RESEARCH ARTICLE

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Anterior Segment Examination with Slit-Lamp Biomicroscope: What Should be Highlighted?

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ABSTRACT

Ocular health assessment consists of various types of examinations that aim to find pathological conditions in the eye so that it helps ophthalmologists to diagnose and provide therapy for ocular disorders suffered by the patients. Slit-lamp biomicroscope is one of the most important eye assessments and has become the standard in assessing the pathological condition of the anterior part of the eye. This examination is performed using a stereoscopic biomicroscope instrument in combination with a bright illumination source. The results of the anterior segment examination using slit-lamp biomicroscope may provide more detailed ocular findings, such as the abnormalities of the eyelid, conjunctival lesions, abnormalities of the cornea, lens, or other parts of the anterior ocular segments. Therefore, the ability to examine slit-lamp biomicroscope is essential for the ophthalmologist. This review will discuss the eye examination using slit-lamp biomicroscope and the findings that will make it easier for clinicians to determine the direction of diagnostic approach in ocular patients.

Keywords: Biomicroscope, eye diseases, diagnostic procedure, ophthalmology.

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I. Introduction

Ophthalmology is a unique medical science. Unlike other pathological conditions, disorders related to the function and structure of the eye are difficult to assess based on a common general examination. Therefore, specific examination of the eyes and their surrounding structures is mandatory to find any eye abnormalities to obtain an accurate diagnosis. Anterior segment examination is the standard procedure in the steps of a general eye examination. In this examination, various anatomical components comprising the anterior eye organs are assessed, including the external structures and adnexa of the eye, eyelid, conjunctiva, cornea, sclera, iris, pupil, anterior chamber, and lens [1].

The slit-lamp biomicroscope is an instrument that has been used in daily clinical practice among ophthalmologists. Developed in the early 19th decade, this instrument has currently been used regularly by both general practitioners and ophthalmologists in performing anterior eye examinations [2]. It can also be combined with other instruments to perform posterior eye examinations and conduct certain ocular therapeutic procedures [1]. The accuracy in performing anterior segment examination using a slit-lamp biomicroscope is essential in order to establish the right diagnosis of eye disorders. This review will discuss various aspects that must be considered in performing anterior segment examination using a slit-lamp biomicroscope, especially for general physicians.

II. Slit-Lamp Biomicroscope

The development of the slit-lamp biomicroscope was initiated around 1911 by a Swedish ophthalmologist named Allvar Gullstrand [2]. Gullstrand is the only eye scientist to win a Nobel Prize in ophthalmology for his findings in the field of optical images and the refraction of light in the eye [3]. Gullstrand's findings continued to be refined, then almost half a century later, the first slit-lamp biomicroscope was introduced for commercial use by a Swiss ophthalmologist named Hans Goldmann [1]-[4].

A slit-lamp biomicroscope is a stereoscopic ocular device consisting of a high-powered binocular microscope combined with a source of bright illumination, which is used to enlarge and improve the quality of the optical image so that a more detailed appearance of the ocular structure can be obtained [5]. The term slit-lamp refers to the use of a light bulb with a vertical filament as a source of illumination. Slit-lamp lighting can also be changed according to the focus of the examination you want to do, for example, in the form of a circular or square light beam. In addition, the width and length of the light beam can be adjusted, and the image can be magnified up from about ten times to 40 times [6]. The slit-lamp biomicroscope is one of the most common instruments that are routinely used in anterior eye examination because it is considered to provide excellent magnification, as well as excellent and variable illumination compared to other ocular instruments, such as direct ophthalmoscopy, penlight, loupe, or Burton lamp [5].

A. Anatomy of The Slit-Lamp Biomicroscope

Until now, the slit-lamp biomicroscopes have continued to advance and have used the LED lamps as a source of illumination. There are two modern types of slit-lamps with different illumination sources developed by Zeiss or Haag-Streit. The difference between the two is in the location of the illumination system placement (Fig. 1). Generally, the slit-lamp anatomy consists of the base, the patient support frame, the illumination system arm, and the biomicroscope (viewing) arm [1], [7].

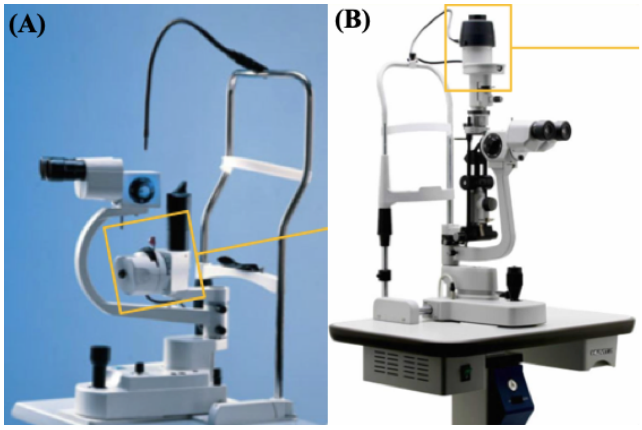

Fig. 1. Different types of slit-lamp biomicroscope based on the illumination system, i.e., the Zeiss type (A) with the illumination comes from below, and Haag Streit type (B) with the illumination comes from above (See the yellow square).

The slit-lamp base consists of an adjustable table that can be raised or lowered to suit the patient's height while sitting. At the base, there is also a power switch, locking carriage, and joystick to move the slit-lamp biomicroscope when examining the left and right sides of the eye while the patient remains fixed. The patient's head is positioned on a support frame consisting of a forehead band and chin rest during the examination. To adjust to different patient facial lengths, a chin height adjustment knob can be adjusted to up or down, with the patient's eye lateral canthus being parallel as the canthus height indicator. The patient may be asked to hold on to the handles under the chin rest for a more comfortable position [1].

The illumination arm is a light source to focus the eye structure object that needs to be examined. On the system, different color filters function to perform specific examinations, such as the white filter to examine the eyes in general, the cobalt blue filter, which is used to examine eyes that have been dripped with sodium fluorescein, and red-free filters to examine eyes that have been given rose-bengal staining and to enhance the contrast for blood vessel examination as in subconjunctival hemorrhages or on the corneas of contact lens wearer [1], [8].

The viewing arm consists of the oculars and a biomicroscope apparatus, classified to Genrough or Galilean biomicroscope based on the type of changer of the magnification control knob. Genrough microscope uses the flip lever to change the object magnification, while Galilean microscope uses a 3-5 steps knob to adjust the magnification [8]. This type of magnification commonly offers stepwise magnification between 6 times and 40 times. The low-power magnifications (6-10 times) help visualize a wide field ocular view for an optimum general examination. The high-powered magnifications (10 times above) help visualize more detailed ocular structures to enhance the pathologic features identified at the low-powered magnification mode [1]. The microscope also includes two individually adjustable eyepieces, typically adjusted up to 3.5 magnification to compensate for the examiner's uncorrected spherical ametropia [9].

Nowadays, biomicroscopes have also evolved to smaller sizes, i.e., the hand-held slit-lamp, which suits patients with special needs, such as children, disabled or bedridden patients. The use of complementary devices can also be combined with a slit-lamp biomicroscope. In addition to developing the modern slit-lamp, Hans Goldmann also discovered the gonioscopy prisms *lens*, which allows the examination of the iridocorneal angle under the slit-lamp [10]. David Volk also found another discovery regarding the spherical aberration-free funduscopic lenses to help the visualization of the posterior segment of the eye when it is placed in front of the slit-lamp ocular [11]. In addition to assisting in diagnostic procedures, the slit-lamp can also be used for therapeutic approaches both without and when combined with supplementary devices. With adequate magnification, several eye management procedures can be performed under the slit-lamp biomicroscope, including epilation, removal of ocular foreign bodies, debridement of the ocular surface, lacrimal canal therapy procedures, and evaluation of contact lenses. Meanwhile, when combined with a laser device, it can also be used to treat retinal hemorrhages [1], [8].

B. Illumination Techniques

To obtain adequate examination results, the clinician needs to understand the technique of adjusting the illumination of the slit-lamp biomicroscope. The examiner can adjust the slit width control knob to set the preferred thickness of the slit light (wide beam or narrow beam). Adjustments can also be made on the slit height control knob to adjust the preferred height or the shape of the slit light (rectangular, conical, or circular beam). To adjust the direction of light that will illuminate the examined eye, the examiner can also make adjustments to the slit angle rotation knob [8], [9].

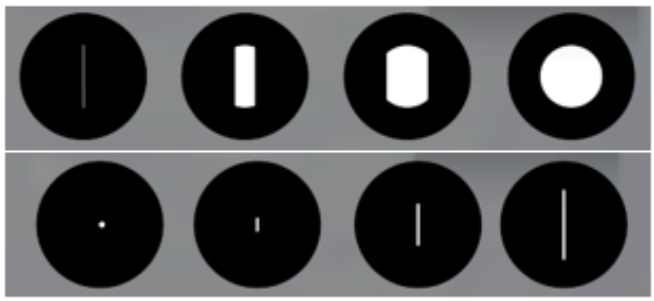

Fig. 2. Different types of thickness beam illumination on the slit-lamp biomicroscope [8].

Additionally, the examiners are also expected to be able to choose the best configurations of illumination, i.e., the direct illumination (diffuse, parallelepiped, optic section, conical beam), specular, tangential, indirect, or proximal, retro illumination, and sclerotic scatter illumination features (Table I) [8], [9], [12].

TABLE I: SUMMARY OF ILLUMINATION TECHNIQUES ON SLIT-LAMP BIOMICROSCOPE [8], [9], [12]

Illumination Techniques	Description	Applications
Direct diffuse illumination	▪ The light projected directly at the maximum beam height and width ▪ Angle: 30°-45° ▪ Magnification: Low to medium (6-10 times) ▪ Illumination: Medium to high ▪ Filter: Diffuse	General gross examination of the anterior ocular structure and surface, media opacities, and contact lens evaluation
Direct diffuse illumination	▪ The light projected directly at one focus of interest ▪ Angle: 40°-60° ▪ Magnification: Depends on technique (10-40 times) ▪ Illumination: Depends on technique ▪ Filter: Depends on the technique	Detailed examination of the cornea with or without fluorescein stain, anterior chamber, lens, anterior part of the vitreous body
Indirect illumination	▪ The light is focused on the area adjacent to the point of interest (decentered beam) ▪ Angle: 0°-90° ▪ Magnification: Low to high ▪ Illumination: 2-4 mm slit with low to medium illumination ▪ Filter: Not necessary	Examination of corneal abnormalities (infiltrates and scars, deposits, epithelial and stromal defects, contact lens complications)
Retro-illumination	▪ The light is reflected at a posterior structure (iris or fundus) to illuminate the point of interest ▪ Angle: 0°-45° ▪ Magnification: Low to high ▪ Illumination: 1-4 mm slit with low to high illumination ▪ Filter: Not necessary	Examination of corneal vascularization, degeneration, dystrophies, keratic precipitates in the corneal endothelium, detailed lens assessment, and opacity media assessment
Specular reflection	▪ Observational and illumination have the same perpendicular angle ▪ Angle: 40°-60° ▪ Magnification: Low to medium ▪ Illumination: Narrow beam with high illumination ▪ Filter: Not necessary	The lipid layer of the tear film assessment, the only technique to evaluate the endothelial layer of the cornea and the epithelial cells of the lens
Sclerotic scatter	▪ Light is focused on the corneal limbus ▪ Angle: 40°-60° over the limbus ▪ Magnification: Low to medium ▪ Illumination: Narrow beam with high illumination ▪ Filter: Not necessary	Corneal abrasion, opacities, foreign bodies, edema, and infiltrates

III. OCULAR FINDINGS ON SLIT-LAMP BIOMICROSCOPE

All clinicians and ophthalmologists should perform a standard examination routine using the slit-lamp biomicroscope with an anterior-to-posterior approach, starting from the eyelids and eyelid margins, tear film, conjunctiva and sclera, cornea, sclera, aqueous humor, iris, lens, and anterior chamber. Each assessment should be done comprehensively and necessarily repeated, to guarantee that nothing is overlooked, and all ocular structures have been examined for abnormalities.

A. Eyelids and Lashes

The eyelid or palpebra is a layered structure known as the outermost part of the eye. The eyelids consist of the upper and lower eyelids, as well as the palpebral fissure in between, which is an opening where the eyeball is exposed to the external environment. The skin of the eyelids is the thinnest skin structure on the human body. This structure consists of the cilia (eyelashes), sebaceous glands, and sweat glands. The skin of the eyelids is also composed of loose connective tissue and does not contain lipid tissue. The presence of physiologic disturbance to this structure often causes an accumulation of blood or fluid under the skin, leading to the swollen eyelid that manifested quickly and excessively. The eyelid margin consists of the lacrimal punctum, which is located superiorly and inferiorly on the medial part of each lacrimal papilla. The superior lacrimal punctum is located more profound and hidden, so it is important to perform an eversion procedure to examine this structure under the slit-lamp [13].

A slit-lamp biomicroscope examination of the eyelid begins by evaluating the gross appearance of external eye structures to find any defects or abnormalities. The technique should be started using the moderate beam thickness, low illumination, and low magnification (less than 10-times magnification), which is then gradually focused. Examination of the eyelids is done when the eyes are open and closed. Some of the abnormalities that can be found in the eyelids can be caused by various factors, including congenital or degenerative abnormalities, infection and inflammation (blepharitis, hordeolum, ophthalmic herpes zoster, *ptyriasis palpebrarum*), due to the growth of abnormal masses on the eyelids, such as chalazion and xanthelasma, and eyelashes abnormalities, including trichiasis, scurf, or collarettes [14].

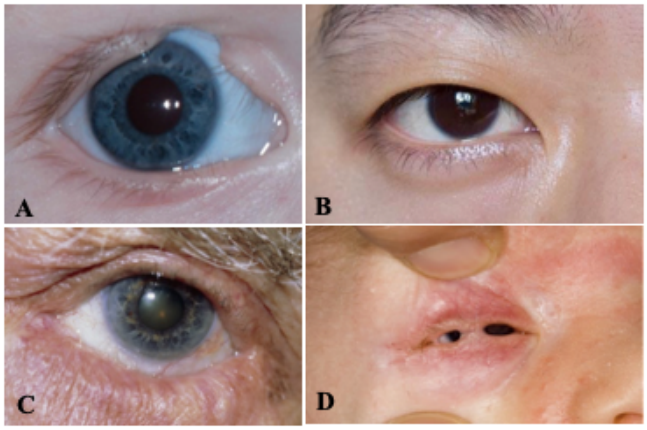

Fig. 3. Eyelid abnormalities, (A) Palpebral coloboma, (B) Epicantus, (C) Entropion, (D) Ankyloblepharon [14].

B. Conjunctiva and Sclera

The conjunctiva is a thin mucous membrane that lines the inside of the eyelids and eyeball. The inside of the eyelids is lined by the palpebral conjunctiva, which is a transparent vascularized membrane. This layer is continued on the fornix conjunctiva and then fuses with the bulbar conjunctiva, which covers the anterior part of the sclera prior to the ending at the limbal corneal sclera. The conjunctiva is the anterior part of the eye that is rich in vascularity. In pathological conditions, such as inflammation of the conjunctiva, the superficial blood

vessels will dilate, causing redness of the eye. The predominant vascular dilatation is seen around the fornix and disappears at the limbus. In addition, administration of epinephrine at a dose of 1:1,000 can constrict blood vessels, thereby reducing the manifestation of a red-eye [14], [15].

The sclera is originated from the Greek term meaning "hard". This refers to the role of the sclera, which is a functioning outer structure of the eyeball that is strong; however, it is still elastic. The scleral layer is composed of collagen fibers and elastin fibrils so that macroscopically it appears as the white layer of the eyeball. According to its anatomical layers, the sclera is divided into the episcleral layer, the substantia propria or stroma, and the lamina fusca. Compared to the conjunctiva, the scleral layer is relatively less vascularized, thus having a slow biochemical activity [14], [15]. However, any abnormalities in the sclera may cause dilation of blood vessels (episcleral injection). An episcleral injection is an external sign of intraocular disease, such as anterior uveitis and glaucoma [16].

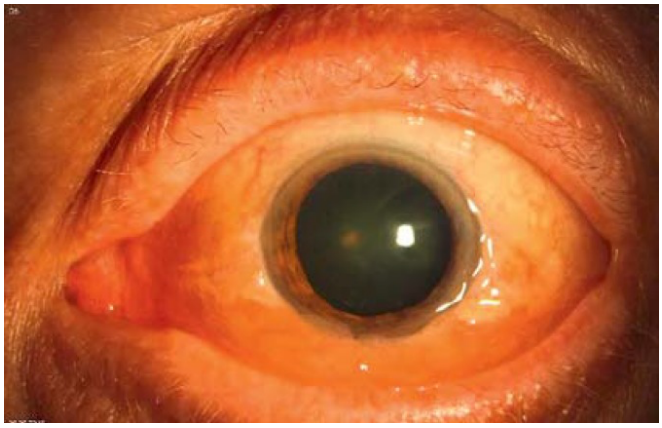

Fig. 4. The gross appearance of conjunctival chemosis.

A slit-lamp biomicroscope examination of the conjunctiva and sclera is initiated with a wide beam illumination and subsequently reduced to 2-3 mm slit beam. The lower lid must be retracted while the patient is instructed to look upward to inspect the inferior part of the palpebral conjunctiva. To inspect the superior part of the palpebral conjunctiva, the upper lid must be everted [1], [8]. Typical disorder abnormalities found in conjunctival disorders are the presence of discharge and red eyes, as seen in conjunctivitis with various etiologies, such as viral, bacterial, fungal, or allergic risk factors. In addition to conjunctivitis, degeneration of the conjunctiva can be found, including the pinguecula, pterygium, and lithiasis. Meanwhile, scleral disorders are generally caused by inflammatory factors, i.e., scleritis and episcleritis, characterized by red eyes due to widening episcleral blood vessels [14].

C. Tear Film

Tear film and tear break-up time (TBUT) examinations are generally performed in patients with dry eye symptoms, such as eye irritation, burning sensation, and red eyes. This examination was carried out using the instillation of fluorescein staining on the eye being examined, then a slit-lamp examination with a cobalt blue filter was performed. During the examination, the evaluation is focused on the anterior part of the cornea. In general, TBUT is considered normal if it lasts longer than 10-15 seconds, while a value below indicates the patient has dry eye syndrome [8].

D. Cornea

The cornea is an avascular transparent tissue consisting of five layers, i.e., the epithelium, Bowman's membrane, stroma, Descemet's membrane, and the corneal endothelium. The cornea is also the strongest refractive organ, so it has a significant role in the physiological process of vision [13]. Corneal abnormalities are very diverse, including abnormalities in the size of the cornea (megalocornea), which is often found in children with congenital abnormalities, keratoconus (conical shape of the corneal surface), keratoglobus (diffuse protrusion of the entire surface of the cornea), corneal surface abnormalities (erosions, ulcers, scar, opacity, foreign bodies), and inflammation and infection (keratitis, neovascularization). Similar to conjunctivitis, keratitis can be caused by various factors, such as bacterial, viral, or fungal infections. However, abnormalities in the cornea are generally distinguished by a decrease in visual acuity or visual acuity due to a disturbance in the main role of the cornea as a medium of refraction [15].

Slit-lamp examination of the cornea was initiated with diffuse illumination and low-powered magnification (10 times) to obtain a general appearance of the entire cornea. Subsequently, change the illumination using the parallelepiped technique for a more specific examination of the corneal surface. First, the illumination arm should be adjusted to a more oblique angle, and then the beam should be set narrow using an optical section technique. Due to the nature of the convex corneal surface, the examiner can adjust the movement of the joystick to adjust the focus during the examination. To gain a more detailed image of the corneal abnormalities, the microscope can also be increased to higher magnification (up to 16 times) [1], [8].

E. Anterior Chamber and Aqueous Humor

The anterior chamber is a structure that holds aqueous humor in the anterior part of the eyeball. The anterior chamber of the eye is surrounded by the cornea anteriorly, and by the diaphragm of the iris and pupil posteriorly. The anterior chamber angle, which lies at the junction of the cornea and iris, constitutes five important structures, namely the Schwalbe line, Schlemm's canal, and trabecular tissue, the scleral spur, the anterior edge of the ciliary body, and the peripheral iris. The mean anterior chamber depth is 3.0 mm, but it can be found deeper in aphakia, pseudophakia, and myopic eyes, but shallower in hyperopic eyes [13].

Anterior chamber abnormalities are closely related to the impaired circulation of aqueous humor flow, which manifests as glaucoma. Glaucoma is an optic neuropathy characterized by a raise in intraocular pressure and is accompanied by characteristic visual field loss and optic nerve papillary atrophy. The narrow anterior chamber angle is one of the risk factors for angle-closure glaucoma. In acute glaucoma conditions, eye abnormalities such as red eyes and pupillary mydriasis can be found [16].

Examination of the anterior chamber should be done in a narrow beam (1 mm wide and 3 mm height). The normal condition of the anterior chamber is transparent. Conical beam illumination technique also helps identify reflective material indicating the inflammation or infection in the

anterior chamber, such as the presence of cells (small white dots) and flare (protein escaping from the blood vessel), which appear as haziness compared to the former to unaffected eye. In severe conditions, there may also be an accumulation of purulent material in the anterior chamber called hypopyon. Ocular trauma and certain diseases may cause the iris's neovascularization or hyphema (blood accumulation in the anterior chamber). To enhance the identification of microhyphema, the examiner may apply the red-free filter, which appears as black spots contrary to the backdrop of the iris or retinal reflex [1], [8].

Evaluation of the anterior chamber angle is essential, particularly among patients with the suspicion of glaucoma. Patients with a narrow anterior chamber angle should receive more consideration because of the tendency to develop acute glaucoma. A slit-lamp examination can be an alternative to standard gonioscopy in assessing the iridocorneal angle. Illumination is directed using the narrow beam, so that it falls at an angle of 60° right at the limbus of the cornea (van Herick technique). The principle of this examination is to determine the depth of the anterior chamber based on the distance of the optical black section formed between the inner corneal surface and the anterior part of the iris. A depth distance of less than a quarter of the corneal thickness indicates a risky narrow anterior angle, making it more susceptible to glaucomatous incidences [1], [8], [18].

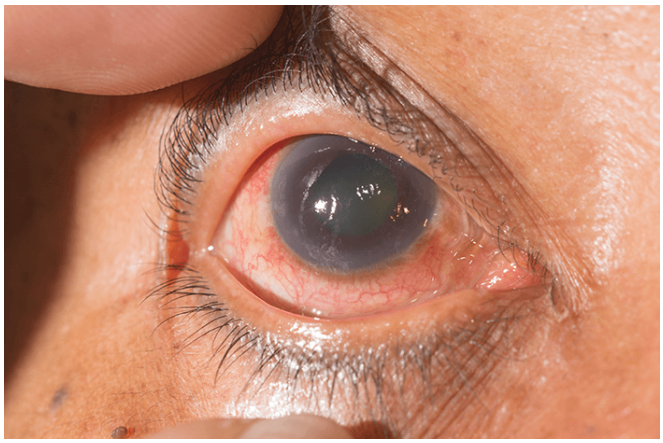

Fig. 5. Clinical manifestation of a mydriatic pupil and red-eye indicating the acute glaucoma attack.

F. Iris and Pupil

The iris is the outermost part of the uveal tract, which lies anterior to the crystalline lens [13]. The presence of muscle in the iris causes changes in the pupillary aperture, which aims to regulate the amount of light entering the eye. Contraction of the radial muscle causes pupillary dilation (mydriasis) so that the iris looks jagged and folded. In contrast, contraction of the circular muscle causes pupillary constriction (miosis) so that the iris looks relatively flat [19].

Abnormalities in the iris and pupil are generally associated with pathological conditions in the muscles and innervation of the eye because of the sympathetic and parasympathetic roles in regulating pupillary movement. In addition, some pupillary abnormalities are often characterized by a relative afferent defect, which is the weakness of one of the direct pupillary reflexes compared to the other indirect pupillary reflexes [20].

To perform a detailed examination of the iris, the retro-illumination technique can be used. Adjust the illumination to be short and narrow beam directly through the pupil, so that the transillumination area of the light reflected on the retina is obtained. The presence of defects in iris transillumination can be found due to the loss of pigmentation in the posterior iris, as seen in iris albinism and pigmentary dispersion syndrome [1], [8].

G. Lens

The crystalline lens is a biconvex structure that functions to focus the light entering the eye so that it is precisely reflected onto the macula of the retinal surface. The lens is an avascular structure so that it looks clear macroscopically. Abnormalities can cause lens abnormalities in the shape of the lens, including lenticonus (deformation of the anterior or posterior surface of the conical lens), microphakia (small lens diameter) associated with Lowe's syndrome, and ectopia lentis (the lens is located not where it should be). In addition, the most common lens abnormalities found are lens opacities caused by cataracts. Cataracts are not only related to age but can be caused by various factors, including those caused by congenital abnormalities, trauma, as well as due to complications of other conditions, and the influence of drugs [15]. Examination of the anterior and posterior lenses of the slit-lamp is generally performed with direct illumination. To examine the lenticular layer in detail, you can adjust the illumination source at 30°. In the presence of lens opacities, you can use the retro-illumination method or the optical section technique [8].

IV. Safe Use of Slit-Lamp Biomicroscope during Coronavirus-19 Pandemic

The increased risk of infection associated with Coronavirus disease-19 necessitates several modifications of the use of slit-lamp biomicroscope in daily ophthalmological practice. Transmission of the virus easily occurs at a distance between individuals with a distance less than one meter; therefore, the eye examination with a slit-lamp biomicroscope becomes challenging to perform because it requires the patient and doctor to be seated opposite to each other. Several recommendations suggest that the use of standardized masks for patients and doctors should be carried out during the examination. Always ask the patient to refrain from speaking during the examination. Installation of physical barriers on slit-lamp devices can also be done as a protective measure. Routine disinfection of the slit-lamp biomicroscope should be carried out in between patient shifting. It is recommended to use an alcohol solution of more than 70% concentration or diluted bleach solution [21].

V. Summary

Anterior segment examination is carried out to assess the anterior segment of the eye, including the external eye structures, conjunctiva, sclera, cornea, anterior chamber, pupil, iris, and lens. Anterior segment examination plays a vital role for clinicians because most eye disorders can be diagnosed based on the abnormalities found on this examination. Slit-lamp biomicroscope is an obligatory device in eye health care services to help diagnose, monitor, and manage anterior segment abnormalities. Through a

comprehensive understanding and qualified skills of using slit-lamp biomicroscope, it is hoped that better eye health services can be achieved and are beneficial for both doctors and patients.

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