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NCLE Study Guide
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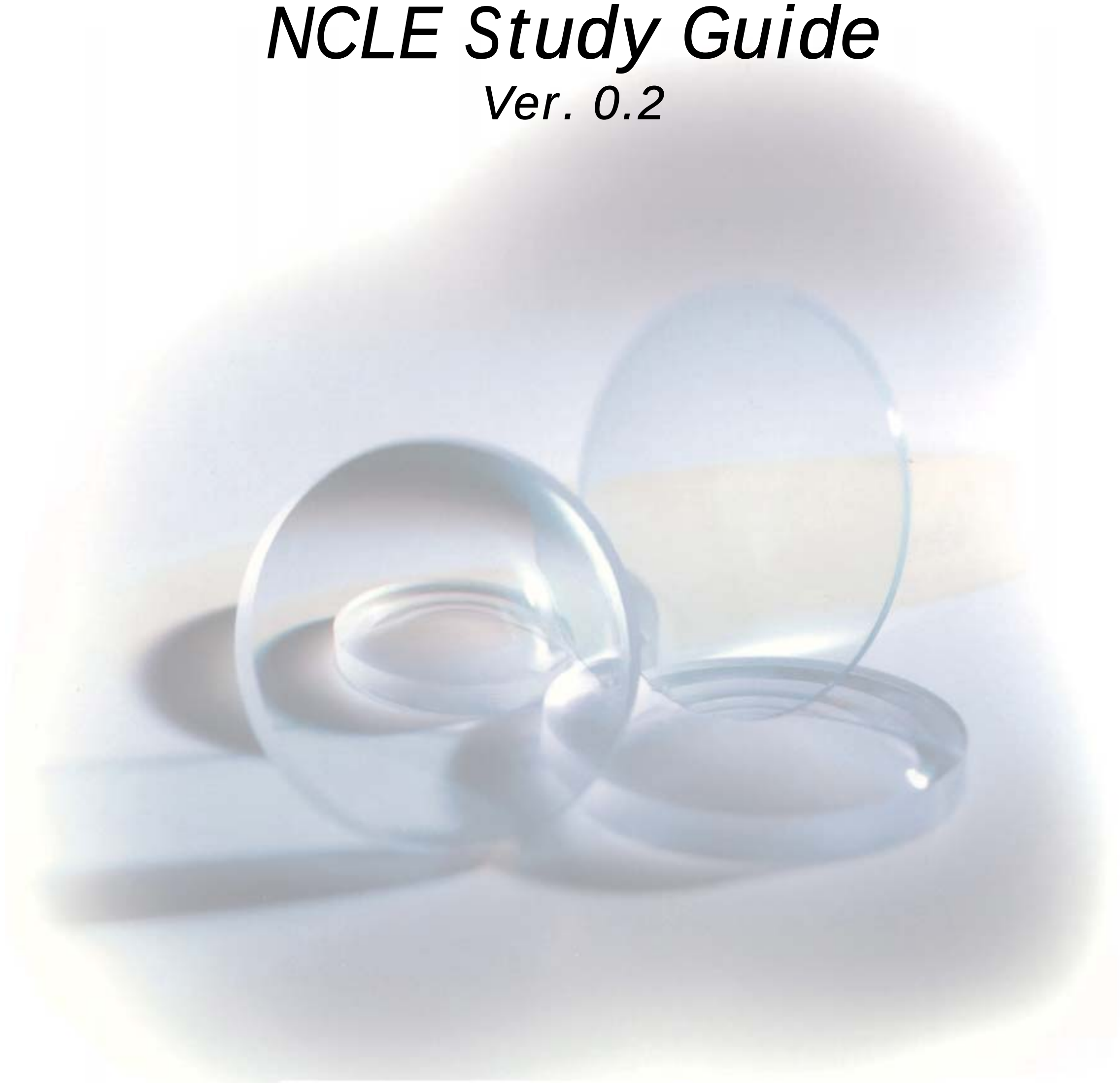

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Chapter 1: ANATOMY AND PHYSIOLOGY

Outer Structures of the Eye

When it comes to the anatomy of the eye, it is important to remember that there is more to the visual system than the eyeball itself. There are special structures that surround the eyeball and aid in its function. These structures are called the Adnexa Oculi.

Lashes

An Important appendage to the eye, and one that is not thought of very often by the contact lens fitter, is the lashes. This structure is the first line of defense in eyeball protection. The lashes are special, modified cilia that are located on the lid margin and are especially sensitive to touch. It is this sensitivity that enables them to act as a warning when something approaches the eye and causes the lid to close. Also, lashes are important in lubrication due to the surrounding sebaceous glands.

The contact lens fitter must pay special attention to the lashes in order to detect lash abnormalities. Common lash problems include:

- Blepharitis- an inflammation of the lid margins that presents itself in dandruff like flakes, itching, swelling, and redness. Blephartis is a chronic condition and is a contraindication for contacts.
- Trichiasis- inward turning of the eyelash. May be helped with a bandage contact

Eyelids

The eyelids are the most visible of the outer structures of the eye. Called palpebrae, these seemingly simple structures are actually very complex and perform a wide range of functions. The palpebrae help control the amount of light that enters the eye, distributes tears across the ocular surface, and they provide protection.

The lids are a multilayered organ. The outermost layer is the skin. Next is the muscle that is responsible for lid closure, the orbicularis oculi. The third layer is

the densest layer of the eyelids. It consists of orbital septum, muscles and tarsal plate. The orbital septum is tissue that separates the fat that is in the boney orbit from the lid itself. The muscles include the levator palpebrae superioris (upper lid raiser in English), the contractor muscle in the lower lid, and the muscle of Muller that helps the lid maintain shape. The tarsal plate runs the length of the lid, provides lid structure, and houses the meibominan gland. The fourth and last layer is the palpebrae conjunctiva. This is a clear mucous membrane that covers the entire inner layers of the lid and the upper portion of the sclera. A complex structure, it will be covered in greater depth in a later section.
The opening between the lids is the palpebrae fissure and its average size is 10mm wide and 30mm long. Where the two lids meet is the canthi. The nasal canthus is called the medial canthus or inner canthus. It surrounds a hill of skin called the caruncle that contains sweat and sebaceous glands. The temporal canthus is called the lateral or outer canthus. Along the lid margin, close to the inner canthus, are openings called puncta. These puncta are openings that act as a drain for tears leading from the eye.

It is very important for the contact lens fitter to examine the lids for any abnormalities prior to fitting. Many lid abnormalities are a contraindication for contacts due to the insufficient wetting, increased inflammation, as well as increased secretions that these abnormalities may cause. Common lid problems are:

- Ptosis- drooping of the upper lid
- Ectropion- outward turning of the lid
- Entropion- inward turning of the lid
- Lagophthalmos- incomplete closure
- Growths- benign or malignant formations on the surface of the lid

Conjunctiva

The conjunctiva is a thin, clear, highly innervated mucous membrane that runs from the inner eyelid to the limbus. It is divided into two sections: palbebral which covers the lids and bulbar which covers the globe. The transitional areas between these two sections are called the fornices. Contained within the conjunctiva are an abundant amount of blood vessels, leukocytes, goblet cells, nerves and mast cells.

The conjunctiva is highly susceptible to inflammation due to its exposure to the elements. Wind, dust, pollen, ultraviolet, and pollution can all cause conjunctival inflammation. Symptoms of irritation include abnormal secretions, burning, swelling, itching, and dilation of the conjunctival blood vessels (injection). When the inflammation is severe, it is called conjunctivitis or “pink eye”. Conjunctivitis can have an allergic, bacterial, chemical, or viral source. To determine the proper origin clinical examination and patient history are critical. Common conjunctival disorders include:

- Giant Papillary Conjunctivitis (GPC) - most closely associated with wearing soiled contact lenses, it is when large bumps called papillae are seen on the palpebrae conjunctiva of the upper lid. It is important to invert the upper lid to check for GPC
- Pinguecula – a raised yellowish discoloration of the nasal or temporal sides of the bulbar conjunctiva that is benign and does not invade the cornea
- Pterygium – wing-like thickening of the connective tissue and blood vessels of the bulbar conjunctiva that does invade the cornea. Usually develops from the inner canthus and spreads past the limbus to the cornea
- Subconjunctival hemorrhage- broken blood vessels just below the surface
- Trachoma- a leading cause of blindness throughout the world, it is a viral infection that causes scarring of the lids that eventually effects the cornea

Precorneal Tear Film

Tears are a complex system that provides many services to ensure the health of the eye. By being a thin film over the cornea and conjunctiva, it provides a smooth ocular surface. In fact, it is actually the first refractive element of the eye. In addition, it flushes away debris from the globe through blinking and it supplies nutrients and antibacterial agents to the eye to prevent eye infections.

A trilaminar structure, tears are composed of a lipid/oily layer, aqueous/water layer, and mucin/mucoid layer. The lipid layer is the outermost layer and its purpose is to prevent evaporation of the tear film and to keep tears from spilling over onto the cheek. Secreted by the meibomian glands and the glands of Zeis, it is the thinnest layer at 0.1 microns thick. The aqueous layer is the thickest layer at 7 microns thick. It is produced by the lacrimal glands and the glands of Wolfring and Krause. It provides hydration, oxygen and the antibacterial agents to the eye. The innermost layer is the mucin layer is produced by the goblet cells of the conjunctiva. It provides a hydrophilic surface for the aqueous layer to adhere to and contributes to tear stability. The mucin layer is approximately .5 microns thick. The average pH of tears is 7.4.

In order for the tear film to function properly, it must move across the surface of the globe properly. The first step in tear kinesis is tear secretion at the lid margins. The secreted tears collect at the lids in a tear pool or tear meniscus. When the lids close in a blink, the tears spread up from the tear pool over the surface of the globe where it stays until the next blink. When the eye closes again, the old tear film is pushed back down the globe and into drainage holes called the puncta. From the puncta it travels through the canaliculi into the lacrimal sac where it would then go to the nasolacrimal duct and empty out the nasal passage.

Disorders with the tear system are numerous and complex. The most common are:

- Keratitis sicca or dry eye syndrome- corneal inflammation due to tear deficiencies. Tear deficiency has many causes. To determine a tear deficiency it is important to determine tear break up time (BUT). BUT is usually 15 seconds, which is fine since the average blink rate is 5 seconds. One of the best methods to determine BUT is through the use of fluorescein
- Dacryocystitis- inflammation of the lacrimal sac
- Dacryoadenitis- inflammation of the lacrimal gland
- Epiphoria- faulty drainage causing the tears to spill over lid margin onto the cheek

Glands

Glands in the eyelids

- Meibomian glands- there is approximately 30 glands on the lid and they open onto the lid margin and secrete the lipid layer of the tear film
- Glands of Zeis- a sebaceous gland that opens onto the lash follicles. Located on the temporal part of the eyelid behind the meibomian glands, it secretes the lipid layer also
- Glands of Moll- a sweat gland that opens onto the lash follicles. It is located by the glands of Zeis
- Glands of Wolfring and Krause- an accessory gland that secretes the aqueous layer of the tear film. It is on the inside surface of the lid near the conjunctival fornix.

Goblet cells are glands located in the conjunctiva and they secrete the mucin layer of the tear film.

Muscles

Eyelid muscles

- Levator palpebrae superioris- elevates and retracts upper lid
- Orbicularis oculi muscle- closes the upper lid
- Muller's muscle- short, smooth muscle that contracts when awake to keep the lid open and relaxes when tired or asleep to let the eyelid droop

Extrinsic muscles- attached to the outer surface or the globe and control the turning of the eye. There are 6 muscles of the eye: 4 recti and 2 oblique.

Recti muscles originate at the annulus of Zinn and attach at the sclera

- Medial rectus- the principal adductor
- Lateral rectus- responsible for abduction
- Superior rectus- elevates the eye and can provide intorsion
- Inferior rectus- depresses eye and can provide extorsion

Oblique muscles

- Superior oblique- originates at the annulus of Zinn, moves through a sling made of cartilage, called the trochlea, which is suspended from the frontal bone. The trochlea acts like a pulley for the muscle and allows it to perform its intorsion motion of the eye
- Inferior oblique- the only muscle that does not originate at the back of the orbit, it originates near the nasolacrimal duct and its main purpose is to elevate the eye

Movement terms for one eye

- Adduction- movement of the eye toward the nose; medial movement
- Abduction-movement of the eye outward; lateral movement
- Elevation- movement of the eye upward
- Depression- movement of the eye downward
- Intorsion- rotation of the eye in the 12 o'clock position downward and inward
- Extorsion- rotation of the eye in a 12 o'clock position downward and outward

Movement terms for both eyes

- Dextroversion- both eyes to the right
- Levoversion- both eyes to the left
- Supraverison- both eyes upward
- Infraversion- both eye downward
- Convergence- both eyes toward the nose
- Divergence- both eyes out toward the temples

Muscle Disorders

Binocular vision is when the brain fuses the two images received by the eye into one. In order for this to happen, the eye must be held stable by the muscles. This alignment is called orthophoria. When orthophoria occurs, the brain can achieve stereopsis. Not only do the two eyes fuse the images into one, but they also have depth. When the eye is not stable, then vision problems can ensue.

- Diplopia- double vision
- Suppression- when only one image from the retinas reach the brain
- Heterophoria- tendency of the eye to deviate
    - Esphoria- inward deviation
    - Exophoria- outward deviation
    - Hyperphoria- upward deviation
    - Hypophoria- downward deviation
- Heterotropia- definite turning of the eye
    - Also called strabismus
    - Same prefixes are the same as in the phorias
- Amblyopia- loss of vision, usually caused by strabismus

Bony Orbit

The bony orbit is a quadrangular shaped space that's primary function is to protect the globe of the eye and its surrounding tissues. A pyramid with the base to the front, it is composed of seven bones that make up the roof, floor, medial wall (nasal), and lateral wall (temporal). The average dimensions are horizontal 4cm, vertical 3.5 cm, and depth of 4.5cm. Contained within the orbit are the globe, extrinsic muscles, orbital nerves, blood vessels, and connective tissues.

Globe

The globe is what is commonly called the eyeball. It is composed of the outer, middle, and inner tunic, as well as encapsulates the vitreous humor, crystalline lens and aqueous humor.

Outer Tunic

The outer tunic, or outer layer, consists of the sclera and the cornea. The primary purpose of the tunic is to protect the eye from infection and trauma, as well as help the eye maintain its shape.

Sclera

The sclera is the white part of the eye. It is densely interwoven collagen fibers that cover the back 5/6 of the globe. The fibers give the globe strength and prevent light from scattering within the globe. The episclera is the outer layer of the sclera that is loose collagen fibers that contain the blood vessels that can be seen when viewing the eye.

Cornea

The cornea is the clear portion of the globe that allows light into the eye. Composing the front 1/6 of the cornea, the radius of curvature when viewed from the front is 7.7 mm and when viewed from the back is 6.8 mm. Some important facts about the cornea are:

- Index of refraction = 1.376
- Most refractive lens in the eye
- Composes 70% of the total refraction of the eye
- Anterior refractive power is +48.8D, the posterior refractive power is -5.8D, the total refractive power is 43.00D
- Diameter is horizontal 11.5mm and vertical 11.2mm
- Completely avascular
- Transparent through all layers
- Has 5 layers, from front to back: epithelium, Bowman's Layer, stroma, Descmet's membrane, endothelium

The epithelium is the outer layer and is 10% of the cornea's thickness. It is 5-6 cells thick and is regenerated about every two weeks. The first line of defense against infection and injury, it regenerates quickly after injury by shifting cells over any break in the surface. It is this regeneration that helps the epithelium to maintain its transparency.

The Bowman's layer is actually the outer, condensed portion of the stroma.

The middle layer that composes the 90% of the corneal thickness is the stroma. It is made up of collagen layers called lamellae that make up right angles to each other. By being arranged in a very regular pattern, the lamellae help the cornea remain transparent by allowing light to enter the eye without being obstructed.

The Descmet's membrane is secreted by the endothelium.

The endothelium is composed of one thin layer of hexagonal cells. Called the endothelial mosaic, it removes excess moisture from the eye, maintaining clarity, through deturgescence.

Limbus

The limbus is the transitional zone between the cornea and sclera. It is approximately 1mm thick.

Common Corneal Ailments

- Neovascularization- new blood vessel growth
- Edema- swelling of the tissue
- Hypoxia- lack of oxygen to the cornea
- Corneal opacities- usually due to damage to one of the layers of the cornea. The endothelium and Bowman's layer doesn't regenerate after injury and the stroma will regenerate but the cells will not be uniform resulting in opacities.
    - Leukoma- dense opacities
    - Macula- medium opacities
    - Nebula- faint opacities
- Infiltrates- white blood cells in the corneal tissue
- Keratitis- inflammation of the cornea
    - Keratitis sicca- inflammation caused by dryness
- Keratoconus- thinning of the central cornea resulting in a cone shaped cornea
- Ulcer- corneal nick as a result of trauma, burns or infection
- Recurrent corneal erosion- reoccurring epithelial loss after corneal injury

- Bullous keratopathy- blisters that are called bullae, are formed by the breakdown of the endothelium, that rise to the epithelial surface where they burst and cause intense pain

Middle Tunic

Also called the uveal tract, its main function is to provide nutrition to the globe. It consists of the iris, ciliary body and choroid.

Iris

The iris, or the colored part of the eye, is an outgrowth of the ciliary body. It contains two muscles. The dilator pupillae muscle which makes the opening of the eye (pupil) larger and the sphincter pupillae muscle which constricts the pupil. These muscles work together to control the amount of light that enters the eye.

The observation of the pupil is important when examining the eye for health. The pupils should be equal, round and regular. Miosis, or pupil constriction, occurs during sleep, when the eyes converge, during bright light situations, or when using miotic drugs. Mydriasis, or pupil dilation, occurs in low light situations or when the person is in a state of excitement.

Ciliary Body

The ciliary body consists of the ciliary muscle and the ciliary processes. The ciliary muscle works with the crystalline lens during accommodation. The ciliary processes secrete aqueous humor into the eye.

Choroid

The choroid is a highly pigmented layer that extends from the optic nerve to the ciliary body. A very dark brown layer, it consists of numerous arteries and vessels that supply the iris, ciliary body, sclera and choroid itself, with nutrients. Only the choroid blood vessels that extend to the episclera and limbus are visible when examining the eye. The color of the vessels can help determine where an eye problem is occurring. If the vessels are red and appear more in the fornices and less at the limbus, then the problem is with the lid and/or conjunctiva. If the vessels appear purplish and with more redness at the limbus, then an inner eye or cornea problem may be assumed.

Common Ailments of the Middle Tunic

Symptoms for uveal tract disorders can include: problems with accommodation, aching pain, irregular pupil shape, injection of vessels, and abnormal pupillary responses. Upon slit lamp evaluation, the contact lens technician may observe flare. Some common ailments are:

- Iridectomy- surgical removal of part of the iris
- Iridocyclitis- inflammation of the iris and ciliary body
- Iritis- inflammation of the iris
- Uveitis- inflammation of the uvea
- Aniridia- congenital absence of the iris
- Anisocoria- unequal pupil size
- Heterochromia- different colored irises
- Rubeosis- Neovascularization of the iris

The Inner Tunic

The inner tunic is the retina. An outgrowth of the optic nerve, the retina is what the eyeball is designed around. It is composed of the outer pigmented layer and the inner nerve layer. When light enters the eye, it focuses on the nerve layer and strikes light sensitive nerves called photoreceptors. These photoreceptors are divided into two classifications: rods and cones

Rods are in the peripheral areas of the retina and they detect objects under low light situations. This is called scotopic vision. In addition, rods only give a sensation of shades of grey and gives better peripheral vision than central vision.

Cones are in the central portion of the retina and work in bright light conditions, resulting in photopic vision. Cones are responsible for color vision as well as clear, crisp central vision.

Once the photoreceptor nerves are activated by the incoming light, the image then travels up the optic nerve to the brain and result in sight.

Retinal Regions

The retina runs along the globe from the optic nerve to the ora serrata. The ora serrata is the scalloped edged front part of the retina that meets the ciliary body.

The macula lutea, or macula, is the central portion of the retina. It is located at the end of the visual axis of a normal eye and measures approximately 4.5mm in diameter. At the center of the macula is the fovea centrallis, and this is where the sharpest.

Located 3mm nasally from the macula is the optic disk. This is the point where the optic nerve leaves the globe and travels to the brain. Due to the lack of photoreceptors, this is the blind spot of the eye.

Between the ora serrata and the optic disk is the peripheral retina. This is the area where the photoreceptors change from cones to rods.

The fundus is not actually a separate region of the retina. In fact, it is just the area of the retina that can be viewed through the pupil utilizing a retinal camera, ophthalmoscope, or slit lamp. This area should include the fovea, retinal blood supply, macula, and optic disk.

Retinal Diseases

Most retinal diseases are painless, but may result in loss of visual acuity, contrast, color vision, and visual fields.

- Macular degeneration- age related breakdown of the macula resulting in loss of central vision
- Retinal detachment- retina separates from choroid resulting in the retina dying from lack of nutrition
- Diabetic retinopathy- hemorrhages in the retina related to diabetes
- Retinitis pigmentosa- a hereditary condition that effects the rods that can lead to partial to total blindness

Crystalline Lens

The crystalline lens is an important part of the eye and it enables an individual to focus from near to distance and back again in a process called accommodation. The lens itself

- Is biconvex
- Has an unaccomodative thickness 3.5-5mm
- Increases thickness .02mm per year due to new layers being added
- Has a Lens diameter of
    - 6.5mm at infancy

    - 9mm teenage and up
- And refractive power
    - Average 20D power unaccommodated
    - Maximum accommodation is between 8-12 years old
    - O accommodation after 50 years of age (presbyopia)
- Is enclosed by a transparent, collagen membrane called the lens capsule

The lens is then attached to the ciliary body by thread like fibers called the Zonules of Zinn. They are attached mostly at the ends of the lens, with a few fibers in the center, and they aid in accommodation. Accommodation is a complex, multi-step process that is stimulated by a blurred, near image on the retina. Next,

- The ciliary muscles in the ciliary body contract
- The Zonules of Zinn relax
- The lens thickens anterior to posterior (bulge)
- The anterior surface moves forward causing anterior chamber to become shallower

The crystalline lens has an accommodative power of +2.50D. This accommodative power is lost when the crystalline lens becomes compact from the layers being added to it and the resulting elasticity loss.

Cataracts

Cataracts are any opacity of the crystalline lens. They can be congenital, the result of a birth defect, caused by age (senile), the result of excessive UV exposure (sun), or caused by injury or disease. Cataracts are categorized by how cloudy they are

- Incipient- early cataract with partial lens opacity with limited impact on vision
- Immature- partially cloudy crystalline lens that has clear areas remaining
- Mature- fully cloudy, ready for surgery
- Hypermature- fully cloudy with fluid degeneration and swelling of lens volume

Cataracts are treated by surgical removal. Aphakia is the name for being without a crystalline lens, and +20.00D of power is lost. When an intraocular implant is placed in the eye to replace the crystalline lens, the patient is then pseudoaphakic.

Chambers of the Eye

Anterior Chamber

Anterior chamber contains aqueous humor and is located between the cornea and iris. It contains the Canal of Schlemm and the trabacular network. These structures act as an exit for the aqueous and allows for nutrient transport.

Posterior Chamber

The posterior chamber is located behind the iris and in front of the vitreous chamber. It contains the zonule fibers and part of the ciliary processes. By allowing the aqueous to flow around the crystalline lens, it provides nutrients and oxygen to the lens.

Vitreous Chamber

The vitreous chamber is filled with vitreous and is the largest portion of the globe. It is attached to the retina along the vitreous base around ora serrata, posterior lens, optic disk, macula, and the retinal vessels by collagen fibers. Most or these attachments weaken with age and the vitreous may become detached. Although not an immediate threat to vision, it needs to be monitored in case it causes the retina to detach.

The vitreous is composed of mostly water, salt and soluble proteins. Its main functions are to provide nutrient transport, act as a shock absorber for the retina, and to aid in the refraction of light.

Chapter 2: OVERVIEW OF CONTACT LENS DEVELOPMENT

1. Earliest contact lens theories and designs
2. Scleral contacts
3. First corneal contacts
4. Development of RGPs
5. Earliest soft contact lenses
6. Introduction of disposables
7. Silicone Hydrogels developed
8. Basic manufacturing procedures

Chapter 3: BASIC CONTACT LENS TERMINOLOGY

Refractive Errors

Emmetropia

Emmetropia is defined as the state in which the eye sees an object clearly at infinity, without accommodation. This is a neutral state and is often referred to as perfect vision, 20/20 vision, or normal vision. This state of vision is a result of the eye's focal power and the axial length of the eye being coincident so that objects come to a focus on the retina.

Hyperopia

Hyperopia is the condition in which the eye focuses objects at infinity behind the retina. This can be attributed to less power than the average eye and/or a shorter axial length then the average eye. Hyperopia is commonly referred to as far-sightedness. This condition results in excess accommodation to see distant objects at infinity. If the degree of hyperopia is too great, images close up can be blurred due to the lack of accommodation required to neutralize the error and focus the eye on close objects. Other complaints and conditions that may arise due to hyperopia are asthenopia (headaches or strain), accommodative and/or binocular dysfunctions, amblyopia, and/or strabismus. Due to the eye's ability to create power through accommodation an individual with hyperopia can appear to have 20/20 vision, when refracted. This patient is said to be a latent hyperope and only through cycloplegia can the latent and manifest amounts of hyperopia be fully realized and the total hyperopia be corrected.

Myopia

Myopia is a condition in which the eye focuses objects at infinity in front of the retina. This condition can be attributed to more power than the average eye and/or a longer axial length than the average eye. Myopia often presents itself with poor distance vision often referred to as near-sightedness.

Astigmatism

Astigmatism can be defined as the eye having two foci perpendicular or 90 degrees apart from one another. This leads to a loss of fine detail for the viewer; can cause objects to appear as though they are leaning or skewed; and/or cause objects to appear elongated. Astigmatism can exist in combination with myopia or hyperopia. There are two types of astigmatism regular and irregular astigmatism.

Irregular astigmatism can be caused by irregularities of the cornea and/or crystalline lens, like scars. The condition can be defined as a different refractive error along the same meridian. Corneal astigmatism can be corrected with contact lenses by allowing the tear film to neutralize the irregularities, where irregularities in the crystalline lens cannot be corrected.

Regular astigmatism is caused by the toricity of the cornea or crystalline lens. Regular astigmatism can be corrected with toric lenses and with contact lenses.

Regular astigmatism can be further classified as simple or compound. Simple astigmatism is the condition in which one of the meridians is emmetropic or contains no power while the other can be either myopic or hyperopic in power. Compound astigmatism is where both meridians contain either hyperopic power or myopic power. There is a special case of compound astigmatism where one meridian is hyperopic and the other myopic and this is referred to as mixed astigmatism.

Examples:

Plano -1.00 x 180 = Simple Myopic Astigmatism
+1.00 -1.00 x 180 = Simple Hyperopic Astigmatism (can be written Plano +1.00 x 090)
-1.00 -1.00 x 180 = Compound Myopic Astigmatism
+2.00 – 1.00 x 180 = Compound Hyperopic Astigmatism (can be written +1.00 +1.00 x 090)
+0.50 -1.00 x 180 = Mixed Astigmatism (can be written -0.50 +1.00 x 090)

Anisometropia

Anisometropia is the condition in which the powers between the two eyes differ to a significant degree, most opticians agree to a difference in refractive error of greater than 2.00 diopters. This can be either myopic or hyperopic with a special case referred to as Antimetropia where one eye is myopic and the other hyperopic. Anisometropia can lead to asthenopia (headaches or strain) or amblyopia in younger patients. Contact lenses are the best solution to this condition, because they allow the refractive error between both eyes to be corrected as well as allow the difference in magnification between both eye's to be better managed. In the case of a young patient, where amblyopia is a concern; the difference in image can be a cause for suppression of the image as well as the blurriness.

Contact Lens Curves

Base Curves

Base curves in contact lenses refer to the back surface of the lens which contacts the corneal surface. This is different than spectacle lens design where the base curve is the front surface of the lens. The base curve is often chosen to follow the contour of the cornea, which is why it is also referred to as the fitting curve. The average cornea has eccentricity of 0.5 which means the cornea gets flatter from the apex to the periphery so this change in curvature has to be accommodated. The most common way to account for the flattening of the cornea is with the use of tables called nomograms. Nomograms take the measured K's and the diameter of the lens and give a compensated value. There are many nomograms and each contact lens manufacturer has nomograms for their particular lens. Another method to determine compensated value is purely mathematical. This method is how nomograms are created. With the use of the most common values and a formula a nomogram can be created. A simple formula for the sag of the cornea could be used, but it's much more accurate to use a formula that incorporates the eccentricity of the cornea. Eccentricity is a value that refers to the change in curvature of the cornea. Most corneas flatten from the apex to the periphery and the accepted average eccentricity value for this degree of flattening is 0.5. If we were to use a the saggital height of the cornea with an eccentricity of 0.5 we can then use that same saggital height to figure out what spherical base curve corresponds to the same height. This will provide us with a three point touch.

p = shape factor
e = eccentricity
K = power in diopters of the cornea (K readings)
r = radius in mm of the cornea
y = semi diameter in mm of the lens (diameter/2)
s = saggital height of the cornea
r_1 = radius in mm of the base curve
D_1 = power in diopters of the base curve

$p = 1 - e^2$

$s = y^2 / [r + \sqrt{(r^2 - p*y^2)}]$

$r_1 = (s^2 + y^2) / 2*s$

The base curve can either be used as the radius measure or converted to diopters with the following formula:

$D_1 = 337.5 / r_1$

This formula can be used to create ones own nomograms. The relationship above is to match the saggital height. If the fitter's philosophy is flatter or steeper then these computed figures should be compensated by the fitter's philosophy further.

Optical Zone

The optical zone of a contact lens, also known as the central posterior curve, is the back surface of the lens which has the base curve ground into it and is used for the fitting and power. This curve is usually smaller in diameter that the entire contact lens. The remainder of the lens is used to create blending as well as used for a tear reservoir. The optical zone diameter is very important in fitting contact lenses as this is the portion of the lens that is used for viewing, too small and the patient will view skewed rays from outside the optical zone and complain of halo's, too large and the lens diameter will increase risking lid interaction and binding.

Intermediate Curves

Intermediate curves are the curves between the optical zone and the peripheral curves of the lens. They are mainly used to increase comfort by gradually blending the curves between the peripheral and the optical zone of the lens. Lenses may contain as many as two intermediate curves and in rare cases more as necessary. The curve immediately adjacent to the optical zone is known as the secondary curve, and the curve following that is known as the tertiary curve. If more curves are present the quandary curve would follow and so on.

Peripheral Curves

Peripheral curves are the outermost curve of the lens and used to both create a tear reservoir to help facilitate the flushing effect blinking has on the tears under the contact lens. Peripheral curves also allow the lens a sufficient angle to avoid negatively interacting with the cornea/sclera transition (limbus). If this curve is fit too steep, it can create a cutting effect on the limbus, cause binding, and/or not provide sufficient tear fluid exchange (tear pump).

Blend Curves

Blended curves are not in and of themselves separate sections of the lens but rather an attempt to blend the junctions of the optical zone and intermediate curve, and/or the intermediate curve and the peripheral curves together more seamlessly. Most RGP labs today apply blended curves to all lenses as they provide better comfort. A second advantage of blended curves to the labs processing is that it becomes difficult to verify the diameter of the various curves due to blending which leads to less rejects due to off tolerance. Most labs allow the fitter to specify the degree of blending in No Blend, Touch or Light Blend, or Complete or Heavy Blend. No blend can be seen as the junction having a clear and separate line of demarcation between the two curves. Touch or light blend can be seen as a blending with a noticeable difference between the two curves. Finally Complete or Heavy Blend will leave the two curves unidentifiable from one another as they should blend together completely.

Anterior Curve

The anterior curve commonly referred to as the power curve, is the front surface of the lens which is used to create the power of the contact lens. In most cases the fitter will specify to the lab the base curve, power, material, diameter, optical zone diameter and design. The lab determines the best thickness and anterior curve to match the power specified by the fitter. The anterior curve is computed to provide the correct back vertex power specified by the fitter. The anterior curve is also at times lenticulated to reduce the lens lid interactions which can lead to discomfort in lens wear as well as reduce the weight of the lenses.

Diameter

Optical Zone Diameter

The optical zone diameter, measured in mm, is chosen based on the base curve of the lens, also referred to as the optical zone radius. The proper optical zone diameter can be determined by using a diameter that is 0.83 mm shorter than the optical zone radius. The average lens is anywhere from 7.0 to 9.0 mm in diameter. The optical zone diameter should be 1.3 to 1.5 mm smaller than the total lens diameter.

It is important to note that the relationship between the diameter and the radius of the optical zone will affect both the fit and power. A rule of thumb exists for the relationship where every 0.10 mm change in lens optical zone diameter must have a change in radius of the optical zone by 0.01mm. This relationship exists due to the change in saggital height. For example: when the diameter is increased, the lens fits flatter, therefore the lens radius must be reduced which leads to the lens becoming steeper leading to a balance. Some fitters suggest that the optical zone diameter be equal in length to the radius of the optical zone.

Intermediate Curve Width

The width of the intermediate curve is typically 0.35 to 0.50 mm. This zone is used more for blending and should align parallel with the cornea. Generally this is done by using an intermediate curve that is 4 to 8 diopters flatter than the average K's of the optical zone. This can be split between 2 intermediate curves with each being 4 diopters flatter than the previous for a total outside intermediate curve of 8 diopters flatter than K's.

Peripheral Curve Width

The peripheral curve width is defined as the outter most curve on the posterior (back surface) of the contact lens. Once again this curve is crucial to create a lens pump and should be flat enough to not cut into the sclera upon movement. A good rule of thumb is to make this curve 3 to 4 diopters flatter than the outside intermediate curve. The width should be anywhere from 0.3 to 0.4 mm in width.

Lens Diameter
The total lens diameter is equal to:

TLD = Total Lens Diameter
OZD = Optical Zone Diameter
ICW = Intermediate Curve Width
PCW = Peripheral Curve Width

TLD = OZD + 2 * ICW + 2 * PCW

Reminder: a good rule of thumb to determine the lens diameter is to add 1.3 to 1.5 mm to the optical zone diameter.

Center Thickness

The center thickness of a RGP contact lens is determined by the power, diameter, and minimum thickness the material can be worked down to. It is important to keep in mind that the minimum thickness a material can be worked down to doesn't necessarily mean the thickness one should order or even get. A great advantage to RGP lenses is that they can be modified once fabricated to allow for slight changes to improve comfort. However, if the lenses were worked to their limits then no further modifications can be carried out. This leads to higher spoilage, wasted time, and higher fees as an end result. If the center thickness is specified the lab should comply within a tolerance of ±0.02 mm.

Lens Power

Lens power is not as straight forward in an RGP lens as it is in spectacles or even soft lenses. First the spectacle power must be vertex compensated to the corneal plane, then the fitter must also take into consideration the tear or Lacrimal Lens created and subtracts this out from the total power of the lens, this leaves the fitter with the contact lens power to be ordered. To vertex compensate a spectacle prescription to the corneal plane first the fitter must know the vertex measure the patient was refracted at as well as the spectacle power, cylinder and axis. Using these parameters the following formula can be used to compensate.

CLV = Contact Lens Vertex in mm
RVD = Refracted Vertex Distance in mm
D = Power in Diopters
Dc = Compensated Power in Diopters
$Dc = D / [1 – (RVD – CLV)*D]$

This must be done for both meridians of power and then converted back to sphero-cylinder form. This is the total power that the lens must have on the corneal plane. The total power is still comprised of the contact lens power and the lacrimal lens power.

Total Power = Contact Lens Power + Lacrimal Lens Power

To determine the lacrimal lens power the base curve and the K readings are necessary. The lacrimal lens an be described as a tear lens having a front surface to match the base curve of the contact lens the fitter has chosen and a back surface to match the corneal plane or K readings in our example. Since this lens is comprised of tears the index of the lens would be the index of the tears or

1.3375 for our purposes this matches the average or Gullstrand index of the eye 1.33 so in essence neutralizes any corneal astigmatism. So in an example:

Power = -2.00 -1.50 x 180
K's = 45.00@090 / 43.50@180
Fit on K

The lacrimal lens front surface would be equal to the flat K (43.50) the back surface would be -45.00@090 and -43.50@180, using a thin lens formula:

Power = Front Surface Power + Back Surface Power

Lacrimal Lens Power = +43.50 + (-45.00@090 / -43.50@180)
Lacrimal Lens Power = -1.50@090 / Plano@180

Now in our contact lens power formula:

Total Power = Contact Lens Power + Lacrimal Lens Power
Contact Lens Power = Total Power – Lacrimal Lens Power

Total Power	-2.00 -1.50 x 180
Lacrimal Lens Power	Plano -1.50 x 180 –

Contact Lens Power	-2.00 Sph

This power is spherical due to point discussed earlier about the refractive index of the tears and eye being so close the corneal astigmatism is neutralized.

Lens Edge Design

Anterior Edge

The anterior edge describes the front surface of the lens at the periphery. This portion of the lens is often in higher powers lenticulated to create a more comfortable lens/lid interaction. The anterior edge can be described as the portion of the lens that starts to deviate from the anterior curve in anticipation to blend with the posterior curve to form the edge apex.

Posterior Edge

The posterior edge describes the back surface of the lens at the periphery. The posterior edge can be described as the portion of the lens that starts to deviate from the peripheral curve in anticipation to blend with the anterior curve to form the edge apex.

Edge Apex

The edge apex is the meeting of the anterior edge and the posterior edge. It is recommended that the edge be as smooth as possible to avoid interactions with the lids, limbus, or sclera.

Lenticular Curve

In higher powers it is difficult to impossible to create a lens with edge thickness of 0.08 to 0.12 mm in thickness which can be described as the optimal thickness. To create this edge profile plus powers lenses will have a secondary carrier lens cut onto the periphery of the lens flattening the anterior curve and minus lenses will have a steeper curve cut into the anterior periphery. These secondary curves on the anterior surface are called Lenticular curves.

Prism Ballast

In toric and bifocal RGP lenses often times base down prism is added the front surface or anterior surface of the lens. The prism is know as prism ballast and is used to stabilize the lens and prevent rotation in toric lenses. In bifocal lenses this additional prism also helps the lens to translate better; this means that the lens will move up on down gaze to allow the patient to see through the reading portion of the bifocal lens. This is caused by the lower lid and lens interaction. This interaction is often referred to as the “watermelon seen principle”. When trying to hold a watermelon seed between two fingers the thick center in combination with the thin edges causes the seed to slip through the fingers, with contact lenses the thin upper portion of the lens slides under the upper lids and creates this same effect on the thicker lower portion of the lens.

Peri-Ballast

Peri-ballast also short for peripheral ballast is the thinning of the lower and upper portions of the lens. With the “watermelon seed principle” in mind, this allows the lens to rotate so that the thicker portions in the center horizontal regions of the lens orient themselves properly. Peri-ballast lenses are also referred to as dynamically stabilized lenses, and dual slab off designs.

Truncation

A truncated lens is a contact lens that has a section of the lens, often times the bottom of the lens removed. Truncation is used to help stabilize the lens and can be applied to both the top and bottom portions of the lens although the most common is to the bottom.

Basic Contact Lens Designs

Spherical

Spherical lens designs are called for when there is no astigmatism and/or when the degree of astigmatism is corneal. A spherical RGP design will have both a spherical anterior curve as well as a spherical optical zone curve. The spherical design allows the lacrimal lens to neutralize any astigmatism. The spherical design is also advantageous in the fact that rotation has no effect on the optics. An example:

Power = -2.00 -1.50 x 180
K's = 45.00@090 / 43.50@180

Corneal cylinder = +1.50 on the 090 (same as the refractive power)

The K's show that the astigmatism is corneal which means that a spherical lens would neutralize the astigmatism leaving only a spherical error for the anterior curve to further neutralize.

Front Surface Toric

Front toric designs are indicated when very little of the refracted cylinder is due to the cornea. Front surface torics have toric surfaces on the anterior surface of the lens and a spherical surface for the back surface optical zone. A front surface toric will need a form of stabilization such as prism ballasting to allow the lens to align properly. A good rule of thumb is if the amount of cylinder is 0.75D more than the corneal astigmatism of K readings, then a front surface toric is indicated. Also, if the axis of the cylinder is off from the K readings, usually by more than 15 degrees, a front surface toric may be indicated. The best method for fitting front surface torics is to use trial lenses with an over refraction, however the proper powers can be determined through mathematical calculations as well. An example:

Power = -2.00 -1.50 x 180
K's = 45.00@090 / 44.50@180
Fit on K (44.50)

Corneal cylinder = +0.50 at 090

This would still leave +1.00 diopters on the 090 to neutralize with the contact lens, so in this case a front surface toric will accomplish this.

Back Surface Toric

A back surface toric lens is rarely used since the effects of the toricity on the back surface are increased optically. This change in cylinder power is the result of the change in index from lens to tears being less than the change in index of air to lens as in the case of the front surface toric. The relationship that best fits the back surface toric model is one where the refractive cylinder is roughly 1/3 higher than the corneal cylinder or K's. An example:

Power = -2.00 -6.00 x 180
K's = 45.00@090 / 41.00@180

Corneal cylinder = +4.00 on the 090

The corneal cylinder is 1/3 less than the refractive cylinder. So, in this case the cylinder would be neutralized by the back surface toric and the higher degree of cylinder would benefit from the stabilization of a toric back surface.

Bitoric

Bitoric lens designs are indicated in cases where the corneal cylinder is high. A bitoric lens will allow the fitter to use a toric on the back surface of the lens to stabilize the lens and use a toric on the front surface to reduce the residual astigmatism. Since these bitoric lenses provide stabilization and correct for residual astigmatism their use is much more common. An example:

Power = -2.00 -6.00 x 180
K's = 45.00@090 / 40.00@180

Corneal cylinder = +5.00 on the 090

Since a back surface toric would be 1/3 stronger optically if a lens with a back toric surface were used of 39.75 / 43.75 then:

Lacrimal Lens = +39.75@180 / +43.75@090 + (-40.00@180 / -45.00@090)
Lacrimal Lens = -0.25@180 / -1.25@090
Lacrimal Lens = -0.25 -1.00 x 180

Total Power	-2.00 -6.00 x 180
Lacrimal Lens Power	-0.25 -1.00 x 180 -

Contact Lens Power	-1.75 -5.00 x 180

This remaining power would need to be incorporated onto the front surface of the contact lens.

Keratometry Readings

Keratometry often referred to as just K's are the dioptric measurements of the corneal surface. This is done with an ophthalmometer which goes by a trade name Keratometer which has become synonymous with ophthalmometers like Kleenex has become synonymous with tissues. The operation of the keratometer takes a little practice but once accomplished is fairly easy and straight forward.

Operational steps:

1. **Focus Eyepiece** – like other ophthalmic equipment the eyepiece must be focused to reduce the effects of accommodation and get accurate readings. This is done by placing the occluder down over the front of the keratometer and focusing the eyepiece from most counter clockwise to the clockwise position until the internal crosshairs are focused.
2. **Position Patient** – The patient should be seated comfortably with their forehead against the upper rest and their chin in the chin rest. This position must be maintained throughout the following procedures.
3. **Position Keratometer** – the keratometer must be positioned both horizontally and vertically so that the patient is properly aligned to view an internal target, this is done by swinging the keratometer off to one side and aligning the silver posts on the side with the patients pupil, then swinging the keratometer back and the fitter aligning the light with the pupil from a viewing position above the keratometer. The other eye should be occluded at this point.

4. **Focus and Position Internal Mires** – at this point the patient should be viewing the inside of the keratometer focused on a blinking light inside or target. With the patient in place, the keratometer should be adjusted until the cross hairs are inside of the lower right hand circular mires. Once this is done, the mires should be focused by adjusting the keratometer along the visual axis with the knob located along the track which holds the keratometer body. Once the mires are in focus, the machine should be locked in place with the locking knob located on the base of the keratometer.
5. **Measure Axis and Power** – with the cross hairs centered and the mires focused, the only thing left to do is measure axis and power. The keratometer body should be rotated until the crosses (+) on the left hand circular mire and the center mire are aligned, then the horizontal power drum should be adjusted until the mires are superimposed. Upon aligning the horizontal axis the vertical axis should also be aligned so that the (-) signs below the top circular mire and the center circular mire can be superimposed use the vertical power drum to superimpose.
6. **Record reading** – both the power and axis should be noted for both vertical and horizontal measures. It is common to write down the measures: first horizontal then vertical or even flat and then steep meridian. Their really in no right or wrong way but the format is often written as:

   K's = 45.00@180 / 47.00@090
   45.00@015 / 47.00@105

   Of course the proper format requires right over left eye.

Chapter 4: PATIENT SELECTION

1. Optical considerations to pick contacts over glasses
   a. Keratoconus
   b. Irregular astigmatism
   c. Fields of vision
   d. Magnification/minification
   e. Anisometropia
   f. Aberrations
2. Ocular Health Needed to Wear Contacts
   a. Lids
   b. Tear film
   c. Conjunctiva

    d. Cornea
3. Contraindications for Contact Lens Wear
    a. Systemic Diseases
    b. Medications
4. Initial Evaluations
    a. Occupations
    b. Hobbies/sports
    c. Patient motivation
    d. Ability to follow recommendations for care

Chapter 5: THE SLIT LAMP (BIOMICROSCOPY)

1. Design
2. What it is used for
    a. Eye health
    b. Contact lens fitting
    c. Detecting contact lens defects
3. Slit lamp illumination types and when to use them
    a. Direct
    b. Diffuse
    c. Indirect
    d. Retro
    e. Sclerotic scatter
4. Filters and their purpose
    a. Blue colbalt
    b. Wratten #12 yellow
    c. Green
5. Fluorescein Patterns
    a. Ideal
    b. Steep
    c. Flat
    d. With the rule
    e. Against the rule
6. Staining
    a. Stippling
    b. Punctuate
    c. Arcuate
    d. Abrasion
    e. Foreign body
    f. Dimple veil
    g. 3-9 o'clock

Chapter 6: KERATOMETRY

1. History and Design
2. How it is used for
    a. Measuring convex surfaces
    b. Measuring concave surfaces
3. How to use
    a. Focusing the eyepiece
    b. Extending the range
    c. Attaching the topogometer
4. Measuring the central cornea
5. Measuring the peripheral cornea
6. Interpreting the K readings
7. Common errors
8. New topographical mapping software

Chapter 7: SOFT CONTACT LENS FITTING

1. Candidates
    a. Children
    b. Athletes
    c. RGP failures
    d. Occasional wearers
2. Contraindications
    a. Environment
    b. GPC
    c. Irregular astigmatism
    d. Conjunctival irregularities
3. Wearjng Schedules
    a. What is the patient looking for
    b. What is feasible
    c. The different types
4. Materials
    a. Group I ~ low water, non-ionic
    b. Group II ~ high water, non-ionic
    c. Group III ~ low water, ionic
    d. Group IV ~ high water, ionic

    e. Oxygen permeability
5. Parameters
    a. Base curve
    b. Diameter
    c. Power
    d. Tints
    e. Thickness
    f. Edge design
6. Fit Evaluation
    a. Corneal coverage
    b. Movement
    c. 3 point touch
    d. Visual acuity
    e. Comfort
7. Lens ordering and verification
8. Delivery Procedures
9. Follow up visits
10. Problem solving

Chapter 8: EXTENDED WEAR CONTACT FITTING

1. Definition of extended wear
    a. Benefits
    b. Most common risks
2. Candidates
    a. Previous wearing history
    b. Occupations
    c. Contact sports
    d. Medical history
3. Fitting procedures
    a. Much the same as soft or rigid contact fitting
    b. Special attention to slit lamp
    c. Watch for corneal swelling
4. Materials
    a. High Dk
    b. Deposit resistant
    c. Water content
    d. Silicone hydrogels
    e. RGP - Fluoro-silicone acrylates
5. Lens Delivery and Care procedures
6. Common Complications

    a. Edema
    b. Solution reaction
    c. Corneal changes
    d. GPC
    e. Blurry vision
7. Follow up appointments

Chapter 9: RIGID GAS PERM CONTACT FITTING

1. Patient selection
2. Spectacle RX conversion
3. K readings
4. Apical Clearance
5. Corneal Alignment
6. SAM/FAP
7. Over-refraction
    a. Diagnostic lenses
    b. Residual astigmatism

Chapter 10: CONTACT LENS VERIFICATION AND IN-OFFICE MODIFICATION

Chapter 11: CONTACT LENS DISPENSING AND CARE PROCEDURES

1. Soft contact
    a. Insertion
    b. Removal
    c. Cleaning
    d. Wearing schedule
    e. Adaptation
    f. Emergencies and complications
2. RGP
    a. Insertion
    b. Removal
    c. Cleaning
    d. Wearing schedule

e. Adaptation
f. Emergencies and complications
3. Cleaning Solutions
4. Wetting Solutions
5. Salines
6. Rewetting Drops
7. Disinfection Systems
8. Preservatives and Disinfectants
9. Written Instructions

Chapter 12: CONTACT LENS FOLLOW UP PROCEDURES (SOAP)

1. Subjective Examination
2. Objective Examination
3. Assessment
4. Plan

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