Al-Furat Al-Awsat Technical University · AL-Najaf Technical Institute · Optometry Department

Refractive Errors

Complete Lecture Series — 1st Stage

Lectures 1 & 2 — Introduction to Refractive Errors

Lecture 3 — Dioptric System of the Eye & Sense of Vision

Lectures 4 & 5 — Emmetropic Eye, Accommodation & Myopia

Lecture 6 — Hypermetropia & Astigmatism

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LECTURES 1 & 2

Introduction to Refractive Errors

Sub: Refractive Errors · 1st Stage · Dr. Mostafa Salim Mohammed

What is Refraction?

Light enters the eye by going through the cornea and lens. These two organs modify light rays by a phenomenon called refraction in order to have a single point — not two — in the fovea as it should be to see clearly.

When light waves travel from a medium with a given refractive index to a medium with another refractive index, at the boundary the wave phase velocity is altered — it changes direction and the amount of bend depends on the refractive index and the angle of incidence.

Refraction Defined:

Refraction is the bending of light as it passes from one object to another. Vision occurs when light rays are bent (refracted) as they pass through the cornea and the lens. The light is then focused on the retina. The retina converts the light-rays into messages sent through the optic nerve to the brain. The brain interprets these messages into the images we see.

What Are Refractive Errors?

Refractive errors occur when the shape of the eye prevents light from focusing directly on the retina. The length of the eyeball (longer or shorter), changes in the shape of the cornea, or aging of the lens can cause refractive errors.

Who is at risk? Presbyopia affects most adults over age 35. Other refractive errors can affect both children and adults. Individuals with parents who have refractive errors may be more likely to develop one.

Signs & Symptoms + Types of Lenses

Signs & Symptoms of Refractive Errors:

- Blurred vision (most common symptom)
- Double vision
- Haziness
- Glare or halos around bright lights
- Squinting
- Headaches
- Eye strain

Lenses — Optical Principles

A lens is a piece of transparent material (like glass) with two faces, at least one curved, which concentrates or disperses light rays by refraction. For a thin lens in air, the focal length is the distance from the center to the focal points. When parallel rays pass through a lens, they converge at one point called the Focal Point.

What is a Spherical Lens?

A spherical lens (singlet) is an optical lens with a curved surface that causes light rays to converge or diverge. It projects images without affecting aspect ratios.

Two Main Types of Lenses:

a) Convex Lens (Convergent) — thicker at center
b) Concave Lens (Divergent) — thinner at center

Convex Lens (Convergent) — Details

A convex lens is thicker at the center than at the edges.

Types of Convex Lens:

1. Double Convex Lens: Both surfaces are convex (Biconvex)
2. Plano-Convex Lens: One surface plane, the other surface convex
3. Concavo-Convex Lens: One surface concave and the other surface convex (Convex meniscus)

Properties of Convex Lenses:

i. Focal length is positive
ii. Image formed is real
iii. A converging lens

Medical Applications:

1. Human eye = convex lens (focal length 2 cm)
2. Magnifying glass
3. Compound microscope

Concave Lens (Divergent): Thinner at center than at edges. Focal length negative, image formed is virtual, it is a diverging lens.

Concave Lens Types + Cylinder Lens

Types of Concave (Diverging) Lenses:

1. Double Concave Lens: Both surfaces are concave (Biconcave)
2. Plano-Concave Lens: One surface plane, the other surface concave
3. Convex-Concave Lens: One surface convex and the other surface concave (Concave meniscus)

What is a Cylinder Lens?

Cylinder lenses are optical lenses which have differing radius in the X and Y axes, causing the lens to have a cylindrical or semi-cylindrical shape. A cylindrical lens focuses light into a line instead of a point.

1. Cylindrical lenses are prescribed to correct astigmatism
2. Used in subjective refraction to diagnose astigmatism and assess the strength and axis of astigmatic power
3. Has one-dimensional amplification → effectively corrects spherical and chromatic aberrations

Converging lens used as: Image Producer and Magnifier — this is why we study the convex lens.

Spherical vs Cylindrical + Ray Diagrams

Difference between Spherical and Cylindrical Lenses:

Property	Spherical Lens	Cylindrical Lens
Shape	Spherical: part of a sphere	Cylindrical: part of a cylinder
Light focus	Spherical: converges/diverges to ONE POINT	Cylindrical: converges/diverges to ONE PLANE
Clinical use	Spherical: corrects Myopia and Hypermetropia	Cylindrical: corrects Astigmatism

Ray Diagrams for Thin Lenses:

Showing the graphical method of locating an image formed by converging (convex) and diverging (concave) lenses.

Ray 1: Parallel to the principal axis → after refraction passes through focal point F_2 (converging) or appears to come from F_2 (diverging)

Ray 2: Passes through the optical center of the lens — does not deviate appreciably

Ray 3: Passes through focus F_1 (converging) or appears to converge toward F_1 (diverging) → after refraction, ray is parallel to the principal axis

Image Properties for Converging Lens

Ray diagrams: image formed by a converging (convex) lens for various object distances (S):

S > 2f	Real, Inverted, Diminished — formed between F_2 and $2F_2$ (at the back of lens)
S = 2f	Real, Inverted, Same size — formed at point $2F_2$ (at the back of lens)
f < S < 2f	Real, Inverted, Magnified — formed at distance greater than 2f (at back of lens)
S = f	Real — formed at infinity
S < f	Virtual, Upright, Magnified — formed in front of the lens

LECTURE 3

Dioptric System of the Eye & The Sense of Vision

Sub: Refractive Errors · 1st Stage · Dr. Mostafa Salim Mohammed

Dioptric System of the Eye — Overview

The human eye is a highly sophisticated optical system designed to capture light, process it, and create visual perception.

The Dioptric System: includes all transparent refractive media that bend (refract) light entering the eye. These structures function together as an optical unit.

Path of Light Through the Eye:

Cornea → Aqueous Humor → Crystalline Lens → Vitreous Humor → Retina (Photoreceptors)

Main Components:

Each component has a unique refractive index and curvature that contributes to the total optical power of the eye.

Cornea	**43D**	RI: 1.376	Most powerful surface — primary focusing element (air-cornea interface)
Aqueous Humor	**Minor**	RI: 1.336	Clear fluid in anterior/posterior chambers — maintains IOP, metabolic support
Crystalline Lens	**18-20D**	RI: 1.386-1.406	Transparent biconvex — changes shape for near vision (accommodation)
Vitreous Humor	**Minimal**	RI: 1.336	Transparent gel in posterior cavity — maintains structure, light transmission

Photoreceptors, Image Formation & Snell's Law

Photoreceptors

Specialized neurons in the retina (rods and cones) that detect light and convert it into electrical signals for the brain.

- Rods: sensitive to dim light, responsible for night vision, no color detection
- Cones: active in bright light, provide color vision and high acuity, concentrated in the fovea

Image Formation on the Retina

Image formed is: Inverted, Reversed, Real, Miniaturized

Steps:

1. Light enters cornea → strong refraction
2. Aqueous guides light to lens
3. Lens fine-tunes focus (accommodation)
4. Vitreous body transmits light
5. Light focuses on fovea centralis

Refraction in the Dioptric System — Snell's Law:

$$n_1 \times \sin(\theta_1) = n_2 \times \sin(\theta_2)$$

n_1, n_2 = refractive indices
θ_1, θ_2 = angles of incidence and refraction

Elements of the Eye:

The human eye is approximately sphere-shaped (radius ~0.024m). Focusing elements: cornea and eyelens. Other elements: pupil, iris, aqueous humor, vitreous humor, sclera, retina.

Normal Eye (Emmetropes, less than 0.5D): parallel rays focus directly on the retina at rest — without accommodation — using its normal power of 60D.

Key Notes — Cornea, Lens & Focusing

1. The cornea does about two-thirds of the focusing; the lens does fine focusing.
2. Nearly all corneal focusing is at the front surface (aqueous has nearly the same RI as cornea).
3. Cornea too curved → nearsighted; not enough curvature → farsighted; uneven curvature → astigmatism.
4. The cornea is a fixed focus element; the lens is variable in shape — focuses objects at various distances.
5. Cornea radius of curvature: ~7.8mm; anterior lens surface: 10mm — so cornea is steeper.
6. Total refractive power of normal eye = 60D (cornea: 43D + lens: 17D).
7. Cornea is more important because: (a) anterior surface is steeper, (b) light passes from air (RI=1.00) through cornea — larger RI difference → more bending.
8. Difference in RI: cornea–air = 0.37; lens–aqueous = 0.05 — hence cornea bends light far more.
9. The lens has a flexible cover supported under tension by suspension fibers.

Key Notes (continued) + Sense of Vision

10. Refractive index is nearly constant for all corneas; curvature varies considerably — responsible for most defective vision.

11. Muscles permit flexible eye movement up/down, sideways, and diagonally.

12. When focusing muscle is relaxed, lens is flattened (lowest power) → eye focused on distant objects (far point).

13. For near-sighted: circular muscle around lens contracts → lens gains greater focusing power (near point).

The Sense of Vision — Three Major Components

1. The Eyes	2. Nerve System	3. Visual Cortex
Focus an image from the outside world on the light-sensitive retina.	Millions of nerves carry information deep into the brain.	That part of the brain where 'it is all put together' — creates the final image we perceive.

⚠ **Blindness results if any one of the three parts does not function.**

LECTURES 4 & 5

Emmetropic Eye, Accommodation & Myopia

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Emmetropic Eye — Normal Refraction

Emmetropia is the ideal refractive state — parallel light rays from an infinite distance are refracted perfectly by the cornea and lens so that they converge to a point directly on the retina. Objects look distinct and sharp, instead of blurry and out of focus.

Refractive power: measured in Dioptres (D). Normal eye total power = 60D (Cornea: 43D + Lens: 17D)

Accommodation:

Contraction of ciliary muscle to increase lens curvature (and so increase its refractive power beyond 17D) to visualize objects closer than 6 meters (near objects). Parallel rays are brought to focus on the retina by the normal lens becoming more complex.

Amplitude of Accommodation:

The difference in the converging power of the eye between maximum accommodation and unaccommodated eye (rest). Depends on: contraction power of ciliary muscles + elasticity of lens capsule. Both decrease with age.

Early life	Age 36	Age 45	Age 60
Focus at 7cm away Lens power can increase from 17D up to 31D	Focus at 15cm Amplitude of accommodation decreases to 6D only	Focus at 25cm Amplitude of accommodation = 4D only	Focus at 1 meter Amplitude of accommodation = 1D only

Ammetropic Eye & Myopia Definition

Ammetropic Eye (eye with vision defects): Most common types of refractive errors are myopia, hyperopia, astigmatism and presbyopia.

1. MYOPIA — Nearsightedness

Myopia is the medical name for nearsightedness — you can see objects that are near clearly but have difficulty seeing objects farther away. You may not be able to make out highway signs until just a few feet away.

Definition: A refractive error where parallel rays of light come to a focus IN FRONT OF the retina when the eye is at rest. There is an increase in refractive power of the eye, so near objects are seen normally, while far objects (parallel rays) are focused in front of the retina.

Aetiological Classification of Myopia:

1. Axial Myopia: Anteroposterior length is longer than normal
2. Curvature Myopia: Increased surface curvature of the lens
3. Index Myopia: Increased refractivity of the lens — due to increased difference between refractive indices of nucleus and cortex

Types of Myopia

1. Simple Myopia

Eye is otherwise healthy. Wearing glasses or contact lenses can easily correct the issues.

2. High Myopia

More severe form of simple myopia. Develops at a young age and gets worse as they grow older. Increases risk of: retinal detachment, glaucoma, cataracts.

3. Pathological Myopia

Newer name for degenerative myopia (severe and progressive). Even with corrective lenses, clear vision may not be possible.
Retinal issues include:

- Lattice degeneration (retinal thinning)
- Retinal atrophy (parts of retina wasted)
- Forster-Fuchs' spot (retinal scarring → blind spots)
- Vision loss glasses cannot correct

Clinical Classification: Simple vs Pathological Myopia

Simple (Stationary): Power <6D, starts after age 4, stationary (stops before 20y), normal physiological variety, VA can be corrected to 6/6.
Pathological (Progressive): Power >6D, starts before age 4, progresses even after 20y, real pathological process, VA CANNOT be corrected to 6/6. Associated with vitreous fluidity and chorioretinal changes.

Feature	Simple Myopia	Pathological Myopia
Power refractive	Smaller than 6D	**Greater than 6D**
Severity	Moderate	**Severe**
Onset	Childhood / adolescence	Early
Axial length	Normal or slightly increased	**Markedly increased**
Ocular changes	No pathological changes	**Definite pathological changes**
VA with correction	Good	**Very poor**
Macula	Normal	**Commonly affected**
Complications	Rare	**Severe vision loss, retinal detachment**
Risk level	Low	**Very high**
Follow-up	Routine	**Close and continuous**

Myopia — Symptoms & Treatment

Symptoms:

1. Objects far away appear blurred or out of focus
2. Headaches or tired eyes after focusing on distant objects
3. Squinting
4. Eye strain and fatigue

Treatment:

1. Eyeglasses: Simplest and safest correction. To correct myopia → use a CONCAVE LENS. Myopic eyes are too powerful; concave lenses diverge light to decrease the overall refractive power of the eye.

2. Contact Lenses: Become the first refractive surface for light rays entering the eye, causing more precise refraction. Provide clearer vision, wider field of vision, and greater comfort. Safe and effective if fitted and used properly.

3. Refractive Surgery: Aims to enhance vision permanently. Changes eye shape to restore focusing power, allowing light rays to focus precisely on the retina for improved vision.

LECTURE 6

Hypermetropia & Astigmatism

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Hypermetropia (Farsightedness) — Overview

Hypermetropia (Hyperopia) is a type of refractive error in which parallel rays of light are focused some distance BEHIND the retina when the eye is at rest. Most hyperopic refractive power is too weak (opposite of myopia), and therefore light converges behind the retina.

Clinical Types of Hypermetropia:

a. Congenital Hypermetropia

This is rare. Usually associated with other congenital anomalies of the eyeball like microophthalmos.

b. Simple or Developmental Hypermetropia

Most common type. A newborn baby is hypermetropic, but with age the eyeball grows in size and hypermetropia gradually diminishes. If growth of the eyeball is retarded, hypermetropia persists.

c. Acquired Hypermetropia

Found in aphakic conditions, commonly following extraction of the lens. This hypermetropia is usually high at about +10.0D.

Hypermetropia — Etiological Classification (Group I: Anatomical)

Group I: Anatomical Hypermetropia

a. Axial Length Hypermetropia

• Caused by shorter-than-normal axial length — normal converging power (60D) but axial length < 24mm (excessively short globe) • Each 1mm decrease ≈ +3.00D hypermetropia • Most common type in children

b. Corneal Hypermetropia

• Due to flat corneal curvature • Seen in conditions such as microcornea or after corneal surgery

c. Curvature Hypermetropia

• Flat lens surfaces due to decreased curvature of the lens — congenitally or from trauma/disease (insufficient refractive power) • An increase of 1mm in its radius of curvature produces hypermetropia of 6.0D

d. Index Hypermetropia

• Decrease in effective refractivity of the lens • Power of lens depends on difference between refractive indices of nucleus and cortex — more difference = more converging power • In index hypermetropia: decrement of this difference

e. Combined Structural Hypermetropia

• When both axial and refractive abnormalities exist simultaneously

Hypermetropia — Group II, Symptoms & Treatment

Group II: Physiological Hypermetropia

a. Developmental Hypermetropia: Found naturally in infants and young children. Eye is physiologically small → mild hypermetropia is normal. Reduces as the eye grows (emmetropization).

b. Age-related Hypermetropia: Occurs with aging due to: lens flattening, decreased refractive index, weakening of ciliary muscles. Gradually increases after age 40.

c. Accommodative Hypermetropia: Results from inefficient or delayed accommodation. Can be seen in children with reduced accommodative tone.

Symptoms of Hypermetropia

1. Blurred vision for near work (needs more power) and even far vision if degree is high beyond amplitude of accommodation
2. Eye strain: headache due to excessive accommodation and dissociation between Accommodative Convergence and Accommodation (AC/A)
3. General symptoms: nausea and fatigue
4. Early presbyopia — clinically at late 30s or early 40s
5. Headache especially frontal

Treatment of Hypermetropia

1. Convex lens (spectacles or contact lenses) — increases overall refractive power (plus lenses) to bring focus forwards onto retina. 2. Excimer laser photorefractive keratectomy — reshapes cornea to increase refractive power (each 1mm decrease in radius increases power by ~6D).

Astigmatism — Definition & Occurrence

Astigmatism is a condition where the eye's cornea or lens has an irregular curvature like an egg (oblong in shape), rather than a football (round), leading to uneven focusing of light on the retina, with two different curves — one steep and one flat — resulting in distorted or blurry vision.
Instead of a single focal point, there are two or more focal lines (depending on the type), separated by a focal interval — or light focuses at multiple points.

How Astigmatism Occurs:

1. Surface of the eye (cornea) or the lens inside the eye has mismatched curves (egg-shaped surface) → blurred vision at ALL distances

2. The lens or cornea has an irregular curve → changes the way light passes (refracts) to the retina → blurry, fuzzy, or distorted vision

Astigmatism is often present at birth and may occur in combination with nearsightedness or farsightedness. In astigmatism, the cornea is irregularly shaped and the light focuses at multiple points.

Etiological Classification:

1. Curvature Astigmatism: Most commonly corneal, less commonly lenticular. Cornea or lens has unequal radii of curvature.

2. Decentering Astigmatism: Subluxation of lens.

3. Index Astigmatism: Due to cataract affecting one meridian more than another.

Types of Astigmatism

1. Regular Astigmatism — Principal meridians always 90° apart; consecutive variation in refractive power from one meridian to another.

Simple Astigmatism	Compound Astigmatism	Mixed Astigmatism
Myopic or hypermetropic — one focal line falls on retina, other in front or behind it.	No focal point falls on retina — both are in front (myopic) or behind (hypermetropic) retina.	One focus in front of and the other behind the retina — most common type. Symptoms: blurry vision, headaches, light sensitivity.

Types by meridian orientation:

a. With-the-Rule Astigmatism: Steepest curve is VERTICAL (cornea is steeper at top and bottom)

b. Against-the-Rule Astigmatism: Steepest curve is HORIZONTAL (cornea is steeper on the sides)

c. Oblique Astigmatism: Steepest curve is at an angle BETWEEN vertical and horizontal

2. Irregular Astigmatism — Meridians are NOT perpendicular to each other, often due to eye injury or diseases. Requires specialized contact lenses or surgery.

Causes of Irregular Astigmatism:

1. Genetics (most cases are inherited/congenital)
2. Eye Injury: trauma or surgery altering corneal/lens shape
3. Complications following eye surgery
4. Ageing

Astigmatism: Diagnosis, Symptoms, Treatment + Presbyopia

Diagnosis:

1. Visual Acuity Test — measures how well you can see at various distances
2. Keratometry — measures curvature of the cornea
3. Autorefraction — machine measures how light is reflected off the retina to determine prescription
4. Corneal Topography — creates a detailed map of corneal surface to identify irregularities

Symptoms:

Blurry/distorted/fuzzy vision at ALL distances · Blurred or distorted vision · Eyestrain or discomfort · Headaches · Difficulty with night vision · Squinting

Treatment:

1. Cylindrical lenses in spectacles — only for simple astigmatism
2. Contact lenses — for compound and mixed astigmatism (correct one meridian by contact lens, other meridian by cylindrical lens)
3. Photorefractive Excimer laser surgery — to correct one meridian
4. LASIK — like Excimer laser, but used for higher refractive error
5. Keratoplasty (corneal graft) — for more than two meridians and central corneal opacity

Presbyopia: Often a person older than 50 has trouble reading fine print due to recession of near point with age (from 7cm early in life to 1m at age 60), due to decreased amplitude of accommodation (from 14D to 1D at 60). Clinically manifested after age 40

Presbyopia: Recession of near point with age (7cm → 1m at age 60). Accommodation decreases (14D → 1D). Manifested after age 40. Treatment: +ve glasses (bifocals) for near work.

Summary: Focusing Problems & Their Characteristics

A summary of the main refractive conditions, their common names, usual causes, and corrections:

Focusing Problem	Common Name	Usual Cause	Corrected With
Myopia	Near-sighted vision	Long eyeball or cornea too curved	**Negative (Concave) Lens**
Hyperopia	Far-sighted vision	Short eyeball or cornea not curved enough	**Positive (Convex) Lens**
Astigmatism	—	Unequal curvature of cornea or lens	**Cylindrical Lens**
Presbyopia	Old-age vision	Loss of accommodation with age	**Bifocals (+ve)**

Presbyopia Details:

A person older than 50 notices trouble reading fine print. Near point recedes with age (7cm early in life → 1 meter at 60 years). Amplitude of accommodation decreases (14D early in life → 1D at age 60). Clinically manifested after age 40. Patient wears +ve glasses during near work (e.g. reading). Problem is due to the loss of accommodation with age.

End of Lecture Series

Refractive Errors — 1st Stage

Lectures 1 & 2 · Introduction to Refractive Errors, Lens Types, Ray Diagrams

Lecture 3 · Dioptric System, Elements of the Eye, Sense of Vision

Lectures 4 & 5 · Emmetropic Eye, Accommodation, Myopia (all types & treatment)

Lecture 6 · Hypermetropia, Astigmatism, Presbyopia & Summary Table

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