جامعة المستقبل

كلية التقنيات الصحية والطبية

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REFRACTIVE ERRORS 3

Lecture Title

Astigmatism

Lecture Number: 2 / course 1

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OPTOMETRIST

Astigmatism

Introduction and Definition

Prevalence and global burden: Astigmatism is the most prevalent form of refractive error. Epidemiological studies indicate that it affects approximately 40% of adults worldwide and roughly 15% of children. Its prevalence varies by region and ethnicity, making it a major contributor to visual impairment and a key public health concern.

Optical mechanism

In an emmetropic eye, all meridians of the cornea and crystalline lens have equal curvature, allowing incoming light rays to focus at a single point on the retina. In astigmatism, one or more meridians differ in curvature, causing unequal refraction of light and the formation of two focal lines instead of a single focus. The steeper meridian has higher refractive power and focuses light sooner, while the flatter meridian focuses light farther back. This results in blurred or distorted vision along specific axes.

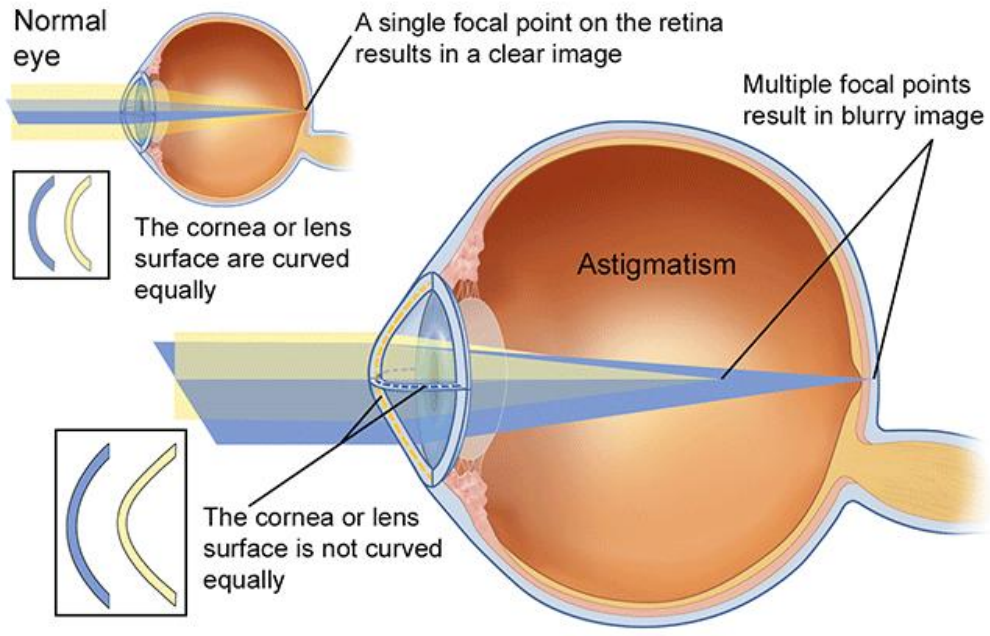


Figure 1. An astigmatic eye showing two focal points.

- **Regular Astigmatism and Sturm's Conoid:** In regular astigmatism, the refracting surface (such as the cornea or lens) is toric, meaning it has two principal meridians that are perpendicular to each other. Each meridian has a different curvature and therefore a different refractive power.

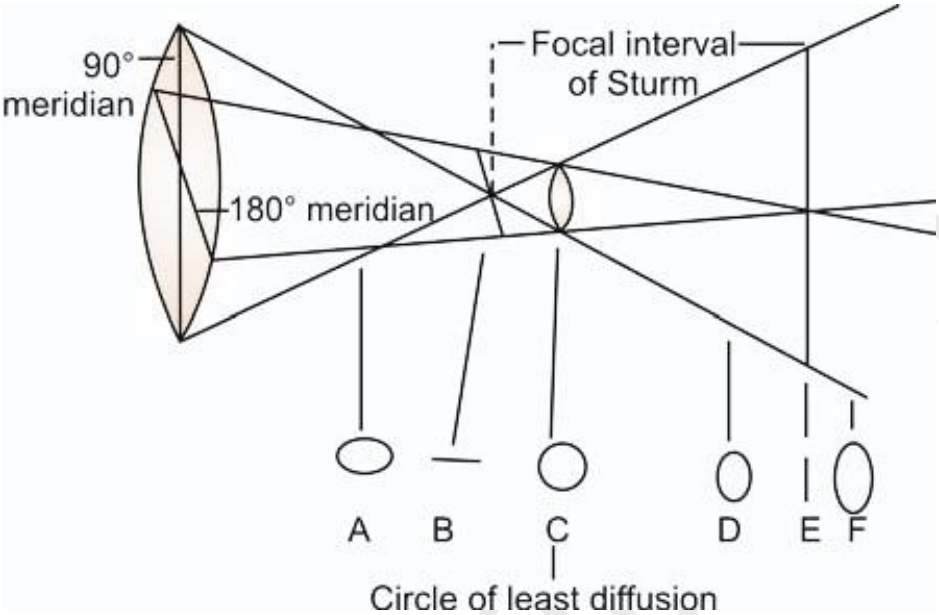


Figure 2. Conoid of Sturm and interval of Sturm.

Figure 2 illustrates a regularly astigmatic surface that has a toric curvature and has the following features:

1. Principal Meridians

- The 90° meridian (vertical) is more curved and has greater refractive power.
- The 180° meridian (horizontal) is flatter and has less refractive power.

2. Focal Lines

When parallel rays of light enter the eye or lens:

- Rays in the more curved meridian (vertical) are refracted more strongly and come to focus closer to the lens.
- Rays in the less curved meridian (horizontal) are refracted less and focus farther away.

As a result, there are two focal lines instead of one focal point:

- The first focal line corresponds to the more powerful meridian.

- The second focal line corresponds to the weaker meridian. The distance between these two focal lines is called the Focal Interval of Sturm.

3. Sturm's Conoid

It is a three-dimensional pattern of refracted rays in astigmatism, formed between two focal lines. The light cross-sections change from elliptical to circular depending on the distance from the lens.

In the diagram (A–F):

A: Vertical ellipse

B: Horizontal line (first focal line)

C: Circle (Circle of least diffusion – best focus)

D: Vertical line (second focal line)

E–F: Vertical ellipse again

4. Circle of Least Diffusion

It is the midpoint between the two focal lines in an astigmatic eye. At this point, the blur is minimal and symmetrical, forming a small, nearly clear circular image. Clinically, it represents the best possible focus when the astigmatism is not fully corrected.

Historical Development of Astigmatism Correction

- Thomas Young first recognized the condition in 1801, and he discovered his own astigmatism.
- George Airy, in 1827, constructed the first cylindrical lens to correct his astigmatism, establishing the foundation for modern optical correction. Over time, optical instruments such as keratometers and topographers enhanced diagnosis.
- In the 20th century, toric contact lenses became available, followed by advanced surgical options like LASIK, PRK, and toric IOL implantation.

Optical Basis and Classification

❖ Based on the angle between the two principal meridians

a) **Regular astigmatism**: the two principal meridians' curvatures are positioned at right angles, i.e., 90° to each other.

b) **Irregular astigmatism (Bi–Oblique)**: Principal meridians are not orthogonal and may vary across the cornea. This type often results from corneal disease (e.g., keratoconus), trauma, or surgical incisions and produces distorted vision that cannot be fully corrected with simple cylindrical lenses.

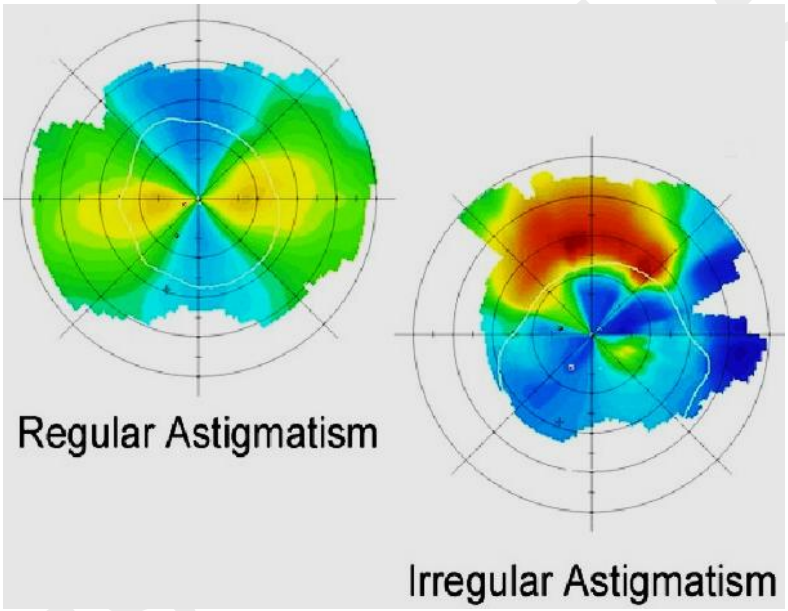


Figure 3. Corneal topography: regular vs irregular astigmatism.

❖ Based on Aetiology

a) **Corneal Astigmatism**

i. ***Astigmatism with–the–rule (WTR)***: usually, the vertical corneal meridian is more curved than the horizontal one, “vertical meridian steeper (~90°)” (Fig. 2A).

ii. ***Astigmatism against-the-rule (ATR)***: the corneal curvature in the horizontal meridian is greater than the vertical one, “horizontal meridian steeper (~180°)” (Fig. 2B).

iii. ***Oblique astigmatism***: here the radii of curvature are aligned at 90° to each other, but the two principal meridians are neither near horizontal nor near vertical "axes between 30–60° or 120–150°" (Fig. 2C).

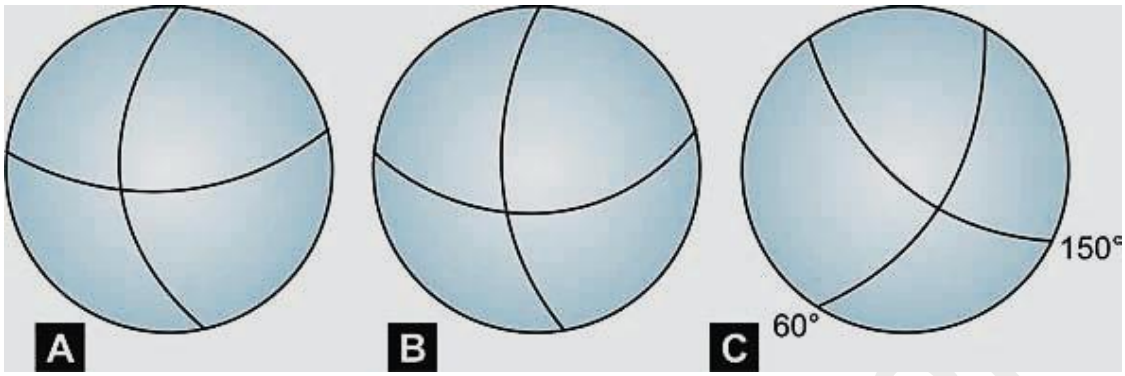


Figure 4. Types of astigmatism based on the orientation of the maximum curvature of the cornea. (A) = With-the-rule, (B) = Against-the-rule and (C) = Oblique

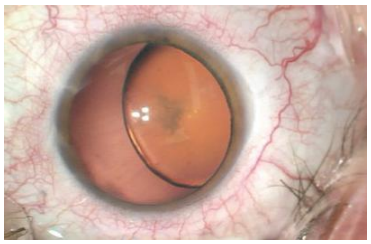
b) Lenticular astigmatism

i. ***Curvature***: It is due to variations in the curvature of one or both surfaces. Lenticular astigmatism is typically against the rule and it tends to neutralize the corneal astigmatism.

ii. ***Index***: It is due to the inequalities of refractive index in different sections of the lens. It is seen in early cataract and is the cause of polyopia in early cataract.

iii. ***Displacement of the refractive element***

- ✓ crystalline lens, i.e., subluxation خلع جزئي
- ✓ decentration or tilting of pseudophakia (IOL).



❖ Based on the refractive status

Regular astigmatism may coexist with myopia or hyperopia and is classified using the refractive status of the two principal meridians:

1. **Simple astigmatism:** here, one image is located in the retinal plane and based on the location of the other image, it may be:

i. ***Simple myopic astigmatism***: The other image is located in front of the retina (Fig.5A).

ii. ***Simple hypermetropic astigmatism***: The other image is located behind the retina (Fig.5B).

2. **Compound astigmatism:** here, both the images are either in front of the retina or behind the retina and are designated as:

i. ***Compound myopic astigmatism***: light focuses in front of the retina in both meridians, but by different amounts (Fig.5C).

ii. ***Compound hypermetropic astigmatism***: both focal lines lie behind the retina, but not at the same distance (Fig. 5D).

3. **Mixed astigmatism:** here, one image is formed in front of the retina and the other image is located behind the retina (Fig. 5E).

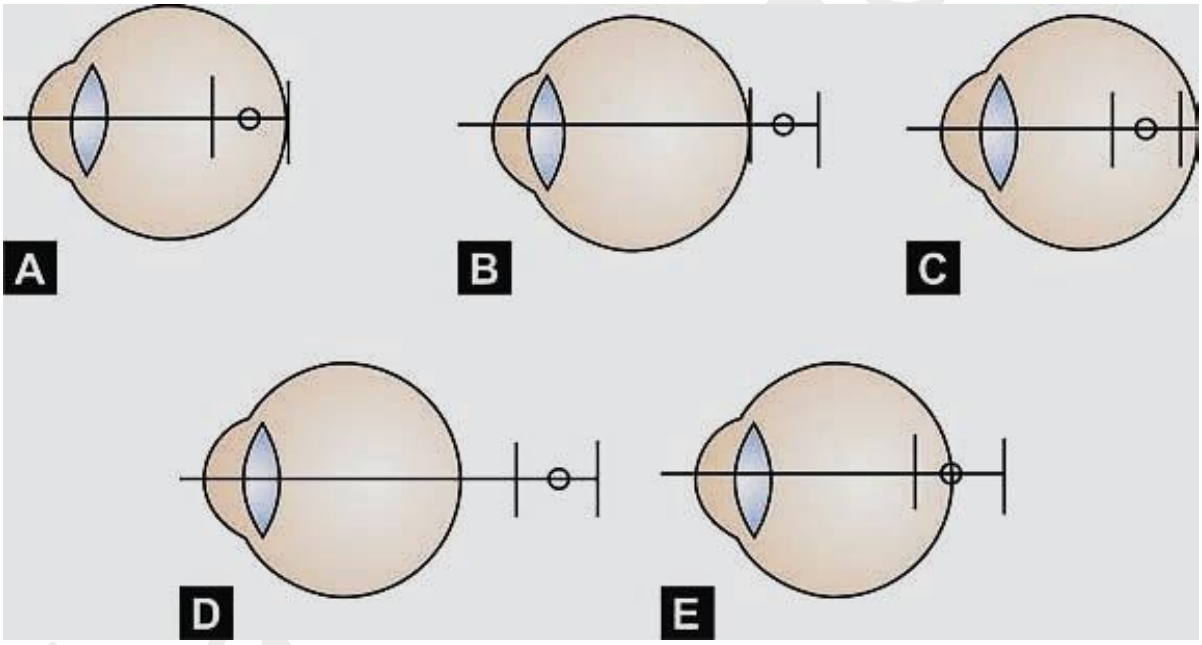


Figure 5. Types of astigmatism, O = Circle of least diffusion

Etiology and Risk Factors

Astigmatism arises when the eye's optical system fails to focus light uniformly across all meridians. Its causes can be genetic, developmental, mechanical, or environmental. Understanding these helps in diagnosis and management.

1. Genetic and developmental factors

- ***Inherited corneal shape***: Many individuals are born with a cornea that is naturally more curved in one meridian than another. Familial clustering and twin studies support a strong genetic component in corneal curvature and toricity.
- ***Embryologic development***: Uneven growth of the cornea or crystalline lens during prenatal and early postnatal periods can establish astigmatism. Developmental anomalies in the eyelids or extraocular muscles may also exert asymmetric pressure on the cornea.

2. Structural and mechanical influences

- ***Eyelid pressure***: The pressure exerted by the eyelids, particularly the upper eyelid, can mould the cornea over time. A tight or asymmetric lid may steepen one meridian more than the other, contributing to with-the-rule astigmatism in youth.
- ***Extraocular muscle tension***: Imbalances in muscle tension can alter globe shape subtly, influencing corneal curvature along specific axes.
- ***Ocular surgery and trauma***: Surgical incisions (e.g., cataract or pterygium surgery) and trauma can induce irregular scarring and alter corneal shape. Suturing technique, incision location and wound healing all affect postoperative astigmatism.

3. Pathologic corneal conditions

- ***Keratoconus and ectasia***: Thinning and progressive steepening of the cornea, as seen in keratoconus or pellucid marginal degeneration, produce irregular astigmatism. These conditions often begin in adolescence and require specialized management.
- ***Corneal scarring***: Injuries or infections that scar the cornea can distort its curvature, leading to unpredictable astigmatism.

4. Lens-related factors

- ***Lenticular toricity or tilt***: Subtle differences in curvature between the anterior and posterior surfaces of the crystalline lens or a slight tilt/decentration of the lens can induce lenticular astigmatism. Changes in lens shape during accommodation can also temporarily modulate the astigmatic component.
- ***Age-related lens changes***: As the crystalline lens ages, it may thicken asymmetrically or undergo nuclear sclerosis, altering its refractive index. These changes can increase pre-existing astigmatism or shift its axis from with-the-rule to against-the-rule.

5. Environmental and Systemic Influences

- ***Ethnicity and gender***: Epidemiologic studies reveal variations in astigmatism prevalence among different ethnic groups, with some populations exhibiting higher rates. Male sex has been associated with a slightly higher risk in certain cohorts.
- ***Refractive errors***: High degrees of myopia or hyperopia often accompany astigmatism. The interplay between axial length and corneal curvature can influence the magnitude and progression of astigmatic error.

- ***Screen exposure and near work***: Excessive screen time and prolonged near tasks during early childhood have been linked to increased risk of developing astigmatism, possibly due to altered visual feedback and prolonged accommodation.
- ***Prematurity factors***: Maternal smoking during pregnancy, premature birth, and low birth weight have been associated with higher rates of refractive anomalies, including astigmatism.
- ***Systemic conditions and obesity***: Emerging research suggests correlations between higher body mass index and certain types of astigmatism, although the mechanisms remain under investigation.

Symptoms and Clinical Manifestations

A comprehensive understanding of how astigmatism presents clinically enables prompt recognition and appropriate management. Symptoms vary depending on the magnitude and type of astigmatism, age, and the presence of other refractive errors.

1. Visual symptoms

Astigmatism causes light to focus at different depths along separate meridians, leading to characteristic visual disturbances:

- ***Blurred or distorted vision*** at all distances; images may appear stretched or shadowed along one axis.
- ***Ghosting or double images (monocular diplopia)*** in moderate to high or irregular astigmatism, especially in low light.
- ***Poor detail resolution***, making tasks like reading small print or recognizing distant signs difficult.
- ***Night-time visual problems***, including halos, glare and starbursts around lights.

2. Asthenopic symptoms

Persistent attempts to compensate for unequal meridional focus can lead to:

- ***Eye strain and fatigue***: The constant effort to achieve focus across different meridians can lead to fatigue of the ciliary muscles and extraocular muscles. Patients often report tired eyes, especially after prolonged near work or screen use.
- ***Headaches***: Sustained squinting and accommodative strain often cause frontal or brow headaches, typically worse later in the day.
- ***Squinting and frowning***: Patients may narrow their eyelids to create a pinhole effect, temporarily improving clarity by limiting peripheral light rays.

3. Pediatric manifestations

- ***Reading difficulties***: Children with uncorrected astigmatism may struggle with reading, lose their place easily or avoid near tasks. Teachers may misinterpret this as a learning disorder.
- ***Amblyopia (lazy eye)***: High astigmatism during visual development can lead to reduced visual acuity in one or both eyes, a condition that is reversible only if detected and treated early.
- ***Head tilt or abnormal posture***: To find a clearer line of sight, children might tilt their head or hold books very close. Persistent head tilt requires evaluation to distinguish between compensatory behavior and musculoskeletal or neurological issues.

Clinical signs

Examination may reveal:

- Improved acuity with pinhole testing.
- A characteristic “scissor reflex” on retinoscopy.
- Distorted keratometry mires or asymmetric topography rings indicate irregular astigmatism.

- Photophobia and tearing in association with ectatic disorders like keratoconus.

Questions

1. Define astigmatism and explain how it affects the focusing of light on the retina.
2. What are the principal meridians, and how do they determine the optical properties of an astigmatic eye?
3. Describe the concept of Sturm's conoid and the circle of least confusion. Why are they clinically important?
4. Differentiate between regular and irregular astigmatism with one example of each.
5. Explain the differences between with-the-rule, against-the-rule, and oblique astigmatism based on corneal curvature.
6. Classify astigmatism based on refractive status (simple, compound, and mixed) with examples.
7. List three major causes or risk factors that can lead to the development of astigmatism.
8. Mention two common clinical symptoms of uncorrected astigmatism and explain why they occur.
9. Name two diagnostic tests used to detect and measure astigmatism, and describe the principle of one of them.
10. Why is early detection and correction of astigmatism important in children?