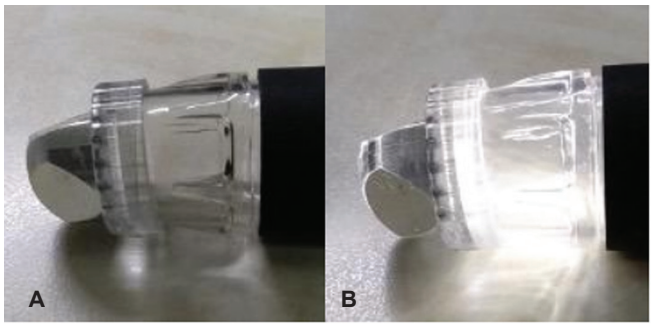

Figure 4. Gonio lens attached to USB microscope with light off (A) and light on (B).

For imaging and recording, a portable USB capture function microendoscope (unbranded, China) was used. Multiple layers of paper placed on top of the light source were used to diffuse light. The gonioscopy lens was attached to the end of the microendoscope. The attachment of the gonioscopy lens was angulated, its magnification was adjusted for better visualization of the angles then and secured in place, focusing at the center of the superior mirror. A focusing knob and photo clicker button are built-in the microscope. This PGS was attached to a laptop (Macbook Pro Retina 2015, California, USA) to capture images and record videos. Images of the iridocorneal angles were viewed, captured and stored using a camera viewer Mac application (Plugable Technologies, Washington, USA).

Description of the Procedure

Participants who consented for the procedure were examined in a clinic. A standard slit-lamp routine ophthalmology examination was done before the procedure. Each patient was seated upright, relaxed, looking towards the front with the patient's line of vision parallel to the floor. As part of a standard

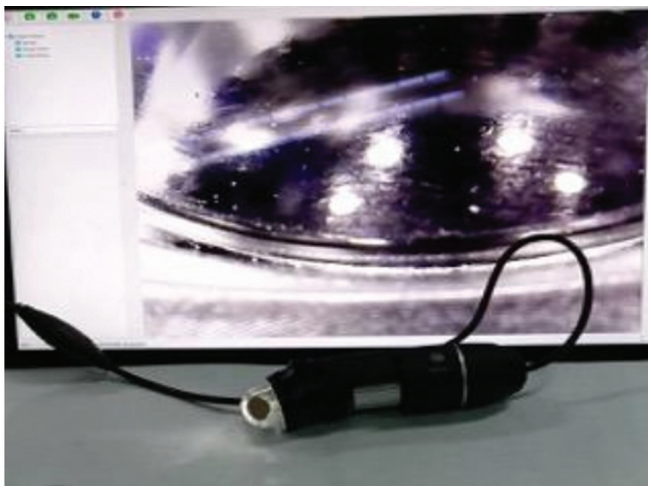

Figure 5. Portable gonioscopy system.

gonioscopy, proparacaine (Alcaine® Alcon, USA) eye drops were instilled for corneal anesthesia prior to testing. A lubricant was applied on the 4-mirror gonio lens to ensure the conjugation of the cornea to the lens. The PGS was placed on the cornea to capture and record images of the iridocorneal angles (Figures 6 & 7). After the procedure, the participants were re-examined under the slit lamp microendoscope to check for possible corneal abrasions incurred during the procedure.

Ethical Considerations

The participants were informed of their free will to sign the consent, and that they could withdraw from the study at any time without compromising patient care. Participants were also informed of risk for

Figure 6. Positioning PGS for viewing of the iridocorneal angles.

Figure 7. Examination of the iridocorneal angles using PGS

corneal abrasions and allergy to medications as well as ocular discomfort such as glare that have equal risk as that of a standard indirect gonioscopy examination. There was no compensation given to participate in the study.

There were no identifying marks linking the participant with gonioscopy images. Captured images and videos were assigned with codes and were not filed with the participants' medical records. The participants' identity and confidentiality were preserved. Participants were also allowed access to the images and videos, and given copies when requested. All images and videos are owned by the researchers and used for educational, research and lecture purposes only.

Results

The researchers took images of how the portable gonioscopy system views the iridocorneal angles. The device is slowly rotated to view other parts of the angle, oftentimes losing focus on the angles. Refocusing and taking images was tricky because both the focusing knob and camera shutter were built in the microscope. Any small movement caused further blurring of the images. The researchers noted and observed rosette lights or reflections because there was only partial diffusion of light. Future adjustments can be made to diffuse the light fully and avoid rosette reflections.

Discussion

A slit-lamp biomicroscope capable of capturing images and videos of the iridocorneal angles is an essential tool used for education and presentation. This machine capable of capturing images is mostly found in tertiary hospitals, eye referral centers and training institutions where they are of most use. However, a standard slit-lamp microscope and gonioscopy lenses are costly to acquire, and not all can afford to own one.

The current method of capturing images and videos of the iridocorneal angles is through the installed camera in the slit-lamp aided by a gonioscopy lens. Patients are required to be seated upright and tall enough to be examined through a slit lamp biomicroscope. The examiner looks through the optics of the slit lamp, placing the gonioscopy lens in contact

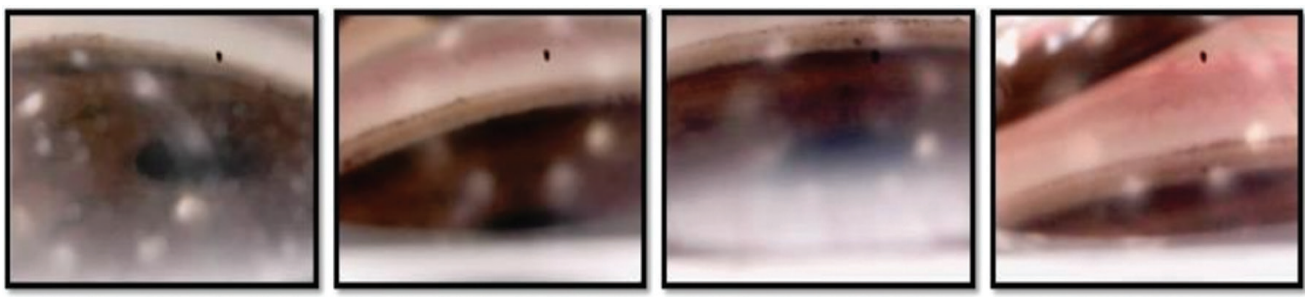

Figure 8. Images of iridocorneal angles using PGS.

with the cornea using one hand, and brings into focus the iridocorneal angles by manipulating the slit lamp microscope with the other hand. In some cases, the examiner's view from the optics is not the same as when viewed in the camera's monitor. The examiner needs to refine the light intensity, angulation and focus while viewing the structures from a monitor. This technique has a learning curve to properly view and capture iridocorneal angles.

There is also an increasing interest in handheld devices in the field of ophthalmology. Currently, portable fundus cameras, automated keratometry devices and refractors, handheld slit lamps, tonometry measurement devices and OCT cameras are being studied and marketed globally, gaining popularity more especially in developing countries, where there is lack of patient access to advanced ophthalmologic centers.

This study combines portability and affordability in viewing and capturing images and videos of the iridocorneal angles. The USB microendoscope has a magnification capacity of 20 to 1000x and can be focused within 0 to 200 millimeters. The microendoscope also has a built-in light and is powered by a laptop through the USB cable. Any filtering material can be used and placed over the light source to evenly diffuse light and limit lux to 200-600 lumen/m^2. The center of a gonioscopy lens mirror is targeted while assembling the PGS. The microscope lens should be perpendicular to one of the targeted 4-mirror gonioscopy lenses to reduce glare. Once the mirror is in focus, it is secured with either a tape or adhesives. The process can be tricky as minuscule movements while securing the gonio lens to the microscope puts it out of focus. An adapter can be used that is capable of finer adjustments of the lens angulation and microscope lens working distance while the gonioscopy lens and microscope are secured in place. The assembly and adjustments are done while the microscope is powered and viewed from the computer monitor. Once the PGS is assembled, viewing of the iridocorneal angle can be done.

The PGS is not limited by the participants' position; hence it can be used whichever position the participants are comfortable with. An anesthetic drop is placed on the participant's cornea, similar to current gonioscopy technique with a slit lamp. The PGS gonioscopy lens tip can be instilled with topical lubricant eye drops or eye gel for better viewing of the angles. The PGS gonioscopy lens tip is carefully placed parallel to the participant's cornea without indenting the cornea. For extra stability, the 4th and 5th fingers can be rested on the participant's cheeks. While the PGS is on the cornea using one hand, the other hand is used for manual focusing of the iridocorneal angles built-in the microscope while viewing from a laptop. Focusing using the PGS can be tricky because small movements may prove to be difficult in maintaining a good view of the iridocorneal angle. Once the angles are in focus, one hand is free while the other hand keeps the PGS in place. The free hand can be used to write notes, draw angle images or capture images or videos from the laptop using a camera viewer application. In this study, the authors utilized a free application for Macintosh, a digital viewer from Plugable Technologies in recording images and videos.

Like gonioscopy through a slit lamp, the examiner must be very careful with movements while doing this procedure as this procedure can cause corneal abrasions. Once the angles are recorded, the PGS is removed and the eye and the cornea is checked for possible abrasions. With the available images of the iridocorneal angles captured, this decreases the need of performing a repeat gonioscopy for other ophthalmologists to recheck or verify the angle findings. Currently, PGS can provide images of the iridocorneal angles but the quality still needs to be addressed. The lighting system also needs better regulations to reduce reflections from the light source. Handling of the PGS has a learning curve and can be challenging especially for those with smaller hands. The investigators experienced difficulties as the system was being designed. Table 1 lists the problems encountered and proposed solutions to overcome them.

The investigators are continuously modifying and improving the PGS design. The shape of the PGS can be, but not limited to, a straight or an L-type design. By adding a mirror in between the gonioscopy lens and microscope lens, the light bends to a desired angle and the visualization is easier. An adapter is also being designed as either a screw-type or clip-type to attach and replace different gonioscopy lenses for a more universal use. Another adapter is also currently being designed to act as a stabilizer holding the PGS against the patient's periorbital area for added safety and ease in performing gonioscopy with PGS. Added features of adjusting angulation, working distance and gonioscopy lens size are currently under study.

Table 1. Problems encountered and proposed solutions.

Problem	Solution
Viewing of iridocorneal angle without slit lamp	Gonio lens viewing of iridocorneal angles through a laptop or smart device using a microscope
Difficulty of adjusting microscope from one mirror to the other with poor stability	Microscope is focused and fixed on one mirror at a time
Images are focused but poor image quality	Microscope is angulated perpendicular to the mirror or at 60 $\pm$ 10 degrees in relation to the center of the targeted mirror for observation
Glare is seen while using built in LED lights from microscope	Filter is added, any material that limits light from LUX 50-600
Increase magnification to better visualize iridocorneal structures	Working distance further decreased to 5-10 mm

A USB OTG (USB on-the-go) and web camera app can also be utilized to connect the PGS to any smart device that can serve as a monitor in viewing the iridocorneal angles. The PGS is also in development using Bluetooth and WIFI technologies for wireless connectivity between PGS and a monitor (computer or smart devices). Due to the fragility of some parts of the PGS, a removal outer case is also being designed to protect the PGS.

For its use, the PGS is basically designed as a viewing mechanism. The investigators foresee its use for therapeutic purposes, as an intraoperative device for doing a micro-invasive glaucoma surgery (MIGS), or doing laser procedures such as, but not limited to, selective laser trabeculoplasty (SLT), in which there will be a provision for attachment of the lasers needed for these procedures.

A software program and application is another future development. It will be designed to guide PGS users step by step in utilizing the PGS and its full features to help integrate the PGS in their daily practice. The PGS software will also aid in proper documentation of iridocorneal angle images and videos for easier access, auto mapping of angle structures and evaluation of the current status if the angles are open or close. The investigators will find new ways, working with other professionals in improving its capabilities, making it more affordable and easier to use to bring comfort both for the doctors and patients in performing gonioscopy. The cost of viewing and recording iridocorneal angles utilizing the standard non-portable method (slit lamp, camera accessory and gonio lens) would amount to at least PhP 300,000. With this current PGS working prototype, the total cost of production is only at PhP25,000.

Iridocorneal angles can be visualized and its images can be recorded using the Portable Gonioscopy System. These images are an effective tool for patient education, student learning, case presentation, case consult, pre- and post-operative evaluation, or self-education. This instrument effectively reduces clinic costs, eliminating the need to purchase separate units of cameras and video recorders. This instrument may be one of the few portable instruments to date that saves clinic space, eliminates the use of expensive machines and has the potential of becoming an essential tool in the field of ophthalmology. This will also be the first to be a portable diagnostic and treatment instrument in the market.

Findings

The primary investigator and her co-investigator covered the expenses for this study.

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