Chapter - 1
THE LENS - APPLIED ANATOMY AND EMBRYOLOGY

The Lens

The lens of the eye is a transparent, biconvex, elliptical, semi solid, avascular body of crystalline appearance located between the iris and the vitreous. Laterally the equatorial zone of the lens projects into the posterior chamber and is attached by the zonules to the ciliary epithelium.

The equatorial diameter of the adult lens is 9-10mm. By direct measurement its axial saggital width is about 3.5 - 4.0mm at birth, about 4mm at 40 years and increases slowly to 4.75 to 5.0 mm in extreme old age. It varies markedly with accommodation. In contrast its equatorial diameter is 6.5mm at birth, 9-10mm in the second decade and changes little thereafter.

The lens has an anterior and posterior surface. The anterior surface, less convex than the posterior, is the segment of a sphere whose radius averages 10mm. The centre of the anterior surface is known as the anterior pole, and is about 3mm from the back of the cornea. The posterior surface is more curved than the anterior and presents a radius of about 6mm (4.5-7.5mm). It lies in a fossa lined by the hyaloid membrane on the front of the vitreous. The equator of the lens forms a circle lying 0.5 mm within the ciliary processes.

The refractive index of the lens is 1.39 which is slightly more than that of the aqueous and vitreous humor (1.33) and hence, despite its smaller radii of curvature, it exerts much less dioptic effect than the cornea. The dioptic contribution of the lens is about 15, out of a total of about 55 diopters for the normal eye. At birth the accommodative power is 15-16 diopters, diminishing to half of this at about 25 years of age and to 2 diopters or less at age 50 years.

When the pupil is dilated, in the slit beam a stratification of the lens into concentric layers may be made out. From the front backwards these are capsule, subcapsular clear zone (cortical zone) and a bright narrow scattering zone of discontinuity, the subcapsular zone of cortex. These make up the superficial cortex. There are two deep cortical or perinuclear zones. The nucleus, which follows, represents the prenatal part of the lens. The nucleus can be divided into various parts i.e. embryonal, fetal and infantile.
Structure

The lens consists of:
1. The lens capsule
2. The lens epithelium and
3. The lens cells or fibers

The characteristics of the lens capsule

The capsule completely envelops the lens and the cells of origin are completely contained in it. The capsule is the basement membrane of the lens epithelium and is the thickest basement membrane of the body. It is much thicker in front than behind and the anterior and posterior portions are thicker towards the periphery (equator) just within the attachment of the suspensory ligament than at the poles. The thickness at the posterior pole is 2.8- 4 µm and at anterior pole is 15.5 µm. Capsule thickness increases anteriorly with age but there is little change at the posterior pole. Under the light microscope the capsule appears transparent, homogenous and under polarized light, birefringent with an indication of a lamellar structure with fibers arranged parallel to its surface. Under electron microscope, the capsule appears to have a relatively amorphous appearance. There are up to 40 lamellae, each of which is 40mm thick.

The lens epithelium

The lens epithelium consists of a single sheet of cuboidal cells spread over the front of the lens, deep to the capsule and extending outwards to the equator. There are about 500,000 cells in the mature lens. There is no corresponding posterior layer because the posterior epithelium of the embryogenic lens is involved in the formation of the primary lens fibers which occupy the centre of the lens nucleus.

There are 3 zones in the lens epithelium. The central zone represents a stable population of cells. The intermediate zone is peripheral to the central zone and its cells are smaller. The germinative zone is the most peripheral and is located just pre-equatorially.
Fiber elongation

Following terminal cell division, one or both daughter cells pass into adjacent transitional zone in which the cells are organized into meridional rows. They differentiate into secondary lens fibres, rotating through $180^0$ and elongating anteriorly and posteriorly.

The lens fibres

The lens fibres are laid down in concentric layers, the outermost of which lie in the cortex of the lens and the innermost in the core of the nucleus. The lens fibres are strap like or spindle shaped cells which arch over the lens in concentric layers from the front to the back. The average width is 10-12 $\mu$m and the average thickness is 1.5-2 $\mu$m at the adult equator. The tips of the fibers meet those of other fibres to form sutures.

Lens sutures

The suture arrangements of the lens become increasingly complex with the growth of the lens. In the fetal nucleus there is an anterior erect Y and a posterior inverted Y suture. After birth more branch points are added to the succeeding suture lines, so that in the adult nucleus the sutures have a stellate structure.

Zonular apparatus

The earliest fibres of the zonular apparatus are a continuation of the internal limiting membrane that thickens over the non pigmented epithelium of the developing ciliary processes. They begin to develop at about the tenth week of gestation (45mm stage). Later, zonular fibrils are synthesized by the ciliary epithelial cells, and the zonules increase in number, strength and coarseness. By the fifth month the zonules have reached the lens and merge with both the anterior and posterior capsule.

Zonular apparatus & anterior capsule

A central 6.0 - 6.5mm area is free of zonular insertions. Hence a bigger sized rhexis will tend to run into zonules and escape peripherally.
Changes in lens shape

The lens undergoes several changes in shape during its embryogenesis. Initially, it is elongated in the anteroposterior direction. However, at the 18-24 mm stage, it is approximately spherical and, with the appearance of secondary lens fibres at the 26mm stage, the lens becomes wider in its equatorial diameter. The lens then increases rapidly in mass and volume as new fibers are laid down and expands in both the sagittal and equatorial planes. At birth the lens is almost spheroidal, being slightly wider in the equatorial plane. The factors that govern these changes are unknown but they may be related in part to other factors such as the steady, but small, dehydration of the entire lens that begins in utero and continues postnatally.

Applied anatomy

Surgically, the lens is divided into four zones which have different characteristics and hence merit different attention. These are the capsular bag, the superficial cortex, the epinucleus, and the hard nucleus. The capsule has been described in detail above. The cortex is a soft thin layer present immediately beneath the capsule. It envelopes the epinucleus. It is aspirated or irrigated out of the capsular bag with ease. The epinucleus is a layer of semi-soft lens matter around the nucleus. This layer is difficult to aspirate and requires a large bore cannula for aspiration. It can be managed better by hydro- or visco-expression. The nucleus is a hard kernel forming the innermost layer of the lens. The cataractous lens can be minified down to the nucleus before extraction. This results in a smaller wound requirement for its exit as the nucleus is usually smaller than the lenticular opacity. The nucleus can be fragmented before its removal from the eye. Pre-operative nucleus grading gives us valuable input towards the surgical plan.
Anatomic considerations in IOL implantation

The average central anterior chamber depth in the normal adult emmetropic eye is approximately 3 mm and becomes most narrow at the midperipheral iris. The anterior chamber deepens to approximately 4.5 mm after cataract extraction.

The diameter of the anterior chamber angle is very important clinically for proper sizing of an angle fixated anterior chamber intraocular lens (ACIOL). A commonly used clinical rule is that the corneal diameter (white to white distance) plus 1 mm is approximately equal to the diameter of the anterior chamber angle. Exact measurement of the anterior chamber angle diameter is less crucial for the flexible open-loop lenses in common use today. The loops of angle-fixated lenses usually rest in the angle recess posterior to the scleral spur. Direct contact with delicate angle structures may cause irritation, with erosion of tissue and chronic inflammation. Glaucoma may result from direct contact or chronic inflammation. When the loops of footplates of the angle-fixated lens are misplaced anteriorly, the resulting direct contact with the peripheral corneal endothelium causes the death of these cells. Human corneal endothelial cells cannot divide; they can only enlarge and migrate to fill in the spaces left by the dead cells. As the central corneal endothelial cells spread and migrate to the periphery, the corneal endothelial cell count drops to a critically low level.

Kelman-style flexible open loop ACIOLs were designed to minimize some of the complications associated with older ACIOLs. The complication rates with these lenses are clearly lower with respect to corneal pathology, inflammation, cystoid macular edema, decentration, glaucoma, and hemorrhage.

The iris acts as a dynamic diaphragm that controls the amount of light entering the eye by regulating the size of its aperture, the pupil. The diameter of the iris is approximately 12 mm and its circumference is about 37.5 mm. The iris thickness is greatest at the collarette (2 mm from the edge of the pupil), where it is 0.5 mm in anteroposterior dimensions. The iris is thinnest at its root where it is attached to the anterior surface of the ciliary body. Near the edge of the pupil, there is a ring of smooth muscle fibers about 1 mm wide, the sphincter pupillae. Peripheral to the sphincter pupillae is the dilator pupillae.
Iris fixated IOLs were in vogue in the past. However, long term problems associated with these lenses have decreased their popularity. The highly mobile iris produced chafing and resultant inflammation. The only iris fixated lens in use today is the Singh - Worst lens which is fixated near the peripheral iris, which is relatively immobile. Recently there has been renewed interest in this lens design for use in phakic IOL implantation for the correction of the refractive errors.

The posterior chamber is bounded anteriorly by the iris and posteriorly by the anterior hyaloid face of the vitreous. The circumference of the posterior chamber consists of the ciliary sulcus and the ciliary body. The lens equator is typically adjacent to the midpoint of the ciliary body. There is a space of 0.2-0.3 mm between the ciliary body and lens equator. After cataract removal, the capsular bag volume collapses to essentially zero as the anterior capsule comes into apposition with the posterior capsule. The equator of the evacuated bag extended laterally, causing the bag diameter to enlarge from the normal 9.5 mm to approximately 10.5mm. At this large diameter, the lens equator directly contacts the ciliary body and the normal psychological space is lost. The equator of the evacuated capsular bag also moves to a location posterior to the ciliary processes.

When a 12mm PMMA PCIOL is implanted into the capsular bag, the bag becomes oval, with dimensions of 11.2 mm x 9.2 mm. The optics of almost all intracapsular IOLs will be positioned at a plane posterior to the ciliary body. One reason for this is that the angulation of the haptics in most IOLs produces direct contact of the optic with the posterior capsule and stretching of the posterior capsule. When the capsular bag is intact, in-the-bag fixation of both haptics is clearly the most optimal method of IOL fixation. Capsular bag fixation avoids direct contact between the haptics and uveal tissue and is associated with a lower likelihood of decentration and central posterior capsule opacification.

The ciliary sulcus, also known as posterior chamber angle, is formed by the junction of the posterior iris with the ciliary body. The average diameter of the ciliary sulcus is 11.0mm. The ciliary sulcus is a common location for PCIOL implantation when the posterior capsule of does not provide sufficient support for the placement of an intracapsular lens and the anterior capsule is intact. When a continuous curvilinear capsulorrhexis has been performed and remains intact, the ciliary sulcus
can be a very stable site of fixation for a posterior chamber lens. As the position of the lens will be slightly more anterior, an adjustment of approximately 0.5 diopter less power will be needed for lens implants to achieve the same intended refraction.

**Sulcus fixation** of an IOL has the inherent disadvantage of direct contact between the implant and the uveal tissue, which may result in several complications. Pigment dispersion and glaucoma may occur if there is contact between the posterior iris and the implant. Erosion of the haptics into the sulcus will result in chronic inflammation. **Sutured scleral fixation** may be required where adequate anterior capsular support is unavailable. The haptics of sutured scleral-fixated PCIOLs ideally are meant to reside in the ciliary sulcus. A needle passed 1 mm posterior to surgical limbus closely corresponds to the ciliary sulcus. The long posterior ciliary arteries and nerves enter the ciliary body at the 3 and 9 o'clock meridians. The anterior ciliary arteries enter the ciliary body at the 3,6,9 and 12 o'clock. Hence, it is most prudent to avoid suture fixation in the vertical and horizontal axes. A scleral fixated sutured PCIOL will most likely be safely and correctly placed in the ciliary sulcus when the needles are passed approximately 0.87 mm - 1 mm posterior to the surgical limbus in the oblique meridians. A reduction of 0.5 diopter in the calculated power of IOL is recommended, as the IOL will rest more anterior as compared to that with intracapsular fixation.