Clinical Optics

Prepared by

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<tr><td>ا. المعلومات والمفاهيم :</td><td>By the end of this course the student will be able to :
Know the fundamentals of the nature of light, and optical phenomena.
Understand the basics light behavior according to the surface curvature.
Define the various types of visual perception and function including visual acuity and brightness sensitivity.
Identify lens power and focal length.
Memorize the basics of refractive errors and eye impairments and the principles of their correction.
Describe corrective ophthalmic lenses types and designs.
Recognize all instruments using for eye examination and eye-glasses measurements.
Explain how to assist the ophthalmologist in refractive surgery.</td></tr>
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الذهنية :</td><td>By the end of this course the student will be able to :
Compare the different types of refractive correction and apply the most appropriate method to individual patients/ client needs.
Differentiate between eye-glasses and contact lenses.
Organize the materials and fitting parameters of both soft and rigid contact lenses.
Apply the operating principles of various optical in instruments in order to use them more effectively.
Use reasoning skills in prioritizing action in assisting ophthalmologist for refractive surgery.</td></tr>
<tr><td>ج- المهارات المهنية الخاصة بالمقرر:</td><td>By the end of this course the student will be able to :
Operate various optical instruments appropriate to the situation to identify relevant causes of eye complains.
Perform basic technical skills of Eye examinations including visual acuity, ocular alignment and motility examination.
Apply principles and concepts of optics to determine how to correct the vision errors by eye-glasses or contact lens including the low visions aids.
Apply basics of ophthalmic dispensing opticianry.
Conduct skillful assistance in refractive surgery.</td></tr>
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By the end of this course the student will be able to : • Demonstrate ability to manage time and resources effectively prioritize for and patient/ client with special needs. • Communicate effectively with patients/ clients, and treat them with friendly manner. • Assist the patient/ client to make informed eye health care decisions. • Discover how to commit to the high end of quality of services and safety.	**د- المهارات العامة :**
1. nature of light 2. Reflection of Light. 3. Refraction of Light. 4. Prisms. 5. Spherical Lenses. 6. Astigmatic Lenses. 7. Refraction by the Eye.(Emmetropia) 8. Optics of Ametropia. .(refractive errors) 9. Aberrations of Optical Systems Including the Eye. 10. Presbyopia. 11. Optical Prescriptions, Spectacle Lenses.(corrective lenses) 12. Contact Lenses. 13. Low Vision Aids. 14. Instruments. 15. Lasers. 16. Practical Clinical Refraction. 17. Refractive Surgery.	**4- محتوى المقرر:**

1- lectures. **2-small group teaching.** **3-demonstrations and teaching videos.** **4-practical clinical hands on.**	**5- أساليب التعليم والتعلم**
	6- أساليب التعليم والتعلم للطلاب ذوى القدرات المحدودة
	7- تقويم الطلاب :
Assessment Quizzes Mid-term exam Final exam	**أ- الأساليب المستخدمة**
Quizzes (3rd , 8th , 12th week) Mid-term exam at 6th week Final practical 13 week Final practical 15 week	**ب- التوقيت**
Year work (20 PTS) Practical (40 PTS) Mid-term (45 PTS) Final exam (45 PTS)	**ج- توزيع الدرجات**
8- قائمة الكتب الدراسية والمراجع :	

أ- مذكرات	------------------
ب- كتب ملزمة	• Optics, 3rd Edition Andrew R. Elkington, Helena j. Frank, Michael J. Greaney. • Clinical Optics and Refraction, Edited by Andrew Keirl, BOptom(Hons), MCOptom, FBDO and Caroline Christie, BSc(Hons), FCOptom, DCLP
ج- كتب مقترحة	• Introduction to Opthalmic Optics (Darryl Meister, ABOM) (james E. Sheedy, OD,PHD) • The Optician Training Manual : Simple Steps to Becoming a Great Optician by David McCleary • Ophthalmic medical assisting fifth Edition.
د- دوريات علمية أو نشرات ...... الخ	• British journal of ophthalmology. • Optometry and vision science - LWW journals

Course Description

This course will provide the technical student with basic knowledge regarding the light theory and optical phenomenon, fundamentals of refractive errors and their correction by different types of corrective lens and contact lenses, low vision aids and the basic principles of refractive surgery.

Core Knowledge

By the end of this course, students should be able to:

- Know the fundamentals of the nature of light, and optical phenomena.
- Understand the basics light behavior according to the surface curvature.
- Define the various types of visual perception and function including visual acuity and brightness sensitivity.
- Identify lens power and focal length.
- Memorize the basics of refractive errors and eye impairments and the principles of their correction.
- Describe corrective ophthalmic lenses types and designs.
- Recognize all instruments using for eye examination and eye-glasses measurements.
- Explain how to assist the ophthalmologist in refractive surgery.

Core Skills

By the end of this course, students should be able to:

- Compare the different types of refractive correction and apply the most appropriate method to individual patients/ client needs.
- Differentiate between eye-glasses and contact lenses.
- Organize the materials and fitting parameters of both soft and rigid contact lenses.
- Apply the operating principles of various optical in instruments in order to use them more effectively.

Course Overview

		Methods of Teaching/Training with Number of Total Hours per Topic				
ID	**Topics**	**Interactive Lecture**	**Field Work**	**Class Assignments**	**Research**	**Lab**
1	Basic optics of light and refraction	9	9		6	15
2	Refraction by the eye	9	9	√	6	15
3	Refraction and spectacle prescription	9	9		6	15
4	Miscellaneous clinical optics topics	9	9	√	6	15
	TOTAL HOURS (156)	**36**	36		24	60

This box color usually contains important rules to be learned by the students.

This box color usually contains useful information to widen the students' knowledge.

Chapter 1

Basic optics of light and refraction

Sections

- **The nature of light**
- **Refraction**
- **Reflection**
- **Prisms**
- **Spherical Lenses**
- **Astigmatic Lenses**

Introduction

In this chapter we will have a brief overview of the basic concepts of ***Optics*** or the study of the laws of light, since light is the medium used by optical instruments and the eye. More details about these principles are discussed in a branch of the science called *Geometrical and Physical Optics.*

Nature of light

1. Light is a transverse, electromagnetic wave that can be seen by the typical human.
    - Light travels through vacuum similar to all electromagnetic waves.
    - Light is sometimes also known as visible light to contrast it from "ultraviolet light" and "infrared light".
    - Other forms of non-visible electromagnetic radiation are occasionally referred to as "light".
2. The speed of light depends upon the medium through which it travels.
    - The speed of light in a vacuum is a universal constant in all reference frames at 300,000 km/s.
    - All electromagnetic waves propagate at the speed of light in a vacuum.
    - The speed of light in a medium is always slower the speed of light in a vacuum. (The difference is usually negligible when the medium is air and the speed in air is considered equal to vacuum.)

3. The frequency of a light wave is related to its color.
    - ***Monochromatic light*** can be described by only one frequency.
        - Laser light is very nearly monochromatic.
        - There are six color bands of monochromatic light for simplicity:
            - *Red, orange, yellow, green, blue, and violet.*
    - ***Polychromatic light*** is composed of multiple frequencies.
        - Every light source is essentially polychromatic.
        - White light is extremely polychromatic.
    - A graph of relative intensity vs. frequency is called a spectrum (plural: spectra) (figure 1).

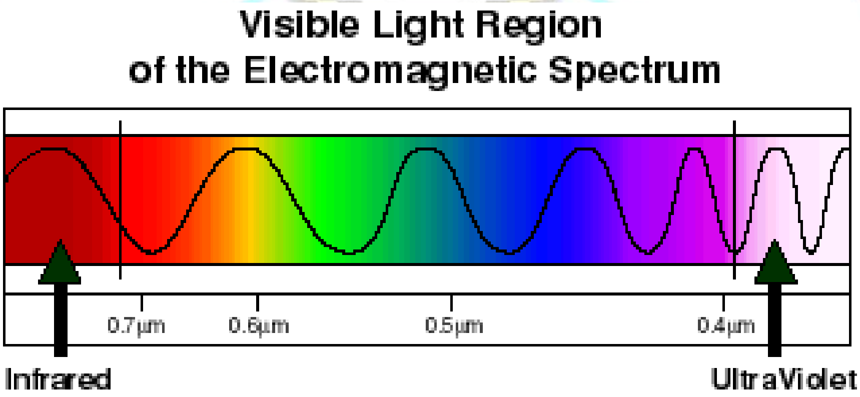

Figure 1: Visible light spectrum.

4. The wavelength of a light wave is inversely proportional to its frequency.
    - Light ranges in wavelength from 400 nm on the violet end to 700 nm on the red end of the visible spectrum.
        - Wavelengths slightly shorter than 400 nm are said to be ultraviolet i.e. "beyond violet".
        - Wavelengths slightly longer than 700 nm are said to be infrared or "below red".

Refraction of light

- Refraction is the bending of a wave when it enters a medium where its speed is different.
- The refraction of light when it passes from a fast medium to a slow medium bends the light ray toward the normal to the boundary between the two media (Figure 2).
- The amount of bending depends on the indices of refraction of the two media and is described quantitatively by *Snell's Law*.
- Prisms and lenses used in ophthalmic practice are refraction devices and will be discussed more in later sections.

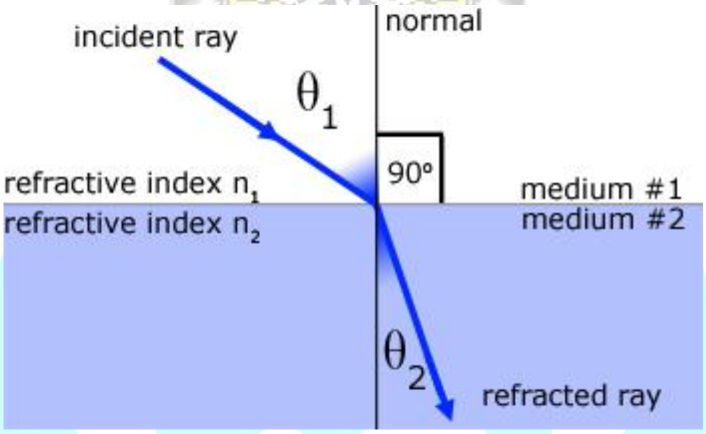

Figure 2: Refraction of light.

- ***The normal:*** a line perpendicular to the surface at the point of reflection.
- ***The angle of Incidence θ_1 (i):*** the angle between the normal and the incident ray.
- ***The angle of refraction θ_2 (r):*** the angle between the normal and the reflected ray.

Reflection of light

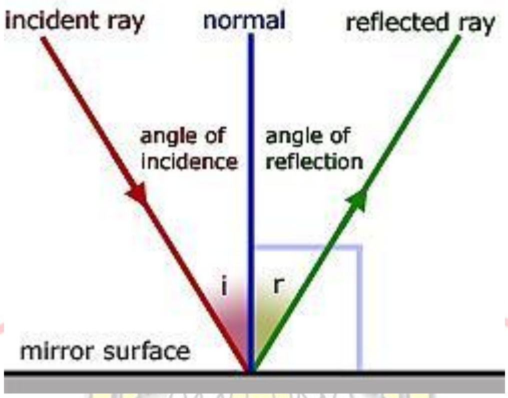

Figure 3: Reflection of light.

- When light rays traveling through a medium reach the edge of other medium, they turn back to the first medium. This phenomenon of turning back of light into the same medium after striking the boundary of other medium is called Reflection of Light.
- Laws of Reflection:
  1. The angle of incident is equal to the angle of reflection i.e. $\hat{\imath} = \hat{r}$ (figure 3).
  2. The incident ray, the reflected ray and the normal lie on the same plane.
- Regular reflection:
  - When a beam of parallel light rays falls on a smooth and plane surface, the reflected rays will also be parallel.
- Irregular Reflection:
  - When a beam of parallel light rays falls on an irregular surface it will be scattered in all directions. This type of reflection is called "Irregular or Diffuse Reflection".

Prisms

- A prism is an optical device composed of two refracting surfaces that are inclined toward one another so they are not parallel.
- The line at which the two surfaces intersect is the apex of the prism. The greater the angle formed at the apex, the stronger the prismatic effect (Figure 4).
- An object viewed through a prism appears to be displaced in the direction of the prism apex, but the focus is not altered and no magnification or minification occurs.

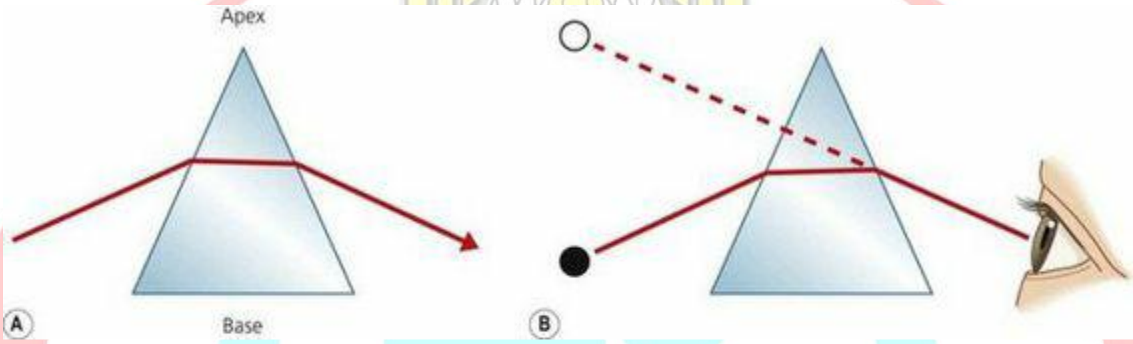

Figure 4: **(A)** Light is deviated by the prism toward its base. **(B)** The observer views an object through the prism and the object appears to be displaced toward its apex. *(From The Ophthalmic Assistant, 9th Edition, H.A. Stein, R.M. Stein and M.I. Freeman, 2013, Elsevier Inc.)*

- The strength of a prism is measured in prism diopters (**Δ**).
  - The prism power is equal to the displacement in centimeters of a light ray passing through the prism measured 1 m from the prism i.e. each diopter displaces a ray of light 1 cm at a distance of 1 m.
  - Two prism diopters of displacement are approximately equal to 1 degree of arc.
- Uses of Prisms :
  - They are usually prescribed to assist a patient with an extraocular muscle imbalance, which results in a deviation of one visual axis relative to the other, so that the patient may achieve single binocular vision or do so more comfortably.
  - They may be oriented in the spectacle correction so as to produce horizontal, vertical, or both horizontal and vertical displacement, as needed.
  - Inverting or reflecting prisms are used in many optical devices to reflect the image and/or invert it (e.g in Keplerian or inverting telescopes) to produce an erect image, making use of the total internal reflection property of its material (Figure 5).

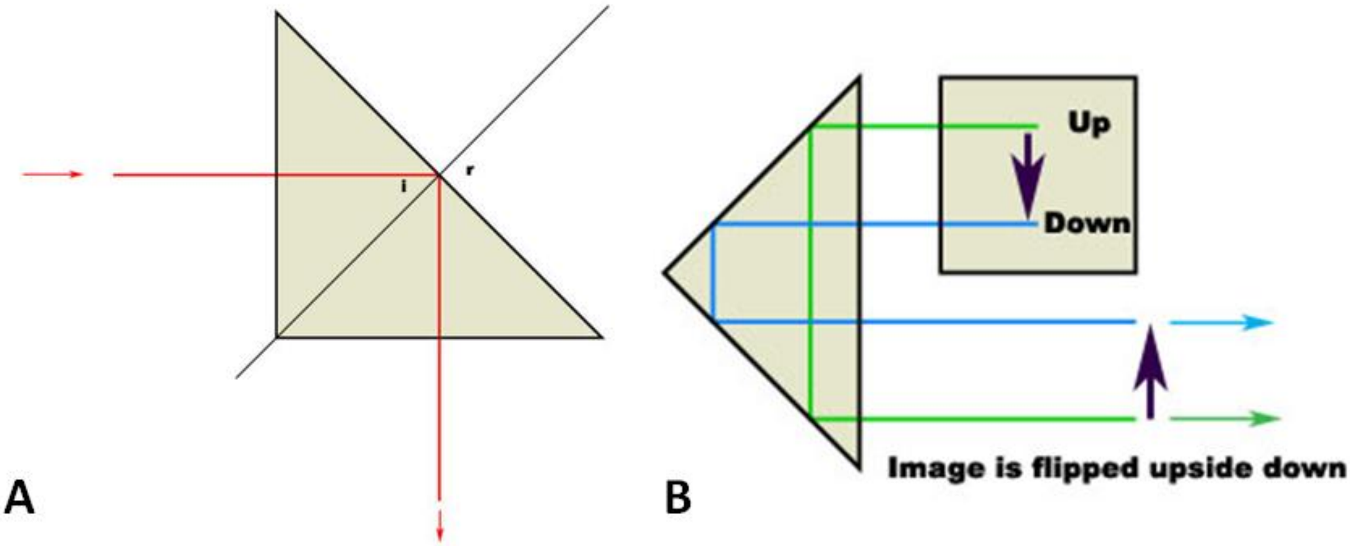

Figure 5: ***(A)*** A right angled prism where the light falls on the hypotenuse side (the longest side opposite to the right angle in a right-angled triangle) by an angle of incidence that is greater than the critical angle so Total Internal Reflection (TIR) occur. ***(B)*** A Porro Prism system uses TIR to reflect an image and reverse it. In the case of binoculars (Keplerian Telescope), the image created by the objective lens is reversed, and the Porro prisms will reverse it to the erect position again.

Spherical lens

- Spherical lenses have equal radii of curvature in all meridia.
  - ***Convex or plus lenses:***
    - Plus lenses are used for the correction of hyperopia, presbyopia, and aphakia.
    - They refract light rays so as to make them more convergent (or less divergent).
    - Plus lenses are *thicker in the middle and thinner at the edges*.
    - A Plus lens in meniscus form (Figure 6), in which the front surface is more convex than the back surface is concave, is the most desirable lens form for spectacles, because there is less aberration over a wider area of the lens. A plano-convex plus lens will also reduce aberration.
    - When a nearby object is viewed through a plus lens, the object looks *larger*.
    - If the lens is moved slightly from side to side, the object appears to move in the direction *opposite* to the movement of the lens.
  - ***Concave or minus lenses:***
    - Minus lenses are used to correct myopia.
    - They refract light rays so as to make them more divergent (or less convergent).
    - Minus lenses are *thin in the middle and thick at the edges*.
    - Minus lenses can be made in many forms (figure 6).
      - The meniscus form is the most common design used in minus spectacle lenses
      - Biconcave (Myodisk) lenses are used on patients who need very strong minus lenses. They induce less peripheral distortion, but offer a smaller focused central field than the meniscus lens.
      - High-density plastic (polycarbonate) lenses have a higher refractive index than crown glass and may be used to reduce the thickness of high minus lenses.
    - When a nearby object is viewed through a minus lens, the object looks *smaller*.
    - If the lens is moved slightly from side to side, the object appears to move in the *same* direction as the lens.

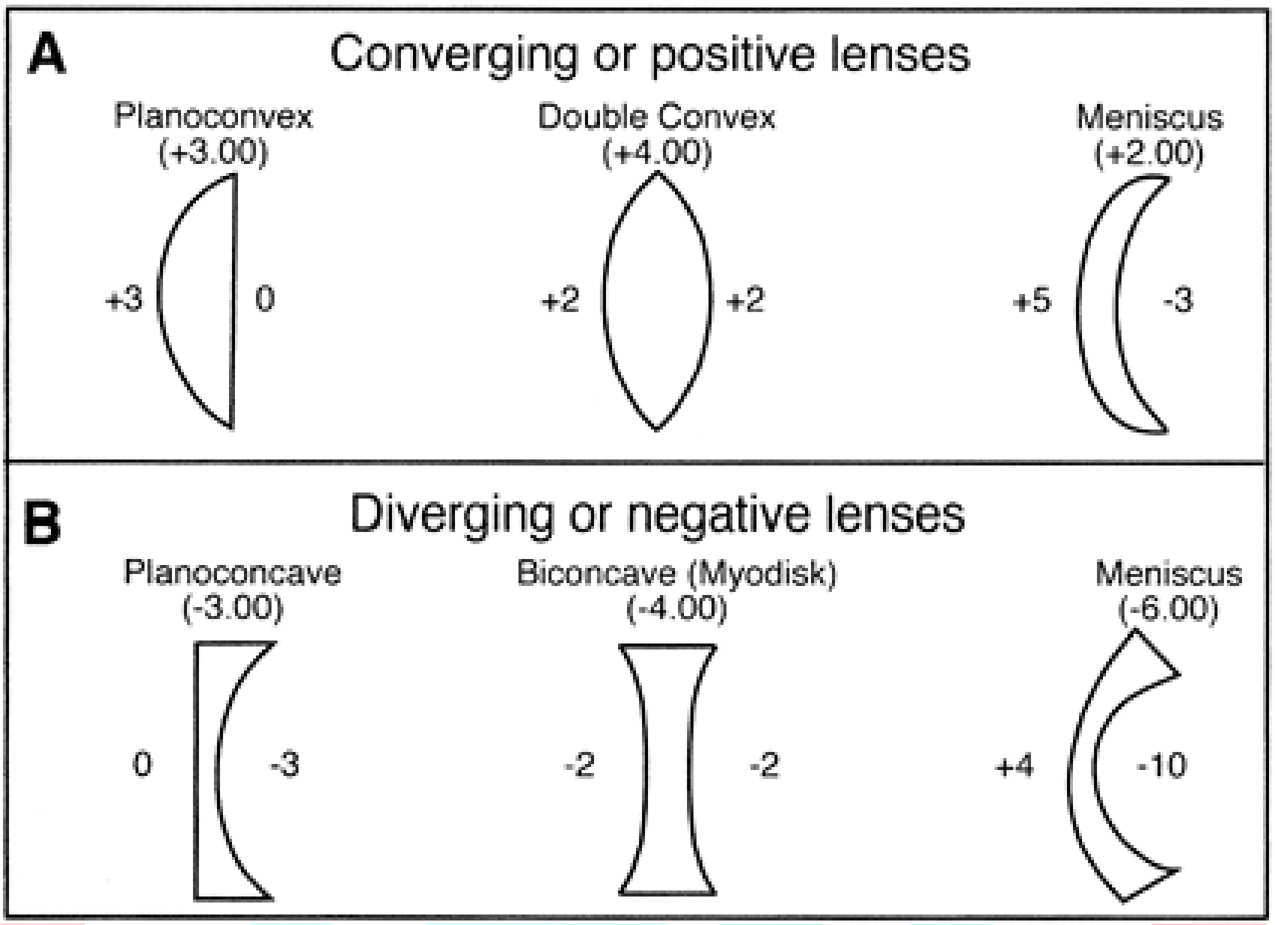

Figure 6: Spherical lens designs. ***(A)*** Plus lenses for correction of hyperopia, presbyopia, and aphakia. ***(B)*** Minus lenses for correction of myopia. *(From Manual of Ocular Diagnosis and Therapy. Pavan-Langston, Deborah, ed. Lippincott Williams & Wilkins, 2008.)*

Astigmatic lens

- Astigmatic or toric lenses are also called spherocylinders.
- These lenses are prescribed to correct astigmatism.
- Toric lenses Design (Figure 7):
  - They have one meridian more curved than all of the others, and the meridian perpendicular to the steepest meridian is flatter than all of the other meridians.
  - The meridians of least curvature and the greatest curvature are always at right angles to one another and are referred to as the principal meridians.
- Toric lenses can be plus lenses, minus lenses, one principal meridian plus and the other minus, meniscus lenses, or they can be constructed in a plano-cylinder form in which one principal meridian has zero optical power.

Manual Identification of lenses

- ❖ Toric lenses can be identified by observing a vertical contour such as a window or door frame through the center of the lens and rotating the lens in a vertical plane (parallel to the surface that is being observed).
- ❖ If the lens is a toric lens, the edge of the vertical contour is broken or discontinuous in the area viewed through the lens. The image will also appear to rotate clockwise or counterclockwise as the lens is rotated back and forth.
- ❖ If the same vertical contour is viewed through the center of a spherical lens, it remains continuous when viewed within and outside the borders of the lens and does not appear to rotate when the lens is rotated.

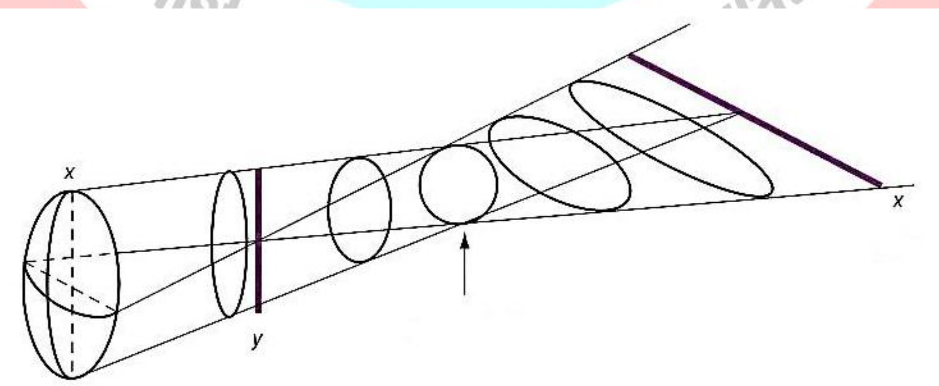

Figure 7: Refraction by a spherocylinder. Because its perpendicular radii of curvature (x, y) are not equal, a spherocylinder does not focus light to a point, but to 2 lines (y focal line, x focal line) in different places. The clearest image is formed at the circle of least confusion. *(Ophthalmic Medical Assisting, An Independent Study Course, E. Newmark & M.A. O'Hara, 6th Edition, 2012, AAO.)*

Chapter 2

Refraction by the eye

Sections

- Refraction by the Eye
- Emmetropia
- Optics of Ametropia (refractive errors).
- Accommodation and Presbyopia.
- Aberrations of Optical Systems (Including the eye).

Refraction by the Eye

The eye as a Camera:

- The likeness of the eye and the camera is remarkable.
    - The focusing elements of the eye are the cornea and the crystalline lens.
    - The “film” is the retina.
- To make the eye as an optical instrument simpler to understand, we use some approximations and resort to ***the schematic or reduced eye***, wherein all light rays are assumed to be paraxial and all elements perfectly aligned on the visual axis (Figure 8).

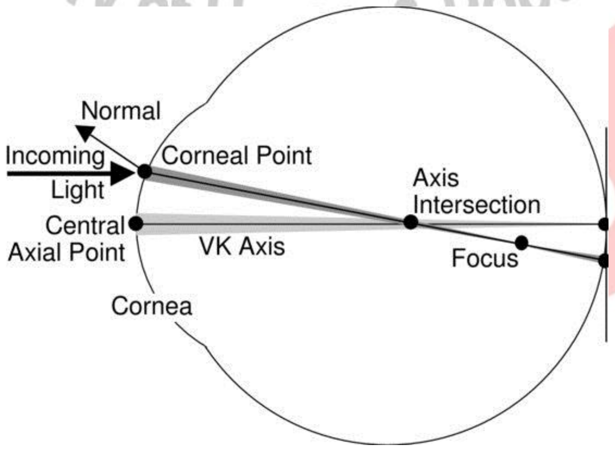

Figure 8: A simple model of the cornea, eye, and the refraction of a ray of incoming light.

- ***The cornea:***
  - It contributes approximately two-thirds of the refracting power of the eye.
  - This is because more deflection of light rays occurs at the air-cornea interface due to of the large difference in index of refraction between these two media.
  - The cornea has an index of refraction of 1.376 and contributes +43 D to the eye (Figure 9).

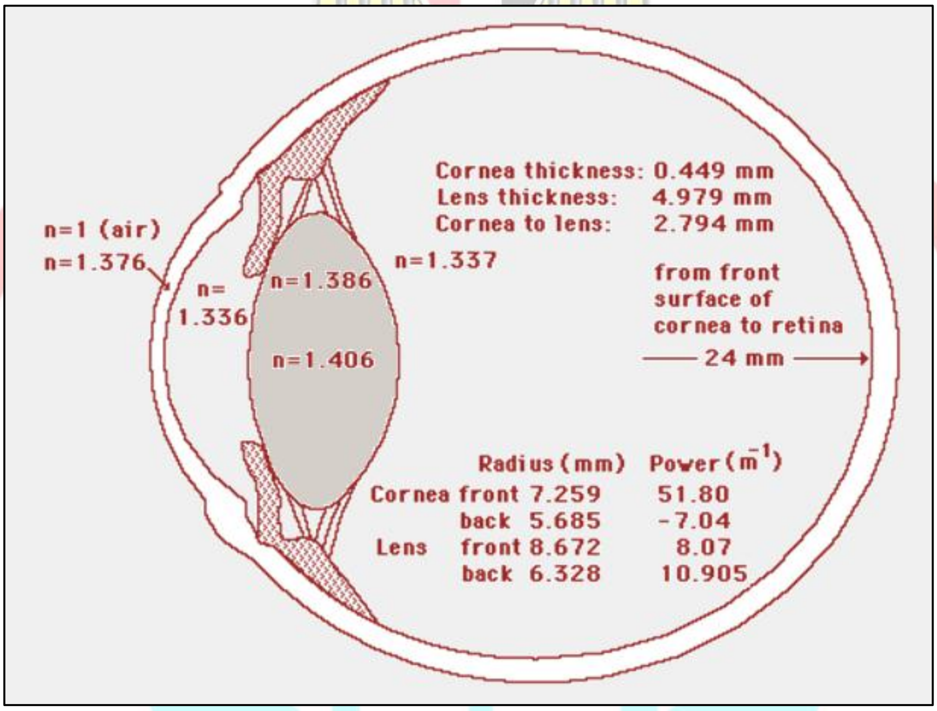

Figure 9: Scale model of the eye.

- ***The crystalline lens:***
  - It has an index of refraction that increases from the cortex to the nucleus, but averages 1.41 with a power of +20 D.
  - Because the cornea and lens are separated, the total power of the eye is not their sum but the equivalent power of +58.7 D (Figure 9).

The crystalline lens is actually a more powerful refracting lens than the cornea in air because it is biconvex and each of its surfaces is more convex than the cornea. The lens, however, is in the aqueous/vitreous medium, and the difference in refractive index at the aqueous/lens and lens/vitreous interfaces is much less.

- ***The pupil:***
  - It is a significant component of the eye's optical system.
  - It can constrict, reducing the amount of light that enters the eye, decreasing aberrations, and increasing the eye's depth of focus.
- ***The retina:***
  - It contains the highly sensitive *rods* for recording images at very low levels of illumination and the color-sensitive *cones* for high resolution and discrimination at high levels of illumination.
- ***Important definitions and Axes of the eye:*** (Figure 10)
  - **The principal line of vision:** is the line passing through the fixation target, perpendicular to the corneal plane.
  - **The pupillary axis:** is the imaginary line perpendicular to the corneal surface and passing through the midpoint of the entrance pupil.
  - **The visual axis**: is the line connecting the fixation target and the fovea.
  - **The optical axis**: is the line that best estimates the line passing through the optical centers of the cornea, lens, and center of the fovea.
  - **The angle alpha (α):** is the angle between the visual axis and the optical axis.
    - This angle is considered positive when the visual axis in object space lies on the nasal side of the optical axis.
  - **The angle kappa (κ)** is the angle between the pupillary axis and the visual axis.
    - *Angle kappa* (κ) is considered positive when the fovea is located temporally, as is the usual case.

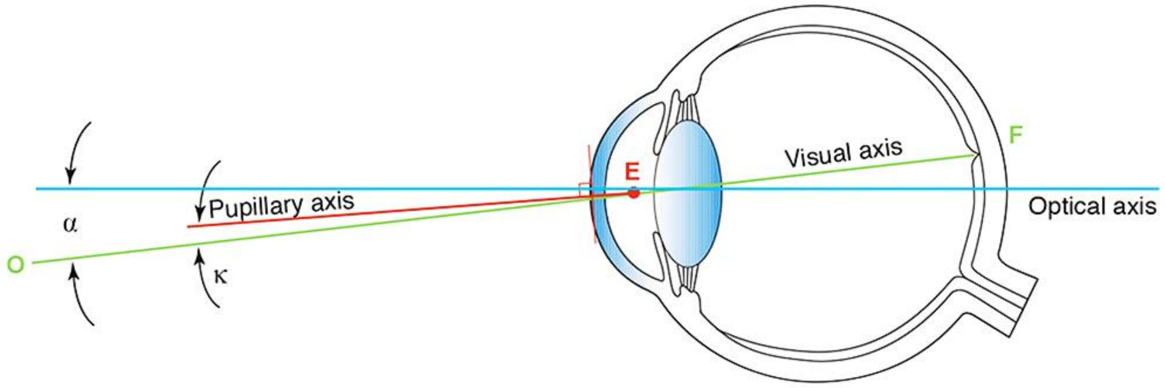

Figure 10: Scale model of the eye. The pupillary axis *(red line)* is represented schematically as the line perpendicular to the corneal surface and passing through the midpoint of the entrance pupil (E). The visual axis *(green line)* is defined as the line connecting the fixation target (O) and the fovea (F). *(From AAO BCSC 3: Clinical optics, 2016-2017).*

Emmetropia

- The eye is considered to be emmetropic if parallel light rays from an object at infinity (i.e. more than 6 meter away) are focused at the plane of the retina when the eye is in a completely relaxed state. (Figure 11)
- An emmetropic eye will have a clear image of a distant object without any internal tuning of its optics.
- It is a rather infrequent condition of the eye.

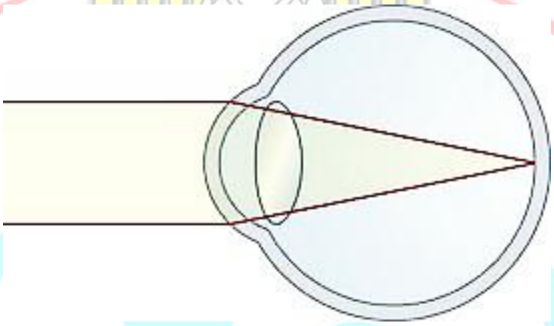

Figure 11: Emmetropic eye. Parallel rays of light come to a focus on the retina. *(From The Ophthalmic Assistant, 9th Edition, H.A. Stein, R.M. Stein and M.I. Freeman, 2013, Elsevier Inc.).*

Optics of Ametropia (Refractive Errors)

- *Ametropia* refers to the absence of Emmetropia and there are three basic abnormalities in the refractive state of the eye (Figure 12):
  - *Hyperopia or hypermetropia*
  - *Myopia*
  - *Astigmatism*

- *Ametropia* can be classified by the likely etiology as:
  - *Axial ametropia:* the eyeball is either unusually long *(myopia)* or short *(hyperopia).*
  - *Refractive ametropia:* the length of the eye is statistically normal (≈24 mm), 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.

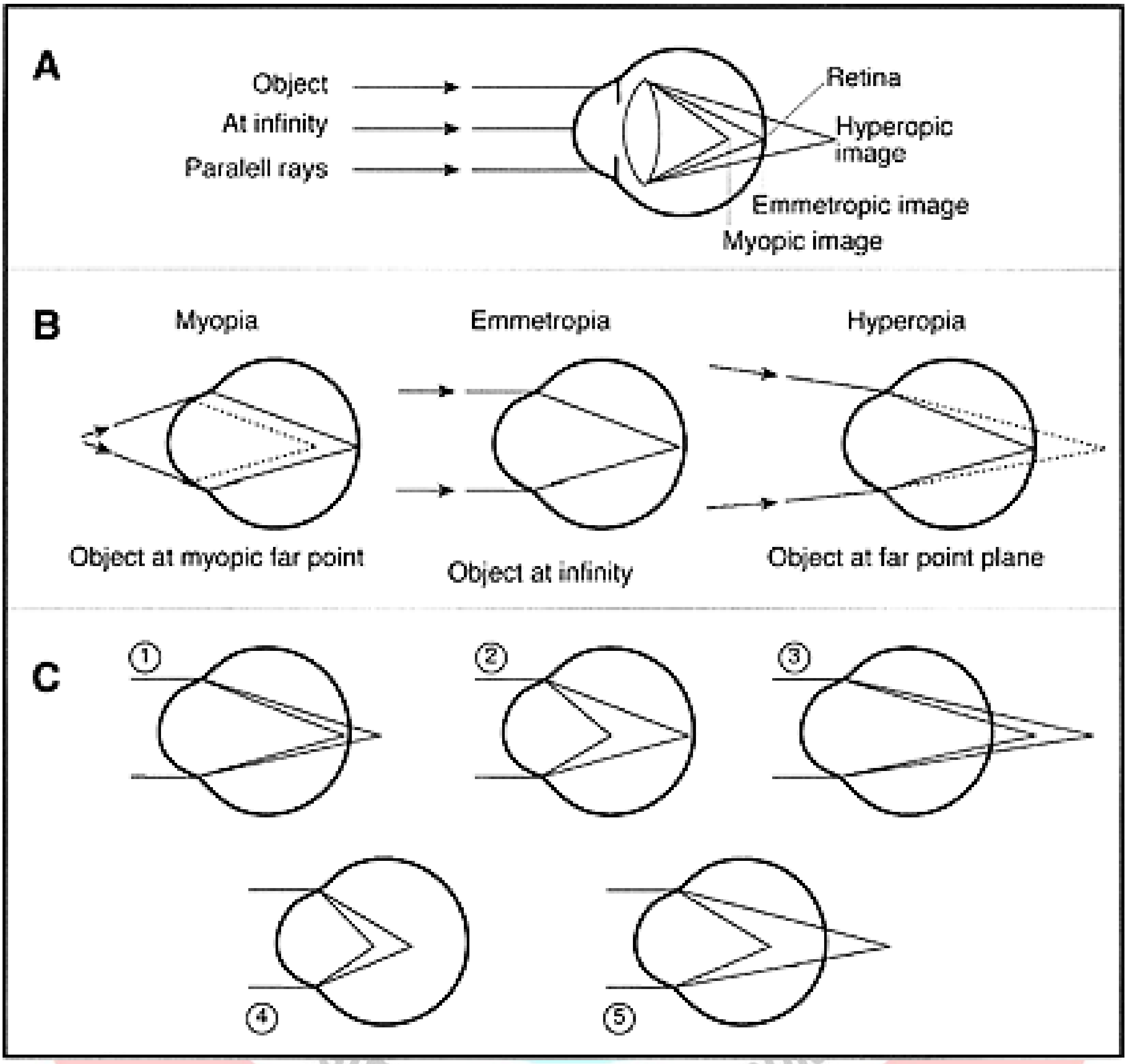

Figure 12: (**A**) Far point (image distance focused on retina in relaxed accommodative state) in myopia, emmetropia, and hyperopia. (**B**) Focal points of myopic, emmetropic, and hyperopic eye with reference to the retinal plane. (**C**) Focal points of astigmatic principal meridians (objects at infinity): (***1***) simple hyperopic astigmatism, emmetropia/hyperopia; (***2***) simple myopic astigmatism, emmetropia-myopia; (***3***) compound hyperopic astigmatism, (***4***) compound myopic astigmatism; (***5***) mixed astigmatism. *(From Manual of Ocular Diagnosis and Therapy. Pavan-Langston, Deborah, ed. Lippincott Williams & Wilkins, 2008.)*

Hypermetropia (Hyperopia):

- This is also referred to as farsightedness.
- It is the condition of refraction when the focused image is formed behind the plane of the retina in ametropia; the eye is too short and is considered hyperopic (Figure 12-A & B).
- ***Structural hyperopia is based on the anatomic configuration of the eye:***
  - In *axial hyperopia*, the eye is shorter than normal in its anteroposterior (AP) diameter, although the refracting portions (e.g., lens, cornea) are normal.
  - *Refractive Hyperopia:*
    - *Curvature hyperopia* results when either the crystalline lens or the cornea has a weaker than normal curvature and consequently lower refractive power.
    - *Index of refraction hyperopia* is the result of decreased index of refraction due to decreased density in some or several parts of the optic system of the eye, thus lowering the refractive power of the eye.

The effect of aging on hyperopia:

- It results from progressive loss of accommodative power, thus moving the eye from latent and facultative hyperopia to greater degrees of absolute hyperopia.
- Most children are born about +3 D hyperopic, but this usually resolves by age 12 years.
- Near images can be blurred unless there is sufficient accommodation, as in children.
- Unless the optical system of the eye is actively altered to produce an increase in its power, hyperopic eyes will have blurred images for distant objects also, as any elderly hyperope will confirm.

- ***Accommodation in hyperopia:***
  - Accommodation is of greater importance than the structural factors leading to it because accommodation is a key dynamic factor in correcting at least part of the refractive error.
    - *Latent hyperopia*:
      - It is that part of the refractive error completely corrected by accommodation.
      - Latent hyperopia is the difference in measurement between manifest hyperopia and the results of the cycloplegic refraction (which reveals total hyperopia, latent and manifest).
    - *Manifest facultative hyperopia*:
      - It is that portion of hyperopia that may be corrected by the patient's own power of accommodation, by corrective lenses, or both.
      - Vision is normal with or without corrective plus lenses, but accommodation is not relaxed without the glasses.
    - *Manifest absolute hyperopia:*
      - It is that part of the refractive error that cannot be compensated for by the patient's accommodation.
      - Distance vision is still blurred, no matter how much accommodative power the patient uses.
      - These patients readily accept the plus lenses.

- ***Treatment of hyperopia:***
  - Glasses:
    - It is usually most satisfactory when slightly less power (1 D) than the total of facultative and absolute hyperopia is given to a patient with no extraocular muscle imbalance.
    - If the total manifest refractive error is small (e.g., 1 D or less), correction is given only if the patient is symptomatic.
  - Contact lenses and refractive may be helpful for selected cases.

Symptoms of hyperopia

- Frontal headaches worsening by prolonged use of near vision.
- "Uncomfortable" vision (asthenopia) when the patient must focus at a fixed distance for prolonged periods (e.g., a television). Accommodation fatigues more quickly when held in a fixed level of tension.
- Blurred distance vision with refractive errors greater than 3 to 4 D or in older patients with decreasing amplitude of accommodation.
- Near visual acuity blurs at a younger age than in the emmetrope (e.g., in the late 30s).
- Light sensitivity (photophobia) is common in hyperopes, is of unknown etiology, and is relieved by correcting the hyperopia without needing to tint the lenses.
- Sporadic sudden blurring of vision is due to a quick change in or spasm of accommodation. The accommodative spasm may be detected by cycloplegic refraction, which will reveal the underlying hyperopia.

Myopia:

- When the focused image is formed in front of the plane of the retina in ametropia, the eye is too long and is considered myopic.
- This is referred to as nearsightedness, because there is a point less than 6 m in front of the eye that will be coincident with the retina when the optical system of the eye is relaxed (Figure 12 –A & B).
- ***Types of myopia***
    - *Axial myopia:*
        - The AP diameter of the eye is longer than normal, although the corneal and lens curvatures are normal and the lens is in the normal anatomic position.
    - Refractive myopia:
        - In *curvature myopia:*
            - The eye has a normal AP diameter, but the curvature of the cornea is steeper than average (e.g. congenitally or as in keratoconus), or the lens curvature is increased (e.g. congenitally as in lenticonus).
        - *Increased index of refraction:*
            - This happens to the lens due to onset of early to moderate nuclear sclerotic cataracts is a common cause of myopia in the elderly. The sclerotic change increases the index of refraction, thus making the eye myopic.
- ***Clinical course:***
    - Myopia is rarely present at birth, but often begins to progress as the child grows. It is usually detected by age 9 or 10 years in the school vision tests and will increase during the years of growth until it becomes constant around 18 years of age, usually at about 5 D or less.
- **Symptoms of myopia:**
    - Blurred distance vision.
    - Squinting to sharpen distance vision *(pinhole effect through narrowing of the palpebral fissures).*
    - ***Headaches are rare.***

- **Treatment of myopia:**
  - Glasses:
    - Children should be fully corrected and, if under 8 years of age, instructed to wear their glasses constantly both to avoid developing amblyopia if the error is high. If the refractive error is low, the child may wear the glasses intermittently as needed, (e.g., at school).
    - Adults are usually comfortable with their full myopic correction.
  - Contact lenses and refractive may be helpful for selected cases.

Pathological (progressive) myopia (Figure 13)

- It is an uncommon form of myopia that increases yearly and is associated with vitreous floaters, liquefaction, and chorioretinal changes.
- The refractive changes usually become stable at about 20 years of age but occasionally may progress until the mid-30s and frequently result in degrees of myopia of 10 to 20 D.

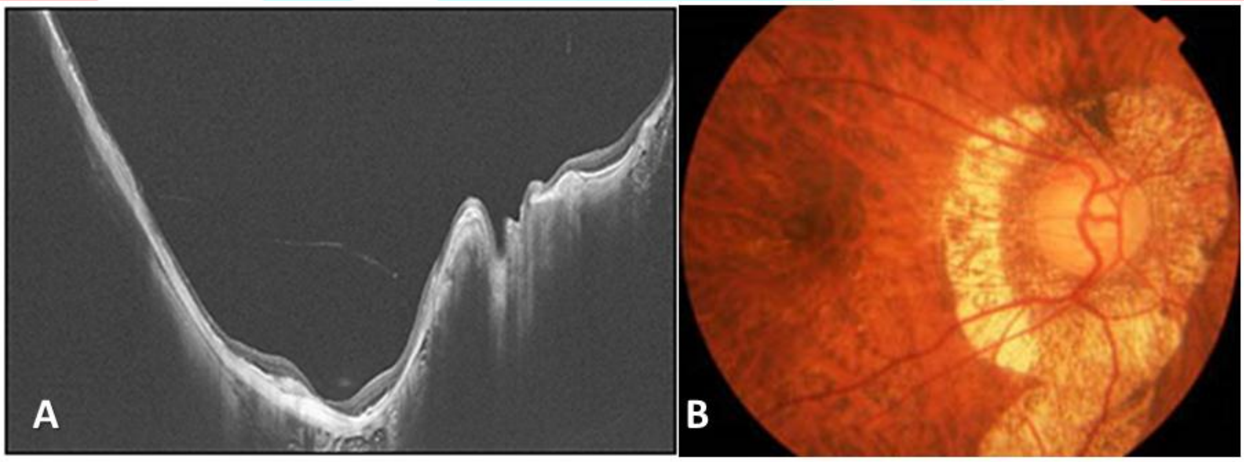

Figure 13: **(A)** Optical coherence tomography (OCT) showing posterior staphyloma in pathological myopia. **(B)** Fundus picture showing chorioretinal degeneration in pathological myopia.

Astigmatism:

- Astigmatism is a type of refractive error where the refraction varies in different meridian; therefore, the rays of light entering in the eye cannot converge on a focus point, but form focal lines.
- Astigmatism causes asymmetric blur, i.e. some parts of an image are more out of focus than others. It causes images to appear distorted, or sometimes even double. Certain letters may be more difficult to read than others, depending on the orientation of the lines within them.
- ***Causes of Astigmatism:***
    1. *Corneal astigmatism:*
        - It results from abnormalities of curvature of the cornea.
    2. *Lenticular astigmatism*: rare.
        - *Curvature*: due to abnormalities of curvature of lens as seen in lenticonus
        - *Positional*: due to tilting, or oblique placement of lens as seen in subluxation
    3. *Retinal astigmatism*:
        - Due to the oblique placement of macula, is seen occasionally in pathological myopia and other less common conditions.
- ***Types**: (Regular and Irregular Astigmatism)*

    A. Regular astigmatism

    - The astigmatism is regular when the refractive power changes uniformly from one meridian to another.
    - Depending upon the axis and the angle between the two-principle meridians, regular astigmatism can be classified into the following three types:
        - Horizonto-vertical astigmatism:
            - The two principal meridians are placed at right angles to one another and those are in the horizontal (180 +/- 20) and vertical planes (90+/- 20). According to the postiton of the steep meridian it is further classified:
            - With the rule astigmatism:
                - When the vertical meridian is steeper than the horizontal meridian

- ♦ This can be corrected either by a – (minus) cylinder x 180 or + (plus) cylinder x 90.
- Against the rule astigmatism:
  - ♦ The horizontal meridian is steeper than the vertical meridian.
  - ♦ It is also known as inverse astigmatism.
  - ♦ It causes more symptoms and should be corrected for minimal error. This can be corrected either by – (minus) cylinder x 90 or + (plus) cylinder x 180.
- ♦ Oblique astigmatism:
  - ▪ When principle meridians are at right angles, but are not vertical and horizontal.

B. **Irregular astigmatism**

- ▪ Irregularities in the curvature of the cornea cause Irregular Astigmatism.
- ▪ The principal meridians are not at right angles.
- ▪ Every meridian in the cornea has a separate type of refraction
- ▪ It can never be corrected by spectacles.

Refractive types of regular astigmatism (Figure 12- C)

- Depending upon the position of the focal lines in relation to the retina, regular astigmatism is further classified into three types,

A. Simple astigmatism:

- ▪ Here the rays are focused on the retina in one meridian and in front or behind the retina on the other meridian, as in simple hyperopic (Figure 12-C 1) or simple myopic (Figure 12-C 2) astigmatism.

B. Compound astigmatism

- ▪ Here neither of the two foci lies upon the retina but are placed in front or behind it. The former is known as compound myopic (Figure 12-C 4), the later as compound hyperopic astigmatism (Figure 12-C 3).

C. Mixed astigmatism

- ▪ One focus is in front of and the other behind the retina, so that the refraction is hyperopic in one direction and myopic in the other (Figure 12-C 5).

Tools used in evaluation of astigmatism: (Figure 14)

- *Examination by placido disc: (Figure 14-A)*
  - This is a flat disc bearing concentric black and white rings. A convex lens is mounted in an aperture in the center of the disc.
- *Retinoscopy by concave mirror/streak.*
- *Use of astigmatic fan: (Figure 14-B)*
  - Astigmatic fan is a construction of vertical lines at a different angle meridian from 0 to 180 degrees.
  - When a patient with astigmatic error looks at the fan some lines seem to be clearer than others, which help to detect the axis of astigmatism.
- *Stenopaeic slit: (Figure 14-C)*
  - The stenopaeic slit can be used to determine the refraction and principle axis in astigmatism.
  - The slit aperture acts as an elongated 'pinhole', only allowing light in the axis of the slit to enter the eye.
- *Keratometry.*
- *Jackson cross cylinder: (Figure 14-D)*
  - The cross cylinder is a spherocylinder lens in which the power of the cylinder is twice the power of the sphere and of the opposite sign. It is used to refine power and axis of cylindrical power.

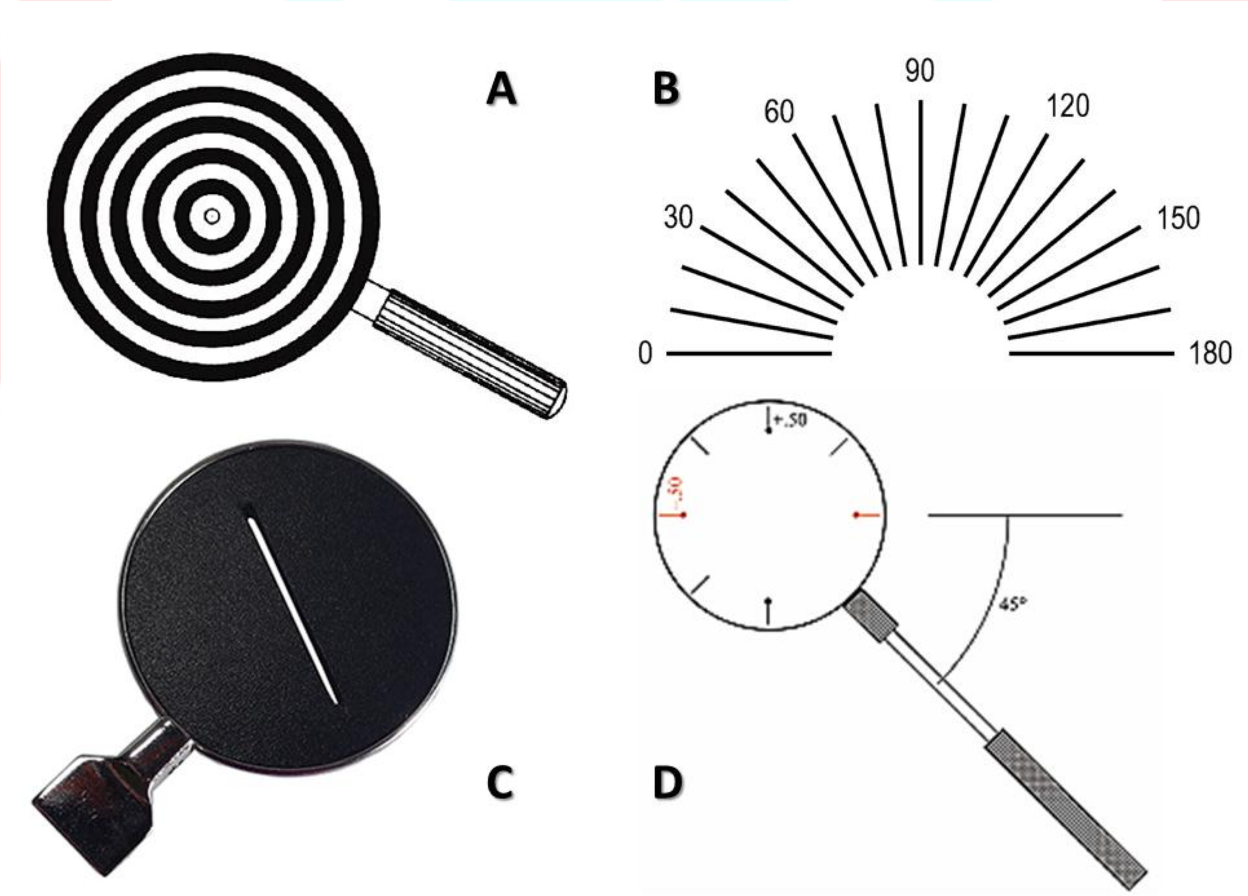

Figure 14: Astigmatism evaluation tools. **(A)** Placido disc. **(B)** Astigmatic fan. **(C)** Stenopaeic Slit. **(D)** Jackson's Cross Cylinder.

Treatment of Astigmatism:

- **Regular astigmatism**
  - Optical correction:
    - Spectacle (spherocylindrical lenses).
    - Contact lens (toric lens - prism balast lenses).
  - Surgical treatment:
    - Laser assisted insitu Keratomileusis (LASIK).
- **Irregular astigmatism**
  - **Hard/semi-soft contact lens.**
  - Surgical treatment:
    - Keratoplasty in central area of conical cornea
    - Excision of scar + replacement by graft.

Key points to remember in correction of astigmatism
- Minimum cylinder, maximum comfort
- Give minus cylinder for more comfort
- For high cylinder, it is better to do keratometry
- Refine axis and power before finalizing prescription
- Check binocular comfort subjectively

Anisometropia

- It is a state in which there is a difference in the refractive errors of the two eyes (i.e., one eye is myopic and the other hyperopic [antimetropia], or both are hyperopic or myopic but to different degrees).
- This condition may be congenital or acquired due to asymmetric age changes or disease.
- In anisometropia, the patient is usually visually uncomfortable due to
  - Visual acuity differences between the two eyes.
  - ***Aniseikonia:*** difference in size of the ocular image in each eye (possibly causing retinal rivalry).
- Treatment
  - In children, both eyes should receive the best visual correction and any muscle imbalance identified and corrected with prisms or surgically.
  - Adults should receive the best correction that *will not result in ocular discomfort*. Usually the more ametropic (poorer) eye is undercorrected in spectacles.
  - Contact lens use allows for full correction in both eyes by minimizing the effects of aniseikonia and thus maximizing binocularity.

Accommodation and Presbyopia

- Accommodation is the mechanism by which the eye changes refractive error by altering the shape of its crystalline lens.
- **Mechanism of accommodation:**
  - The key feature of accommodation is an *increase in the curvature of the lens* which affects mainly the anterior surface. This occur secondary to contraction of the ciliary muscle and relaxation of the zonules holding the lens in place (Figure 15).
  - This alteration in shape inverses the convergent power of the eye, so that the focus can be altered as and when required.
- **Types of accommodation:**
  - *Physical accommodation (Accommodative response)*
    - The ability of the lens to alter its shape is called physical accommodation. It is measured in diopters.
  - *Physiological accommodation (Accommodative effort)*
    - The power of the ciliary muscle to contract is called physiological accommodation.
- **Characteristic features of accommodation:**
  - *Range:*
    - Distance between the far point of accommodation and near point of accommodation is known as range of accommodation.
  - *Amplitude:*
    - The dioptric difference between the far point of accommodation and near point of accommodation is known as amplitude of accommodation.

- **Far point of accommodation:**
  - The maximum distance from the eye where a clear image can be formed on the retina
  - In emmetropia, it is at infinity. In myopia, it is in front of the eye. In hyperopia, it is behind the eye.
- **Near point of accommodation:**
  - The closest distance from the eye where a clear image can be formed on the retina.

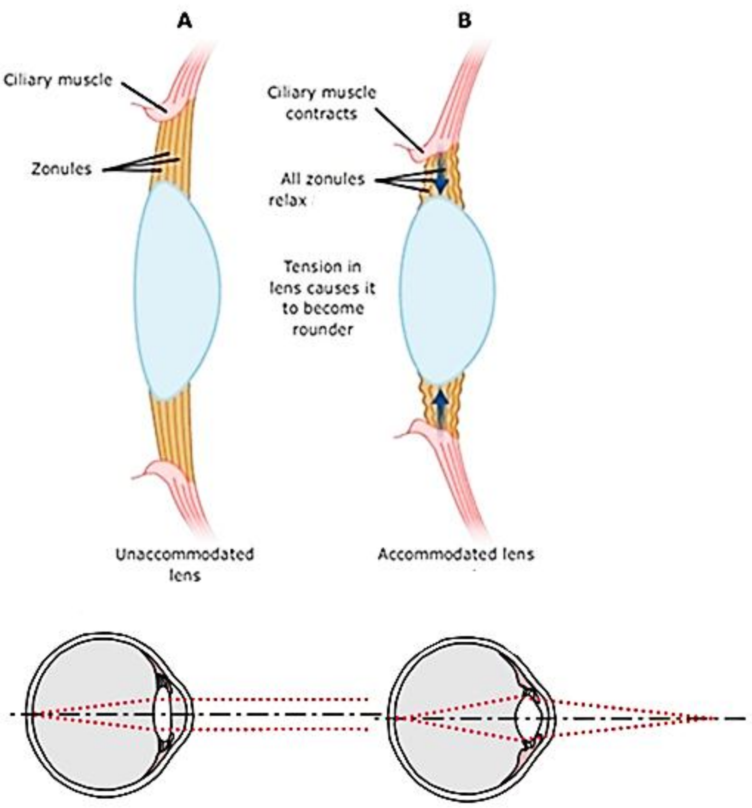

Figure 15: Accommodation. **(A)** Accommodation relaxed. **(B)** Accommodation reflex in response to viewing a near object.

Presbyopia:

- It is an age related progressive loss of the focusing power of the lens.
- This results in difficulty in reading and seeing near objects.
- People usually notice the condition around age 40; after they realize that they need to hold reading materials further away in order to focus.
- **Etiology:**
  - Not actually known but theories suggest that loss of accommodation is either due to gradual loss of contracting power of the ciliary muscle and/or a gradual decline in the the inherent elasticity of the lens with advancing -age.
  - This causes inability to read at normal reading distance (33 cm to 40cm).

Treatment

Presbyopia can be corrected with appropriate lenses, so that his accommodation is reinforced and the near point is brought within the useful working distance.

- Know the working distance of the patient for proper addition
- Refraction
- Determine the amplitude of accommodation
- Supplement this by lens - allowing him a sufficient reserve of accommodation.

For example

- Emmetropic working distance = 25 cm, Requires amplitude of accommodation = 4 D (100/25)
- Near point receded at - 50 cm, so Accommodation - 100/50 = 2D
- Keep 1/3 reserve for comfort - 1/3x2 = 0.66 , so the available accommodation will be (2/3 of amplitude) = 1.3D (2-0.66)
- Required lens = 4-1.3 D=2.7 DS

Types of corrective spectacle for presbyopia

1. Single vision reading glasses.
2. Bifocals: where glasses are given for near and distance (Figure 16-A).
3. Trifocals: where glasses are given for distance, intermediate and near vision (Figure 16-B).
4. Varifocals (Multifocal): progressive addition lens (Figure 16-C).
5. Monovision correction: one eye is corrected for distance and the other eye for near

Key points to remember

- *Presbyopic spectacle should never be prescribed automatically based on age.*
- *Lenses must be comfortable.*
- *Vision for the particular work for which their spectacle is intended must be kept in mind.*
- *Start with an addition of +0.75D.*
- *Better to under correct than overcorrect.*
- *Lenses that bring the near point closer than 28cm are rarely tolerated.*
- *Usual discomfort for presbyopic optical correction is due to over correction.*

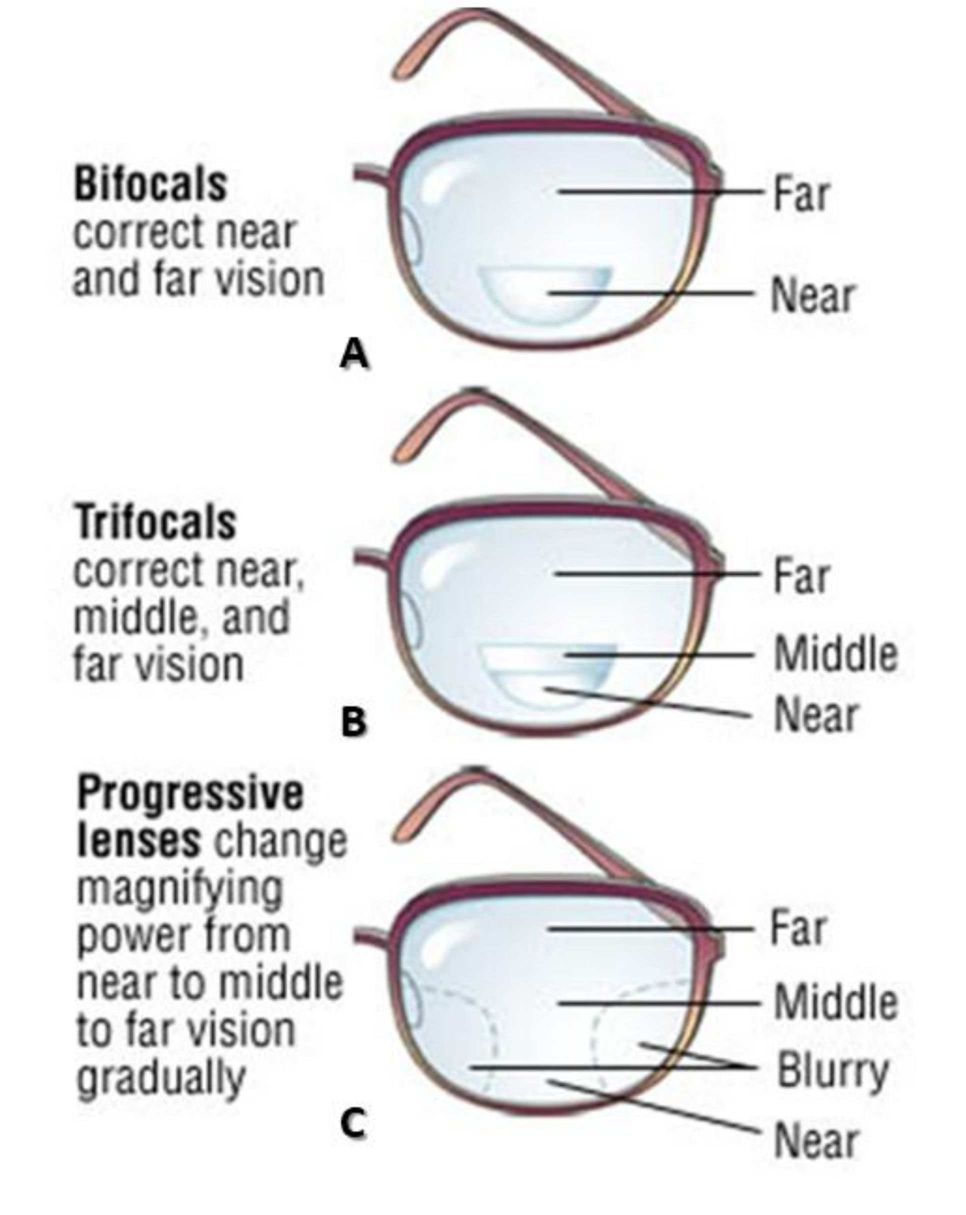

Figure 16: Presbyopic multifocal spectacles. **(A)** Bifocal design. **(B)** Trifocal design. **(C)** Varifocal or progressive lens design.

Aberrations of optical systems including the eye

- Optical aberrations are sources of image distortions due to imperfect optical systems (i.e. non-Ideal optics). These aberrations affect all optical systems including the eye.
- There are three major categories of optical aberrations:
  - ***On-axis or Axial aberrations:***
    - Chromatic aberrations (Figure 17-A)
    - Spherical aberrations (Figure 17-B)
  - ***Off-axis Aberrations*** include coma (Figure 15-C), oblique astigmatism, and field curvature.
  - ***Geometrical distortion*** which includes both **barrel** and **pincushion** distortion (Figure 17-D).
- There are many ways that can reduce or eliminate the aberrations of optical systems such as:

a) **Pupil (iris/diaphragm):**
  - The pupil of the eye or aperture in a diaphragm block peripheral and off-axis rays and allow only axial and central rays to pass.
  - This helps in reduction of Spherical and off-axis aberrations.

b) **Aspheric lens design:**
  - The lens is designed to have flatter periphery than center.
  - This will help reduce spherical aberration.

c) Changing the refractive index of lens parts:
  - As in doublets which combined lenses with different Refractive indices
  - This is beneficial in elimination of chromatic aberrations.

d) A combination of these solutions can be implemented to optimizes the optical system e.g. Use of Aspheric doublets.

> The eye has iris and pupil which work as a diaphragm to block the off axis rays and the cornea and lens have slightly aspheric design that add to the reduction of aberrations of the eye as an optical system.

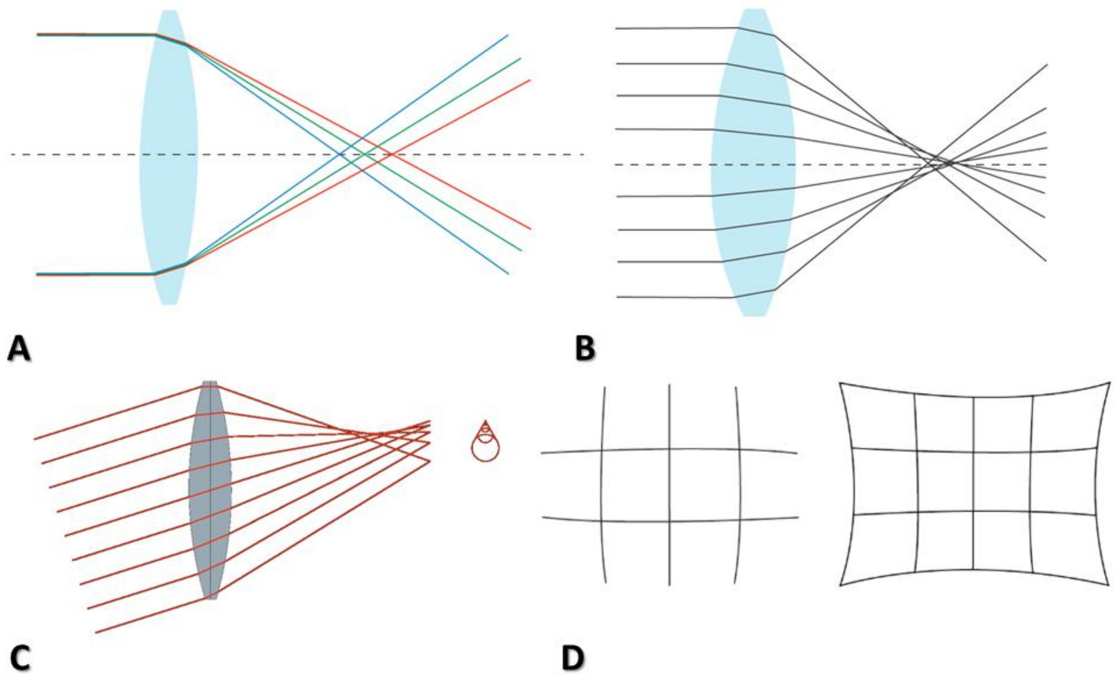

Figure 17: Examples of common optical aberrations encountered in different optical systems. **(A)** Chromatic aberrations. **(B)** Spherical aberration. **(C)** Coma Aberration. **(D)** Barrel and Pincushion distortions.

Pinhole effect (Figure 18)

- The pinhole disc, if placed before the eye, eliminates peripheral rays of light, improves contrast and generally improves vision to almost within normal limits if the patient has a refractive error.
- The pinhole disc serves to differentiate visual loss caused by refractive errors from poor vision resulting from disease of the eye which does not improve when a pinhole disc is placed before the eye

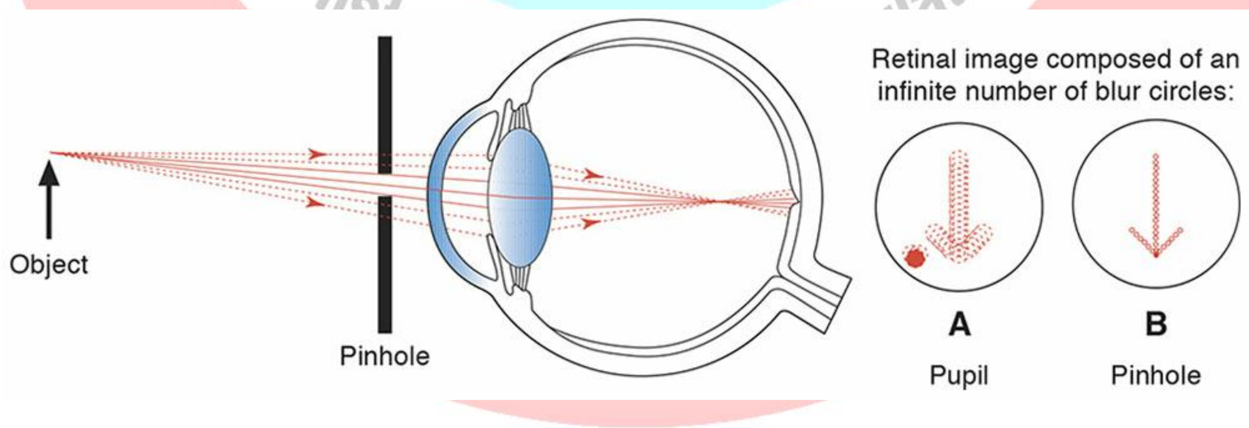

Figure 18: Light rays from an object *(upright arrow)* form a blur circle on the retina of a myopic eye. **(A).** If a pinhole is held in front of the eye, the size of each blur circle is decreased; as a result, the overall retinal image is sharpened **(B).** *(From AAO BCSC 3: Clinical optics, 2016-2017).*

Chapter 3
Refraction and spectacle prescription

Sections

- Refraction and retinoscopy
- Spectacle prescriptions
- Contact lenses

Refraction and retinoscopy

- Refraction is the term applied to the various testing procedures employed to measure the refractive errors of the eye to provide the proper correction.
- Refraction can be done by two main methods :
  - Objective refraction by a retinoscope or an autorefractometer.
  - Subjective refraction by a trial lens set and vision chart.

> Refractive errors are by far the most common cause of decreased vision.

- ***Objective refraction:***
  - **<u>Retinoscopy(Manual refraction):</u>**
    - It is an objective method of analyzing the optics of the patient's eye to determine the refractive error.
    - A retinoscope (figure 19) is a handheld instrument that the examiner uses to illuminate tithe inside of the patient's eye and observe the light rays (reflected from the retinal pigmented epithelium and choroid) as they emerge from the patient's eye.

Figure 19: Handheld streak retinoscope.

- This process involves moving the streak of light back and forth across a series of lenses held in front of the patient's pupil, resulting in a linear light reflex moving in the same (hyperopia) or opposite direction (myopia) as the light (Figure 20).

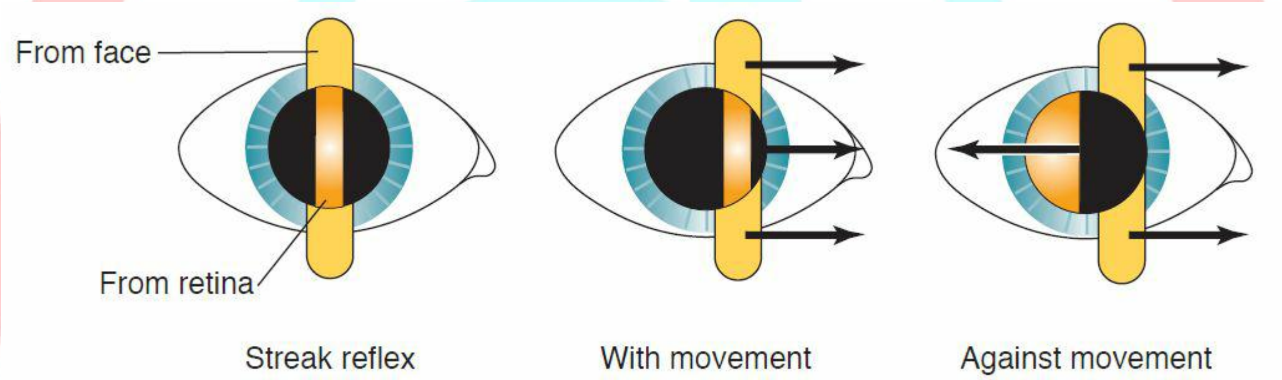

Figure 20: Retinal reflex movement. Note movement of the streak from face and from retina in *with* versus *against* movement. *(From AAO BCSC 3: Clinical optics, 2016-2017).*

- The filling of the entire pupil with light that does not move indicates neutralization of the refractive error in that meridian and is the end-point reading for that meridian (Figure 21).

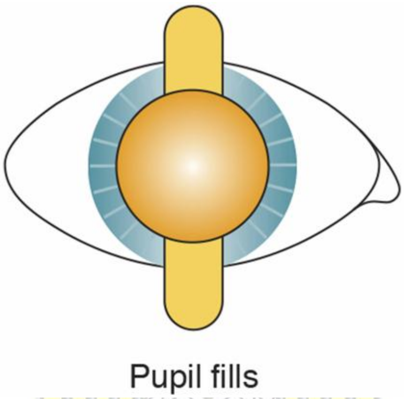

Figure 21: Neutrality reflex in retinoscopy. *(From AAO BCSC 3: Clinical optics, 2016-2017).*

- The linear streak of light can be rotated 360 degrees through the pupil to examine different meridians of the eye.
- In the case of astigmatism, the retinoscope streak must be aligned along a principal meridian (the clearest light streak as the retinoscope light is rotated) (Figure 22) and plus or minus lenses put up until movement of light in that meridian is neutralized and the lens power recorded. This is repeated in the meridian 90 degrees away for the second lens and axis.

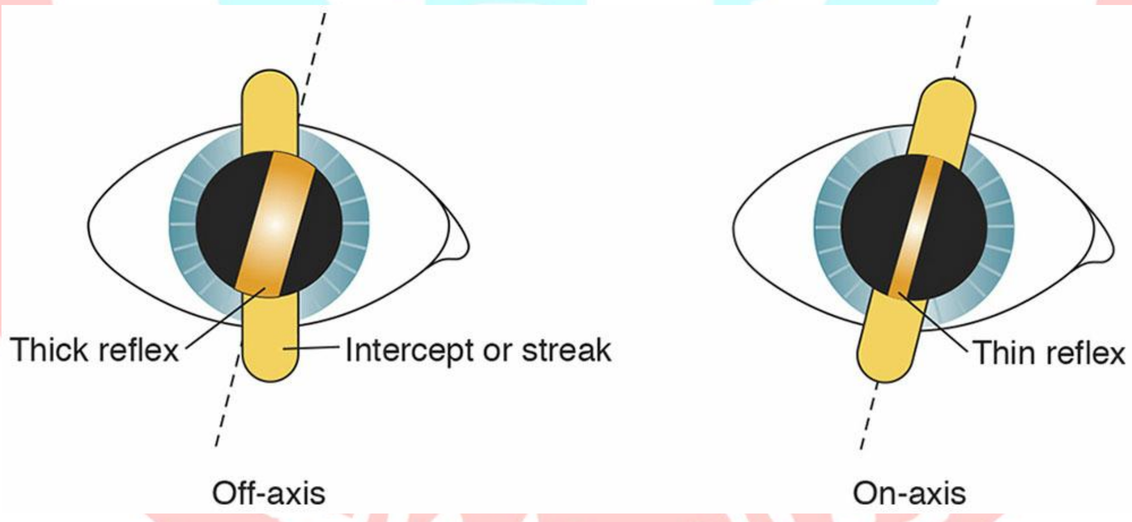

Figure 22: Width, or thickness, of the retinal reflex. The examiner locates the axis where the reflex is thinnest *(dashed lines)*. *(From AAO BCSC 3: Clinical optics, 2016-2017).*

- By knowing what lenses are required, it is a simple matter to calculate the amount of ametropia.
- Opacities of the media, tiny pupils, poor fixation by the patient, or distortion of the light reflex can all be sources of error and difficulty.
- A practical summary of the retinoscopy technique is provided in appendix 1.

➢ **<u>Automated refraction:</u>**

- In general, automated refractometers (figure 23) are highly accurate.
- The instrument must be properly in line with the patient's visual axis, accommodation must be relaxed, the pupil must be of satisfactory size, and the media must be sufficiently clear.
- The primary role for these instruments is increased efficiency with which eye care is delivered by obtaining the ***approximate refractive error***, which then should be manually refined by the specialist.

> ✓ Prescribing lenses on the basis of retinoscopy findings (or the autorefractometer) alone can too often result in a prescription that is not well tolerated by the patient.
>
> ✓ Refinement by subjective refraction is mandatory to ensure patient comfort.

Subjective refraction:

- ➢ In this method the examiner relies on patient responses to reach the final prescription.
- ➢ Retinoscopy/automated refraction findings or previous spectacle power may be the starting guide for subjective refraction.
- ➢ In the absence of astigmatism, the refraction is simply a matter of adding more plus or minus power until the patient reads his or her best visual acuity with ***the most plus or least minus power***.
- ➢ Refractions involving astigmatism are refined by the fogging technique, astigmatic fan, stenopaeic slit and Jackson cross-cylinder (JCC) techniques as discussed before (figure 14).
- ➢ A practical summary of different refinement techniques is provided in appendices 2-4.

Cycloplegic refraction:

- ✓ Cycloplegia is the use of pharmaceutical agents to temporarily paralyze the ciliary muscle, hence stabilizing the eye's accommodative reflex and allowing for the measurement of a definitive end point.
- ✓ Cycloplegic refraction is particularly useful in young patients (especially children below 7 years of age) with highly active accommodation.
- ✓ This confirms complete relaxation of the ciliary muscle, allowing for the accurate measurement of the ametropia in young hyperopes, thereby avoiding overcorrection.
- ✓ Methods of inducing cycloplegia include 1% cyclopentolate, one drop every 10 minute for two applications *in the office* 30 minutes prior to refraction, or atropine 1%, one drop three times/day for *3 days before the refraction*.

Spectacles

- Most forms of ametropia can be corrected by spectacles.
  - Plus (convex) lenses are used to correct hyperopia, presbyopia, and aphakia.
  - Minus (concave) lenses are used to correct myopia.
  - Spherocylindrical lenses are utilized for the correction of regular astigmatism.
- Most corrective lenses are made in the meniscus form to reduce aberrations and to provide a better cosmetic effect.
- **Lens material and safety:**
  - Lenses are generally made impact resistant; that is, they must comply with American National Standards Institute (ANSI) standard Z-87.1-1989 and withstand the impact of a 1.5-cm steel ball dropped from a height of 127 cm.
  - Glass lenses are generally made of crown glass with an index of refraction of 1.523, with a minimum thickness of 2 mm, and they are heat-treated or chemically altered to make them shatterproof.
  - Plastic lenses are naturally shatterproof and lighter in weight, but tend to scratch more easily. Because most plastic resins have a density less than that of crown glass, they may be a little thicker than the same diameter glass lens of equal power.
  - Glass and plastic are equally acceptable for the correction of ametropia, but depending on the power required and the frame style, one may have benefits over the other in certain conditions.
- **Lens shapes in extreme corrections:**
  - In high minus lenses, a myodisc form (Figure 23) may be used to reduce the weight by grinding the peripheral portion of the lens surfaces parallel to one another so that only the central portion is corrective. This also reduces the edge thickness.
  - High plus lenses can be made in a lenticular form (Figure 24), in which only the central portion is corrective and the peripheral surfaces are parallel to one another.
  - High plus and high minus lenses can also be made in an aspheric form by modifying the lens curvature peripherally to reduce aberrations and provide better peripheral vision.

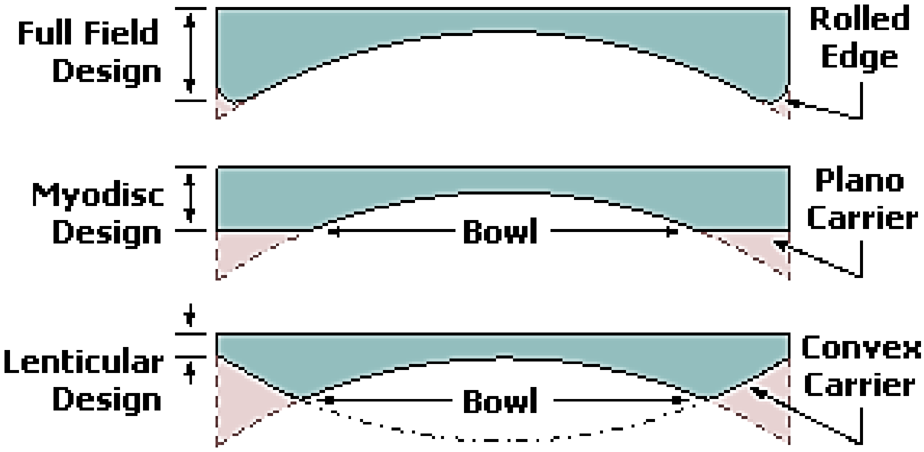

Figure 23: lens designs for high myopia.

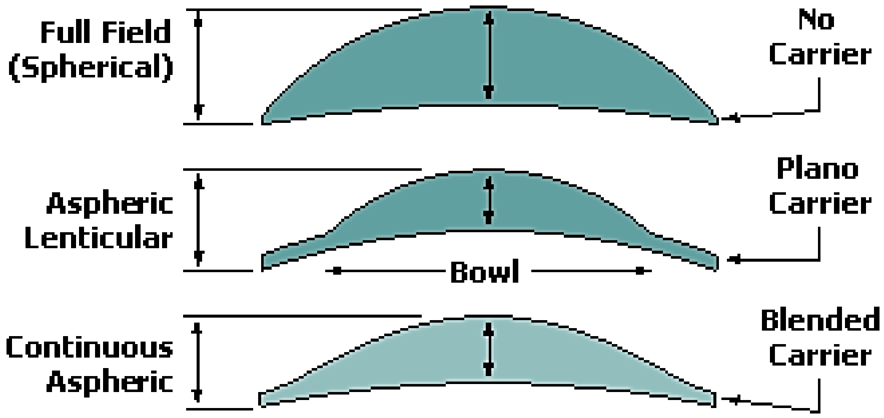

Figure 24: lens designs for high hyperopia.

Tinted lenses:

- Lenses may be tinted for comfort, safety, or cosmetic effect.
- Sunglasses are generally tinted green or gray, according to individual preference. To be effective, they should be dark enough to absorb 60% to 80% of the incident light in the visible part of the spectrum and almost all of the ultraviolet and infrared.
- Both glass and plastic absorb ultraviolet very effectively, but glass lenses are more effective in the infrared range.
- ***Photochromic lenses:***
    - These alter their absorptive characteristics according to the amount of ultraviolet exposure are available.
    - Antireflective coatings or tints should never be added to plastic photochromic lenses, because the additions will reduce the ability of the

lens to absorb UV light as they will lose a small amount of dye pigment when heated.

- Photochromic lenses will not function as efficiently indoors or in a vehicle.
- Also, the darkening process occurs quite rapidly, but the lightening process is much slower, requiring 1 minute and 20 minutes, respectively, for a 75% alteration in transmission.
- Photochromic lenses may be slightly less efficient for night driving, and maximum absorption of the lens pigment cannot be varied.

Notes on prescribing spectacles:

- The amount of ametropia measured and what the patient will tolerate are frequently not the same. For example,
  - The young hyperope frequently cannot fully relax accommodation and will not tolerate full correction.
  - The patient with astigmatism that has previously been uncorrected may be uncomfortable if all of his or her astigmatism is corrected at once.
- Presbyopes of the same age have different body configurations, visual habits, and work requirements, all of which will affect with the appropriate amount of reading correction.
- In high degrees of ametropia, if the distance at which the spectacle lens is resting in front of the cornea varies from the distance at which the ametropia was measured, an adjustment of power must be made. This distance is known as the ***vertex distance***. Notice that the vertex distance is of particular importance when fitting contact lenses.
- In most patients, particularly high myopes and astigmats, accurately aligning the patient's pupillary distance and the spectacle lens optical centers is crucial to avoid induced prism and thus avoid severe asthenopia.
- Safety considerations, the use of appropriate tints, ultraviolet coating (unless the lens material already blocks UV), antiglare coating, occupational considerations, and appropriate frame design for the patient's facial features must also be taken into consideration.
- Cosmesis is a concern, but should not overrule functionality.
- The dispensing optician should be skilled in advising patients with regard to these aspects of the prescription, in addition to ensuring that the prescription is filled accurately.

Contact lenses (CL)

- Prescribing and fitting contact lenses have become an integral part of comprehensive ophthalmology practice.
- **Indications:**

a) *Optical:*

- To correct an error of refraction that can hardly be corrected by glasses as in aphakia, high myopia, high hypermetropia, anisometropia, and astigmatism. This is particularly important in unilateral aphakia.

b) *Therapeutic:*

- To treat a corneal disease as recurrent erosions, exposure keratopathy, and small corneal perforations or wound leaks.

c) *Cosmetic:*

- To improve an individual appearance e.g. to replace glasses and in a disfiguring eye which can be covered by a tinted contact lens with an artificial iris pattern.

- **Contraindications for CL use:**

a) Ocular surface diseases:

- Such as Dry eye, lid problems such as active blepharitis, stye, chalazion, entropion.

b) Infections and inflammation of the eye:

- Such as Acute and chronic conjunctivitis, corneal abrasions, hyphema, Vth cranial nerve paralysis, hypopyon uveitis and iritis.

c) Systemic conditions:

- Such as allergies, uncontrolled diabetes, during pregnancy and pterygium.

Figure 25: a soft contact lens.

- **Advantages of contact lenses:**
  - **a)** The size of the retinal image is near to normal.
  - **b)** The field of vision is larger than spectacles as it moves with the eye and not restricted with a frame.
  - **c)** No spherical or chromatic aberrations
  - **d)** Safer for athletes and in contact sports.

- **Disadvantages of contact lenses::**
  - a) Special care is required for its cleanliness and storage.
  - b) Some people do not tolerate them and others develop allergy to contact lens solutions.
  - c) Traumatic corneal abrasions may occur during manipulation.
  - d) Infection is always a risk with bad hygiene.

- **Types of Contact lenses:**
  - a) Soft: Made of various hydrogel plastics (Figure 25).
  - b) Hard: Made of polymethyl-methacrylate.
  - c) Rigid gas permeable: Made of various silicone and plastic polymers.

Chapter 4
Miscellaneous clinical optics topics

Sections

- Low vision Aids
- Lasers in ophthalmology
- Refractive surgery

Low Vision Aids

Definition:

- Low-vision aids are devices designed to improve visual performance in patients with low vision, thus enabling academic and social adaptation and providing improvement of everyday capabilities.

Types of low vision devices:

a) Optical aids:

- When regular lenses do not provide the needed visual acuity, aids that have optical properties capable of providing better visual performance through lenses are indicated.
- Types of optical aids:
  - *Optical Aids for Distance and Intermediate Distance:*
    - The telescopic systems or telescopes are optical instruments that improve the resolution of an object by increasing the size of the image projected on the retina, making it closer. It is available for far, near, and middle distances (Figure 26).

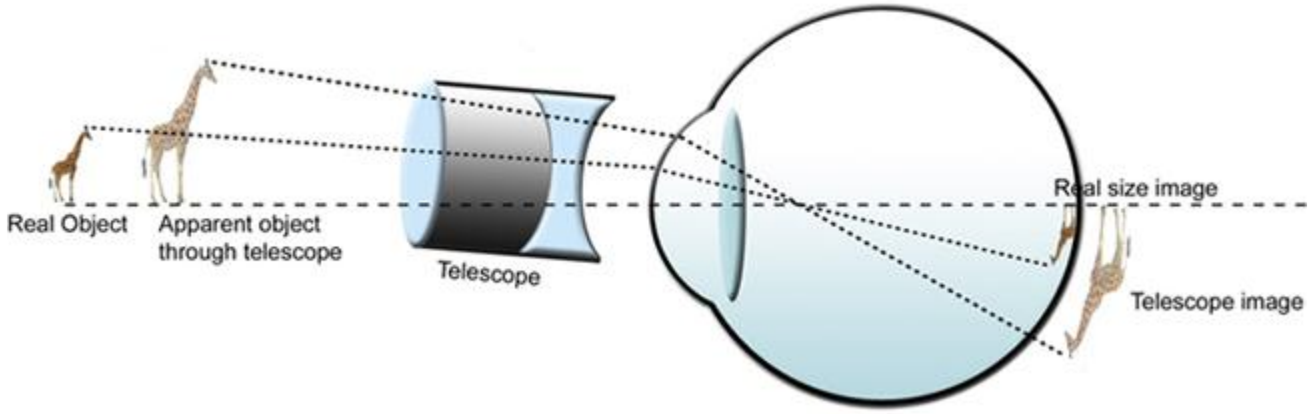

Figure 26: A telescope for distant view.

- **Types of Telescopes:**
    - Galilean or Keplerian
    - Hand-held, spectacle-mounted, or clip-on
    - Monocular or binocular
    - Fixed focus, focusable telescope, or autofocus

➢ *Optical Aids for Near Tasks:*

- High-plus spectacles:
    - High-plus spectacles are convex (plus) lenses mounted in a spectacle frame. They provide maximum magnification when objects are positioned at or near the focal distance of the lens, producing parallel rays and the image forming at optical infinity.
- Hand-held magnifier
    - They increase the size of a retinal image and bring the image into focus, producing a virtual and erect image located in a distance greater than the focal length of the lens. Hand-held magnifiers provide maximum magnification when an object is standing at or close to its focal distance, producing parallel rays and the image forming at infinity optically

- Stand magnifier:
    - Stand magnifiers are convex (plus) lenses designed with a rigid mounting placed close to the object and can be illuminated (Figure 27).
    - Rays emerging from the stand are not parallel, but divergent, requiring accommodative effort or a moderate reading aid to bring the image into focus.
    - It is the aid of choice for patients who cannot hold a lens or tolerate the distance of microscopes.
- Telescope system for near (telemicroscope).

Figure 27. Optical aids for near tasks.

b) *Non-optical aids:*

- Non-optical aids are visual aids that do not use magnifying lenses to improve visual function.

- They can improve the other visual aid's function or can even replace optical aids.
- They enhance visual function by:
  - ♦ Linear magnification:
    - Relative size or linear magnification is magnification brought about by enlarging the object itself.
    - The most familiar objects using this technique are large-print books, newspapers, and magazines
  - ♦ Lighting control:
    - Diseases such as aniridia, achromatopsia, and albinism require low-level lighting and/or optical filters (figure 28);
    - Glaucoma, retinitis pigmentosa, and optic atrophy require high illumination.

Tips for illumination adjustment for reading:

- The light should be flashed directly on the reading material, avoiding reflective surfaces.
- The focus should be placed at shoulder height corresponding to the better-seeing eye, forming a 45-degree angle with the visual axis.
- When using natural light, the patient should sit with their back to the window or on the side leading to the best lighting and visualization.

  - ♦ Enhanced contrast and reduction of glare:
    - A typoscope, caps or visors, side shields, and/or polarizing lenses should be prescribed to control the reflection of light.
    - A typoscope can also be used as a guide to reading, writing, and signature in cases of large defects of visual field (Figure 28).
  - ♦ Improving physical comfort (accessories) e.g. 45

Figure 28. Typoscope and yellow filter.

c) *Electronic aids (Assistive technology):*

- High-tech aids are progressively more beneficial to people with low vision.
- Electronic devices include:
  - Video magnifier systems,
  - Closed-circuit televisions,
  - large-print computer programs such as Zoom Text,
  - Screen reader programs such as Virtual Vision and Jaws.
  - Tablet computers.
- Electronic devices can be very helpful in moderately or severely visually impaired children and in children who do not respond to other proposed aid.

Lasers in ophthalmology

- The word laser is an acronym derived from a brief description of its mechanism of action "**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation".
- **Characteristics of laser light:**
  - Mono-chromatic (one wave length).
  - Uni-directional (parallel to each other with little tendency to diverge over distance).
  - Coherent (its waves moves in phase to strengthen each other)
- **Uses of Lasers in Ophthalmology:**
  - According to their tissue interaction in the eye LASERs used in ophthalmology are divided into:
    - ***Photocoagulation lasers:***
      - *Principle:*
        - Absorption of Laser light energy by ocular pigments such as Xanthophyll, Melanin and Hemoglobin.
        - The laser energy is converted into heat to induce coagulation.
      - *Types:*
        - Gas laser as Argon (wave length 532).
        - Solid semiconductor laser as Diode (wave length 910).
      - Used in Retinal photocoagulation as in Diabetic retinopathy or vein occlusion.
    - ***Photodisruption lasers:***
      - *Principle:*
        - High power pulses causing optical breakdown of membranes or thin tissues.
      - *Types:*
        - Solid crystal laser as Neodymium-Yttrium-Aluminium Garnet (Nd-YAG) laser (wave length 1064).
        - Ultrashort pulse laser i.e. Femtosecond (FS) laser is an infrared laser with a wavelength of 1053nm with same tissue interaction as Nd-YAG but with much less collateral damage.

- Uses:
  - Nd-YAG laser is used mainly in anterior segment interventions such capsulotomy or iridotomy
  - The femtosecond laser is used in corneal surgery e.g Lasik flap creation, and in laser assisted cataract surgery.

- ***Photovaporization lasers:***
  - *Principle:*
    - The laser causes breakdown of bonds between molecules of tissues leading to their vaporization.
    - It cannot penetrate more than few microns of tissues (hence safe for use on the cornea).
  - *Types:*
    - Gas as Argon- Fluoride (Excimer) Laser (wave length 1064).
  - Uses:
    - Correction of refractive errors (myopia, hypermetropia and astigmatism).

- ***Photodynamic treatment (PDT) laser:***
  - *Principle:*
    - Depends on intravenous injection of a radio-active substance which has a great affinity to abnormal vascular tissues, then this tissues are exposed to certain types of laser of longer wavelengths to destroy it.
  - *Types:*
    - Solid semiconductor laser as Diode (wave length 910).
  - Uses:
    - Treatment of sub-retinal neo-vascular membranes at the macular area.

Refractive surgery

- Refractive surgery is the modification of refraction of the eye by surgical interference.
- **Indications:**
  - It is only indicated when there is intolerance to contact lenses and glasses cannot be used due to:
    - **Optical causes:**
      - Such as anisometropia.
    - **Mechanical causes:**
      - Such as nose and orbit configuration difficult to fit spectacles.
    - **Cosmetic and occupational causes:**
      - Such as people working in the media and sport fields.
- **Types of refractive surgery:**
  - ***Corneal surgery:***
    - **Radial Keratotomy:**
      - Old and obsolete nowadays.
      - Radial incisions were done to weaken the cornea and make it flatter by the effect of intraocular pressure (IOP) to correct low myopia up to -4.00 D.
    - **Astigmatic keratotomy (AK):**
      - Corneal incisions are done to flatten the steep meridian.
    - **Excimer laser ablation: (Figure 29)**
      - Laser applied to ablate the anterior corneal surface either by PRK (Photorefractive Keratectomy) or LASIK (Laser in Situ Keratomileusis).
      - This can correct low and moderate myopia, astigmatism, and low hyperopia.

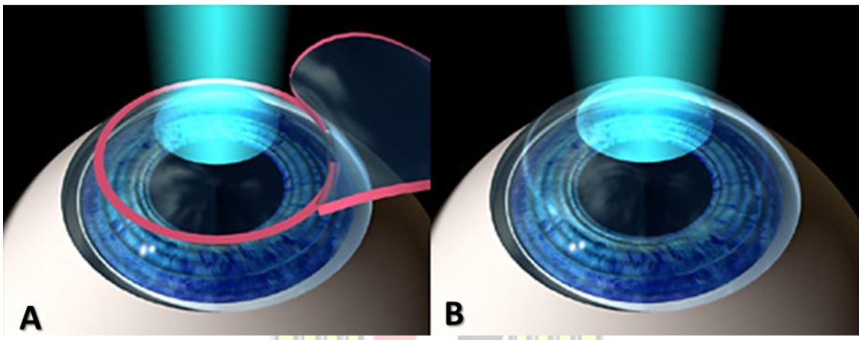

Figure 29 : Excimer Laser Ablation. **(A)** LASIK. **(B)** PRK.

LASIK vs PRK

- ✓ In PRK:
  - The laser ablation is done on the surface of the cornea after removing the overlying epithelium.
  - Recovery is prolonged and painful (5-7 days after surgery).
  - Mild regression may occur after a while
  - Suitable in thinner corneas than LASIK
- ✓ In LASIK:
  - A corneal flap is made using a special microkeratome or by femtolaser.
  - The excimer laser is directed to the center of the cornea, ablating (removing) part of the corneal thickness in a calculated manner.
  - The flap is returned again.
  - Recovery is rapid and much less painful than PRK (1-3 days after surgery)
  - More stable than PRK.

- ***Lenticular surgery:***
  - *Clear lens extraction:*
    - With implantation of an IOL with the desired power aiming for emmetropia.
    - The patient will lose the accommodation and usually needs reading glasses afterwards.
    - Used in high errors in people near or **after the age of presbyopia**.
  - *Phakic IOL implantation:*
    - Either in the anterior chamber, e.g. Artisan phakic lens (Figure 30) or the posterior chamber i.e. intraocular contact lens (ICL).
    - May lead to intraocular complications like uveitis and

cataract, so careful monitoring is advisable.

- Used mainly for high errors in people **below the age of presbyopia**.

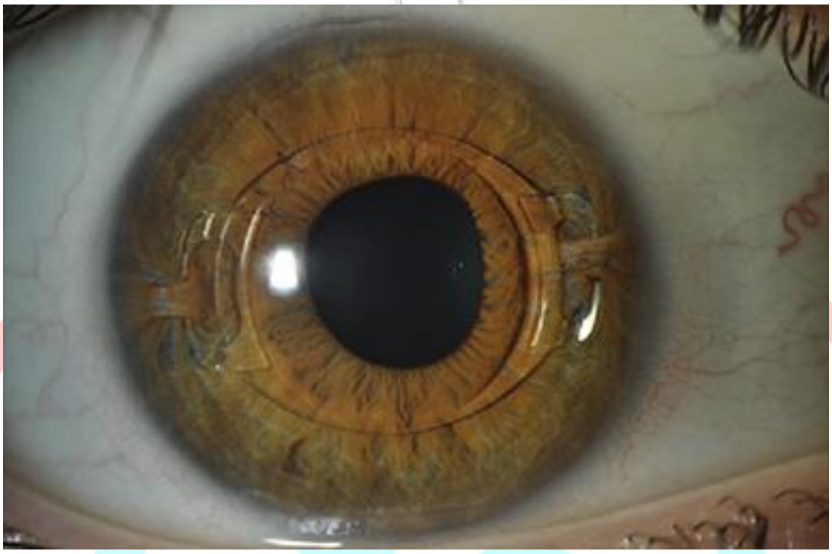

Figure 30: Artisan iris fixated phakic IOL.

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APPENDICES

Appendix 1 - Summary of Retinoscopy Steps

1) Establish alignment in front of the patient's pupil.
2) Shine the retinoscope light into the patient's eye while maintaining a constant distance between yourself and the patient.
3) Rotate the streak to determine the meridian that you wish to neutralize first. This will depend on whether you are using plus cylinders, minus cylinders, or spheres Only. As you move a horizontal streak up and down, you are neutralizing the vertical meridian with the axis at 180°. As you move a vertical streak to the right and the left, you are neutralizing the horizontal meridian, for which the axis is 90°.
4) Neutralize the reflex at the chosen axis.
5) Orient the streak 90° to the original orientation and neutralize the reflex at that axis.
6) Note the power of the lenses needed to achieve neutrality at both orientations.
7) Calculate the power of the resultant eyeglass prescription (remember to subtract the dioptric equivalent of the working distance).
8) Refractionists should review videotapes about retinoscopy, read more detailed textbooks, and gain hands-on training in order to master the finer details of neutralization, estimation of cylinder axis and power, and interpretation of aberrations.

Appendix 2 – Summary of Astigmatic dial refraction

1. Obtain the best visual acuity using spheres only (figure, A).
2. Make the patient artificially myopic (fogged) by putting plus spheres before the eye to focus all meridians anterior to the retina (figure, B). This brings forward compound, simple, or mixed hyperopic astigmatism meridians where both (the

former) or one (the latter two) focal plane is posterior to the retina. By making all meridians myopic, this inhibits accommodation, thus stabilizing the refractive error of the eye, and allows use of minus cylinders to determine the principal meridians.

3. Ask the patient to identify the blackest and sharpest line of the astigmatic dial.
4. Add minus cylinder with the axis perpendicular to the blackest and sharpest line until all lines appear equal. (figure, C) (If using a positive cylinder phoropter, add plus cylinder with the axis parallel to the blackest and sharpest line until all lines appear equal.)
5. Reduce plus sphere (or add minus) until the best visual acuity is obtained with the visual acuity chart (figure, D).

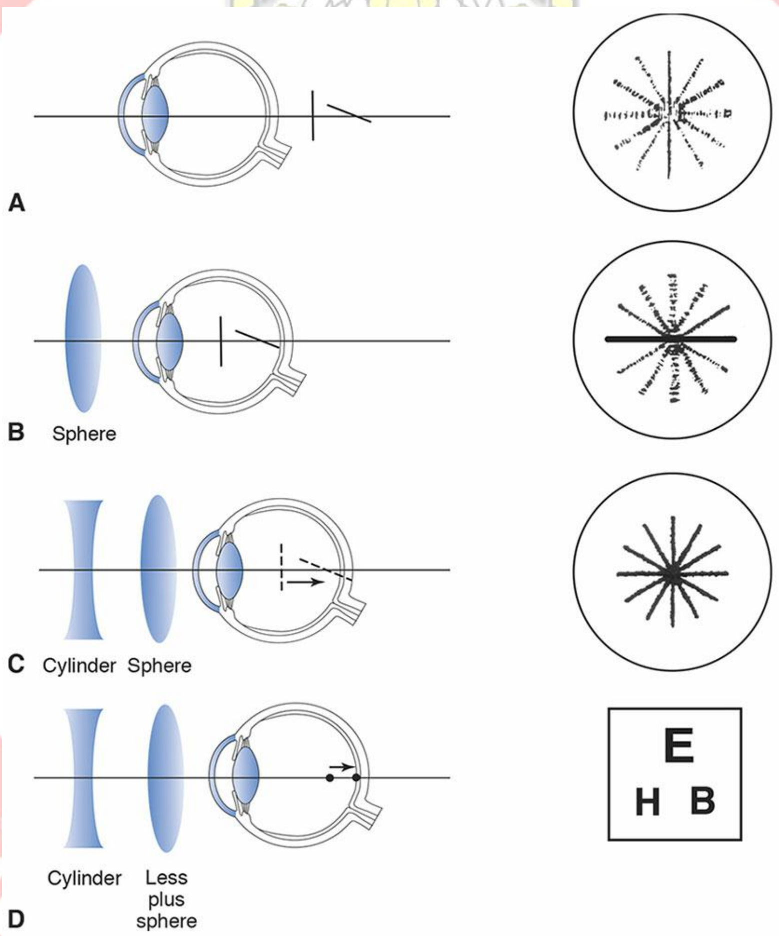

Figure: Astigmatic dial technique. **A,** Conoid of Sturm and retinal image of an astigmatic dial as viewed by an eye with compound hyperopic astigmatism. **B,** Fogging to produce compound myopic astigmatism. **C,** The conoid of Sturm is collapsed to a single point. **D,** Minus sphere is added (or plus sphere subtracted) to produce a sharp image, and a visual acuity chart is used for viewing.

Appendix 3 – Technique of Stenopaeic Slit

1) The stenopaeic slit is an opaque trial lens with an oblong slit whose width forms a pinhole with respect to vergence perpendicular to the slit.
2) If an examiner is unable to interpret the astigmatism by performing the usual retinoscopy because of the subject eye’s irregular astigmatism or unclear media, he or she may neutralize the refractive error with spherical lenses and the slit at various meridians to find a spherocylindrical correction. This correction can then be refined subjectively.
3) This process is especially useful for patients with small pupils and lenticular or corneal opacities.
4) If the subject can accommodate, fog and unfog using plus sphere to find the most plus power accepted.
5) Then turn the slit until the subject says the image is sharpest.
6) If, for example, –3.00 D sphere is best there, when the slit is oriented vertically, this finding indicates –3.00 D at 90° in a power cross. If the best sphere with the slit oriented horizontally is –5.00 D, then the result is –3.00 –2.00 × 90.

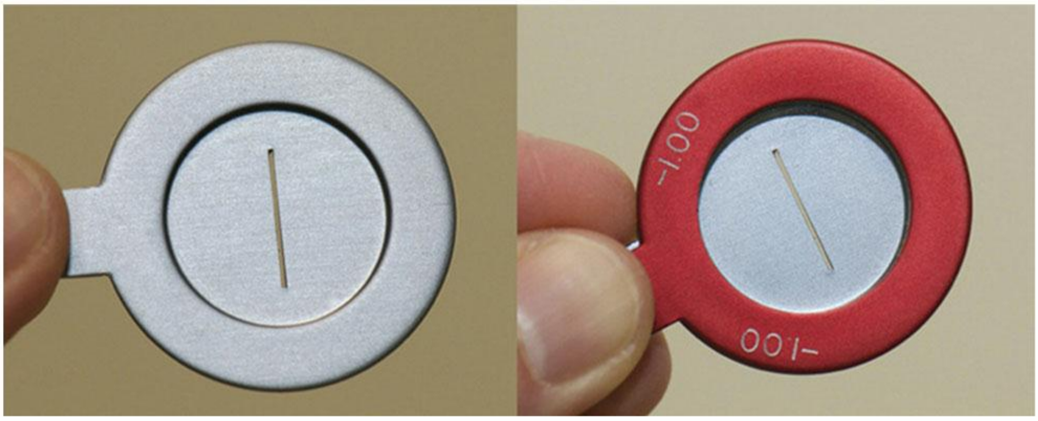

Figure: Stenopaeic slit. The image on the right demonstrates the placement of a spherical lens in front of the stenopaeic slit in order to determine the best visual acuity.

1) Adjust sphere to the most plus or least minus that gives the best visual acuity.
2) Use test figures that are 1 or 2 lines larger than the patient's best visual acuity.
3) If cylindrical correction is not already present, look for astigmatism by testing with the cross cylinder at axes 90° and 180°. If none is found there, test at 45° and 135°.
4) Refine axis first. Position the cross-cylinder axes 45° from the principal meridians of the correcting cylinder. Determine the preferred flip choice, and rotate the cylinder axis toward the corresponding axis of the cross cylinder. Repeat until the 2 flip choices appear equal.
5) Refine cylinder power. Align the cross-cylinder axes with the principal meridians of the correcting cylinder. Determine the preferred flip choice, and add or subtract cylinder power according to the preferred position of the cross cylinder. Compensate for the change in position of the circle of least confusion by adding half as much sphere in the opposite direction each time the cylinder power is changed.
6) Refine sphere, cylinder axis, and cylinder power until no further change is necessary.

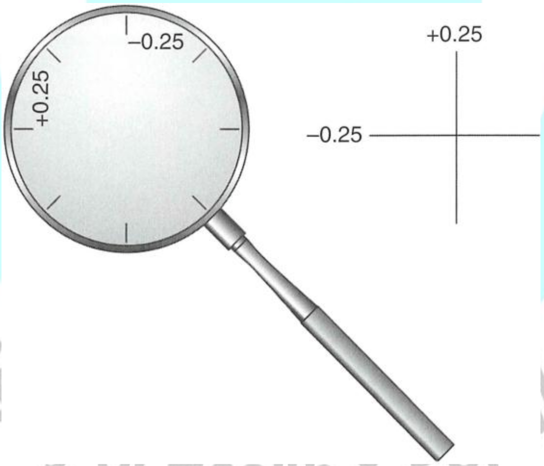

Figure : Jackson Cross Cylinder, used to refine the selection of corrective cylindrical lenses for astigmatism.

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