College of Health and Medical Technologies - Al-Dour
Department of Optics Technologies
The second stage

Physiology of the eye and vision

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11- Visual acuity

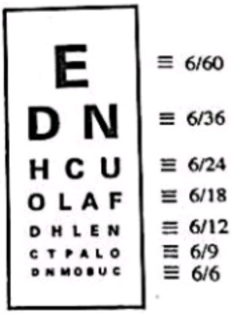
<u>Introduction</u>:

Visual acuity (sharpness of vision) is the shortest distance by which two lines can be separated and still be perceived as two lines.

The curvature of the optic lens alters to adapt the focal length to suit the varying distance of the entering light rays and produce a clear, focused image.

Visual acuity measurement is a good screening tool because normal visual acuity requires that all levels of the visual system function properly. The optical system of the eye must project a sharp image of the outside world onto the retina. The retina must then be able to translate this image into neural impulses. Finally, the neural impulses must travel to the brain, where they are analysed and recognized. Therefore, a wide array of different visual disorders (but not all) can affect visual acuity, however visual acuity (tested by chart test) is used primarily to detect refractive errors while other visual disorders is recognised by other sophisticated techniques.

<u>Snellen's test type</u>, is a series of letters of different sizes, the top letter is visible to the normal eye at 60 m., and the subsequent lines at 36, 24, 18, 12, 9 and 6 m. respectively. The letters are in lines, each line has types of same size. The top row of types contains large letters and succeeding rows contain gradually smaller and smaller letters, **figure (11-1).**



Snellen's test types

Figure 11-1: Snellen chart

V = d / D

V = Visual acuity.

d = distance of from the type (6 meters).

D = distance at which the eye should be capable to read it clearly.

Emmetropia means normal refractive status of the eye

Ametropia means refractive error might be caused by aberrations in the shape of the eyeball, the shape of the cornea, and reduced flexibility of the lens.

Types of ametropia:-

***Hyperopia (farsightedness)*:**

The eye ball is shorter than normal one; the rays of light from distant object are brought to focus behind the retina. The defect can be corrected by using glasses with convex lenses.

Myopia (nearsightedness):

The antero-posterior diameter of the eye ball is too long; the light rays from distant object fall in front of retina. Myopia is said to be genetic in origin. In young adult humans the extensive close work involved in activities such as studying accelerates the development of myopia. This defect can be corrected by glasses with biconcave lenses, **figure (11-2).**

Astigmatism

Occur when the cornea is irregularly curved preventing light rays from focusing properly on the retina. As a result, vision becomes blurred at any distance figure (11-3).

Presbyopia

Presbyopia is the gradual loss of eyes ability to focus on nearby objects because the lens loses its ability to accommodate for near objects. It's a natural, often annoying part of aging. Presbyopia usually becomes noticeable in early to mid-40s and continues to worsen until around age 65.

Objective: To examine the visual acuity of eyes.

Subjects and instruments:

1- Subjects.

2- Snellen's letter chart. 22

Methods:

1- The subject is placed at a distance of six meters from the test types (chart).

2- Each eye is tested separately.

3- Snellen visual acuity is expressed as 6 (the distance at which the chart is read) over the number corresponding to the lowest line read. This indicates the distance at which someone with normal vision should be able to read that line, i.e. Snellen visual acuity of 6/60 indicates that at 6 metres patients can only see letters they should be able to read 60 metres away.

4- If the person can't see the biggest letter at 6 meters bring him to 1 meter and visual acuity will be 1/60. If the person see nothing at 1 meter; visual acuity is tested as:

a- Counting finger (CF).

b- Hand movement (HM).

c- Perception of light (PL).

5- If the subject wears glasses, test eyes with and without them.

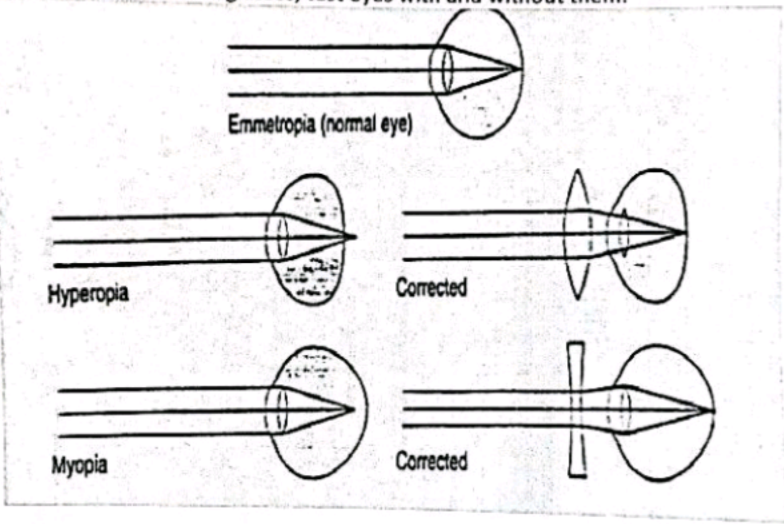


Figure 11-2: hyperopia and myopia

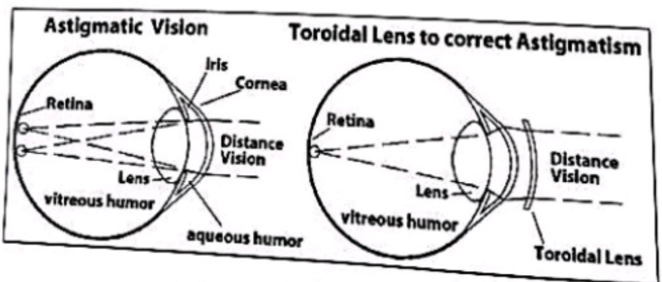


Figure 11-3 stigmatism

Binocular vision

Binocular vision is vision in which both eyes are used together. The word binocular comes from two Latin roots, bini for double, and oculus for eye. Having two eyes confers at least four advantages over having one.

First, it gives a creature a spare eye in case one is damaged.

Second, it gives a wider field of view. For example, humans have a maximum horizontal field of view of approximately 180 degrees with two eyes, approximately 120 degrees of which makes up the binocular field of view (seen by both eyes) flanked by two uniocular fields (seen by only one eye) of approximately 30 degrees.

Third, it gives binocular summation in which the ability to detect faint objects is enhanced.

Fourth it can give stereopsis in which parallax provided by the two eyes' different positions on the head give precise **depth perception.**

Such binocular vision is usually accompanied by singleness of vision or binocular fusion, in which a single image is seen despite each eye's having its own image of any object

Singleness of vision

Once the fields of view overlap, there is a potential for confusion between the left and right eye's image of the same object. This can be dealt with in two ways: one image can be suppressed, so that only the other is seen, or the two images can be fused. If two images of a single object are seen, this is known as double vision or diplopia.

Stereopsis

Stereopsis is an ability to make fine depth discriminations from parallax provided by the two eye's different positions on the head.

What causes loss of binocular vision?

There are lots of reasons why binocular vision might become reduced or lost altogether. Reasons include:

- Reduced vision in one eye

• Loss of coordination of movement between the two eyes (squint)

• Problems with the brain comparing images from both eyes

1-Reduced vision in one eye

The brain needs clear images from each eye to compare any slight differences. The differences allow the brain to work out depth and speed of movement. If the sharpness of vision from one eye becomes poor the brain will be less able to do this. Binocular vision will become poorer. If the image becomes very blurred binocular vision may become lost altogether.

2-Loss of co-ordination of movement between the two eyes

The brain needs images of the same visual scene to compare any slight differences. The differences allow the brain to work out depth and speed of movement. If the eyes do not point in the same direction then the visual scenes will be too different. The brain will be unable to work out depth and speed of movement. Binocular vision will be lost.

When the eyes point in different directions it is called squint or strabismus.

There are many different causes of squint. One of them is itself loss of binocular vision.

3-Problems with the brain comparing images from both eyes

There is a special part of the brain that compares the slight differences in the images coming from both eyes. If this bit of the brain does not develop properly or becomes damaged binocular vision may become lost. There are many different causes of poor development or damage to this part of the brain. Most of the time no cause can be identified

Eye dominance

When each eye has its own image of objects, it becomes impossible to align images outside of Panum's fusional area with an image inside the area. This happens when one has to point to a distant object with one's finger. When one looks at one's fingertip, it is single but there are two images of the distant object.

When one looks at the distant object it is single but there are two images of one's fingertip. To point successfully, one of the double images has to take precedence and one be ignored or suppressed (eye dominance). The eye of the image that takes precedence is called the dominant eye.

Optics of Human Eyes

Light focused by the human eye is refracted by multiple curved surfaces before falling on the retina, where an electrical impulse is generated, eventually perceived as vision.
The corneal tear film, corneal layers, and anterior and posterior lens surfaces all affect the quality of the image formed on the retinal receptors.
If the secondary focal plane of the combined refracting elements is at the retina, the eye sees well. If not, a refractive error is present.

Refractive States of the Eyes

Emmetropia is the refractive state in which parallel rays of light from a distant object are brought to focus on the retina in the non-accommodating eye. The far point of the emmetropic eye is at infinity, and infinity is conjugate with the retina.

Ametropia refers to the absence of emmetropia and can be classified by presumptive etiology as axial or refractive. In *axial ametropia*, the eyeball is either unusually long (myopia) or short (hyperopia). In *refractive ametropia*, the length of the eye is statistically normal, but the refractive power of the eye (cornea and/or lens) is abnormal, being either excessive (myopia) or deficient (hyperopia). An ametropic eye requires either a diverging or a converging lens to image a distant object on the retina.

Ametropia may also be classified by the nature of the mismatch between the optical power and length of the eye.

In myopia, the eye possesses too much optical power for its axial length, and (with accommodation relaxed) light rays from an object at infinity converge too soon and thus focus in front of the retina. This results in a defocused image on the retina; the far point of the eye is located in front of the eye, between the cornea and optical infinity.

In hyperopia, the eye does not possess enough optical power for its axial length, and (with accommodation relaxed) an object at infinity comes to a focus behind the retina, again producing a defocused image on the retina; the far point of the eye (actually a virtual point rather than a real point in space) is located behind the retina.

Astigmatism is an optical condition of the eye in which light rays from a point source on the eye's visual axis do not focus to a single point. Typically, light rays from a single object point are refracted to form 2 focal lines, perpendicular to each other. Each astigmatic eye can be classified by the orientations and relative positions of these focal lines. If 1 focal line lies in front of the retina and the other is on the retina, the condition is classified as *simple myopic astigmatism.* If both focal lines lie in front of the retina, the condition is classified as *compound myopic astigmatism.*

If, in an unaccommodated state, 1 focal line lies behind the retina and the other is on the retina, the astigmatism is classified as *simple hyperopic astigmatism.* If both focal lines lie behind the retina, the astigmatism is classified as *compound hyperopic astigmatism.* If, in an unaccommodated state, one focal line lies in front of the retina and the other behind it, the condition is classified as *mixed astigmatism.* The orientations of the focal lines reflect, in turn, the strongest and weakest meridians of the net refracting power of the anterior segment refracting surfaces (the cornea and lens). These are referred to as the principal axes.

If the principal axes of astigmatism have constant orientation at every point across the pupil, and if the amount of astigmatism is the same at every point, the refractive condition is known as regular astigmatism. Regular astigmatism may be classified as with-the-rule or against-the-rule astigmatism.

In with-the-rule astigmatism (the more common type in children), the vertical corneal meridian is steepest, and a correcting plus cylinder is placed with the cylinder axis near 90°.

In against-the-rule astigmatism (the more common type in older adults), the horizontal meridian is steepest, and a correcting plus cylinder should be placed with the axis near 180°.

The term oblique astigmatism is used to describe regular astigmatism in which the principal meridians do not lie at, or close to, 90° or 180°, but instead lie nearer 45° or 135°.

In irregular astigmatism, the orientation of the principal meridians or the amount of astigmatism changes from point to point across the pupil. Although the principal meridians are 90° apart at every point, it may sometimes appear by retinoscopy or keratometry that the principal meridians of the cornea, as a whole, are not perpendicular to one another.

Correction of Ametropia

Ametropia is a refractive error; it is the absence of emmetropia. The most common method of correcting refractive error is through prescription of spectacle or contact lenses.

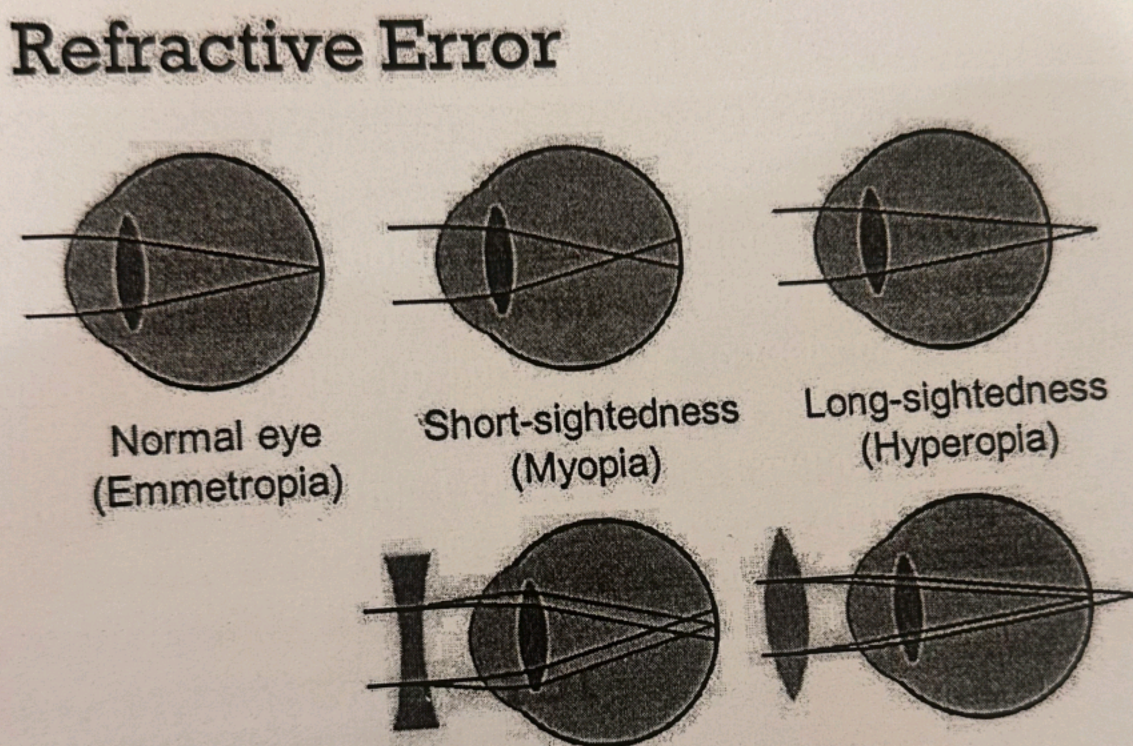
Spherical Correcting Lenses and the Far Point Concept

The far point plane of the non-accommodated eye is conjugate with the retina. For a simple lens (plus or minus sphere), distant objects (those at optical infinity) come into sharp focus at the *secondary focal point* (F2) of the lens. To correct the refractive error of an eye, a correcting lens must place the image it forms (or its F2) at the eye's far point. The image at the far point plane becomes the object that is focused onto the retina. For example, in a myopic eye, the far point lies somewhere in front of the eye, between it and optical infinity. In this case, the correct *diverging lens* forms a virtual image of distant objects at its F2, coincident with the far point of the eye.

The same principle holds for the correction of hyperopia. However, because the far point plane of a hyperopic eye is behind the retina, a *converging lens* must be chosen with appropriate power to focus parallel rays of light to the far point plane.

Cylindrical Correcting Lenses and the Far Point Concept

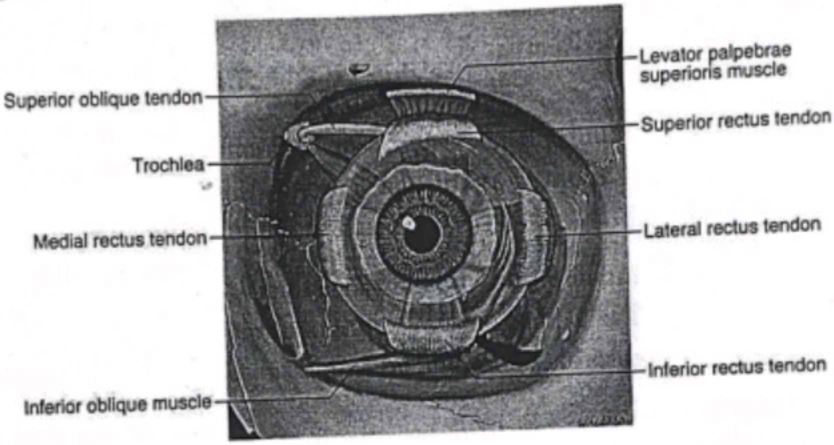
The far point principles used in the correction of hyperopia and myopia are also employed in the correction of astigmatism with spectacle lenses.



EXTRA-OCULAR MUSCLES:

There are 7 extra-ocular muscles (EOMs) in the human eye: the 4 rectus muscles (lateral, medial, superior, and inferior), the 2 oblique muscles, and the levator palpebrae superioris muscle.

Cranial nerve (CN) VI (abducens) innervates the lateral rectus muscle; CN IV (trochlear), the superior oblique muscle; and CN III (oculomotor), the levator palpebrae, superior rectus, medial rectus, inferior rectus, and inferior oblique muscles.



- The primary action of a muscle is its major effect when the eye is in the primary position.
- Subsidiary actions are the additional effects; these depend on the position of the eye.

Ocular movements:

Ductions

Ductions are monocular movements. They consist of adduction, abduction, elevation, depression, intorsion and extorsion. They are tested by occlude the fellow eye and asking the patient to follow a target in each direction of gaze.

Versions

Versions are binocular, simultaneous, conjugate movements (conjugate–in the same direction, so that the angle between the eyes remains constant).

•Dextroversion and laevoversion (gaze right and gaze left), elevation (upgaze) and depression (downgaze).

• Dextroelevation and dextrodepression (gaze up and right; gaze down and right) and laevoelevation and laevodepression (gaze up and left; gaze down and left).

Vergences

Vergences are binocular, simultaneous, disjugate movements (disjugate – in opposite directions.Convergence is simultaneous adduction (inward turning); divergence is outwards movement from a convergent position.

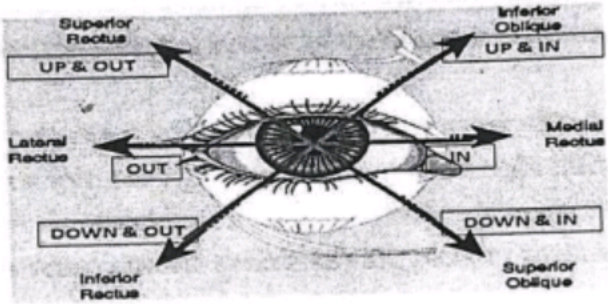
	Action	Innervation
IR	Eye looks down	Oculomotor nerve [III]
MR	Eye looks medially	Oculomotor nerve [III]
SR	Eye looks up	Oculomotor nerve [III]
LR	Eye looks laterally	Abducens nerve [VI]
IO	Eye rolls, looks up	Oculomotor nerve [III]
SO	Eye rolls, looks down	Trochlear nerve[IV]

• **Agonist–antagonist** pairs are muscles of the same eye that move the eye in opposite directions. The agonist is the primary muscle moving the eye in a given direction. The antagonist acts in the opposite direction to the agonist. For example, the right lateral rectus is the antagonist to the right medial rectus.

• **Synergists** are muscles of the same eye that move the eye in the same direction. For example, the right superior rectus and right inferior oblique act synergistically in elevation.

• **Yoke muscles** (contralateral synergists) are pairs of muscles, one in each eye, that produce conjugate ocular movements. For example, the yoke muscle of the left superior oblique is the right inferior rectus.

MUSCLE TESTING: CARDINAL POSITIONS



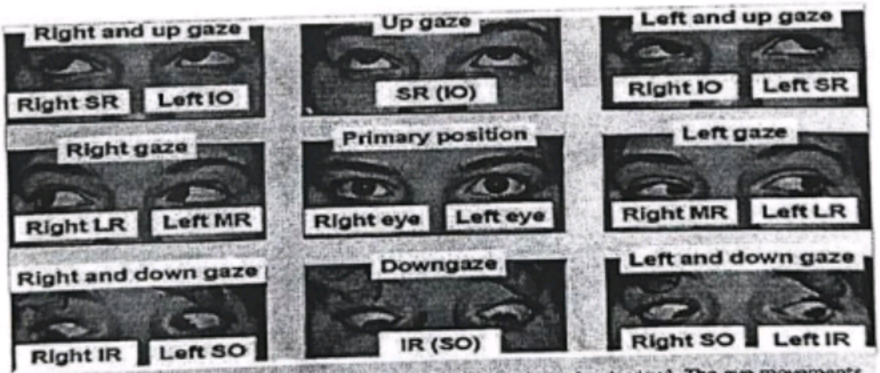


Fig. 13.5 Full extraocular movements in a normal subject (examiner's view). The eye movements must be examined in the nine cardinal positions of gaze. IO, inferior oblique; IR, inferior rectus; LR, lateral rectus; MR, medial rectus; SO, superior oblique; SR, superior rectus.

Pupillary Light reflex

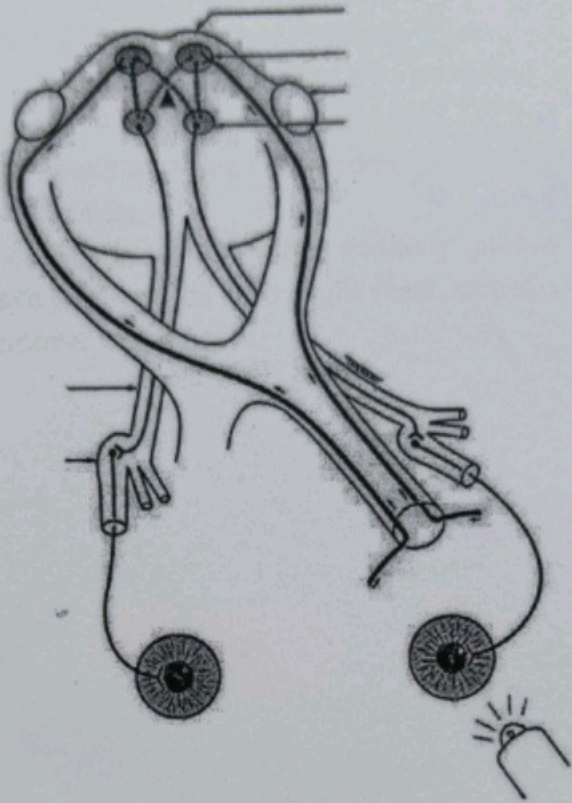
The light reflex is mediated by the retinal photoreceptors and subserved by four neurones.

- **First** (sensory) connects each retina with both pretectal nuclei in the midbrain at the level of the superior colliculi. Impulses originating from the nasal retina are conducted by fibres that decussate in the chiasm and pass up the opposite optic tract to terminate in the contralateral pretectal nucleus. Impulses originating in the temporal retina are conducted by uncrossed fibres (ipsilateral optic tract) that terminate in the ipsilateral pretectal nucleus.

- **Second** (internuncial) connects each pretectal nucleus to both Edinger–Westphal nuclei. Thus a uniocular light stimulus evokes bilateral and symmetrical pupillary constriction.

- **Third** (preganglionic motor) connects the Edinger–Westphal nucleus to the ciliary ganglion. The parasympathetic fibres pass through the oculomotor nerve, enter its inferior division and reach the ciliary ganglion via the nerve to the inferior oblique muscle.

- **Fourth** (postganglionic motor) leaves the ciliary ganglion and passes in the short ciliary nerves to innervate the sphincter pupillae. The ciliary ganglion is located within the muscle cone, just behind the globe. It should be noted that, although the ciliary ganglion serves as a conduit for other nerve fibres, only the parasympathetic fibres synapse there.



Near reflex

The near reflex is activated when gaze is changed from a distant to a near target. It comprises accommodation, convergence and miosis. Although the final pathways for the near and light reflexes are identical (i.e. third nerve, ciliary ganglion, short ciliary nerves), the centre for the near reflex is ill-defined. There are probably two supranuclear influences: the frontal and occipital lobes. The midbrain centre for the near reflex is probably located more ventrally than the pretectal nucleus.

Afferent pupillary defect :

An absolute afferent pupillary defect is caused by a complete optic nerve lesion and is characterized by the following:

- The involved eye is completely blind (i.e. no light perception).
- Both pupils are equal in size.
- When the affected eye is stimulated by light neither pupil reacts.
- When the normal eye is stimulated both pupils react normally.
- The near reflex is normal in both eyes.

Cornea Transparency ,Responses toWounding

Transparency of the cornea:

The cornea is highly transparent tissue with less than 1% of light being scattered within it. The cornea transparency is maintained by two essential factors, the physical characteristic of the cornea and controlled hydration, also there are other factors are important in corneal transparency.

The transparency of the cornea is the result of the following:

1- Its anatomic structure which include the following factors:

a) The absence of blood vessels and pigments in the cornea.

b) The regular arrangement of the epithelial and endothelial cells.

c) The scarcity of cell nuclei in the stroma.

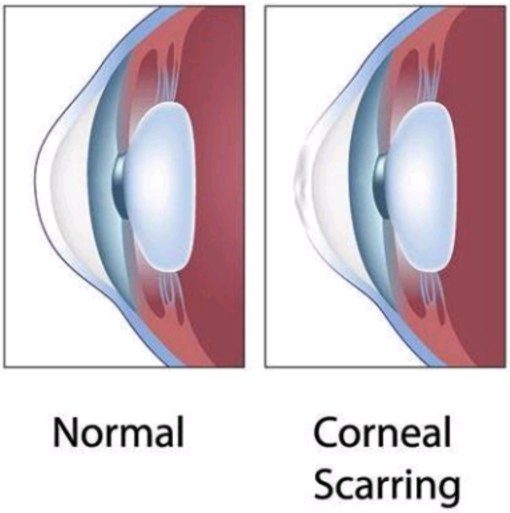
d) The epithelial cells are not keratinized.

e) The anterior surface of tears forms a regular refracting surface

2- The tight junction of the epithelial cells that are not permeable to aqueous solution.

3- The dynamic balance between ions and water in the stroma that is maintained by an endothelial pump mechanism that controls corneal dehydration.

Corneal injury, is a wound to the part of the eye known as the cornea.



Causes

Injuries to the cornea are common.

Injuries to the outer surface may be due to:

- Abrasions -- Includes scratches or scrapes on the surface of the cornea
- Chemical injuries -- Caused by almost any fluid that gets into the eye
- Contact lens problems -- Overuse, poor fit, or sensitivity to contact lens care solutions
- Foreign bodies -- Exposure to something in the eye such as sand or dust
- Ultraviolet injuries -- Caused by sunlight, sun lamps, snow or water reflections, or infections may also damage the cornea.

Symptoms

- Blurred vision
- Eye pain or stinging and burning in the eye
- Feeling like something is in your eye (may be caused by a scratch or something in your eye)
- Light sensitivity
- Redness of the eye
- Swollen eyelids
- Watery eyes or increased tearing.

Revision Questions Lec 3: Cornea Transparency ,Responses to Wounding

1. Choose of right answer, the cornea transparency is maintained essential factors, except:

a. physical characteristic of the cornea.

b. controlled hydration.

c. absence of blood vessels.

d. keratinization of epithelial cells.

2. T or F , the tight junction of the epithelial cells that are permeable to aqueous solution.

3.Choose right answer in cornea, The dynamic balance between ions and water in the --------- that is maintained by an endothelial pump mechanism that controls corneal dehydration.

a. stroma

b. endothelium

c. epithilium.

d. lumina fusca.

4. Choose right answer, Injuries to the cornea are------ (common vs rare).

5.choose right answer , Symptoms of cornea abrasion are all of following except
a.Blurred vision

b. Painless of eye.

c.Light sensitivity

d. Redness of the eye