CORNEA
Anatomy, Physiology and Pathology
by
Joseph Bacotti, MD, FACS

After completion of this course the reader should be able to:
1. Describe the anatomy of the cornea and surrounding tissues
2. Describe each of the layers of the cornea
3. Describe the functions of the corneal tissues in relation to vision and a healthy eye
4. Describe the shape of the cornea and how this relates to vision
5. Discuss how the corneal shape relates to contact lens fitting and vision
6. Describe various disease states of the cornea

ANATOMY of the CORNEA

The cornea is the anterior most part of the eyeball. It comprises approximately 1/6 of the total eyeball. The cornea is the transparent, optical portion of the eye. The word cornea is derived from Latin meaning horny. The cornea is an avascular, transparent tissue composed of an anterior convex surface and a posterior concave surface that accounts for the optical properties it possesses.

The main purpose of the cornea is optical to allow refraction of light entering the eye and the cornea accounts for approximately 70% of the refractive power of the eye as a whole (43.50D). Clearly there are other functions of the cornea; protection of the eye, maintaining structural integrity of the eye globe, to keep the inner contents in place and protected.

The dimensions of the cornea are calculated from the limbus area where the cornea joins the sclera and conjunctiva. There are blood vessels in the limbus that extends 360° around the cornea, and the blood vessels terminate at the limbus in loops returning to the sclera in healthy eyes. The overall shape of the cornea anteriorly is elliptical. Anteriorly, the cornea measures vertically about 10.8mm (10-11) and is slightly larger in males about 11.5 mm. Horizontally the cornea measures approximately 11.5 mm (11-12). The posterior of the cornea is usually more spherical and measure 11.7 mm. In infants the corneal dimensions are about 1 mm less horizontally and vertically.

The thickness of the cornea varies from center to limbus, with the thinnest area centrally of approximately 550 microns thick and increasing to 660 microns of thickness at the limbus.

The cornea has several centers; the optical center is where the cornea curvature is greatest and usually corresponds to the apex of the cornea or the area of greatest curvature. The visual center is the actual area of the cornea that the patient uses for vision function with the light passing thru to the fovea. The geometric center is the exact middle where the point is equidistant from all edges of the cornea. The centers may not be and are usually not all located at the same point on the corneal surface. The steepest area or apex (and usually the thinnest area) is located slightly down and nasal from the geometric or visual center. The thickness of the cornea at various areas is important when consideration is given for laser vision correction, to assure that there is sufficient thickness and calculating glaucoma Goldman applanation tonometry correction factor for intraocular pressure.

The cornea topography is curved on the anterior and the posterior surfaces, ellipsoid or aspheric in shape on the anterior surface and more spherical on the posterior. The anterior surface gradually flattens as we move from the geometric center of the cornea to the edges at the limbus. The differences in the anterior and the posterior curvatures forms a lens based on Snell’s law, the law of refraction, that the difference of the 2 refractive indices of air and the corneal surface refractive index of 1.3375 used for most common calculations of eye/cornea refractive power. The anterior surface, elliptical and flattening from the optical center to the limbal periphery can be considered as 45.00 diopters or 7.50 mm. The posterior radius of curvature for the cornea varies in individuals and can range from 6.40mm to 6.72mm or about 52.00 diopters.

Changes in the flattening of the corneal surfaces along differing meridians from that of a sphere leads to a condition called astigmatism. With the rule astigmatism is when the vertical meridian of the cornea is steeper than the horizontal. A minus cylinder lens in front of the eye place at the horizontal meridian compensates for with the rule astigmatism; or a plus lens at the vertical meridian or axis. Conversely, an against the rule astigmatism would have the steeper meridian on the horizontal corneal plan and would be corrected by a...
minus cylinder lens at the 90 axis or a plus at the 180.

Overlying the cornea is the precorneal tear layer. The tear layer serves several purposes and is actually composed of 3 layers that each serves a specific function for the eye and cornea. Where the epithelial cells abut against each other there is a junction and irregularity created. These irregularities are not optically compatible with sharp vision. The tear layer fills in the spaces and evens out the surface of the cells and actually becomes the new front surface of the cornea. The outermost layer of the tear layer is the oily or lipid component and serves to prevent evaporation of the watery component of the tear layer. The lipids spread evenly across the tear film providing a smooth surface and good optics. The meibomian glands openings are found along the lid margins and the glands are arranged in the lids along more or less parallel rows.

The middle layer of the tear film is aqueous or watery in nature and contains salts and electrolytes and it is the major part of the tear layer as a whole. The tears help wash away debris and contain an antibacterial agent to help ward off infections called lysozymes enzymes. Tears provide nutrition and oxygen to the avascular cornea as well. Tears are secreted mainly by the lacrimal gland.

The layer closest to the epithelial corneal cells is the mucin layer, which is secreted by the conjunctival goblet cells, the mucin helps to stabilize the tear layer.

Epithelium  
Bowman’s membrane  
Stroma  
Descement’s membrane  
Endothelium

The anterior surface of the cornea is covered by five or six layers of epithelial cells that are continuous with those of the conjunctiva, except that there are no conjunctival goblet cells. The corneal cells become more numerous from the center of the cornea to the limbus, where they are approximately 12-13 cell layers thick. The epithelium has stratified, squamous and non-keratinized cells. Basal cells are the cells that reform-regenerate the epithelium when injured. Desmosomes form lateral adhesion between the cells and the Zona Occludens form tight juncture at the surface cell layers in addition to the Desmosomes. Healing of injuries occurs by mitosis and migration. Mitosis is by cell division that takes place near the limbus and moves centrally and migration the moving of adjacent cells over the defect in the cornea. Superficial injuries to the cornea, abrasions usually heal in 24 to 48 hours.

Bowman’s membrane is the basement membrane for the epithelial basal cells and lies between the epithelium and the stroma. If an injury or disease process penetrates the Bowman membrane then usually a scar will form. There are no cells in Bowman’s membrane. The epithelial cells can easily be scraped or separated from Bowman’s. This is done for disease states and laser vision correction known as PRK or PhotoRefractive Keratectomy.

The stroma is bordered on its anterior side by Bowman’s membrane, a band of randomly arranged collagen that, under the light microscope, has no resolvable structures.

The lamina propria or stroma constitutes 80% to 90% of the total corneal thickness (about 500 microns of the total 550 microns of the cornea) and consists of about 200 lamellae of collagen fibrils running parallel with the surface and superimposed upon one another at right angles. There is little or no interweaving of these ribbon like bands, accounting for the ease with which the cornea can be surgically split into thin layers. Flattened stromal cells (keratocytes) lie between the collagen lamellae. The keratocytes or fibroblasts are cells that remain more or less dormant until an injury occurs then they aid in repairing the tissue. The stroma blends into the sclera at the limbal area. The arrangement of the stromal collagen fibrils aids in the clarity of vision.

Descemet’s membrane is a regularly arranged in layers of fine collagen filaments. The most posterior collagen lamella of the stroma merges with the thick basement membrane (Descemet's membrane) of the endothelium.

The endothelial cells form a single layer of cells separating the stroma and Descemet’s membrane from the aqueous humor. The endothelial cells are more numerous at birth, numbering approximately 6000 per square millimeter. The endothelial cell count decreases rapidly to about 4000 per square millimeter at age 5 years and gradually decreases with age. Injury and disease can cause a reduction in endothelial cells, and the cells adapt by enlarging to cover the area of cells lost to disease or injury. At around 400 to 500 cells per square millimeter signs of corneal edema are seen resulting in microcystic or Bullous keratopathy.
Corneal edema leads to decreased vision and if cystic can be very painful and the cysts reach the epithelium and rupture into the tear layer. A genetic predisposition to endothelial cell loss is called Fuch’s Dystrophy.

The cornea has a rich supply of sensory nerve fibers that are derived from the ophthalmic branch of the trigeminal nerve that perforate into the anterior 1/3 of the stroma. The ciliary nerves branch and then turn upward to the corneal surface passing through Bowman’s membrane to the epithelium. Corneal nerves are found in all layers of the cornea. Most of the nerve endings are found in the anterior 1/3 of the stroma. The nerves lose the myelin covering or sheath divide and as they enter the cornea. The fact that there is no myelin covering the nerve endings adds to the clarity of the cornea. The rich and abundant supply of nerve fibers in the cornea leads to significant pain if there is an injury, infection, allergy or inflammation.

Some conditions to consider include the following.

Corneal epithelial edema can result from increased intraocular pressure as well as with over wearing of contact lenses. Fuch’s dystrophy and Bullous Keratopathy are diseases of the endothelium that result in corneal edema. Injuries that damage the epithelium, chemicals, ultraviolet (welder’s), burns (hot metal) all can result in corneal edema.

Bullous Keratopathy
Note lack of clarity and thickening of the cornea

There are other congenital and developmental syndromes that can precipitate corneal edema and lack of clarity; iridocorneal endothelium syndrome, Chandler’s syndrome (ICE syndrome).

Corneal dystrophies and disorders:

Microcornea
Corneal diameter is less than 10 mm and the globe is normal size. Cataract, high myopia and nystagmus are commonly associated findings.

Megalocornea
The corneal diameter is more that 13 mm. Myopia and pigment dispersion, Kruckenberg spindles and glaucoma may be seen.

Corneal Dermoids
Dermoids are choristomas of mesenchymal origin covered by epithelium. Most are located near the limbus.

Trachoma
Is a disease that affects only humans and is caused by the Chlamydiacae bacteria passed from one person to another. It can led to corneal scarring and decreased vision. Usually associated with underdeveloped areas of the world.

Rosacea

Roseacea keratitis is a finding associated with this skin disorder that causes the skin vessels to dilate giving the patient a ruddy complex. The disease creeps up onto the conjunctiva and the cornea leaving neovascularization of the cornea, scaring and decreased vision.

Roseacea causing neovascular changes on the cornea most frequently seen inferiorly

Syphilis
A venereal disease caused by the Treponema pallidum spirochete. The cornea is usually not affected by acquired disease but is affected in congenital disease. Ghost blood vessels are seen in the cornea called interstitial keratitis.

Cogan’s Syndrome
Consisting of non-syphilitic interstitial keratitis, patchy vascularization of the stroma hearing loss and vertigo.

Map-Dot-Fingerprint Dystrophy
Abnormal regeneration of the basal epithelial cells on the basement membrane or Bowman’s membrane led to disorientation of the cells with slit lamp findings that are reminiscent of the disorders name.

Stromal Dystrophies
Granular dystrophy leads to granular deposits in the stroma. There are several types of the genetic disorder. These stromal dystrophies are genetically inherited. The slit lamp reveals discrete white like deposits in the anterior and central areas of the stroma. They may start as small dots and then with time progress to
the granular appearance. The deposits interfere with vision and can result in significant decreased vision. The deposits may also cause a foreign body sensation when blinking. They can be removed by scraping or laser but generally the deposits will recur with time.

**Granular dystrophy of the stroma**

Dendrite formation with Herpes Simplex.
A similar response can be seen at times with Herpes Zoster.

**Healthy Cornea**
**Compromised Cornea**
**Pediatric**

<table>
<thead>
<tr>
<th>Healthy Cornea</th>
<th>Compromised Cornea</th>
<th>Pediatric</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Staphylococcus</em></td>
<td><em>Staphylococcus aureus</em></td>
<td><em>Pseudomonas</em></td>
</tr>
<tr>
<td><em>Streptococcus</em></td>
<td><em>Staphylococcus epidermidis</em></td>
<td><em>Staphylococcus</em></td>
</tr>
<tr>
<td><em>Pseudomonas</em></td>
<td>α-Hemolytic <em>Streptococcus</em></td>
<td><em>Fungi</em></td>
</tr>
<tr>
<td><em>Enterobacteriaceae</em></td>
<td>β-Hemolytic <em>Streptococcus</em></td>
<td><em>Pseudomonas</em></td>
</tr>
<tr>
<td><em>Moraxella</em></td>
<td><em>Proteus</em></td>
<td></td>
</tr>
</tbody>
</table>
Corneal ulcer caused by Staph. Aureus in a contact lens wearer.
Note the dense area and the surrounding inflammatory region and vessels growing into the cornea from the limbus.

Corneal ulcer caused by Strep. Pneumonia associated with a hypopyon.

Pseudomonas keratitis
One of the most aggressive bacterial infections of the cornea that can cause scarring and loss of vision in 24 hours.

Ulcer and hypopyon associated with pseudomonas infection in a contact lens wearer.

Contact lenses and the cornea:
Giant Papillary conjunctivitis is common and is similar to an allergic response causing swelling of the lids and itching; the contact lens becomes uncomfortable, wearing time decreases, and lens movement and decentration can occur. The cornea becomes involved showing a superficial punctate keratopathy or abrasion.

Corneal edema from overwear or sleeping with the contact for several nights and days makes the cornea more prone to diseases. The bacteria form a slime or gel on the contact lens that protects the bacteria from normal ocular control of the health of the eye. The slime can also make treatment of the underlying infection more difficult to respond to normal antimicrobials due to the inability of many antibacterials to penetrate the slime.
This is only a short introduction to the cornea and I hope it helps you understand the workings of this section of the eye.

These are TRUE or FALSE Questions

Questions cornea opticians

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>T</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The normal cornea thickness is about 550 microns.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>2</td>
<td>The thickest area of the cornea is at the optical center.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>3</td>
<td>The clarity of the cornea is due to many factors including the tear layer that covers the front surface. T or F</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>4</td>
<td>Fuch's is a disease, dystrophy, of the epithelium of the cornea.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>5</td>
<td>If blood vessels enter the cornea centrally this can adversely affect the visual acuity.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>6</td>
<td>The nerves that enter the cornea are from the rectus muscles that surround the eye.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>7</td>
<td>Wearing contact lenses for extended time without removing them can lead to corneal problems.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>8</td>
<td>Corneal ulcers are more common with extended wear contact lenses and contacts not properly cared for.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>9</td>
<td>Corneal scars always lead to decreased vision.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>10</td>
<td>Keratocytes are found in the epithelium and help repair injury.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>11</td>
<td>There is no way that the vision of patients with keratoconus can achieve improved vision.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>12</td>
<td>Staphylococcus aureus is a bacterium that can be found with improper contact lens care and may cause corneal ulcers.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>13</td>
<td>The apex of the cornea is always the visual center.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>14</td>
<td>Contact lens fitting is based on the fact that the cornea is perfectly spherical.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>15</td>
<td>Collagen cross-linking a new modality to treat keratoconus is based on UV light and a vitamin drop called boflavin</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>