The purpose of gonioscopy is to permit visualization of the iridocorneal angle (or simply “angle”). This is the area in which the trabecular meshwork lies and is therefore the part of the eye that is responsible for aqueous outflow. Before exploring gonioscopic techniques and findings, it is important to review the anatomy and function of the structures of the angle (1-1 and 1-2).

**Anatomy of the Angle**

The labeled structures (listed alphabetically) are:
- **A. Ch.**, anterior chamber; **Bo.**, Bowman’s layer; **Chor.**, choroid; **Cil. ep.**, ciliary epithelium; **Cil. m.**, ciliary muscle (longitudinal); **Cil. pr.,** ciliary process; **Cil. r. + c.,** ciliary body (radial and circular muscles); **Coll. v.,** collector veins; **Cor. ep.,** corneal epithelium; **Cor. w.,** corneal wedge; **Cr.,** iris crypt; **Desc.,** Descemet’s membrane; **Desc. en.,** corneal endothelium (or Descemet’s endothelium); **F.,** iris furrow; **H.,** Hanover’s canal; **Hy.,** hyaloid; **Ir. ep.,** iris pigment epithelium; **L. c.,** lens cortex; **Lim. v.,** limbal vessels; **M. c.,** major circle of iris; **Non pig.,** nonpigmented ciliary epithelium; **Ora.,** ora serrata; **P.,** Petit’s canal; **Pig.,** pigmented ciliary epithelium; **P. Ch.,** posterior chamber; **P-I. s.,** postlenticular space; **Ret.,** retina; **Schl.,** Schlemm’s canal; **Schw.,** Schwalbe’s line; **Sin.,** angle recess (or sinus); **Sph.,** sphincter; **S. sep.,** scleral septum; **S. sp.,** scleral spur; **Suprach. s.,** suprachoroidal space; **Tr.,** trabecular meshwork; **W.,** Wieger’s ligament; **Z.,** zonules. (Because this sketch was drawn in the 1940s, some of the terms, such as Descemet’s endothelium, are different from those used today.)
Iris

When examined with the slit lamp, the iris is seen to have two main zones: a central pupillary zone and a peripheral ciliary zone (1-3). A wavy border, the collarette, separates these areas. There are intermittent crypts, which can extend deep into the stoma, and concentric furrows, which become more prominent as the pupil dilates.

The iris is composed of an anterior stromal layer and a posterior epithelial layer. The stroma is vascular connective tissue that has no anterior epithelial covering. The musculature of the iris lies within the stroma. A 1 mm wide band of sphincter muscle rings the pupil. The myoepithelial cells of the dilator muscle are spread throughout the stroma from the iris root as far centrally as the sphincter. Blood vessels in the iris are mostly located in the stromal layer and have a radial orientation. They are frequently visible in lightly pigmented eyes. The greater circle of the iris is found in the ciliary body or in the root of the iris and is often partially visible in a gonioscopic examination.

Posteriorly, there are two epithelial layers. As in the ciliary body, the cells of these two epithelial layers are aligned apex to apex. The anterior layer has little pigmentation and is continuous with the outer (pigmented) layer of the ciliary body. The posterior layer is densely pigmented and faces the posterior chamber. This layer is continuous with the nonpigmented layer of ciliary epithelium.

The iris generally inserts at a variable level into the face of the ciliary body, which is posterior to the scleral spur. Less commonly, the iris will insert on, or anterior to, the scleral spur. The iris thins at the periphery near its insertion.

Ciliary Body Face

The ciliary body lies behind the iris. Its functions include the manufacture of aqueous humor, the control of accommodation, the regulation of aqueous outflow, the secretion of hyaluronate into the vitreous, and the maintenance of a portion of the blood–aqueous barrier. There are two major muscle groups in the ciliary body: the circular muscle fibers, which are responsible for accommodation, and the longitudinal muscle fibers,
which control the outflow of aqueous by pulling open the trabecular meshwork and Schlemm’s canal.

The ciliary body face is the portion of the ciliary body that borders on the anterior chamber. The degree to which the ciliary body face is visible depends on the level and angle of iris insertion. In some eyes, the ciliary body face is not visible, being completely obscured by iris.

Although most outflow of aqueous occurs through the trabecular meshwork, approximately 10% is by nonconventional routes, primarily through the ciliary body face into the suprachoroidal space (Bill and Phillips, 1971), but also through the root of the iris. Uveoscleral outflow is pressure-independent. Cholinergic agents, such as pilocarpine, compact the fibers in the ciliary body and decrease uveoscleral outflow. Anticholinergic drugs, such as atropine, increase nonconventional outflow through the ciliary body face (Bill and Phillips, 1971). In some eyes with severe compromise of trabecular outflow, anti-cholinergic medications may lower intraocular pressure, while cholinergic drugs may, paradoxically, increase intraocular pressure. The prostaglandin F$_2$$_\alpha$ drugs appear to promote a marked increase in nonconventional outflow through the ciliary body face (Gabelt and Kaufman, 1989) and are now routinely used as first-line agents in glaucoma therapy.

Scleral Spur

The scleral spur is composed of a ring of collagen fibers that run parallel to the limbus. It marks the posterior border of the trabecular meshwork. The spur projects slightly into the anterior chamber and is seen as a white to yellowish line in most eyes. The longitudinal muscle of the ciliary body attaches to the scleral spur and opens the trabecular meshwork by pulling on the spur. On histopathologic slides, the scleral spur can be located by following the longitudinal muscle of the ciliary body forward to its point of attachment (1-4). The structural integrity supplied by the scleral spur may prevent the ciliary muscle from causing Schlemm’s canal to collapse (Moses and Grodzki, 1977).

Trabecular Meshwork

The trabecular meshwork is located between the scleral spur and Schwalbe’s line. Most of the trabecular meshwork sits within the scleral sulcus (1-4). Approximately 90% of aqueous outflow is through the trabecular meshwork. This flow is pressure-dependent, increasing as intraocular pressure increases. Aqueous humor flowing through the trabecular meshwork enters Schlemm’s canal and from there flows into the scleral, episcleral, and conjunctival venous systems. For aqueous to exit the eye by this route, the intraocular pressure must be higher than the episcleral venous pressure. At pressures below episcleral venous pressure (8 to 15 mm Hg), all aqueous outflow must be via nonconventional routes (1-5) (Pederson, 1986).

The trabecular meshwork consists of three layers (1-6). Closest to the aqueous is the uveal meshwork,
which consists of endothelium-coated collagen beams separated by large (25 to 75 μm) spaces (1-7). The uveal meshwork extends from the ciliary body in the angle recess to Schwalbe’s line and covers the ciliary body face, the scleral spur, and the trabecular meshwork. In most eyes the uveal meshwork is colorless and is either not visible or is seen only as a glistening veil in the angle of young patients. In some eyes the uveal meshwork is dense and pigmented, giving a rough appearance to the trabecular meshwork and occasionally obscuring portions of the scleral spur. The uveal meshwork does not provide any resistance to aqueous outflow. Iris processes appear as thicker strands in front of the uveal meshwork and extend from the periphery of the iris to the trabecular meshwork (Chapter 5).

The corneoscleral meshwork lies deep to the uveal meshwork. It is the central layer that extends from the scleral spur to the anterior wall of the scleral sulcus. It is a layer of five to nine sheets of endothelium-coated collagen fibers perforated by holes of 5 to 50 μm (Flocks, 1956). This layer, like the uveal meshwork, does not offer significant resistance to aqueous outflow.

The deepest layer of the trabecular meshwork is the juxtacanalicular tissue, the last layer that aqueous crosses before entering Schlemm’s canal. The juxtacanalicular tissue has trabecular endothelium on one side and Schlemm’s endothelium on the other. Between these endothelial layers is a loose connective tissue. This juxtacanalicular tissue provides the most resistance to aqueous outflow. The aqueous must travel through the endothelium of Schlemm’s canal to enter the canal. There are no direct routes of any significance between endothelial cells into Schlemm’s canal.
Sondermann’s canals have been described in the past as being direct passages through the juxtacanalicular tissue to Schlemm’s canal, but there is doubt that such passages actually exist.

Aqueous outflow occurs primarily through the posterior portion of the trabecular meshwork—which is the portion that overlies Schlemm’s canal. With time, this posterior portion of the meshwork usually becomes pigmented, whereas the anterior meshwork usually remains relatively nonpigmented.

The endothelial cells in the trabecular meshwork differ from corneal endothelial cells in that they are larger with less prominent cell borders (1-8) (Spencer et al, 1968). A function of endothelial cells is to digest phagocytized foreign material. After engulfing foreign material some endothelial cells undergo autolysis or migrate away from the trabecular meshwork into Schlemm’s canal (Grierson and Chisholm, 1978). With age or repeated insult the endothelial cell count decreases, as does aqueous outflow.

### Schlemm’s Canal

Schlemm’s canal, which is a tube 190 to 350 µm in diameter at the base of the scleral sulcus, collects aqueous and drains it into the venous system (Hoffmann and Dumitrescu, 1971). Occasionally, the canal is a plexus rather than a single, discrete vessel. On the trabecular side of Schlemm’s canal, there are many vacuoles through which aqueous traverses the endothelial cells. The vacuoles and the prominent nuclei of the endothelial cells lining the trabecular side of the canal give it a roughened appearance (1-9) (Tripathi, 1968). On the scleral side of Schlemm’s canal, the endothelium is much smoother and is intermittently perforated by 25 to 35 aqueous collector channels.

Schlemm’s canal is not a rigid structure, although it does contain septa, which provide some support. At high intraocular pressures the canal collapses and resistance to aqueous outflow increases. The longitudinal muscle of the ciliary body can open Schlemm’s...
canal by pulling on the scleral spur. Cholinergic drugs decrease resistance to outflow through this action.

**Schwalbe’s Line**

Schwalbe’s line occurs in a 50 to 150 µm transition zone (zone S) between the trabecular meshwork and the corneal endothelium (1-10). It is the anterior border of the trabecular meshwork and the posterior border of Descemet’s membrane. There is also a transition from the scleral curvature to the steeper corneal curvature at Schwalbe’s line, which can cause a settling of pigment in this area.

![Image of Schwalbe's line](image_url)

1-10 Schwalbe’s line, demonstrating transition from trabecular meshwork endothelium (TM) to corneal endothelium (C). (Courtesy of Carmen Rummelt and Volker Rummelt, MD, University of Erlangen-Nürnberg.)
Gonioscopy is a relatively young science, having been developed entirely within the twentieth century.

The Greek ophthalmologist Alexios Trantas (2-1) first reported examination of the angle in 1907. He viewed the angle in a patient with keratoglobus using a direct ophthalmoscope while indenting the sclera with his finger (Trantas, 1907). Some years later he presented remarkably detailed drawings of the angle (2-2) (Trantas, 1918). He coined the term “gonioscopy”, meaning “observation of the angle”, from the Greek (Dellaporta, 1975).

Maximilian Salzmann (2-3) recognized that the normal angle was not visible owing to total internal reflection (Salzmann, 1914). He was the first to view the angle through a contact lens and, in 1915, presented a paper with excellent drawings of the angle obtained by means of his newly developed contact lens (Salzmann, 1915). Salzmann stressed the importance of gonioscopic examination in patients with a history of angle closure. He recognized that the development of synechiae in the angle did not always lead to elevated intraocular pressure. Salzmann was also the first to describe blood in Schlemm’s canal.


2-2 This drawing of the angle, made by Trantas in 1918, demonstrates remarkable detail. The angle was viewed with an ophthalmoscope while the limbus was indented by the examiner’s finger. (Reprinted from Survey of Ophthalmology, Vol 20, Dellaporta A, Historical notes on gonioscopy, pages 139–149, copyright 1975, with permission from Elsevier.)
Mizuo (1914) examined the inferior angle in patients by everting the lower lid and filling the cul-de-sac with saline. The technique was difficult to perform because the saline lens was lost when the patient blinked.

The introduction of Zeiss' slit lamp permitted significant advances in gonioscopy. Koeppe (1919) used the Zeiss slit lamp to examine the angle with his newly developed lens, which was thicker and more convex than Salzmann's lens. Gonioscopy was performed with the patient seated at the slit lamp. A knotted bandage rested on a central depression in the lens to secure it to the patient. This technique was effective only for evaluating the nasal and temporal sectors of the angle.

In 1925 Manuel Uribe Troncoso developed a self-illuminating monocular gonioscope that permitted examination of all parts of the angle (Troncoso, 1925).

Thorburn was the first to photograph the angle. In 1927 he photographed an instance of angle closure brought on by mydriatics and subsequently reversed by eserine. He also observed that the majority of his patients with glaucoma had open angles (Thorburn, 1927).

Otto Barkan used a slit lamp suspended from the ceiling and a hand-held illuminator to view the angle through a Koepppe lens (Barkan et al, 1936). His technique had the advantage of bright illumination and sufficient magnification, and his apparatus brought gonioscopy into practical clinical application. He subsequently made the distinction between “deep-chamber” and “shallow-chamber” glaucoma, and suggested that iridectomy be used for shallow-chamber glaucoma only (Barkan, 1938).

Barkan was also the first to describe goniotomy under direct visualization (Barkan, 1937).

Indirect gonioscopy was introduced with the Goldmann mirrored contact lens (Goldmann, 1938). The Allen lens, developed a few years later, used a totally refractive prism rather than a mirror (Allen and O'Brien, 1945). This was later modified into the Allen-Thorpe gonioprism, which had four prisms and permitted most of the angle to be viewed without rotation of the lens (Allen et al, 1954).

The first attempt to grade the angle was that of Gradle and Sugar (1940). Scheie (1957) developed a grading system based on visible structures. The widely used Shaffer grading technique was developed 3 years later (Shaffer, 1960). Spaeth modified this system to provide information regarding the angle of iris approach, the level of iris insertion, and the configuration of the iris (Spaeth, 1971). The techniques of angle grading are described more completely in Chapter 6.

An excellent review of the history of gonioscopy has been provided by Dellaporta (1975).
Principles of Gonioscopy

Viewing the anterior chamber of a normal eye directly (3-1) is not possible. Light from the junction of the iris and cornea strikes the tear–air interface at a shallow angle, and it is totally reflected back into the eye (3-2). This is the principle of total internal reflection. If light from the interior of the eye strikes the cornea at an angle steeper than 46° (the critical angle), the light will exit the eye and the trabecular meshwork will be visible (Shields, 1992). Rarely, this may occur in eyes with keratoconus, keratoglobus, or severe myopia (3-3). The angle of approach to the trabecular meshwork can be altered if the limbus is indented, as shown by Trantas in his initial description of gonioscopy (3-4) (Trantas, 1907).

3-1 Slit-lamp view attempting to visualize the angle in a normal eye. No angle structures are visible because of total internal reflection.

3-2 Light from the anterior chamber angle (a) undergoes total internal reflection at the tear–air interface and is not visible to the examiner.

3-3 In an eye with keratoconus light from the trabecular meshwork (a) strikes the cornea at a steep enough angle to permit direct visualization of the trabecular meshwork by the observer (Obs.). This is an uncommon situation.

3-4 Indentation of the limbus brings angle structures (a) into direct view without a lens. It is very difficult to obtain an undistorted view in this manner.
In modern gonioscopy, contact lenses are used to overcome the problem of total internal reflection. Two basic types of lens are used: the direct lens and the indirect lens.

**Direct Gonioscopy**

Direct gonioscopy is performed with a steeply convex lens, which permits light from the angle to exit the eye closer to the perpendicular at the interface between the lens and the air (3-5). The Koepppe lens (3-6), which is a 50-diopter lens, is placed on the eye of a recumbent patient using saline to bridge the gap between lens and cornea (3-7). The examiner views the angle through a hand-held binocular microscope, which is counterbalanced to permit ease of handling. Illumination is provided by a light source that is held in the other hand (3-8). The Koepppe lens magnifies ×1.5. This, in combination with the ×16 magnification of the oculars, yields a total magnification of ×24. There are Koepppe lenses in several sizes to suit infants to adults.

Direct lenses are used for surgical procedures such as goniotomy and goniosynechialysis. The Hoskins-Barkan (3-9 to 3-11) and Swan-Jacobs (3-12) lenses are most commonly used. These lenses can also be used to examine sedated infants with an operating microscope or a portable slit lamp (3-13 and 3-14).
Indirect Gonioscopy

The lenses used in indirect gonioscopy use mirrors to overcome total internal reflection. The mirror redirects light from the angle so that it exits the eye perpendicularly to the lens-air interface (3-15). The examination is performed at the slit lamp and takes advantage of the latter’s flexible illumination and magnification system.

The Goldmann three-mirror lens (3-16 and 3-17) has one mirror dedicated to viewing the angle. There are two additional mirrors for examination of the peripheral retina. The Goldmann lens is coupled to the cornea by means of a viscous methylcellulose fluid. The lens has a broad (12 mm) area of contact with the globe and, under the application of pressure, can artificially close the angle or reflux blood into Schlemm’s
canal. The single-mirror Goldmann lens has only the gonioscopic mirror (3-18). The Ritch trabeculoplasty laser lens (3-19) is similar to the Goldmann lens except that all four of its mirrors are directed at the angle; two mirrors face the angle at 59° and the other pair approaches it at 64°. In front of one of the 59° mirrors and one of the 64° mirrors are convex buttons that increase magnification ×1.4 and concentrate laser energy (Ritch, 1985). The Magna View lens (3-20 and 3-21) is a single-mirror lens that is similar to the Goldmann one-mirror lens except that it has a wider field and provides ×1.3 magnification. It was designed for the delivery of laser energy to the angle and photography.

The Posner lens (3-22) has four identical mirrors that permit examination of four quadrants with no rotation of the lens (3-23). By turning the lens through only 11°, the small areas between the mirrors can be brought into view. Because the lens has a small (9 mm) area of contact with the cornea, the angle can be deepened by pushing on the lens (indentation gonioscopy). The small gap between lens and cornea is filled with tears or topical anesthetic. This keeps the cornea free of viscous fluids and permits clear examination and photography of the optic nerve head following gonioscopy. The Zeiss lens (3-24 and 3-25) is similar to the Posner lens but is made of glass instead of plastic. It is no longer commercially available. The Sussman lens (3-26 and 3-27) is also similar to the Posner lens, except that it has no handle.

3-15 Indirect gonioscopic lenses use mirrors or prisms to reflect the light from the irido-corneal angle (a) so that it leaves the eye perpendicular to the face of the contact lens.

3-16, 3-17 Goldmann three-mirror lens. The shortest mirror is for examining the angle. The other two mirrors are for examining the peripheral retina. Like all indirect lenses, the central area can be used to examine the fundus. (Courtesy of Haag-Streit.)
Special mention should be made of the Allen-Thorpe gonioprism (3-28 and 3-29), which was used in preparing all of the paintings reproduced in this Atlas (Allen et al, 1954). Rather than mirrors, this lens has four prisms. It has a flange that holds it in place (3-30) and requires methylcellulose to couple it to the cornea. The lens is no longer commercially available.
Array of Posner four-mirror lenses with fixed handle and plastic lens. This lens has four identical mirrors for rapid gonioscopy. No methylcellulose coupling solution is required. The small area of contact allows for indentation gonioscopy. This lens is very similar to the Zeiss four-mirror lens, which is no longer commercially available. (Courtesy of Ocular Instruments.)

Four quadrants visible through Zeiss four-mirror lens.

Zeiss four-mirror lens on Unger fork (Carl Zeiss).

The Sussman four-mirror lens is like the Zeiss or Posner lens but without a handle. Some examiners prefer to hold the lens directly. (Courtesy of Ocular Instruments.)
Comparison of Direct and Indirect Gonioscopy

Both direct and indirect gonioscopy have advantages and disadvantages.

Although direct gonioscopy is no longer widely practiced outside of the operating room, it does have certain advantages over indirect gonioscopy. Direct gonioscopy, as the term suggests, provides a straight-on view of the angle rather than the mirror image given by the indirect lenses. Direct gonioscopy permits the examiner to vary the angle of visualization more readily—to enable one to look over the curvature of iris bombé, for example. The view with direct gonioscopy is more panoramic than with indirect gonioscopy.

Two Koeppe lenses may be used to compare the angles of the two eyes in order to determine whether one eye has suffered a traumatic recession.

The major disadvantage of direct gonioscopy is its inconvenience. The patient has to lie down, usually in a special room with special equipment. The inconvenience of direct gonioscopy led to the development of the van Herick system of estimating the depth of the anterior chamber based on examination by slit lamp. Van Herick stated that “In the routine examination of nonglaucomatous patients, it is impractical to perform gonioscopy” (van Herick et al., 1969). Fortunately, the convenience of indirect gonioscopy allows one to perform it quickly as part of a routine evaluation of glaucoma patients.

Indirect lenses have several advantages that have made them the preferred lenses for most ophthalmologists. The first advantage, specific to the four-mirror lenses, is that they do not require viscous coupling agents. This is particularly important if a patient is to have fundus photography at the same visit. Gonioscopy can be performed quickly with the same anesthetic as that used for tonometry. Additionally, no special equipment is required when performing indirect gonioscopy with any lens. The slit lamp serves as a source of variable magnification and illumination. The slit beam can create a corneal wedge to help to define the structures of the angle.
(Chapter 4). Indentation gonioscopy can be performed with the Posner or Sussmann lens to distinguish appositional from synechial angle closure (Chapter 4). Additionally, gonioscopic photography and videography can be performed in combination with indirect gonioscopy.

Indirect lenses have the disadvantage of giving a mirror-image view of the angle, which can be somewhat confusing. It is also easy to open or close the angle inadvertently by applying excessive pressure to the indirect lenses. These lenses may exaggerate the degree of angle narrowing and are less able to provide a view into the depths of a narrow angle (Shaffer, 1962). The four-mirror lens is somewhat more difficult to learn to use than the other lenses but, once mastered, is extremely convenient.

Because direct gonioscopy is rarely used in routine clinical practice, this Atlas concentrates on slit-lamp (indirect) gonioscopy. For further information on direct gonioscopy, refer to the works of Troncoso (1947), Shaffer (1962), Becker (1972), and Kimura (1974). Although these texts are no longer in print, they are available in many medical libraries.
General Guidelines

The eye should be examined carefully with the slit lamp before beginning gonioscopy. One might see a prominent Schwalbe’s line, atrophy of the iris, or evidence of previous inflammation, surgery, or trauma. Such findings can provide valuable information that will guide the gonioscopic examination. An estimation of chamber depth can be obtained at the slit lamp (van Herick et al, 1969), although it should not be substituted for gonioscopic evaluation of the angle. Tonometry should be performed before gonioscopy, as excessive pressure on the eye can artificially lower the intraocular pressure.

The eye should be anesthetized with a topical agent, such as proparacaine. Seat the patient comfortably at the slit lamp with the head pressed firmly against the headband (4-1). It is important that both the patient and the examiner be comfortable and braced. Align the lateral canthus of the patient’s eye with the canthal marker of the slit lamp (4-1). This will permit sufficient vertical excursion of the slit lamp to enable the superior and inferior mirrors to be viewed. The examiner’s elbow should rest on the slit-lamp table or a support (4-2). The magnification of the slit lamp should be set at ×10 to ×25, typically starting at low power first for a more panoramic view. It is often advantageous to use bright illumination first to identify landmarks, and then lower the beam length. For grading the angle, a fairly short and narrow beam of light is preferred to avoid allowing light to enter the pupil. Pupillary
constriction will place the iris on stretch and may make a narrow angle appear more open; this phenomenon has been confirmed by ultrasound biomicroscopy (Barkana, 2007). A beam that is 2 to 3 mm long works well. The examiner can adjust the beam width to achieve additional illumination as needed.

It is most important to put the patient at ease during gonioscopy. This becomes much easier with experience—that of the examiner as well as that of the patient. The patient may be disconcerted to be told that a lens will be placed on the eye. Alternatively, the examiner can simply point out that the lens will be close to the eye and may be felt against the lashes. If a patient is having particular difficulty, both lids can be held wide open and the lens placed directly on the cornea without touching the lids. If the examiner moves smoothly and efficiently, the examination will not be unpleasant for either party.

**Video Clip on DVD**

**General Techniques**

**Goldmann and Similar Lenses**

The Goldmann one-mirror lens, the Goldmann three-mirror lens, the Ritch lens, and the Magna View lens are all handled in a similar manner. All have mirrors that are directed at the angle. In addition to the gonioscopic mirror, the Goldmann three-mirror lens has two mirrors through which the peripheral retina can be viewed. As with all slit-lamp goniolenses, the central optic can be used to examine the posterior pole of the fundus. The Goldmann lens provides an outstanding view of the optic disc and fundus.

The concave face of the Goldmann lens should be filled with a methylcellulose coupling fluid before it is applied to the eye. Care should be taken to keep air bubbles out of the solution. Any air bubbles can seriously interfere with examination and photography. Air bubbles can be avoided in a number of ways. The methylcellulose bottle should be stored upside down. If a slow stream of methylcellulose is first squeezed from the bottle onto a tissue, any air trapped in the tip of the bottle will escape (4-3). The stream is then transferred to the Goldmann lens (4-4). Alternatively, some examiners remove the top of the dropper to avoid squeezing air into the lens (4-5).

While the patient is looking up, the examiner brings the inferior edge of the Goldmann lens into contact with the inferior sclera (4-6). As the patient looks straight ahead, the lens is tilted forward over the cornea (4-7). A seal forms when the lens is pressed forward, helping to hold it in place. The examination is carried out through the shortest mirror of the three-mirror lens.
The Goldmann lens is brought into contact with the inferior sclera.

Goldmann lens tipped up into position.

Goldmann lens held with three fingers. The remaining two fingers are braced against the patient’s face. The other hand is free to control the slit lamp.

Holding the lens with three fingers of one hand, the examiner can rotate the lens easily, leaving the other hand free to operate the slit lamp. The thumb, index, and middle finger are used to hold the lens, and the other two fingers are braced against the patient’s cheek to enable the examiner to keep up with small movements of the head (4-8). The lens should be held lightly. Excessive pressure can cause reflux of blood into Schlemm’s canal. The suction created by pulling on the lens may make the angle appear artificially deep.

Sometimes, these lenses are difficult to remove because a tight seal has formed between the lens and the eye. Gentle pressure with the index finger on the globe next to the lens will break the seal.

Four-Mirror Lenses

The Posner, Sussman, and Zeiss lenses are normally used with only the tear film coupling them optically to the cornea. Occasionally, a drop of topical anesthetic, viscous tetracaine, or saline in the concavity of the lens will make the contact easier. The Posner or Zeiss lens is used on a handle that is held between the thumb and forefinger with the remaining three fingers braced against the patient’s face (4-9). The lens is usually held squarely to the eye, which is the most comfortable position for both examiner and patient (4-9). Examiners with long arms may prefer to hold the lens in a diamond orientation (4-10) or to use the Sussman lens. The corners of the four-mirror lens can irritate the eyelids when the lens is held in the diamond configuration. The lens should be applied lightly, just until the air disappears from the corneal interface. The appearance of folds in Descemet’s membrane is an indication that too much pressure is being applied (see 4-29). It is better to allow intermittent loss of contact with the cornea and the resulting loss of any view, than to allow excessive pressure to alter the exam.
The View

Slit-lamp gonioscopy is performed through a mirror. The part of the angle that is viewed is 180° away from the mirror that is being used. The examiner must remember that the image is a mirror image. The view, unlike that seen with indirect ophthalmoscopy, is not an inverted mirror image. In slit-lamp gonioscopy, the angle seen in the superior part of the temporal mirror is the superior part of the nasal angle.

Variable illumination is an advantage of slit-lamp gonioscopy. One can use diffuse illumination (4-11), focal illumination with a broad beam (4-12), and focal illumination with a narrow beam (4-13). It is helpful to vary the type of illumination and the orientation of the light. Subtle findings can best be appreciated in this manner. Note that in 4-11 to 4-13, the switch from a diffuse beam to a slit beam brought the solitary iris process into view and allowed the corneal wedge (as described below) to be seen.

By using a thin slit of light, inclined from the angle of the oculars, two separate corneal reflections are perceived—one on the inner aspect of the cornea...
and one on the outer. In addition to the inner and outer cornea, the narrow beam illuminates the interface between the cornea and the face of the opaque sclera (4-14). These reflections form a wedge-shaped line termed the “corneal wedge” (4-15). The lines of the corneal wedge intersect at Schwalbe’s line. By pointing to Schwalbe’s line, the corneal wedge locates the anterior border of the trabecular meshwork. This wedge can have a variable appearance, depending on the anatomy of the cornea and sclera (4-16 to 4-18). In lightly pigmented angles (4-19) or in angles with a confusing anatomy (4-20), the corneal wedge will locate the trabecular meshwork. 

**Figure 4-14** Drawing showing gonioscopic view in combination with microscopic cross-section. Note the corneal light reflex that is formed as the slit beam illuminates the inner and outer cornea and the interface of clear cornea and opaque sclera. This forms the corneal wedge (arrow).

**Figure 4-15** The corneal wedge points to Schwalbe’s line—the anterior border of the trabecular meshwork. The corneal wedge in this eye has a rounded contour that reflects the rounded interface between cornea and sclera.
Narrow, V-shaped, corneal wedge; this is seen more commonly in the superior angle.

Rounded, long corneal wedge, the anterior surface of which disappears behind the trabecular meshwork. The vascular pattern of the corneal margin of the limbus is seen.

Only the tip of the corneal wedge is seen in this view because of an arcus senilis in the upper portion of the view.

meshwork when no other clear landmarks are present. Although initially a challenge, finding the corneal wedge eventually becomes a natural part of an examination. By gently sliding the gonioscopy lens in the direction of the mirror being used, a better view is gained of the cornea and the corneal wedge.

The design of the slit lamp is such that the corneal wedge is best identified in the superior or inferior mirror
The corneal wedge points to Schwalbe's line in this lightly pigmented angle of an 11-year-old child.

In this angle the two pigment lines were felt to represent the pigmented trabecular meshwork (line nearest the iris) and a Sampaolesi's line. The corneal wedge reveals that both of these pigment lines are anterior to Schwalbe's line, which is at the level of the iris attachment. Synechiae have caused the trabecular meshwork to be covered by the iris. The pigment lines have arisen from chronic contact of the iris with the cornea or from inflammation.

because it is easiest to generate an inclined vertical slit beam in these mirrors. An inclined horizontal slit beam can be obtained in the nasal and temporal mirrors (4-21), but this requires considerable manipulation of the slit lamp. It is usually best to examine the inferior angle first (in the superior mirror of a four-mirror lens). The inferior angle is the easiest to examine because it is the most open and most pigmented. One should then proceed clockwise; it is easiest to remember findings by their clock hours if proceeding in a clockwise order. If the corneal wedge is used to identify the structures of the inferior or superior angle, it is usually sufficient to study the nasal and temporal angles with broad illumination (4-22). Once one has become oriented to the patient’s anatomy, the remainder
Iris bombé makes a direct view of the angle difficult. The forward bowing of the iris blocks the observer’s (Obs.) view of the angle. This will allow the examiner to look over the iris and into the angle (4-23 and 4-24). The examiner must not press while the patient’s gaze is shifted towards a mirror because this can make the angle appear more narrow than it is. If a patient is using cholinergic drops, he or she may have a steep approach to the angle due to pharmacologically induced anterior movement of the lens and iris. If the angle is not capable of closure, anticholinergic drops can be given to deepen the central chamber and improve the view. This is helpful in laser trabeculoplasty, although it must be remembered that dilating a glaucomatous eye can cause an increase in intraocular pressure, especially if the patient is using a cholinergic agent, such as pilocarpine (Shaw and Lewis, 1986).

Most examiners use gonioscopy to evaluate the trabecular meshwork, but the examination should include attention to the iris and cornea. In the dilated eye the gonioscope can be used to examine the ciliary body.

4-23 Iris bombé makes a direct view of the angle difficult. The forward bowing of the iris blocks the observer’s (Obs.) view of the angle.

4-24 If the patient’s gaze is turned towards the examining mirror or the lens is shifted towards the angle being examined, it is possible to look over the iris and into the angle (a).

Indentation Gonioscopy

In 1966 Forbes described using the Zeiss four-mirror lens to distinguish between angle closure due to synchiae and appositional closure (Forbes, 1966). An eye with appositional angle closure would be expected to do well after surgical iridectomy or laser iridotomy, whereas an eye with extensive synchiae would probably require surgery. Forbes noted that direct pressure on the cornea from the Zeiss lens caused aqueous to be pushed into the angle (4-25). This deepened appositionally closed angles, allowing the examiner to see the trabecular meshwork (4-26 to 4-29). Angles closed by synchiae either would not open with indentation or would open only partially, with synchiae tethered to the cornea or trabecular meshwork (4-30 to 4-33). For angles that were especially narrow Forbes suggested offsetting the lens a few millimeters in the direction...
Indentation with Zeiss four-mirror lens causes deepening of the anterior chamber, which opens areas of appositional angle closure or exposes synechiae. (Reprinted with permission. Arch Ophthalmol. 1966;76:488–492. Copyright © 1966, American Medical Association. All Rights Reserved.)

Top illustration (4-26) is of gonioscopy without indentation showing angle closure. Bottom illustration (4-27) is of same eye with indentation, showing that the angle closure was appositional. (Reprinted with permission. Arch Ophthalmol. 1966;76:488–492. Copyright © 1966, American Medical Association. All Rights Reserved.)

The deepening of the angle as a result of indentation probably arises from a combination of forces. Aqueous is forced into the angle, which pushes the iris of the mirror being used (away from the area being studied). It is usually sufficient to apply direct pressure perpendicular to the cornea. Although some distortion is unavoidable in indentation gonioscopy due to the folds in Descemet’s membrane (see 4-29), this should not preclude an adequate view. At very high intraocular pressures, indentation is quite difficult and is minimally effective.

The top photograph (4-28) is a Zeiss four-mirror view of iris bombé in an elderly hyperopic patient. The trabecular meshwork is not visualized. The bottom photograph (4-29) is of the patient when a Zeiss lens is used to indent the cornea. The trabecular meshwork is visible (arrow). Note the corneal folds.
Indentation gonioscopy is effective with lenses such as the Zeiss, Posner, Sussman, and Allen-Thorpe. These lenses all have areas of contact that are smaller than the cornea. Lenses with large areas of contact, such as the Goldmann and Koeppe lenses, may make the angle shallower with indentation.

Indentation permits the examiner to look deep into the angle recess for iridodialyses, foreign bodies, or cyclodialysis clefts. Closure of a cyclodialysis cleft with an argon laser while using indentation gonioscopy has been described in an eye with a shallow chamber (Partamian, 1985). Additionally, indentation can sometimes be the step that clarifies the angle anatomy. This is particularly true for beginners who are struggling to view the corneal wedge. For example, if a Sampaolesi’s line is present in an eye that is appositionally closed, indentation will reveal the trabecular meshwork. This can prevent the examiner from mistaking the Sampaolesi’s line for the meshwork itself. Similarly, finding the ciliary body face with indentation can help identify an angle as being open in someone who has no trabecular meshwork pigment. Examples of indentation gonioscopy are included on the DVD accompanying this text.

Once mastered, indentation becomes a natural part of the examination. It affords a dynamic view of the relationship of the iris and the corneoscleral angle.
Cleaning of Gonioscopic Lenses

Human immunodeficiency virus and other infectious agents have been isolated in the epithelium of the eye and in tears. Although transmission of human immunodeficiency virus has not been documented in ophthalmic examinations, it is important to disinfect lenses after each use (American Academy of Ophthalmology, 1989, 00). The human immunodeficiency virus is sensitive to heat and to a variety of commonly used disinfectants, such as alcohol, glutaraldehyde, sodium hypochlorite (household bleach), formalin, and phenol (Conte, 1986). Unfortunately, many gonioscopic lenses are quite fragile and may be damaged by some of the recommended techniques for disinfection.

In 1988 the American Academy of Ophthalmology, the National Society to Prevent Blindness, and the Contact Lens Association of Ophthalmologists jointly issued guidelines for disinfection. They suggested inverting the contact lens and wiping the surface with an alcohol sponge. For added protection the lens can be inverted and the concave contact area filled with a solution of 1:10 household bleach, which is left for 5 minutes and then rinsed off with water and dried. This method allows cleaning of the outer surface of the lens as well as the contact portion without exposing the anti-reflective coating on the operator surface of the contact lens to the bleach. It is important to rinse to avoid corneal de-epithelialization that might be caused by residual disinfectant solution (American Academy of Ophthalmology, 1989, 00). Some manufacturers recommend soaking lenses in 2% glutaraldehyde or dilute (1:10) household bleach (Ocular Instruments, Bellevue, Washington). Most lenses can be gas-sterilized and some glass lenses can be autoclaved. With all lenses the manufacturer’s instructions for disinfection should be followed to prevent damage to the lens.
The Normal Angle

The best preparation for recognizing angle pathology is to become familiar with the many variations of normal. Careful gonioscopic evaluation of the anterior segment follows a routine that evaluates all visible structures in a systematic fashion. This chapter focuses on normal findings, beginning at the iris and moving to the periphery.

Iris

Examination of the iris begins centrally, looking for deposits at the pupillary border that are suggestive of pseudoexfoliation.

Moving peripherally, the contour of the iris is usually found to be flat or slightly convex. Hyperopic eyes have more convex irides, while myopic or aphakic eyes typically have flat or slightly concave irides. Abnormal convexity is noted in pupillary block, with large lenses, and with tumors and cysts of the iris and ciliary body. Abnormal concavity is seen in the pigment dispersion syndrome and the iris-retraction syndrome.

The normal iris demonstrates radial markings with crypts (5-1, also see 1-3). Blue irides have more prominent markings and crypts than thick, brown irides. It is valuable to compare these surface features between the two eyes. In some pathologic conditions, such as Fuchs heterochromic iridocyclitis, the normal markings are lost, giving the iris a flat, featureless appearance.

The iris also has concentric contraction rolls, which are most prominent when the pupil is large and the iris bunched. The most peripheral role of the iris is frequently more prominent than other contraction rolls (5-1). In some eyes this last roll can obscure visualization of the trabecular meshwork. An abnormally prominent last roll of the iris is a feature of plateau iris syndrome, a form of angle closure that is described in Chapter 8.

5-1 Normal iris with distinct radial markings and crypts. As in many normal angles, the last contraction roll of the iris is prominent but does not obstruct the view of the angle structures.
The iris should be examined for the presence of nevi, tumors, atrophy, iridodonesis, and abnormal pigmentation.

As the angle is approached, the stroma of the iris becomes thinner and smoother. There may be a scalloped border where the iris inserts into the face of the ciliary body.

**Ciliary Body Band**

The iris usually inserts into the concave face of the ciliary body, leaving some of the ciliary body visible anterior to the iris. The ciliary body band is seen as a light gray to dark brown band located just anterior to the iris and posterior to the scleral spur (5-2 to 5-4).

5-2 Broad, gray ciliary body band, seen most commonly in lightly pigmented eyes.

5-3 Lavender-colored ciliary body band, common with all types of iris pigmentation (superior angle).

5-4 Dark brown ciliary body band usually associated with hazel or brown irides.
This band can be quite wide in myopic or aphakic eyes and narrow to absent in hyperopic eyes or eyes with anterior insertions of the iris. If the ciliary body band is abnormally deep and not symmetric with the other eye, the possibility of angle recession, cyclodialysis, or unilateral high myopia must be considered. Both angle recession and cyclodialysis are described in Chapter 9.

**Scleral Spur**

The scleral spur is a ridge of scleral tissue that lies anterior to the ciliary body band and marks the posterior border of the trabecular meshwork. It appears as a thin band that is usually white or light gray (5-5) but which may have a yellowish cast in older individuals (5-6). It may be difficult to distinguish from trabecular meshwork in lightly pigmented eyes except for the striking contrast of the adjacent ciliary body band (5-7). Although the scleral spur is

5-5 Narrow, light gray scleral spur accentuated by a low, sharp ridge at the iris root (superior angle).

5-6 Wide, yellowish scleral spur line, an appearance seen more often in the elderly. The major circle of the iris is visible.

5-7 Scleral spur of the same color as the trabecular meshwork, identified only by contrast with the color of the ciliary body band.
usually visible, it may be obscured by iris processes, a high insertion of the iris, iris bombé, peripheral anterior synechiae, or heavy pigmentation.

**Trabecular Meshwork**

The trabecular meshwork lies between the scleral spur and Schwalbe’s line. The meshwork is nonpigmented and smooth in infants but becomes coarser and more pigmented with advancing age. Flow through the trabecular meshwork is through the posterior portion. For this reason, the posterior trabecular meshwork is generally more pigmented than the anterior trabecular meshwork. Most of the dark brown or black pigment present in the angle is intracellular, having been ingested through phagocytosis. Skin and hair color show little correlation with trabecular pigmentation (Scheie, 1957). There may be patchy areas of increased pigmentation over the circumference of the pigmented trabecular meshwork. These are located over aqueous collector channels and represent areas that have more outflow than the less pigmented areas. Patchy pigmentation is seen more frequently in eyes with glaucoma than in normal eyes (Tanchel et al, 1984).

Pigment in the angle is usually heaviest inferiorly owing to gravitational settling and aqueous circulation. With narrow angles, there can be more pigment superiorly than inferiorly as a result of apposition of the iris against trabecular meshwork (Desjardins and Parrish, 1985). Similarly, patients with pigment dispersion syndrome have been noted to be more pigmented superiorly than inferiorly during the regression phase, known as the “pigment reversal sign” (Ritch, 1996).

A nonpigmented angle is a pale gray color (5-8). Trabecular pigmentation usually appears deep within the posterior trabecular meshwork (5-9). Sometimes pigment is deposited on the surface of the posterior trabecular

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5-8 Narrow trabecular band of normal gray color (superior angle).

5-9 Deep pigment in the trabecular meshwork near Schlemm’s canal forming a smooth, brown band. A solitary iris process is present.
meshwork (5-10) or over the anterior trabecular meshwork and Schwalbe’s line (5-11). Heavy pigmentation may cover all angle structures (5-12 and 5-13). Increased pigmentation of the angle can be caused by many pathological processes; these are discussed in detail in Chapter 9. Heavy angle pigment can accumulate in a line anterior to Schwalbe’s line as a Sampaolesi’s line. Sampaolesi’s line is a nonspecific finding in heavily pigmented angles, whether physiologic or pathologic.

The corneal wedge can help in locating Schwalbe’s line and in defining whether the pigmentation is in the trabecular meshwork or anterior to it. Systems for grading angle pigmentation are discussed in Chapter 6.

The anterior border of the trabecular meshwork is usually smooth, but it can be wavy and irregular (5-14).

5-10 Discrete pigment on the surface of the trabecular meshwork overlying Schlemm’s canal.

5-11 Discrete pigment along the anterior margin of the trabecular meshwork with a few flecks anterior to Schwalbe’s line (identified by the corneal wedge).

5-12 Heavy angle pigmentation with a wavy band of pigment on the corneal endothelium anterior to Schwalbe’s line (Sampaolesi’s line).
Schlemm’s Canal

In most individuals Schlemm’s canal is not visible. It lies deep within the posterior (pigmented) trabecular meshwork, anterior to the scleral spur, and becomes visible only when filled with blood (5-15). Blood can occasionally be found in Schlemm’s canal in normal eyes. It may also be seen in situations where the flow of aqueous humor from Schlemm’s canal to the episcleral venous system is impeded. This can occur when a contact lens with a large diameter (such as a Goldmann lens) is pressed too firmly against the eye, compressing the episcleral veins. It can also be seen when the pressure in the episcleral venous system is high or when the intraocular pressure is low. Pathologic causes of blood in Schlemm’s canal are discussed in Chapter 9.
Schwalbe’s Line

Schwalbe’s line represents the anterior border of the trabecular meshwork. It is the termination of Descemet’s membrane. Schwalbe’s line is usually subtle, marked only by a slight change in color and density from trabecular meshwork to cornea (5-16) and, occasionally, by a faint white line (5-17). The line is often too faint to be identified, particularly in an eye with a very lightly pigmented trabecular meshwork. The corneal wedge, described in Chapter 4, is invaluable in identifying Schwalbe’s line. In most eyes the line is a flat transition zone between trabecular and corneal endothelium. In some eyes it forms a ridge-like structure (5-18). A line that is prominent and anterior is termed “posterior embryotoxon.” This is usually a normal variant. A very prominent roll of tissue in this location is associated with the Axenfeld-Rieger syndrome (Chapter 7). Pigment deposited on and anterior to Schwalbe’s line is called a Sampaolesi’s line, as described above.
Other Regions

The cornea can also be viewed gonioscopically, demonstrating pigment, keratic precipitates, or endothelial changes. The ciliary body can be examined in a widely dilated or an aniridic eye.

Iris Processes

Iris processes are often found in normal angles. These are uveal extensions from the iris on to the trabecular meshwork. They generally insert close to the scleral spur but sometimes insert as far anteriorly as Schwalbe’s line. Usually delicate and lacy (5-19 and 5-20), these processes can sometimes be so dense as to obscure the scleral spur. They are abnormally numerous and prominent in Axenfeld-Rieger syndrome (Chapter 7). Iris processes range in color from light gray (in blue-eyed individuals) to dark brown.

It is important—and occasionally difficult—to distinguish iris processes from peripheral anterior synechiae. Iris processes are usually fine wisps of iris and extend into the posterior portions of the trabecular meshwork. They usually follow the concavity of the angle recess but can bridge the angle. Iris processes do not inhibit the movement of the iris with indentation and they do not interfere with aqueous outflow. Peripheral anterior synechiae tend to be broad and irregular, attaching iris stroma to the trabecular meshwork. They bridge the angle recess, rather than follow it, and they obscure underlying structures. Synechiae inhibit posterior movement of the iris during indentation gonioscopy. They drag normal radial iris vessels with them. There is frequently pigmentation on the cornea anterior to the synechiae caused by the underlying pathology, such as inflammation or angle closure.

With traumatic angle recession, iris processes can be broken. This is a very helpful sign of recession in patients with already deep angles.

5-19 Dense band of nonpigmented iris processes bridging the angle.

5-20 Heavily pigmented iris processes against the wall of the superior angle.
Angle Blood Vessels

Typically, normal angle blood vessels have a radial orientation in the iris or form looping branches from the major arterial circle. Although the major circle is usually located in the ciliary muscle, it may occasionally be seen in the periphery of the iris. Short segments of the major circle are often visible in lightly pigmented irides and are sometimes visible in darkly pigmented irides (5-21) (Henkind, 1964). This is in contrast to pathologic angle vessels, which tend to be fine, cross the scleral spur, and branch. They do not follow any radial or circumferential pattern. Pathologic vessels have associated fibrous tissue, which is not visible, and causes increase in intraocular pressure even before synechial closure of the angle.

Angle Width

The angle between the iris and the cornea is usually wide enough to permit a good view of all angle structures (5-22). The angle is generally quite wide in myopic eyes (5-23) and narrower in hyperopic eyes. Angle closure is rare in myopic eyes, although there are exceptions (van Herick et al, 1969), most notably in eyes with spherophakia. Aphakic and pseudophakic eyes tend to have rather wide angles because of the loss of lens thickness behind the iris.

Many factors determine the width of the angle, including the level of insertion of the iris into the angle, the shape of the iris, pupil size, lens thickness, and the degree of lens-iris apposition. Sometimes the iris inserts so far anteriorly that it obscures the ciliary

![5-21](image1.png) Major circle of the iris visible in the angle. This normal structure is usually seen in blue or hazel eyes.

![5-22](image2.png) Chamber angle of average width. In most eyes, the inferior angle is widest, the lateral quadrants are narrower, and the superior angle is narrowest.
body band, the scleral spur, and even parts of the trabecular meshwork (5-24).

The angle narrows with age. Raeder (1923) attributed this to increasing thickness of the lens. A study of 947 normal subjects showed that the mean age for a closed angle was 85 years, while the mean age for a Shaffer grade IV angle was 25 years (Spaeth, 1971). Van Herick et al (1969) used the slit lamp to examine 2185 individuals. They found that grade I and II angles were present in 6% of those over 60 years of age and in none of those under 20 years of age.

Usually the superior angle is the narrowest, the inferior angle is the widest, and the lateral angles are of intermediate width (Barkan et al, 1936).

Cholinergic stimulating agents, such as pilocarpine, cause the lens-iris diaphragm to move forward. This narrows the angle and makes the approach to the angle steeper. Rarely, cholinergic agents can cause pupillary block and closure of the angle. Angle narrowing caused by cholinergic agents can be reversed by anticholinergic drugs, which tend to widen the angle but can also cause crowding of the peripheral angle with dilation of the pupil. This is particularly evident in patients with plateau iris.

Uneven angle width can be caused by cysts of the iris or ciliary body, angle recession, and cycloidalysis.
Grading systems permit the recording of gonioscopic findings for communication and for future reference. Several systems for grading the angle have been proposed. Gradle and Sugar (1940) quantified the depth of the angle through a Koepppe lens. They measured the distance from the plane of the iris to Schwalbe’s line with a graticule that was etched in the oculars of the microscope. Some grading systems are quite simple—for example the “wide, intermediate, and narrow” classification of Gorin and Posner (1967). The three primary alphanumeric systems that are currently used for grading the angle are those of Scheie, Shaffer, and Spaeth.

**Scheie System**

Scheie (1957) developed a grading system in which Roman numerals were used to describe the degree of angle closure. In his system one determines the angle structures that are visible on gonioscopy (6-1). Larger numbers signify a narrower angle. The term “wide” was used to describe an angle in which all structures were visible. Scheie also described angle pigmentation on a scale from 0 (no pigmentation) to IV (heavy pigmentation) (6-2).
Shaffer System

A more commonly used grading system is that of Shaffer (1960, 1962). This system describes the degree to which the angle is open rather than the degree to which it is closed. Whereas Scheie’s grade IV denotes a closed angle, on the Shaffer scale grade 4 refers to a wide-open angle. The Shaffer system approximates the angle at which the iris inserts relative to the trabecular meshwork (6-3). If the angle between the iris and the meshwork is 20° to 45°, the angle is felt to be at no risk of closure. Angles from 0° to 20° are considered capable of closure (Table 1).

Many ophthalmologists use a variation of Shaffer’s system in which 4 is wide open and 0 is closed, but the determination is usually a rough estimate of angle width that is not strictly based on degrees.

Table 1. Shaffer system for grading angle widths.

<table>
<thead>
<tr>
<th>Grade number</th>
<th>Angle width</th>
<th>Description</th>
<th>Risk of closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>45°–35°</td>
<td>Wide open</td>
<td>Impossible</td>
</tr>
<tr>
<td>3</td>
<td>35°–20°</td>
<td>Wide open</td>
<td>Impossible</td>
</tr>
<tr>
<td>2</td>
<td>20°</td>
<td>Narrow</td>
<td>Possible</td>
</tr>
<tr>
<td>1</td>
<td>≤ 10°</td>
<td>Extremely narrow</td>
<td>Probable</td>
</tr>
<tr>
<td>Slit</td>
<td>Slit</td>
<td>Narrowed to slit</td>
<td>Probable</td>
</tr>
<tr>
<td>0</td>
<td>0°</td>
<td>Closed</td>
<td>Closed</td>
</tr>
</tbody>
</table>

Spaeth System

Spaeth considered that available grading systems provided limited information and proposed a system that grades the three major features of the angle’s anatomy: the level of iris insertion, the width of the angle, and the configuration of the iris (Spaeth, 1971).

The level of iris insertion is represented by letters “A” through “E.” If the iris inserts anterior to Schwalbe’s line, it is described as grade “A” (for “anterior”). If it inserts anterior to the posterior limit of the trabecular meshwork, it is grade “B” (for “behind” Schwalbe’s line). If insertion is posterior to the scleral spur, the iris is grade “C” (for the “c” in sclera). Insertion into the ciliary body face is recorded as grade “D” (for “deep”) or grade “E” (for “extremely” deep) (6-4).

Angular width is the estimated angle between a line tangential to the trabecular meshwork and a line tangential to the surface of the iris about one-third of the way from the periphery. The angle is expressed in degrees (6-5).

The third characteristic that is described is the curvature of the peripheral iris: “r” for a regular or flat configuration, “s” for a steep curvature or iris bombé, and “q” for a “queer” or concave curvature (6-6). This system was subsequently modified in order to be more...
descriptive, using “f” to denote a flat configuration, “c” to describe the concave or back-bowed iris, “b” to describe the forwardly bowed iris, and “p” for a plateau iris configuration.

Spaeth graded posterior pigmented meshwork in the 12 o’clock angle on a scale of 0 to 4+. He also graded the type and number of iris processes.

The Spaeth system permits the inclusion of information obtained by indentation gonioscopy. If indentation demonstrates that the insertion is a “D” when it originally appeared to be a “C”, this would be indicated as “(C)D”. Therefore an angle is carefully defined by an alphanumeric description—such as (C)D30S—as is illustrated in 6-7 (Spaeth, 1977).
**Becker Goniogram**

Becker (1972) described the goniogram (6-8) as a means of drawing gonioscopic findings. He felt that this would allow description of the variable anatomy of an angle within a quadrant. It also provides a convenient way to record synechiae, tumors, foreign bodies, and so on.

**Van Herick System**

Mention should be made of the van Herick method of using the slit lamp to estimate the width of the angle (Table 2) (van Herick et al, 1969). A narrow slit beam is placed perpendicular to the most peripheral part of the cornea. The oculars are adjusted to give a view at an angle of about 60° from the light beam. The depth of the anterior chamber is graded by comparison to the thickness of the cornea. If the anterior chamber is thicker than the cornea, the angle is a wide-open grade 4 (6-9). If the thickness of visible aqueous is one-quarter of the corneal thickness or less, the angle is dangerously narrow, or “slit” (6-10).

Van Herick devised the system because routine Koeppe gonioscopy was felt to be impractical; gonioscopy was undertaken only if the angles were thought to be narrowed. Because slit-lamp gonioscopy can be rapidly performed on almost any patient, the van Herick estimation should not be relied upon as a replacement.

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### Table 2. Van Herick system of angle estimation.

<table>
<thead>
<tr>
<th>Grade of angle</th>
<th>Depth of peripheral chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Closed angle</td>
</tr>
<tr>
<td>1</td>
<td>&lt; 1/4 corneal thickness</td>
</tr>
<tr>
<td>2</td>
<td>1/4 corneal thickness</td>
</tr>
<tr>
<td>3</td>
<td>1/4 to 1/2 corneal thickness</td>
</tr>
<tr>
<td>4</td>
<td>≥ corneal thickness</td>
</tr>
</tbody>
</table>

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6-8 Becker’s goniogram, on which gonioscopic findings are drawn. The central dark line represents the scleral spur. The three lines outside the dark line represent the trabecular meshwork. The three lines inside the dark line represent the various levels of iris insertion into the ciliary body. A color code is provided for recording findings. (Courtesy of Stanley C. Becker, MD.)
The van Herick test can be helpful in the evaluation of confusing angles because it augments gonioscopic findings by giving a separate indication of the depth of an angle. However, the test does not provide any information about the angle except depth. One could miss tumors, foreign bodies, synechiae, neovascularization, and a host of other pathologies by relying on the van Herick test alone.

6-9 Angle estimation with the slit lamp by the van Herick method. The beam of the slit lamp is inclined at 60° from the oculars and is placed on the most peripheral cornea. The depth of the anterior chamber is compared to the thickness of the cornea. The depth of this chamber (arrow) is equal to or greater than the corneal thickness and is classified as grade 4.

6-10 By van Herick testing this angle is narrowed to a slit and the anterior chamber is barely visible between cornea and iris. This is an angle capable of closure.
Primary Infantile Glaucoma

Primary infantile glaucoma results from failure of the angle to develop normally. The outflow of aqueous humor through the incompletely developed trabecular meshwork is impaired, resulting in increased intraocular pressure. Unlike the adult eye, the infant eye stretches in response to this elevated pressure. The infant cornea also develops edema at relatively lower pressures than the adult cornea.

The diagnosis of infantile glaucoma is usually made when parents notice photophobia with blepharospasm, tearing, cloudy corneas, or large eyes. Although the disease can present at any time within the first three years of life, symptoms usually develop by the age of three months and the diagnosis is usually made by the end of the child’s first year. Most cases of primary infantile glaucoma are bilateral. It is inherited in an autosomal recessive pattern, and a percentage of cases are associated with mutations in the CYP1B1 gene (Stoilov et al, 1997).

On physical examination, the eyes are often observed to be large (buphthalmos), with large corneas (7-1). The corneas are edematous (7-2) and may show breaks in Descemet’s membrane (Haab’s striae), which appear as parallel lines with a horizontal or circumferential orientation (7-3). Gonioscopic examination requires sedation or general anesthesia. The examination is usually performed with a direct goniolens, such as a Koepp, Hoskins-Barkan, or Swan-Jacobs lens (see 3-5 to 3-15). Gonioscopy is made difficult by the lightly pigmented, amorphous appearance of infant angles and by the corneal edema that is often present in infantile glaucoma.
The angles in primary infantile glaucoma are immature (7-4 to 7-6). They demonstrate a rather flat iris configuration. The periphery of the iris is thin and the deeper pigment epithelium may show through in areas. There is a high, often irregular, insertion of the iris into the angles. The trabecular meshwork has a generalized sheen due to the thick trabecular beams. This gives the appearance of a membrane, which is referred to as Barkan's membrane—although there is no histologic evidence for such a membrane (Anderson, 1981). The radial blood vessels of the iris are often visible and the major arterial circle can often be seen (7-7) (Worst, 1966).

Viewed histopathologically (7-8), the trabecular pillars are thick. The anterior ciliary body and iris insert over the posterior trabecular meshwork. There is histopathological and clinical evidence of traction on the pillars. The traction may cause compaction of the trabecular spaces, with impairment of aqueous outflow. Direct gonioscopy plays a key role in the surgical treatment of primary congenital glaucoma. Both goniotomy and trabeculotomy achieve their common goal of lowering resistance to aqueous outflow by cutting through the tight pillars and relieving the compaction of the trabecular spaces (Anderson, 1981). Goniotomy involves using a small blade or needle to cut through the trabecular meshwork. This requires a clear view of the angle via direct gonioscopy, which is sometimes not possible due to the associated corneal edema. In cases where the corneal edema precludes adequate viewing of the angle, trabeculotomy is the preferred procedure. Trabeculotomy requires canalization of Schlemm's canal externally, which can be extremely challenging.
Fifteen-year-old with primary infantile glaucoma. She was first seen at age 6 with severe buphthalmos. There is generalized atrophy of the iris with islands of visible pigment epithelium. The iris inserts anterior to the scleral spur. The cornea anterior to the trabecular meshwork is opaque and thin.

The angle of a young adult with primary infantile glaucoma. An undulating greater circle of the iris is visible in the angle.

Histopathology of primary infantile glaucoma. The iris and anterior ciliary body cover the scleral spur and posterior trabecular meshwork. The intratrabecular spaces are compacted. (Courtesy of the National Museum of Health and Medicine, Armed Forces Institute of Pathology.)

Posterior Embryotoxon

Posterior embryotoxon is the name given to a prominent and anterior Schwalbe’s line. This can be seen on slit-lamp examination and is found in about 10% of the general population (7-9). On gonioscopy, Schwalbe’s line is observed to be prominent and to protrude into the anterior chamber as a ring (7-10). The ring of tissue may be partial or may extend through 360°. Although an extreme variation of it is present in most cases of
Posterior embryotoxon. An anterior and prominent Schwalbe’s line is a frequent finding in slit-lamp examination of normal individuals.

Axenfeld-Rieger Syndrome

The family of disorders known as the Axenfeld–Rieger syndrome includes Axenfeld anomaly, Rieger anomaly, and Rieger syndrome. These are developmental abnormalities that represent a spectrum of anatomic changes ranging from localized ocular abnormalities to systemic abnormalities. Like primary infantile glaucoma, they are developmental disorders of the anterior chamber, but they are morphologically distinct from primary infantile glaucoma. These conditions are usually bilateral and are inherited in an autosomal dominant manner. Mutations in the genes PITX2 and FOXC1 (formerly FKHL7) have both been shown to cause Axenfeld–Rieger syndrome and other similar conditions (Alward et al, 1998, and Nishimura et al, 1998). Glaucoma develops in about 50% of cases, generally in late childhood or early adulthood (Shields et al, 1985).

Posterior embryotoxon seen gonioscopically as a prominent Schwalbe’s line. There are fine iris processes in this eye.
Axenfeld anomaly is characterized by posterior embryotoxon with multiple iris processes that extend to Schwalbe’s line (7-11 and 7-12). This line may be dramatically thickened (7-13). It may be suspended from the cornea by a fine membrane and can break free from the cornea, leaving portions hanging into the anterior chamber (7-14) (Wolter et al, 1967). The iris processes can be broad (7-15) or lacy and delicate. The changes to the angle generally affect the entire angle, but they may also be restricted to a small area (7-16). The iris usually inserts anteriorly and obscures the scleral spur.

Rieger anomaly demonstrates all of the changes seen in Axenfeld anomaly with the addition of abnormalities of the iris. The iris is thinned, with areas of atrophy and hole formation (7-17). This leads to polycoria (multiple pupils) (7-18) and corectopia (a displaced pupil) (7-19). Hole formation generally occurs 180° from the direction of the displaced pupil. Occasionally the changes to the iris can be progressive (Judisch et al, 1979, and Honkanen et al, 2006).
In Rieger syndrome the ocular changes of Rieger anomaly are associated with systemic abnormalities. The most common abnormalities include maxillary hypoplasia (7-20), small and missing teeth (microdontia and hypodontia) (7-21), redundant periumbilical skin (7-22), and hypospadius.

7-13 Histopathology of Axenfeld-Rieger anomaly. Note the markedly thickened Schwalbe’s line (S) with adherent iris process (arrow).


7-15 Broad iris process and evident posterior embryotoxon in a patient with a known FOXC1 mutation.

7-16 The angle of a man examined because his infant son was diagnosed as having bilateral Axenfeld anomaly with severe secondary glaucoma. The family history is otherwise negative for Axenfeld anomaly and for glaucoma. This man had one small area of prominent Schwalbe’s line with iris adhesions. In other respects, both eyes were normal and the intraocular pressures were normal.
7.17 Marked iris hypoplasia in Rieger anomaly.

7.18 Polycoria in Rieger anomaly.

7.19 Corectopia in Rieger syndrome. The pupil has been stretched horizontally. The superior and inferior iris are thin. The same patient is shown in 7.20 to 7.22. (Reprinted with permission. Arch Ophthalmol. 1979;7:2120–2122. Copyright © 1979, American Medical Association. All Rights Reserved.)

7.20 Rieger syndrome, showing poorly developed maxilla with flat face (same patient as in 7.19, 7.21, and 7.22). (Reprinted with permission. Arch Ophthalmol. 1979;7:2120–2122. Copyright © 1979, American Medical Association. All Rights Reserved.)


Aniridia

Although aniridic patients usually appear to have no iris on examination with a slit lamp, some iris tissue is always present. In general the iris stump is so small that it can be seen only gonioscopically (7-23, 7-24) or histopathologically (7-25). Because of corneal and lenticular disease, gonioscopy can be difficult, but a clear view into an aniridic angle often provides a view of the angle structures, ciliary processes, and even peripheral retina (7-26).

Aniridia shows many variations. Most patients also have corneal pannus (7-27), nystagmus, cataract (7-28), foveal hypoplasia (7-29), and poor vision. The disease is usually autosomal dominant but may be autosomal recessive or sporadic. Mutations in the PAX6 gene are associated with aniridia (Jordan et al, 1992).

The autosomal recessive form may be associated with mental retardation. The sporadic form may be associated with Wilms tumor. Some aniridic families have relatively normal visual acuity (Elsas et al, 1977) but most have poor acuity at birth due to foveal hypoplasia, or gradual vision loss associated with progressive corneal pannus, cataract, and glaucoma.

Glaucma develops in approximately 50% of patients with aniridia, usually in late childhood or early adulthood. The angle is typically open at birth and closes over time. The mechanism of glaucoma development is thought to be rotation of the iris stump over the trabecular meshwork. This may be due to the contraction of strands of iris that extend to the trabecular meshwork from the root of the iris (Grant and Walton, 1974).
7-24 Superior angle in aniridia demonstrating a small stump of iris that covers the scleral spur and part of the posterior trabecular meshwork. The trabecular meshwork has no pigmentation and is identified by the corneal wedge. The patient is aphakic. The peripheral fundus is visible.

7-25 Histopathology of aniridia. The iris is very small and barely extends past the ciliary processes. (Courtesy of the National Museum of Health and Medicine, Armed Forces Institute of Pathology.)

7-26 Angle of a patient with aniridia, showing that the peripheral retina can be viewed gonioscopically.

7-27 Phakic patient with aniridia. Corneal pannus obscures the view of the angle in the inferior portion of the photograph.

7-28 Cataract in a patient with aniridia (same patient as in 7-27).
The rare condition of iris coloboma is usually found inferiorly in an eye that is otherwise normal (7-30). It represents a failure of closure of the embryonic cleft. An iris coloboma in isolation is not typically associated with glaucoma.
Primary Angle Closure

Pupillary block

Pupillary block is the result of abnormal contact between the iris and the lens that prohibits the free flow of aqueous from the posterior chamber to the anterior chamber. Aqueous trapped in the posterior chamber pushes the iris forward (8-1), giving it a convex appearance, which is termed “iris bombé” (8-2). The outflow of aqueous is impaired when the iris is pushed on to the trabecular meshwork. Hyperopic eyes are at highest risk of angle closure. Such eyes have shallow anterior chambers and small corneas (Tornquist, 1956, 1957). Angle closure is uncommon in myopic eyes, although it is seen in myopic eyes with spherophakia, plateau iris, and retinopathy of prematurity. If a myopic patient presents with narrow angles, one should consider looking for a specific cause. The elderly are more susceptible because the growth of their lenses moves the lens-iris diaphragm forward. Angle closure is especially prevalent among Asians. Pupillary block gives rise to three forms of primary angle closure: acute angle closure, intermittent angle closure, and chronic angle closure.

Acute angle-closure glaucoma is the most dramatic. On the basis of symptoms it was classified as acute congestive glaucoma until the late 1930s, when Barkan was able to classify it by its mechanism (Barkan, 1938). Patients experience sudden, severe pain with blurred vision and may have nausea and vomiting. Attacks generally occur in dark environments or during periods of intense emotion. Pupillary block is most likely to occur in middilation, when there is greatest lens-iris contact. A patient who does not develop pupillary block when the pupil is fully dilated in the physician’s
office may develop an attack later in the day when the pupil returns to middilation.

In acute angle-closure glaucoma, the affected eye is dramatically injected, showing corneal edema and a shallow anterior chamber (8-3). It may be difficult to examine the angle during an acute attack due to corneal haze (8-4). On gonioscopic examination, the iris bows forward and obscures the view of angle structures (8-5).

8-3 Acute angle-closure glaucoma with marked injection and a steamy cornea.

8-4 Gonioscopic view after an attack of acute angle closure. The cornea is edematous, which limits visualization. The trabecular meshwork has a ruddy appearance.

8-5 Iris bombé. No trabecular structures are visible. Note that the inner and outer lines of the corneal wedge do not meet in the anterior chamber, meaning that Schwalbe’s line and the trabecular meshwork are hidden by the iris.
Indentation gonioscopy is difficult during an acute attack owing to the high intraocular pressure. The other eye should be examined; in most cases of primary angle closure the contralateral eye will also have a markedly narrowed angle. Although asymmetric angles are unusual, they can be seen in eyes with unilateral mature cataracts, anisometropia, or trauma. If the attack of angle closure breaks spontaneously, there may be an anterior chamber cellular reaction and aqueous hyposecretion. The patient may be diagnosed erroneously as having iritis. This may be seen more frequently in patients classified as having intermittent angle closure. Eyes that have undergone previous episodes of angle closure may show evidence on slit-lamp examination of damage from high pressure, such as atrophy of the iris (8-6), cataract (8-6), or spiral changes of the radial iris fibers (8-7). Very high pressures can also cause necrosis of the lens epithelium, which appears as opaque areas (glaukomflecken) beneath the anterior lens capsule (8-8).

Intermittent (subacute) angle closure presents less dramatically. Patients may be asymptomatic or report episodic blurred vision, colored haloes around lights, and headache. Because intermittent headache may be the only symptom, many of these patients are misdiagnosed as migraineurs. If left untreated, intermittent angle closure can progress to chronic angle closure.

Chronic angle closure results in an insidious rise in intraocular pressure without symptoms. In both conditions gonioscopy will reveal iris bombé with very narrow angles (see 8-5). Trabecular structures may be visible only with indentation (Chapter 4). Synechiae may be present—especially superiorly, where the angle is narrowest. There may be a dusting of pigment on the cornea from contact with the iris, which might cause one to mistake it for the pigmented trabecular meshwork (8-9; see also 4-20). Indentation gonioscopy and the corneal wedge are most helpful in determining the true location of the trabecular meshwork. Changes in the optic nerve and visual field may be noted, especially in chronic angle closure.
The treatment of angle closure due to pupillary block is surgical iridectomy or laser iridotomy. Medical management using aqueous suppressants is used to temporize and to clear the cornea sufficiently to permit laser iridotomy. Once an iridotomy (or surgical iridectomy) has been performed in an eye with narrow angles, the anterior chamber should be noticeably deeper (8-10). Although they deepen, the angles do not usually attain a normal depth. After iridotomy, it is unusual to see grade 3 or 4 angles (Shaffer scale), or to see beyond the scleral spur. If angle closure persists after such treatment, the possibility of synechial angle closure or plateau iris syndrome should be considered. Both are discussed later in this chapter.

It is important to recognize that markedly elevated intraocular pressure is not always associated with angle closure. One should perform gonioscopic examination first and should not proceed directly to iridectomy or iridotomy. Other processes, such as glaucomatocyclitic crisis, can cause acute and marked pressure elevations. It is also not safe to assume that a marked pressure rise after dilation is due to angle closure. Patients with open angles may show pressure spikes after dilation. These spikes can be quite high, especially in patients with open-angle glaucoma who are taking cholinergic drops (Shaw and Lewis, 1986).

Video Clips on DVD
Pupillary Block
Pupillary Block + Peripheral Anterior Synechiae

8-9 Pigment accumulation on the corneal endothelium could be mistaken for trabecular meshwork in this eye with synechial angle closure. The corneal wedge shows that Schwalbe’s line and the trabecular meshwork are hidden by the iris.

8-10 Gonioscopic view of an eye with angle closure following surgical iridectomy. This is the same eye as in 8-5. There are extensive synechiae and only the most anterior portion of the trabecular meshwork is seen in some areas with the slit-lamp beam.
Plateau iris

Plateau iris configuration refers to a condition in which the iris exhibits a flat approach to the angle. The iris appears to be on a plane with Schwalbe’s line or the anterior trabecular meshwork and has a prominent last roll that blocks the view of the angle, especially on dilation. As the angle is approached, the iris drops off sharply to insert just below the scleral spur (8-11 and 8-12). The central anterior chamber is relatively deep, especially in comparison to patients with a convex iris associated with pupillary block. Patients with plateau iris configuration can also develop pupillary block, which can be treated with peripheral iridotomy. If the angle remains compromised, the patient would be diagnosed as having plateau iris syndrome.

Plateau iris syndrome is an unusual form of primary angle closure that is not caused by pupillary block. The angle is closed by the prominent last roll of the iris and the abnormal approach of the iris to the angle. A patent peripheral iridectomy or iridotomy must be present for a diagnosis of plateau iris syndrome. In such eyes, the ciliary processes are abnormally far forward. After iridotomy, the iris is held forward by the ciliary body (Pavlin et al, 1992). On indentation, the central iris is pushed back but the peripheral iris is held up by the ciliary processes (8-13 and 8-14). Anterior segment imaging techniques are also helpful in supporting the diagnosis of plateau iris.

8-11 Sketch of plateau iris configuration. There is a relatively deep central chamber. The iris takes a flat approach towards Schwalbe’s line. There is a prominent last roll of the iris before a steep drop-off into the chamber angle.

8-12 Gonioscopic view of an eye with a plateau iris configuration. Note the prominent peripheral rolls of the iris and the steep drop-off into the chamber angle.
Aqueous misdirection (ciliary block, malignant glaucoma)

Aqueous misdirection is an uncommon form of glaucoma in which aqueous is misdirected into the vitreous cavity, causing the lens and iris to be pushed forward (8-15). The central anterior chamber tends to be very shallow or flat (8-16). Gonioscopy is difficult to perform in aqueous misdirection because of the extreme shallowing of the anterior segment, but an example is shown in figure 8-17. The mechanism of aqueous misdirection is uncertain. It may be that apposition of the ciliary body to the lens or vitreous body creates a seal that directs aqueous humor posteri-
Aqueous misdirection occurs most frequently after intraocular surgery, particularly after filtration surgery in patients with narrow angles. It can occur at an early postoperative stage or later when anticholinergics are discontinued or cholinergics are begun. Aqueous misdirection must be differentiated from other causes of flat chamber with high intraocular pressure. Pupillary block can be difficult to distinguish from aqueous misdirection. In the former the central chamber is usually deeper than the peripheral chamber (see 8-2), whereas in aqueous misdirection the central chamber is very shallow or flat (see 8-16). If there is a patent iridectomy or iridotomy, pupillary block can be ruled out; if there is no iridectomy or iridotomy, one should be performed prior to a diagnosis of aqueous misdirection. Suprachoroidal hemorrhage can present with a shallow chamber and high pressure after surgery. Patients with suprachoroidal hemorrhage often give a history of abrupt-onset, severe pain. The choroidal elevation can be seen with the ophthalmoscope or by echography.

Secondary Angle Closure

Secondary angle closure can occur with or without pupillary block. In eyes without pupillary block, the iris can be pushed over the trabecular meshwork by inflammation, neovascularization, or membranes in the anterior chamber. In eyes with secondary angle closure but without pupillary block, peripheral iridectomy or iridotomy is of no benefit and should not be performed.

Secondary pupillary block

Pupillary block can develop secondarily if the iris becomes adherent to the lens or vitreous body or if lens or vitreous becomes trapped within the pupil. Peripheral iridectomy or iridotomy can relieve angle closure in secondary pupillary block.

Central posterior synechiae are inflammatory adhesions of the iris to the anterior lens capsule or face of the vitreous body. If synechiae develop over 360°, the pupil becomes secluded. Aqueous is trapped in the posterior chamber, driving the iris forward (8-18 and 8-19). Dilation can break the synechiae if they are of recent onset. Iridotomies performed in patients with iris bombe associated with uveitis are more likely to fail (Spencer et al, 2001). It is usually appropriate to make these iridotomies larger if possible, but it is equally important to use topical corticosteroids afterward to avoid excessive inflammation.

A partially dislocated lens can move forward and directly shallow the anterior chamber or cause pupillary block (8-20 and 8-21). A dislocated lens in the anterior chamber can lead to pupillary block (8-22). In pseudoexfoliation syndrome, the loose zonules allow the lens to move forward slightly, potentially narrowing the angle and causing pupillary block. Microspherophakia describes the condition in which there is an abnormally round, thick lens and short axial eye length, resulting in lenticular myopia (8-23 and 8-24). The condition can be isolated or may occur with the Weill-Marchesani syndrome. Less commonly, microspherophakia has been seen in Marfan syndrome or homocystinuria. Eyes with microspherophakia can develop lens subluxation resulting in pupillary block. Alternatively, the abnormally thick lens can cause a direct pupillary block from its native position. Pupillary block can occur in aphakia when vitreous (8-25) or an intraocular lens (8-26) is trapped by the iris.
8-18 Secondary pupillary block due to central posterior synechiae. Inflammatory synechiae have formed over 360°, trapping aqueous in the posterior chamber and leading to iris bombé.

8-19 Gross photograph of eye with secondary pupillary block and iris bombé. There is adhesion of the iris to the lens capsule, causing aqueous to be trapped in the posterior segment. Broad-based peripheral anterior synechiae are noted (between arrows). (Courtesy of the National Museum of Health and Medicine, Armed Forces Institute of Pathology.)

8-20 The lens is dislocated and has moved forward, causing pupillary block. Note how the iris drapes over the lens, giving a "volcano" appearance. (Courtesy of Robert Ritch, MD, New York Eye and Ear Infirmary.)

8-21 Gonioscopic view of eye shown in 8-20. The iris is draped across the lens. The anterior position of the lens provides a view of the ciliary processes. (Courtesy of Robert Ritch, MD, New York Eye and Ear Infirmary.)
Ectopia lentis with the lens dislocated into the anterior chamber. If the lens becomes trapped in the pupillary space, pupillary block glaucoma can develop.

Pupillary block secondary to microspherophakia. This patient is an 18-year-old female with progressive myopia and elevated intraocular pressure. Note that the angle is closed and the anterior chamber is very shallow.

Same patient as in 8-23. After dilation the anterior chamber is substantially deeper. The trabecular meshwork is still not visible due to 360° of synechiae. Note that the lens is small and round, with the zonules being visualized through the pupil.
Prolapse of vitreous body through pupil. In aphakic patients the vitreous body can prolapse into the pupil, causing a pupillary block unless there are patent peripheral iridectomies, as in this patient.

Secondary pupillary block due to an anterior chamber intraocular lens. Note ballooning of iris around intraocular lens. There is a patent iridectomy at 5 o’clock, but this is covered by the optic of the intraocular lens.

In phacomorphic glaucoma, a mature, intumescent lens can cause pupillary block or can directly compromise the anterior chamber (8-27).

Closure of the angle by synechiae
Peripheral anterior synechiae develop when the iris becomes adherent to the ciliary body, trabecular meshwork, or peripheral cornea (8-28 and 8-29). Synechiae may be small, or they can be so extensive that they close the entire angle. They must be distinguished from iris processes. Synechiae are thick and opaque, whereas iris processes are usually delicate and lacy (see 5-19 and 5-20). Iris processes are rarely sufficiently numerous to obscure the scleral spur. Synechiae tether the iris to the angle and interfere with the posterior motion of the iris during indentation gonioscopy; iris processes do not. Synechiae bridge the angle recess, while processes tend to follow the recess. The cornea may be pigmented anterior to synechiae (8-30).

Most synechiae attach to the scleral spur or trabecular meshwork. Although it is unusual for the iris to adhere to the cornea, this does happen in the iridocorneal-endothelial syndromes or after prolonged contact between the two bodies.

When synechiae are of recent origin, they can sometimes be broken with the laser or by surgery (goniosynechialysis), although successful synechialysis is not a guarantee that the underlying trabecular...
Extensive angle closure in chronic granulomatous uveitis. Trabecular meshwork can be seen only in the left-hand portion of this illustration, the remainder of the angle having been closed by synechiae. There are also central posterior synechiae at the pupil. Keratic precipitates are visible on the corneal endothelium.

Histopathologic view of angle closed by peripheral anterior synechiae (between arrows). There is a large granuloma on the surface of this eye with a syphilitic infection. (Courtesy of the National Museum of Health and Medicine, Armed Forces Institute of Pathology.)

Gonioscopic view of eye with peripheral anterior synechiae due to inflammation of unknown etiology. Peripheral anterior synechiae have developed over 360°. Pigment has been deposited anterior to the peripheral anterior synechiae at 6 o’clock.
meshwork will regain any function. Some of the many conditions that can lead to the growth of synechiae are described on the following pages.

**Neovascularization** Blood vessels are frequently seen in normal angles. The vessels are circumferential at the base of the iris or are radial. Normal vessels do not cross the scleral spur on to the trabecular meshwork. Abnormal vessels can cross the scleral spur (8-31 and 8-32) and may arborize into fine branches that dive into the trabecular meshwork. While the larger branches are seen as small twigs, smaller vessels may appear only as a red blush. Neovascular vessels have an associated membrane that frequently impairs aqueous outflow despite an apparently open angle (8-33). With time this fibrovascular membrane may contract, leading to closure of the angle by synechiae (8-34). Many patients with neovascularization of the anterior segment will first demonstrate new vessels near the pupillary margin (8-35) although they can be found anywhere on the iris.

Neovascularization can result from many processes. Most cases are due to retinal disease—such as diabetic retinopathy, central retinal vein occlusion retinopathy of prematurity, tumor, chronic retinal detachment, Eales disease, or sickle cell disease. Ocular ischemia, either in isolation, or associated with nonembolic
central retinal artery occlusion, can also cause neovascularization of the anterior chamber. Chronic inflammation can make normal angle vessels become more prominent or can cause true neovascularization. The neovascularization of Fuchs heterochromic iridocyclitis rarely leads to the development of synechiae. This disease is therefore described under open-angle mechanisms in Chapter 9.

Iridocorneal-endothelial syndromes The iridocorneal-endothelial (ICE) group of diseases have in common changes in the corneal endothelium and the formation of peripheral anterior synechiae (8-36). They appear to be the result of an abnormal growth of corneal endothelium throughout the anterior segment. The corneal endothelium demonstrates a characteristic hammered silver appearance on examination by slit lamp (8-37). Specular microscopy reveals markedly abnormal endothelial cells (8-38). The ICE syndromes are unilateral and are most prevalent in women in their 30s and 40s. They frequently cause a secondary angle-closure glaucoma that can be very difficult to treat, both medically and surgically. This appears to be due to the persistent growth of the abnormal corneal endothelium across the anterior chamber and angle structures, as well as glaucoma surgical sites and drainage devices.

The ICE syndromes are usually divided into three types, but there is substantial overlap. In Chandler syndrome the corneal changes described above predominate (see 8-37). There may be corneal edema. Abnormalities of the iris are minimal. In essential iris atrophy the iris changes predominate. The iris demonstrates evidence of melting and membrane contraction. These result in the development of stretch holes and melt holes (polycoria) and a displaced pupil (corectopia) (8-39 and 8-40). In iris-nevus (Cogan-Reese) syndrome nevi-like elevations develop on the face of the iris; these consist of normal iris protruding through a membrane that coats the iris (8-41 and 8-42). The unilateral,
acquired, and progressive presentation of ICE syndrome allows it to be easily distinguished from Axenfeld-Rieger syndrome, in which many of the iris findings can be similar, but are bilateral and congenital. No definitive cause of ICE syndrome has been identified, although herpes simplex virus has been detected in the aqueous of affected eyes (Groh et al, 1999).

**Posterior polymorphous dystrophy** Posterior polymorphous dystrophy (PPMD) is an uncommon bilateral corneal dystrophy. It is usually an autosomal dominant disease but may be sporadic. Mutations in the gene TCF8, a transcription factor involved in
collagen production, have been identified as a cause of approximately one-half of PPMD cases (Krafchak, 2005). PPMD is characterized by the presence of endothelial vesicles (8-43); these may appear in groups, sometimes with a linear orientation (8-44). Often the vesicles are surrounded by a corneal haze. There can be opacification of the posterior cornea. Glaucoma develops in about 14% of cases and is usually due to a membranous overgrowth of the trabecular meshwork (8-45). Open angles with high iris insertions have been seen, suggesting a primary angle abnormality (Krachmer, 1985).

After surgery and trauma Flat anterior chambers following surgery can lead to the development of peripheral anterior synechiae (8-46), the location of which may be anterior to Schwalbe’s line (8-47).

Epithelial downgrowth is a rare outcome of penetrating trauma or surgery, particularly since the transition to small-wound cataract surgery. It may occur particularly when there is inadequate wound apposition. Epithelium seeded into the anterior chamber may form a cyst (8-48) or a sheet of epithelium (8-49). The sheets are clear and can be difficult to identify. Their presence on the iris can be detected by blanching when heated with argon laser energy; normal iris does not demonstrate blanching. As the epithelium coats the inner surfaces of the eye it covers the chamber angle (8-50), leading to intractable glaucoma.

The synechiae formed by argon laser trabeculoplasty are usually small, conical adhesions of peripheral iris to the posterior meshwork (8-51), but they can be extensive if the laser is aimed far to the posterior and high energy levels are used (8-52) (Rouhiainen et al, 1988).

Inflammation Inflammation can lead to the formation of synechiae as consolidation of the inflammatory
8-46 Formation of synechiae in the superior angle following filtration surgery. Ciliary body processes are incarcerated within the filtration fistula. On the right of the figure is a broad synechia. On the left, the trabecular meshwork is open with scattered low synechiae to the scleral spur. The painting is positioned to show the superior angle viewed through an indirect lens. The artist’s name therefore appears upside down.

8-47 Extensive synechiae and iris adherent to wound (arrow) in patient with prolonged flat chamber following extraction of a cataract. No trabecular meshwork is visible. The painting is positioned to show the superior angle viewed through an indirect lens. The artist’s name therefore appears upside down.

8-48 Epithelial inclusion cyst in the anterior chamber of a young man who had previously been struck in the eye with a knife.

8-49 Sheet of epithelial downgrowth over the superior portion of the corneal endothelium following extraction of a cataract. (Courtesy of William W. Culbertson, MD, Bascom Palmer Eye Institute.)
material in the angle draws the iris over the trabecular meshwork. Synechiae may develop when the iris is apposed to the trabecular meshwork for a prolonged period. If there is both apposition and inflammation, as in a flat chamber following surgery, the tendency for synechiae to form becomes marked.

**Posterior pressure**
Cysts and tumors in the peripheral iris and ciliary body can lead to closure of segments of the angle (8-53). They do not usually close enough of the angle to result in glaucoma. Some iris cysts can be opened with a laser to relieve compromise of the angle (8-54 and 8-55). Dislocated lenses can also cause the closure of angle segments.

**Swelling of the ciliary body and choroid**
Swelling of the ciliary body (or anterior choroid) can result in angle closure (8-56). Compromise of venous drainage or inflammation of the ciliary body may lead
8-53 Narrowing of segmental angle due to ciliary body melanoma. Note that the iris is pushed forward in the center of the figure and obscures the trabecular meshwork, which is visible both to the right and to the left of this area. This patient has a rather prominent Schwalbe’s line and has blood in Schlemm’s canal.

8-54 Cyst of the iris with segmental angle closure.

8-55 Same patient as in 8-54, showing deepening of the chamber following laser opening of the iris cyst.

8-56 Shallow anterior chamber due to swelling of the ciliary body, the result of extensive panretinal photocoagulation.

to such swelling. Swelling can also occur after scleral buckling procedures, after extensive panretinal photocoagulation and with ciliochoroidal detachment as a result of inflammatory pseudo-tumor (Gass, 1967). Other choroidal inflammatory processes such as Vogt-Koyanagi-Harada or posterior scleritis can also result in angle closure. Angle closure associated with topiramate (Topamax) is due to ciliochoroidal detachment as well (Banta, 2001). Angle closure due to swelling of the ciliary body and/or anterior choroid does not respond to iridectomy or iridotomy. Cholin-
8-57 Eye of patient with iridoschisis; the anterior and posterior portions of the inferior iris have split, causing the anterior iris to bulge forward and segmentally close the angle (right eye).

8-58 Illustration of the process shown in 8-57, demonstrating how iridoschisis can cause angle closure.

8-59 Same patient as 8-57. The left eye showed fragmentation of the anterior iris. These iris strands were touching the cornea but had not yet caused corneal decompensation.

8-60 Gonioscopic photograph of eye shown in 8-59. Fragments of the iris touch the corneal endothelium in an eye with an open angle.

Anticholinergic agents can worsen the condition by moving the lens-iris diaphragm forward and breaking down the blood-aqueous barrier. Anticholinergic and steroid therapy along with aqueous suppression is the preferred management.

Iridoschisis

Iridoschisis is a rare iris disorder of the elderly. In this disease there is a bilateral separation of the stroma, especially of the inferior iris. Early in the disease an intact sheet of anterior stroma may split and balloon forward (8-57 and 8-58). The anterior iris can obstruct the angle. Later the anterior layer of the iris may fragment (8-59 and 8-60). The fragments may come into contact with the corneal endothelium, leading to localized corneal edema. Glaucoma can arise as a result of angle closure either because of the anterior iris layer covering the trabecular meshwork or as a result of pupillary block (Rodrigues et al, 1983). Open-angle glaucoma can result from the presence of fragments of pigment and iris in the trabecular meshwork.
Fuchs endothelial dystrophy

Fuchs endothelial dystrophy is a slowly progressive degeneration of the corneal endothelium. The loss of endothelial function leads to an accumulation of water in the cornea accompanied by an increase in its thickness (8-61). In rare cases the thickening of the cornea can cause angle closure, particularly in an eye with already narrow angles.

8-61 Fuchs endothelial dystrophy. Marked thickening of the cornea with extensive guttata. Rarely, these patients will develop angle closure. (Courtesy of Jay H. Krachmer, MD, University of Minnesota.)
Primary Open-Angle Glaucoma

Primary open-angle glaucoma is the most prevalent form of glaucoma. It is mentioned here only to note that there are no characteristic gonioscopic abnormalities in primary open-angle glaucoma, ocular hypertension, or normal-tension glaucoma.

Material Deposited in the Angle

Pigment

Pigment dispersion syndrome In the pigment dispersion syndrome there is an accumulation of pigment on structures throughout the anterior segment. The pigment originates from the iris pigment epithelium, which is abraded against the lens zonules (Campbell, 1979). As the pigment circulates throughout the anterior segment, it is deposited at many sites. The syndrome is most common in young myopic individuals. These patients are at increased risk for retinal detachment. Although the pigment dispersion syndrome is equally prevalent in both sexes, pigmentary glaucoma develops more commonly in males.

With the slit lamp, pigment deposited by aqueous convection currents can be seen as a vertical band on the corneal endothelium—the Krukenberg spindle (9-1). The dusting of pigment on the surface of the iris (9-2) can occasionally be sufficiently dense to cause heterochromia (9-3). Characteristic spoke-like defects of the

9-1 Krukenberg spindle in the pigment dispersion syndrome. Pigment released from the pigment epithelium of the posterior iris is deposited by convection currents on the corneal endothelium in a vertical band.

9-2 Pigment dusting on the iris associated with pigment dispersion syndrome.
Iris pigment epithelium are seen by transillumination (9-4). These can be identified more easily with infrared transillumination when available.

Gonioscopic examination reveals dense black pigmentation of the trabecular meshwork and throughout the angle (9-5). Pigment is frequently deposited anterior to Schwalbe’s line as a Sampaolesi’s line, which is a nonspecific sign of increased pigmentation. There may be a concavity of the mid-peripheral iris, which probably contributes to iris-zonule contact (9-6). Peripheral iridotomy frequently resolves this iris configuration, although the role for iridotomy in the treatment of the condition is controversial. After dilation pigmentation may be seen where the zonules attach to the posterior lens capsule. Pigment in this area is called a Scheie’s stripe. Scheie’s stripe can occasionally be seen with the slit lamp (9-7) but is best seen by gonioscopic examination (9-8).

**Pseudoexfoliation (exfoliation syndrome, glaucoma capsulare)** In pseudoexfoliation there is a deposition of basement membrane-like material throughout the
anterior segment of the eye. Similar material has been identified at many other sites throughout the bodies of patients with pseudoexfoliation (Streeten et al, 1992). There are conflicting reports as to whether there is any association between pseudoexfoliation and cardiovascular disease (Shrum et al, 2000, and Citirik et al, 2007). Eyes with pseudoexfoliation show an increased incidence of open-angle glaucoma and, occasionally, angle-closure glaucoma. This process can occur in one or both eyes and is a major cause of unilateral glaucoma. It occurs primarily among the elderly and is most prevalent among those of Scandinavian heritage. Certain haplotypes of the gene LOXL1 have been shown to be responsible for a large percentage of pseudoexfoliative glaucoma (Thorleifsson et al, 2007).

On examination a granular or flaky deposit is observed on the anterior lens capsule, often with a clear zone where the iris has rubbed some of the deposited material off the lens (9-9). The edges of this material can curl at the pupillary border or can be seen there as dandruff-like debris. With transillumination patchy iris defects are often apparent at the pupillary border. Pigment may collect on the iris or corneal endothelium. The zonules are frosted with pseudoexfoliative material (9-10). The zonules are fragile, making zonular dehiscence a risk in extracapsular cataract extraction (Skuta et al, 1987). Even after cataract surgery, the intraocular lens/capsular complex is prone to subluxation or dislocation (9-11). In aphakic eyes pseudoexfoliative material may be seen on the ciliary processes (9-12) or on the face of the vitreous body (9-13).

Marked pigmentation of the angle is found on gonioscopic examination. The pigment typically has a more granular, brown character than the dense black pigment that is seen in the pigment dispersion syndrome (9-14 to 9-16).
9-9 Slit-lamp photograph of pseudoexfoliative material on the anterior lens capsule. This material has a ground glass-like appearance and has areas that have been rubbed away by the motion of the iris against the lens capsule.

9-10 Gonioscopic view of pseudoexfoliative material on zonules. This view is through a peripheral iridectomy after a trabeculectomy. Note the frosted appearance of the zonules.

9-11 Subluxed IOL in patient with pseudoexfoliation.

9-12 Gonioscopic photograph of pseudoexfoliative material on the ciliary body of an aphakic patient. (Courtesy of Richard K. Parrish II, MD, Bascom Palmer Eye Institute.)

9-13 Pseudoexfoliation on the anterior vitreous face of an aphakic patient.

9-14 The angle in pseudoexfoliation. Note the clumped brown pigment over the pigmented trabecular meshwork. There is also a line of pigment along Schwalbe’s line and another, wavy line of pigment anterior to this line.
Oculodermal melanocytosis In oculodermal melanocytosis there is abnormal pigmentation of the periorbital skin and globe. The involvement of the skin takes the form of a deep, dermal pigmentation in the ophthalmic and maxillary distributions of the trigeminal nerve. If only the eye is affected, the condition is termed “melanosis oculi” (9-17). Ocular pigmentation most commonly affects the episclera but may also involve the iris, fundus, conjunctiva, and trabecular meshwork (9-18). The disorder is more common in women than in men. It is seen most often in darkly pigmented individuals. Glaucoma has been reported in 10% of a large sample of patients with the condition (Teekhasaenee et al, 1990).

Inspection of the angle of patients with glaucoma in oculodermal melanocytosis shows the trabecular meshwork to be covered by pigment or to be obscured by many pigmented iris processes (9-19 and 9-20). The ciliary body band is generally dark. The mechanism of glaucoma development is thought to be melanocytic infiltration of the trabecular meshwork and the dispersion of pigment. Evidence for the pigment dispersion mechanism is the finding of endothelial deposits of pigmentation with a Krukenberg spindle-like distribution (Teekhasaenee et al, 1990).
Other causes of increased angle pigmentation

There may be a release of pigment after surgery. This can occur after incisional surgery (9-21) or after laser surgery. A malpositioned intraocular lens can rub against the posterior iris and release pigment into the angle. Peripheral laser iridotomy is a common cause of increased angle pigmentation, particularly of the inferior angle. Some patients with severe iridocyclitis may show a marked release of pigment into the anterior chamber (9-22). With angle closure there can be pigmentation of the angle from chronic iris contact. Melanomalytic glaucoma results from the release of pigment by a large melanoma, usually of the choroid.
This is a very uncommon cause of increased angle pigmentation.

**Blood**

Blood may be observed in the anterior chamber secondary to a range of etiologies, such as trauma, surgery, and neovascularization. Blood settles into the inferior angle under the influence of gravity. Small amounts of blood can be seen only by gonioscopy (9-23 and 9-24). Small hyphemas do not usually result in an increase in intraocular pressure. Large hyphemas are more likely to cause problems with intraocular pressure as the trabecular meshwork fills with blood. Very large hyphemas that extend into the posterior chamber can occlude the pupil and cause elevated pressure secondary to pupillary block. In some patients with recurring hyphemas—especially following surgery—gonioscopy can be used to locate bleeding vessels and to treat them with a laser. Small balls of pigment may be seen in the angle long after a hyphema has resolved (see 9-50). It is important to remember that gonioscopy must be performed very gently when

9-23 Gonioscopic view of inferior angle in a 16-year-old boy who was struck in the eye. There is blood lying on the trabecular meshwork.

9-24 A higher-magnification gonioscopic view of the inferior angle of the eye of a 17-year-old boy shortly after he was struck in the eye. There is a small amount of blood anterior to the trabecular meshwork and also in Schlemm’s canal.
a hyphema is present, due to the risk of rebleeding early after a traumatic hyphema occurs. It is often best to defer gonioscopy to a later time to look for angle recession.

Ghost-cell glaucoma is an unusual disorder that is seen in patients with vitreous hemorrhage. Red blood cells denature within the vitreous body and take on a spherical form, in contrast to the normal biconcave shape (9-25). The cells are inflexible and pass through the trabecular meshwork with difficulty (Campbell et al, 1976). Such cells are more likely to raise intraocular pressure than red blood cells. Ghost erythrocytes may be identified by their characteristic khaki color on slit-lamp (9-26) and gonioscopic examination. Glaucoma is most likely to develop in aphakic eyes or in eyes with zonular breaks through which the ghost cells can gain access to the anterior chamber.

**Inflammation**

In the inflamed eye one can see precipitates on the internal cornea and on the trabecular meshwork. Sometimes the precipitates are revealed only by gonioscopic examination (9-27). A small hypopyon may be visible in the inferior angle with gonioscopy. Peripheral anterior synechiae are frequently observed after chronic inflammation as large precipitates consolidate (9-28 and 9-29) and cause the iris to become adherent to the trabecular meshwork. Closure of the angle by synechiae is discussed in Chapter 8.

Fuchs heterochromic iridocyclitis is a form of inflammatory glaucoma with a unique constellation of findings. Examination reveals frequent heterochoria (9-30 and 9-31), mild inflammation of the anterior chamber, diffuse fine stellate keratic precipitates (9-32 and 9-33), cataract (9-34), and neovascularization of the iris (9-35) and angle (9-36 and 9-37). These fine angle vessels do not often lead to the development of synechiae. The vessels are very fragile and can bleed on paracentesis of the anterior chamber (Amsler and Verrey, 1946) and even on gonioscopy (Begg, 1969). The most consistent feature of Fuchs heterochromic
Slit-lamp photograph showing a large sarcoid granuloma in the inferior angle. This inflammatory mass can consolidate and pull the iris over the trabecular meshwork. (Reprinted from Clinical Atlas of Glaucoma, 1st ed, E. Michael Van Buskirk, copyright © 1986, with permission from Elsevier.)

Gonioscopic view of a sarcoid granuloma of the inferior angle. Same patient as in 9-28.

Normal right eye of a patient who has Fuchs heterochromic iridocyclitis in the left eye.

Left eye of the patient in 9-30. This eye has Fuchs heterochromic iridocyclitis. Note the surgical iridectomies from filtration surgery and also the hypochromia of this iris when compared with the right eye. The iris is flat and featureless and lacks the normal crypts seen in the other eye.

Same patient as 9-30 and 9-31. A closer view of the left eye demonstrates diffuse, small, keratic precipitates over the entire corneal endothelium.
9-33 A example of a keratic precipitate in Fuchs heterochromic iridocyclitis. Note that the precipitate is clear with dendritic projections. (Reprinted with permission from Tasman W. Jaeger. Duane’s Clinical Ophthalmology, “Uveitic Glaucoma” by W. L. M. Alward. 1989. Courtesy of Lippincott Williams & Wilkins.)

9-35 Diffuse neovascularization of the iris in Fuchs heterochromic iridocyclitis.

9-36 Neovascularization of the angle in Fuchs heterochromic iridocyclitis. These vessels are extremely fragile and bleed with minor trauma. Unlike other forms of neovascularization, the tendency to form synechiae is minimal.

9-37 More substantial neovascularization of the angle in Fuchs heterochromic iridocyclitis.
Iridocyclitis is a flat, featureless iris (9-31 and 9-38) (Kimura et al, 1955). The disease appears to be associated with rubella virus, as intraocular antibodies to rubella virus have been isolated from the aqueous of patients with Fuchs heterochromic iridocyclitis (de Groot-Mijnes et al, 2006). Its prevalence has decreased in the United States since vaccination has become commonplace (Birnbaum, 2007).

Glaucomatocyclitic crisis is an uncommon, usually unilateral, mild inflammation accompanied by strikingly elevated intraocular pressures of 40 to 60 mm Hg. There are often a few small, colorless keratic precipitates over the inferior corneal endothelium. There may be slight pupillary dilation and iris hypochromia is occasionally observed on the affected side. The high pressure can cause corneal edema. The angle is open and has normal pigmentation. Synechiae do not develop (Posner and Schlossman, 1948). The sudden, strikingly high intraocular pressure rises can lead to a mistaken diagnosis of acute angle closure unless gonioscopy is performed.

A rare syndrome of precipitates on the trabecular meshwork was described by Chandler and Grant in 1965. This presents like primary open-angle glaucoma but demonstrates a paradoxical increase in intraocular pressure with cholinergic agents. On examination fine inflammatory precipitates are seen on the trabecular meshwork (as in 9-27). The eye is otherwise generally quiet. The pressure usually responds to corticosteroids and aqueous suppressants, but recurrences are the rule and patients frequently require indefinite therapy. Some cases develop full-blown inflammation of the anterior chamber, while others never experience inflammation beyond the trabecular meshwork. Synechiae are a common development.

**Lens material**

When the lens is ruptured, the fragments may cause obstruction of the aqueous outflow. In lens-particle glaucoma, a fine glistening can be seen in the angle due to the presence of lens fragments (9-39 and 9-40). Fragments of lens are identified on tapping the anterior chamber.
Phacolytic glaucoma is seen in eyes with mature or hypermature cataracts (9-41). The affected lenses leak denatured protein through an intact capsule into the anterior chamber. Macrophages engulf the material and are seen floating in the anterior chamber amid a heavy flare. White material observed on the anterior lens capsule probably represents collections of macrophages. The trabecular meshwork becomes obstructed by macrophages (9-42 and 9-43) and protein (Epstein et al, 1978). Pressure elevation is often abrupt and can reach very high levels. The eye is usually injected and the cornea is frequently edematous.

**Foreign bodies**

Foreign bodies can be found lodged in the anterior chamber angle after trauma (9-44 and 9-45). They are usually located in the inferior angle and may be found on routine examination. Most are inert and damage the eye only if they traumatize the corneal endothe-

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9-39 Patient with recent trauma demonstrating a tear of the sphincter. The patient had a marked elevation of his intraocular pressure.

9-41 A hypermature cataract with a liquefied cortex and a brunescent nucleus that has sunk to the inferior portion of the lens.

9-40 Gonioscopic view of the eye shown in 9-39. The patient had glistening material on the surface of the trabecular meshwork. An anterior chamber tap demonstrated lens particles. Note that the angle is probably recessed.

9-42 Phacolytic glaucoma in an eye with traumatic angle recession and a hypermature lens. Lens protein-filled macrophages are identified in the recessed angle. (Courtesy of the National Museum of Health and Medicine, Armed Forces Institute of Pathology.)
9-43 Scanning electron micrograph of intratrabecular space from an eye with phacolytic glaucoma. A red blood cell (white arrow) and a macrophage (black arrow) are seen between the trabecular pillars. Note the ruffled surface of the macrophage.
(Courtesy of Robert Folberg, MD, University of Iowa.)

9-44 Glass in the inferior angle after trauma. The patient had broken his glasses while working in a sawmill. A fragment of glass was removed earlier. The patient presented with discomfort and injection. The chip of glass is wedged between the trabecular meshwork and the iris, distorting both structures. There is a small tear in the iris and clotted blood under the fragment. Some blood is present in Schlemm's canal.

9-45 Sand in the inferior angle after a land-mine explosion.
lium. If a patient presents with focal corneal edema, 
gonioscopy may reveal that a foreign body has lodged 
in the angle. When such bodies are removed, the edema 
usually clears (McDonald and Ashodian, 1959). Some 
metallic and vegetable foreign materials are poorly 
tolerated. Siderosis is a late effect of a retained foreign 
body composed of iron or steel. The iron oxidizes and 
ions are dispersed through the eye, resulting in toxicity 
to the trabecular meshwork, lens, cornea, and retina. 
The trabecular meshwork may take on a rusty hue 
(9-46), and the eye may develop late glaucoma. The 
most striking slit-lamp finding is a rust-colored 
anterior cataract (9-47). The most serious effects of 
siderosis arise from toxicity to the retina.

Traumatic Angle Changes

Iridodialysis

Iridodialysis, or tears in the iris (9-48 and 9-49), occur 
as the result of blunt trauma. Bleeding from the tears 
can result in hyphemas. By themselves iridodialyses 
generally cause no problems. Occasionally there will 
be some flattening of the pupil in the quadrant of the 
tear. Some patients may notice extra images through 
the iris defect. An iridodialysis mostly serves as an 
indicator that the eye has previously sustained a substan-
tial impact and should alert one to the possibility of 
angle recession or retinal damage. Some iridodialyses 
occur so far towards the periphery that they can be 
appreciated only by gonioscopy.

Angle recession

A recessed angle occurs as a result of severe blunt 
trauma in which there is a tear in the face of the ciliary 
body, usually between the longitudinal and circular 
muscles. The tear can occur over a limited area or may 
involve the entire angle. Angle recession is important 
because of the accompanying increased risk of 
glaucoma. Glaucoma occurs in about 9% of patients 
with recessed angles and may develop months or years 
after the injury (Kaufman and Tolpin, 1974). Most 
patients with significant hyphemas will be found to
Gonioscopic view of traumatic iridodialysis in the inferior angle found on routine examination. The patient remembered having sustained blunt trauma to the eye several years previously. Ciliary processes can be seen through the iris defect.

Abnormalities Associated With an Open Angle

have angle recession after the hemorrhage clears (Tönjum, 1966).

Gonioscopic examination shows a wide ciliary body band and a deep anterior chamber (9-50 and 9-51). The ciliary face may appear lighter in the recessed area because there is little ciliary tissue overlying the sclera (9-50 and 9-52). The presence of torn tissue may give the ciliary face a cobweb appearance, and the ciliary body face may have a linear defect suggesting that a cyclodialysis cleft had almost formed with the injury (9-53). Iris processes will be broken and the scleral spur may appear whiter than normal because the uveal meshwork has been torn from the surface. It is useful to compare eyes to determine if one eye has an abnormally wide ciliary body band and/or broken ciliary processes (9-54 and 9-55).
Cyclodialysis cleft

A cyclodialysis cleft is the disinsertion of the ciliary body from the scleral spur. This permits free access of aqueous into the suprachoroidal space and usually results in decreased intraocular pressure, sometimes resulting in hypotony. Cyclodialysis clefts can occur as a result of trauma or can be created surgically. Surgical cyclodialysis is rarely performed now because of problems with hemorrhage and hypotony and the failure to provide long-term control.

A cyclodialysis cleft appears as a very deep angle with a cleft through which the white color of the sclera is visible (9-56 and 9-58). As in angle recession, there will be rupture of any iris processes in the area of the cleft and the scleral spur may appear to be whiter than in other areas.

A cyclodialysis cleft is a detachment of the ciliary body from the scleral spur (9-57), while a recessed angle is a tear into the face of the ciliary body. A comparison of the histopathology shown in 9-52 and 9-57 illustrates this difference clearly. Angle recession is associated with
a normal or elevated intraocular pressure, whereas a cyclodialysis cleft is associated with a normal or decreased intraocular pressure.

Cyclodialysis clefts may close spontaneously or they can be closed surgically. In both cases there may be a dramatic elevation of intraocular pressure as aqueous outflow is suddenly diverted back to the trabecular meshwork.

**Tumors**

Tumors of the posterior segment, iris, and ciliary body can elevate intraocular pressure by closing the angle, as discussed in Chapter 8. Open-angle mechanisms by which tumors can elevate pressure include tumor seeding into the angle, a ring melanoma, or shedding of pigment from a large choroidal melanoma (melanomalytic glaucoma) (Yanoff, 1970).

Glaucoma occurs more frequently with tumors of the anterior segment, particularly malignant melanoma. Uveal malignant melanomas of the anterior segment lead to the development of glaucoma in over 41% of cases—compared to 14% of posterior melanomas (Yanoff, 1970). Eyes with melanomas of the anterior segment associated with glaucoma have a poorer
prognosis than eyes in which glaucoma has not developed (Shields and Klintworth, 1980). Other tumors of the anterior segment can cause glaucoma, but less commonly than melanoma.

A gonioscopic examination is critical in evaluating the extent of tumor involvement in eyes with malignancies of the anterior segment. The examination may reveal a direct invasion of the angle (9-59 and 9-60).

9-59 Gonioscopic view of malignant melanoma of the ciliary body invading through the iris into the angle.

9-60 Large malignant melanoma of the ciliary body extending into the anterior segment and covering the nasal angle.
or even peripheral cornea. Even if this is not demonstrated, diffuse invasion of the angle cannot be ruled out (9-61 to 9-63).

**Blood in Schlemm’s canal**

The presence of blood in Schlemm’s canal (9-64 and 9-65) may be caused by an abnormal flow relationship between the anterior chamber and the episcleral venous channels. The normal episcleral venous pressure is 8 to 10 mm Hg and the normal intraocular pressure is 10 to 21 mm Hg. The higher intraocular pressure normally causes aqueous flow to be directed towards the venous system. If the episcleral venous pressure is higher than the intraocular pressure, blood flows into Schlemm’s canal. This can occur idiopathically, or with intraorbital or intracranial vascular abnormalities, such as carotid-cavernous fistulas, dural–sinus fistulas, and Sturge-Weber syndrome. In these conditions conjunctival and episcleral vessels are usually dilated and tortuous (9-66). These vessels are “arterialized” and remain largely dilated all the way to the limbus.

If the eye is hypotonic from any cause, blood can reflux into Schlemm’s canal. If a Goldmann lens is pressed too tightly against the globe, episcleral venous outflow will be impeded and blood will appear in the canal. Blood can also be seen in Schlemm’s canal in some normal eyes.

**Postsurgical Changes**

Many changes occur in the angle following surgery to the anterior segment. After surgery for glaucoma, gonioscopy is a valuable tool for examining the surgical site. A patent internal sclerostomy should be visible after a trabeculec-tomy. Gonioscopy can identify blockage of the sclerostomy by blood, vitreous, or lens capsule. In some cases, the iris or ciliary body may become incarcerated (9-67). A blood clot or bleeding site can be identified. In iridencleisis some iris tissue is intentionally pulled into the

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9-61 Slit-lamp photograph of inferonasal mass of the iris with ectropion uvea. This patient suffered from elevated intraocular pressure and very poor vision due to glaucoma.

9-62 On gonioscopy the mass seen in 9-61 does not appear to extend into the chamber angle.

9-63 On histopathology, the mass seen in 9-61 and 9-62 is found to be a malignant melanoma affecting the iris root, trabecular meshwork and ciliary body through 360°.
Color Atlas of Gonioscopy

9-64 Gonioscopic view of an angle showing blood in Schlemm’s canal. There is, incidentally, a prominent Schwalbe’s line.

9-65 Blood in Schlemm’s canal in a patient with idiopathic episcleral venous pressure elevation. Note the very faint red hue seen through the pigmented trabecular meshwork, not easily seen without suspecting its presence.

9-66 Engorged, tortuous blood vessels in a patient with elevated episcleral venous pressure due to a low-flow dural-sinus fistula. Note the dilated vessels reach the limbus, which is not seen in other conditions in which episcleral vessels may also be dilated.

9-67 Angle after trabeculectomy with incarceration of uveal material into the filtering sclerostomy.

edges of the wound (9-68). This procedure is no longer routinely performed. Setons are usually visible with the slit lamp, but they may be located so far into the angle that gonioscopy is necessary to evaluate the location and patency of the tube (9-69). Gonioscopy is particularly helpful in identifying the location of the tube following corneal transplantation, as the view of the tube is often obscured by an edematous peripheral cornea on the host side.

After cataract extraction the anterior chamber is generally quite deep because of the loss of lens thickness (9-70). The cataract wound can be visualized internally (9-71). Depending on the type and location
of a cataract wound, many ocular structures may become incarcerated in the wound, including zonules (9-71), iris (9-72), or vitreous (9-73). One may see evidence of traumatic changes resulting from surgery, such as a scroll of detached Descemet’s membrane (9-74). In an eye with an anterior chamber intraocular lens, gonioscopy can be helpful in evaluating the placement of the haptics (9-75 and 9-76).
Internal view of cataract incision in eye of aphakic patient. A small strand of zonular fibers adheres to the wound.

A large band of iris incarcerated in a cataract wound. The painting is positioned to show the superior angle viewed through an indirect lens. The artist’s name therefore appears upside down.
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9-73 Gonioscopic view after intracapsular cataract extraction showing a sheet of vitreous that passes through the iridectomy and into the wound.

9-74 Inferior scroll of Descemet's membrane after surgery.

9-75 Haptics of an anterior chamber lens in the anterior chamber angle.

9-76 Haptics of an anterior chamber lens in the chamber angle. Note that the haptic to the left is embedded in the anterior surface of the iris.
Miscellaneous Conditions

Iris-retraction syndrome

The rare iris-retraction syndrome occurs when a rhegmatogenous retinal detachment occurs in an eye with a secluded pupil (Campbell, 1984). Patients with secluded pupils develop iris bombe as aqueous humor trapped in the posterior chamber pushes the iris forward. When there is a rhegmatogenous retinal detachment, there is some flow of aqueous through the break. If patients with secluded pupils and rhegmatogenous retinal detachments are placed on aqueous suppressants, they may make so little aqueous humor that it is all able to flow through the retinal break, causing the iris to be pulled back—often dramatically (9-77 and 9-78) If aqueous suppressants are discontinued, the eye may develop iris bombe again (Campbell, 1984).

Corneal disease

Some corneal diseases can be examined gonoscopically. External tumors can be seen through the cornea (9-79) and one can evaluate for internal spread. The vasculature of interstitial keratitis can be visualized (9-80).

9-77 Patient with a rhegmatogenous retinal detachment and secluded pupil. When treated with acetazolamide the patient developed a marked back-bowing of the iris, typical of the iris-retraction syndrome. The markedly concave shape of the iris should be noted.

9-78 Iris-retraction syndrome. Eye of the same patient as in 9-77, seen here with diffuse illumination and higher magnification. Note that the iris is pulled very far posteriorly and iris vessels are exposed and stretched.

9-79 A patient with melanoma at the limbus visible by gonioscopy. The patient had had a small pigmented spot at the limbus since birth. Over the preceding nine months the spot had enlarged and grown on to her cornea. After gonioscopic examination the tumor was locally excised and found to be a malignant melanoma.
Gonioscopic view of eye of patient with interstitial keratitis showing blood vessels in the cornea that are visible only to the level of the trabecular meshwork.
Both laser and incisional surgery are performed with the aid of gonioscopic visualization of the angle. Incisional surgery includes goniotomy, goniosynechiolysis, internally created filtration procedures, and internal revisions of filtration fistulas. Such procedures are performed by only a small proportion of ophthalmologists and generally fall outside the scope of this atlas. Goniotomy is briefly discussed in Chapter 7. Gonioscopic lenses are used more often for laser surgery than for incisional surgery. The most common gonioscopic laser procedures are trabeculoplasty and iridoplasty. These procedures will be discussed in some detail. Transpupillary cyclophotocoagulation of the ciliary body is also performed gonioscopically, but it has limited effectiveness and is rarely used. Various forms of ab interno laser fistulas and laser lysis of synechiae have been described as well as new devices for ab interno incisional surgery are being evaluated for their utility in treating various forms of glaucoma. These procedures have not reached general use and are not discussed.

**Argon and Selective Laser Trabeculoplasty**

Argon and selective laser trabeculoplasty are the most frequently performed procedures for glaucoma.

**Argon laser trabeculoplasty**

Argon laser trabeculoplasty (ALT) successfully lowers intraocular pressure in about 80% of patients with primary open-angle glaucoma (Thomas et al, 1982). The affect on intraocular pressure is proportional to that before treatment (Thomas et al, 1982; Wise and Witter, 1979). ALT is efficacious in treating primary open-angle glaucoma and some secondary open-angle glaucomas, such as those associated with pseudoexfoliation and the pigment dispersion syndrome. It is less successful in patients with infantile glaucoma, angle recession, inflammatory glaucoma, and aphakia and in young patients (Thomas et al, 1982; Wise and Witter, 1979).

A Goldmann three-mirror lens is usually used for ALT. The lens should have an antireflective coating to allow maximum delivery of the laser energy to the angle. Some ophthalmologists prefer to use the Ritch lens, which has magnifying “buttons” to focus the laser energy on to a smaller area. The Ritch lens (see 3-19) also has mirrors that are designed specifically for the superior and inferior angles (Ritch, 1985).

An understanding of the anatomy of the angle is a critical requirement for performing ALT. The burns are applied at the junction of the pigmented and nonpigmented trabecular meshwork (10-1). Delivery of laser energy too far posteriorly results in increased inflammation and an increased number of peripheral anterior synechiae (Rouhiainen et al, 1988) (see 8-52 and 8-53). Laser energy delivered too far anteriorly may result in overgrowth of the trabecular meshwork by corneal endothelium (Rodrigues et al, 1982). The techniques described in Chapter 4 can be used to help define the anatomy. If the angle is confusing, one should look inferiorly at the deepest and most pigmented portion of the angle to become oriented to the patient’s
anatomy. The corneal wedge can be invaluable in determining the location of Schwalbe’s line. In patients on cholinergics with steep approaches to the angle, dilation can be used to improve the visibility of the angle. In patients with a poor view of the angle secondary to pupillary block, one may need to perform a peripheral iridotomy with a laser. In eyes with plateau iris configuration and in other cases where the angle is crowded, it may be helpful to perform iridoplasty before carrying out trabeculoplasty.

It can be difficult to maintain one’s bearings while performing ALT because of the mirrored view of the angle. If a long series of laser spots is delivered and the lens is then rotated for a second series of spots, it is easy to become lost unless there are visible angle landmarks such as iris processes, nevi, or distinct laser burns. One can hold the Goldmann lens with three fingers (see 4-8) and rotate the lens slightly after every few applications, keeping the area undergoing treatment near the center of the mirror.

A 50-µm spot of argon—green light is normally used. The duration of delivery is 0.1 s. The power required varies from 200 to 1200 mW and is adjusted until an adequate uptake of energy is noted. In an angle with average pigmentation one should generally start with approximately 700 mW. In a darkly pigmented angle, as found in cases of pseudoexfoliation and pigmentary glaucoma, one should start at a lower energy, approximately 300 mW. In extremely lightly pigmented angles, no visible uptake of laser energy may be apparent despite a power level of 1200 mW. An adequate response to treatment is signified by blanching or the formation of small bubbles in the trabecular meshwork (10-1). If a crater, a large bubble, or a shower of bubbles forms, the intensity is too high. The use of power levels greater than 1000 to 1200 mW is not recommended. A therapeutic effect may result from treatment at this power level, even if no visible angle changes occur.

It is important to have the burn strike the trabecular meshwork perpendicularly. When properly aligned, a crisp round spot will be formed by the aiming beam. This is easiest to judge if the aiming beam is kept fairly dim. If the spot is distorted or oblong, the Goldmann lens is probably being held at an unusual angle. It is often helpful to look around the slit-lamp oculars and adjust the lens so that the front surface is parallel to the plane of the patient’s face. This should help to give a distinct, round spot. In the case of patients with steep approaches to the trabecular meshwork, who are looking into the mirror in order to allow the physician to treat the meshwork, there will be some distortion of the beam because of the angle of approach. A flatter approach, parallel to the iris, is preferred. Some authors suggest that the patient should be asked to look slightly away from the mirror so that a flat approach into the meshwork can be obtained (Palmberg, 1989). With most patients, however, satisfactory results are obtained if they look straight ahead through the entire procedure. ALT can be performed for any portion of the angle but is
typically performed over 180° or 360°. Typically, 40 to 50 laser applications are applied over each 180°.

The most common complication from ALT is postoperative elevation of the intraocular pressure. Apraclonidine has been shown to decrease the number and intensity of pressure spikes markedly after laser trabeculoplasty and is generally administered at the time of the procedure (Robin et al, 1987). Brimonidine is now used routinely in the same way. There should be postoperative monitoring for intraocular pressure spikes at 1 hour after the procedure.

Re-treatment of a previously treated angle has met with varying success. Although some authors have found re-treatment to be safe and efficacious in selected patients (Jorizzo et al, 1988), others have reported an unacceptable number of pressure spikes and a low success rate (Brown et al, 1985).

**Selective laser trabeculoplasty**

Selective laser trabeculoplasty (SLT) represents a relatively new addition to the treatment options for open-angle glaucoma. Many similarities exist between argon and selective laser trabeculoplasty, including technique, efficacy, and role in the glaucoma treatment algorithm. Nevertheless, numerous differences also exist.

SLT uses a Q-switched, double-frequency, neodymium:yttrium-aluminum-garnet (Nd:YAG) laser (532 nm). This is intended to target pigmented trabecular meshwork while concurrently avoiding thermal injury to the trabecular beams (Latina et al, 1998). SLT does not require that the spot size (400 µm) or duration (3 ns) of the application be adjusted. Unlike ALT, the laser energy does not need to be precisely applied over the trabecular meshwork alone, as long as the trabecular meshwork is covered by the laser application. In angles with confusing anatomy or limited pigmentation, this can be a useful advantage over ALT. These advantages of SLT over ALT are countered by the current requirement that a separate laser unit must be employed to treat with SLT, and many practitioners find this to be cost- or space-prohibitive.

The energy used for SLT is typically between 0.5 to 1.5 mJ per application. It is usually titrated up while watching for a few small bubbles to arise from the trabecular meshwork after each shot (see 10-1). If a large shower of bubbles occurs, or if pigment is dispersed with the laser application, it should be titrated down. The energy required to see the small bubbles appears to be related to angle pigmentation. SLT can be effective even if no bubbles are seen during the procedure. As with ALT, SLT is performed using a mirrored lens. The Goldmann three-mirror lens works well, as does the Latina SLT lens, which has one mirror. The lens should be rotated frequently enough to keep the view clear and avoid tangential application of the laser to the angle structures. Forty-five applications per 180° is a reasonable number, and both 180° and 360° treatments are routinely performed.

Both prospective and retrospective trials suggest that SLT compares favorably to ALT, although there is not yet data to identify long-term risks or benefits of the procedure (Damji et al, 2006, and Juzych et al, 2004). As with any relatively new procedure, it is important to discuss the lack of long-term follow-up with patients during the consent process. Patients should be treated prophylactically with brimonidine before and after the procedure to avoid a pressure spike. Monitoring of the pressure 1 hour after the procedure is appropriate to identify the small number of patients that do have a pressure elevation after SLT despite pretreatment with brimonidine. Recent evidence suggests that highly pigmented angles may be particularly susceptible to these pressure spikes (Harasymowycz et al, 2005). Other complications are exceedingly rare, including the formation of peripheral anterior synechiae.

Re-treatment with SLT after prior ALT is controversial, although potentially effective (Latina et al, 1998, and Damji et al, 2006). We generally do not recommend repeating the procedure after a history of failed ALT procedures, although the limited side effects make it a safe alternative in patients for whom the remaining options involved incisional surgery. There is
not enough evidence to date to discuss the efficacy of re-treatment with SLT after previously successful SLT, although many practitioners currently do this.

**Laser Iridoplasty**

Laser iridoplasty is used to pull the iris away from the angle. This is done in eyes with plateau iris configuration, when laser trabeculoplasty is difficult due to a crowded angle, and, rarely, in eyes with acute angle closure in which laser iridotomy cannot be performed. Laser iridoplasty can be performed either through a Goldmann three-mirror lens or directly through the cornea without the use of a lens, aiming at the most peripheral iris (10-2). In either case, iridoplasty is done with large, slowly applied spots of low power. This power is chosen to shrink, not perforate, the iris. Spots of 200 to 500 µm with durations of 0.2 to 0.5 s are used. The power is adjusted until visible shrinkage is noted; this usually requires power settings of 150 to 300 mW.

10-2 Scars from argon-laser iridoplasty. The energy was administered through the cornea without a gonioscopic lens in this patient with plateau iris syndrome.
While gonioscopy remains the gold standard by which the angle is evaluated, numerous anterior segment imaging techniques exist to assist in determining anterior segment structure. The two most commonly employed techniques are ultrasound biomicroscopy (UBM) and slit-lamp-based optical coherence tomography (OCT). Additional techniques, such as Scheimpflug photography, can give estimates regarding angle depth; since the angle is not directly evaluated, this is not discussed further here. Both UBM and OCT provide inherent advantages over gonioscopy in that both can provide information about the angle without direct visualization. Each of these technologies can provide information about structures beyond those normally seen on gonioscopic exam, including the ciliary body, posterior iris, and lens. Both techniques can potentially be helpful in augmenting or replacing gonioscopy in situations in which a view of the angle is precluded by corneal edema or other media opacity. At this time, these technologies are not a replacement for gonioscopy. The equipment is costly compared to gonioscopy and compressive evaluation cannot be used. They can, however, provide valuable information regarding the dynamic appearance of the angle in various states of illumination. When gonioscopy and either UBM or OCT are used together, a great deal of structural information about the angle can be obtained.

Ultrasound Biomicroscopy

UBM was first introduced in 1990 by Pavlin, Sherar, and Foster (Pavlin et al, 1990). A 50 MHz transducer is used in a B-scan mode, with tissue penetration of approximately 5 mm. An immersion technique is used to improve image clarity (Pavlin et al, 1991, and Tello et al, 1994). With the patient in the supine position, a 20 mm cup is placed on the eye to hold a coupling medium (methylcellulose or normal saline). The probe is placed within the coupling medium and the images are captured in real time (Liebmann, 2001). A resolution of approximately 25 µm is typically achieved. Although image acquisition is straightforward, reproducible measurements require an experienced examiner and the supine position can alter the physiologic anatomical configuration of the angle.

Optical Coherence Tomography

Anterior segment OCT was first described in 2000 (Hoerauf at al, 2000). That technique utilized a slit-lamp adaptation of the original OCT technology, using light at a wavelength of 830 nm, rather than sound waves, to obtain an image based on the reflection of this light back to the probe (Fujimoto et al, 1995). The resolution of the image depends on numerous factors including patient cooperation, tissue opacity, and the wavelength of light used. Since the original design, higher-resolution OCT has become available using light at 1300 nm wavelength (Radhakrishnan, 2005). Axial resolution in this system is typically 18 µm. Anterior segment OCT has the clear advantage over UBM in that it is a noncontact examination and can be performed with the patient sitting upright. Disadvantages include a slightly less dynamic examination
and the inability to visualize the ciliary body and the other structures behind the iris.

**Applications**

At its inception, anterior segment imaging was most frequently used to determine angle anatomy, although its uses have greatly expanded over the years (11-1 to 11-8). Specifically, angle occludability and closure can be carefully measured (Pavlin, 1995, and Tello et al, 2002). Iris configuration change after peripheral iridotomy, both in narrow angles and in pigment dispersion syndrome (Pavlin et al, 1992, and Barkana et al, 2007), can also be measured. Additionally, the response of the angle to pupil constriction to light and dark has been studied (See, 2007, Barkana et al, 2007).

It is worth noting that gonioscopy can also be used in these situations. One of the most useful aspects of anterior segment imaging is the ability to determine anterior segment configuration not always well appreciated on gonioscopic examination. For example, in plateau iris configuration, anterior segment imaging is very effective in recognizing both the anteriorly rotated ciliary body and the narrow peripheral angle (Pavlin et al, 1992). Similarly, any mass, cyst, or swelling in the ciliary body or posterior iris can be well appreciated. Anterior segment imaging is useful diagnostically in aqueous misdirection, demonstrating the anterior rotation of the ciliary body, and tight apposition of the iris and lens to the cornea (Ishikawa, 2004). Structures such as IOL haptics, filtering blebs, and intraocular foreign bodies have all been evaluated by UBM or anterior segment OCT.

Anterior segment OCT also holds particular promise in evaluating the cornea after lamellar surgery. However, these techniques continue to evolve, and at no point should they be used as a substitute for gonioscopic examination of the angle.

11-1 Normal anterior chamber imaged by UBM.

11-2 Normal anterior chamber imaged by anterior segment OCT.

11-3 Narrow angle seen on UBM. Note that the exact angle of the iris insertion can be easily visualized.
11-4 Very narrow angle seen on UBM. The iris is being vaulted forward by the lens, suggesting that peripheral iridotomy may be of limited benefit.

11-5 Iris back-bowing seen on anterior segment OCT in a patient with no prior evidence of pigment dispersion syndrome.

11-6 Evaluation of the angle on anterior segment OCT in light (upper figure) and dark (lower figure). Note the remarkable difference in angle configuration caused by pupil constriction.

11-7 An example of plateau iris seen on anterior segment OCT. The peripheral iris appears to drop off just before inserting in its normal location.

11-8 An example of a posterior iris cyst seen on UBM. The cyst causes focal narrowing of the angle.
References


References


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