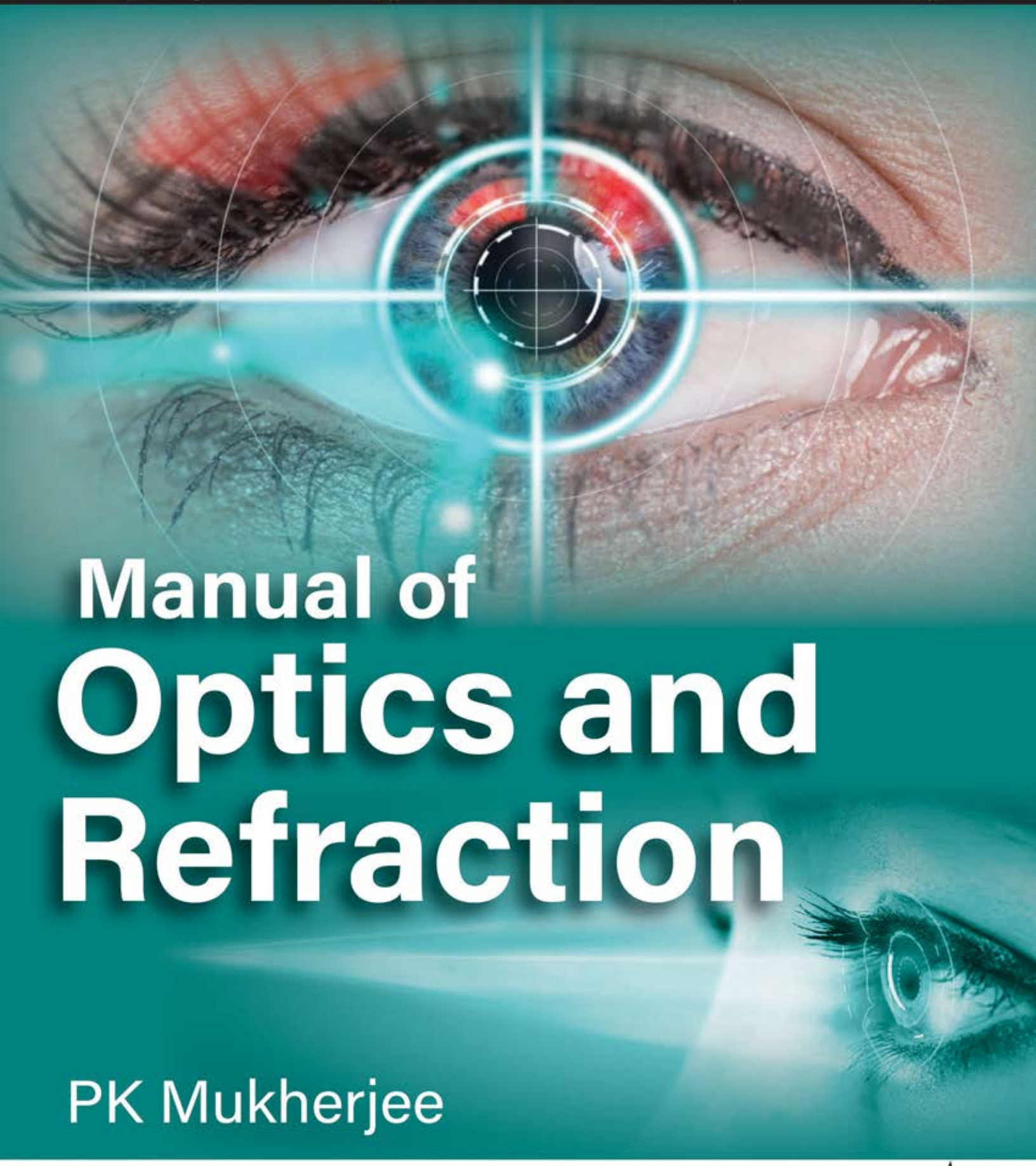

Manual of Optics and Refraction

PK Mukherjee

SECOND EDITION

JAYPEE

Manual of
Optics and Refraction

Second Edition

PK Mukherjee MS (Ophth)
Retired Professor and Head
Department of Ophthalmology
Pt Jawahar Lal Nehru Memorial Medical College
Raipur, Chhattisgarh, India

JAYPEE BROTHERS MEDICAL PUBLISHERS
The Health Sciences Publisher
New Delhi | London

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CHAPTER

6 Errors of Refraction

Errors of refraction are the most common ocular disorders for which people seek ophthalmic consultation. About 20–25% of populations have some error of refraction or the other. It inflicts all the races and both the sexes. Different age groups have predilection for different types of errors of refraction. Children under 15 are more likely to have myopia while persons above 40 are more prone to get hypermetropia unmasked. Generally, errors of refraction are bilateral and almost equal in two eyes, gradually developing and progressing slowly. It is not uncommon to have difference in diopter or type in two eyes, i.e., spherical/astigmatism and myopia/hypermetropia. Rapid change in power requires investigation to exclude central nuclear sclerosis, hyperglycemia, neglected blunt trauma, and chronic simple glaucoma.

The most common symptom of error of refraction in the eye inflicted is diminished distant vision, which is inevitable in myopia. No myopic eye can have normal vision. However, it may be normal or subnormal in hypermetropia. With proper treatment, distant vision improves to 6/6–6/9 and near vision improves to n/6.

Absence of error of refraction is called emmetropia and presence of error of refraction is called ametropia, which can be spherical or astigmatic. Both eyes can be myopia, hypermetropic, or may have different types of error of refraction.

EMMETROPIA

In emmetropia, the parallel rays of light are brought to pinpoint focus on the photosensitive layer on the retina, when accommodation is at rest **(Fig. 1)**.

If the eye accommodates, the retinal image in emmetropia moves forward away from the retina resulting in a circle of blur on the retina **(Fig. 2)**.

This produces mild-to-moderate myopia, diminishing distant vision. An emmetropic eye accommodates for near as per age and distance of the near point from the retina (refer "Accommodation" in Chapter 8). Lesser is the age, more is the accommodation. Similarly, shorter the near point more is accommodation required.

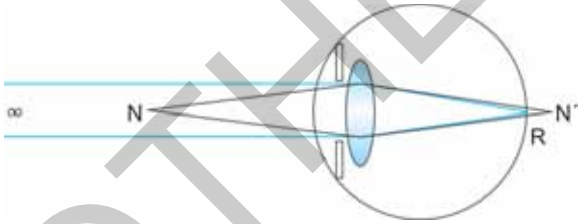


Fig. 1: Emmetropia rays from infinity are brought to focus on the retina (R) and the rays from near point (N) are brought to focus behind the retina at N' when accommodation is at rest.

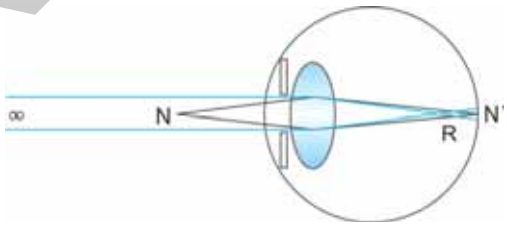


Fig. 2: Accommodation in an emmetropic eye.

Features of an Emmetropic Eye

- The anteroposterior length from anterior surface of the cornea to retina is 24 mm.
- The average diameter of cornea is 11 mm vertically and 12 mm horizontally.
- This makes cornea more curved in vertical meridian.
- The curvature of the cornea is 7.8 mm.
- The central 3 mm of the cornea is more spherical than the periphery.
- The total dioptric power of an emmetropic eye is +60D with anterior focal length of 15 mm and posterior focal length of 24 mm.
- The parallel rays are focused on the photosensitive layer of the retina when accommodation is at rest.
- The unaided vision in an emmetropic eye is 6/6 provided, the media are clear and the fundus is normal.
- In an emmetropic eye, the angle kappa is 5° positive.
- An emmetropic eye is generally orthophoric, but can be heterophoric or heterotropic.

- The accommodation of an emmetropic eye varies with age. It is more in young people as compared to old people.
- Near point also varies with age. In prepresbyopic adult, it is about 30 cm and gradually increases with age.

AMETROPIA

Ametropias are a group of refractive disorders of the eye where the parallel rays are not brought to pinpoint focus on the retina when accommodation is at rest. Accommodation worsens myopia and astigmatism facultative hypermetropia is corrected by accommodation.

In compound hypermetropic astigmatism, the error is partially abolished because, the refraction in all meridians shifts toward the retina, reducing the circle of blur.

Ametropia can be divided into two types:

1. Spherical
2. Cylindrical

Both spherical and cylindrical errors can either be myopic, corrected by minus lens and hypermetropic, corrected by plus lens.

Etiology

The following are the ways by which ametropia can be produced:

- Abnormal axial length of the eyeball
- Change in curvature of the ocular media:
  - *Cornea*:
    - Steep
    - Flat
  - *Lens*:
    - Increased
    - Decreased
- Alteration in refractive index of ocular media:
  - *Lens*:
    - Increased
    - Decreased
    - Absent
  - *Cornea*: Increased.
- *Position of the ocular media*: This is seen only in lens:
  - Move forward
  - Move backward
  - Tilt
  - Absent

Abnormal Axial Length of the Eyeball

The normal adult emmetropic eye is 24 mm long. 1 mm of change in axial length produces an ametropia of 3D, i.e., if the eyeball is 25 mm long, it will become myopic by 3D and if it is 23 mm long, it will become hypermetropic by 3D. The axial length may be as less as 20 mm or as much as 30 mm. Thus, making them hypermetropic by (24 – 20) × 3 = 4 × 3 = 12D or myopic by (30 – 24) × 3 = 6 × 3 = 18D, respectively. Such a high hypermetropia is infrequent except in aphakia. Changes in the axial length are the most common cause of ametropia as compared to other causes.

Change in Curvature of the Ocular Media

The change is more marked and frequent in cornea. The change in lenticular curvature is relatively rare and seen only in congenital conditions of lenticonus.

For all clinical purposes, the corneal curvature is taken as 8 mm. An increase in 1 mm curvature will produce 6D–7D of myopia, while flattening of curvature by same degree will produce hypermetropia of 6D–7D. The example of increased corneal curvature, resulting in myopia is keratoconus. Flattening of corneal curvature is of less clinical importance. It can be seen in microphthalmos, microcornea, and cornea plana. The cornea in a soft eye is relatively flatter. Irregular change in corneal curvature induces astigmatism.

Alteration of Refractive Index of Ocular Media

Abnormality of refractive index of lens is very common acquired cause of ametropia. Less common is change in the refractive index of cornea. Refractive indices of aqueous humor and vitreous humor are not known to change.

The normal refractive index of a clear lens is 1.337. If it becomes more as seen in central nuclear sclerosis, early concussion cataract and hyperglycemia, the error of refraction shifts toward myopia. This change in myopia may be very little or may be as much as –3D. In contrast to this, if the refractive index becomes <1.337, the ametropia shifts toward hypermetropia. The most common cause of such shift is drug-induced hypoglycemia following initiation of antidiabetic treatment or steep increase in dose of antidiabetic drug in patient already undertreatment for diabetes or skipping the diet. This can also happen following switching to unaccustomed exercise regime. Some other drugs such as acetazolamide and its derivatives are known to cause mild-to-moderate myopia. Corneal edema also produces moderate myopia.

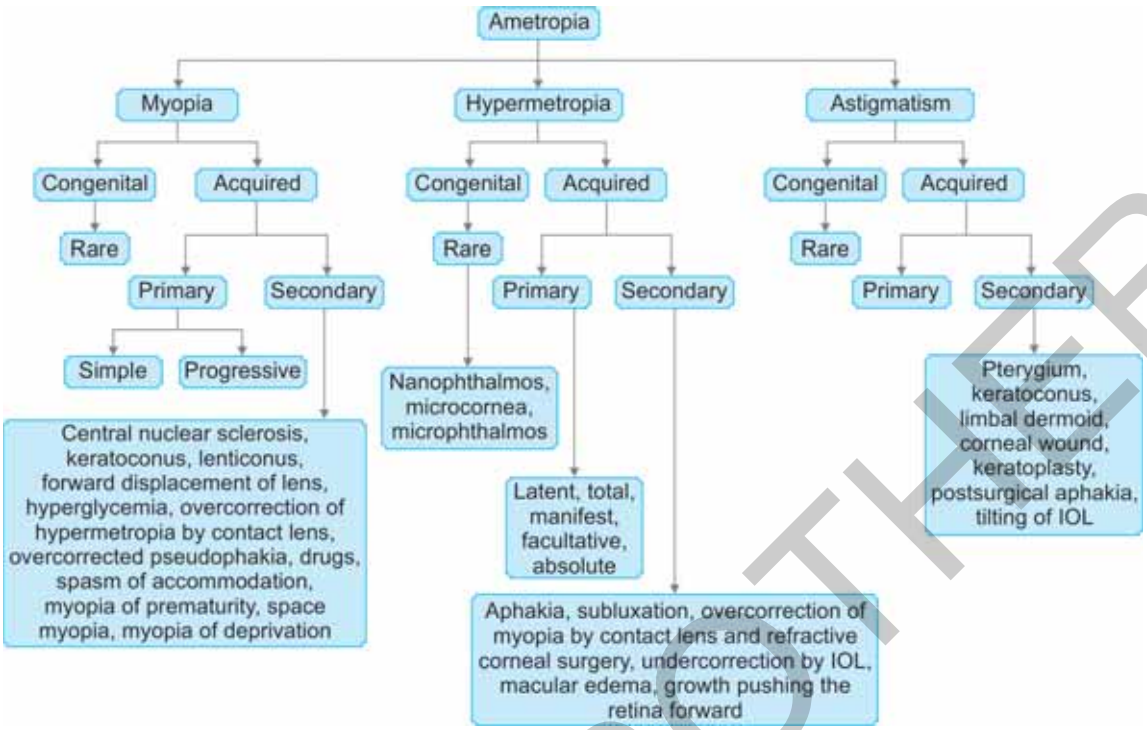
Position of Ocular Media

Out of four components of the ocular media, i.e., cornea, aqueous humor, lens, and vitreous humor, only lens can undergo displacement. Posterior shift of the whole lens can cause hypermetropia, anterior shift of the whole lens causes myopia. Tilting of the lens induces astigmatism.

CLASSIFICATION OF AMETROPIA

Ametropia is mainly classified into myopia, hypermetropia, and astigmatism **(Flowchart 1)**.

Flowchart 1: Outline of classification of ametropia.



Myopia

Myopia is that error of refraction where parallel rays are brought to focus in front of the retina when accommodation is at rest **(Fig. 3)**. Accommodation worsens myopia **(Figs. 4A and B)**. The myopic far point is at a finite distance in front of the eye.

Myopia is the most common form of error of refraction all over the world. Primary myopia is more common in children. Central nuclear sclerosis is the common cause of acquired secondary myopia after 50 years of age.

In myopia, parallel rays are brought to focus in front of the retina at the secondary focal point of the eye forming a circle of blur on the retina. More is the myopia, larger is the circle of blur, and farther is the image from the retina.

The far point of the myopic eye is between cornea and infinity from where the rays arise to behave like parallel rays. The far point is equal to a concave lens, the focal point of which coincides with it. The near point of the myopia of the 4D is 25 cm.

Accommodation worsens the myopia as it shifts the image forward making the circle of blur larger **(refer Figs. 4A and B)**.

The most common form of myopia is axial myopia, followed by index myopia. Myopia is prevalent world over; some races are more prone than others. It is equal in both sexes. It is generally bilateral and almost equal in both the eyes. Most of the time, myopia is gradual in onset, when acute, the causes other than axial myopia should be sought. Most of the myopias stabilize after few years. It has strong genetic influence. 20% of myopic children are born to parents who are myopes. If one parent has myopia, this figure drops to 10%. Rest of the myopias are sporadic who may pass the

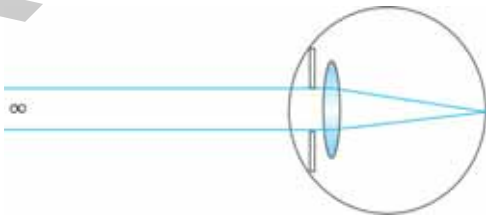
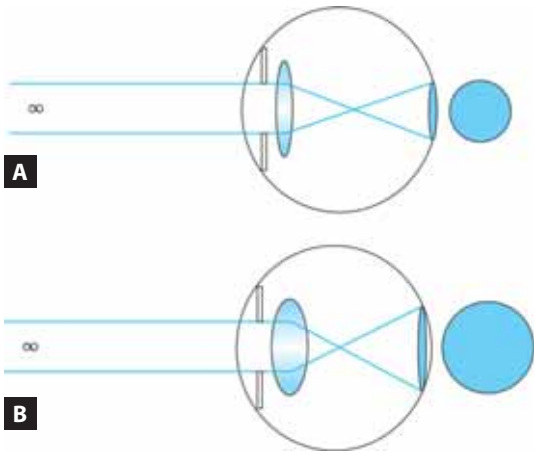
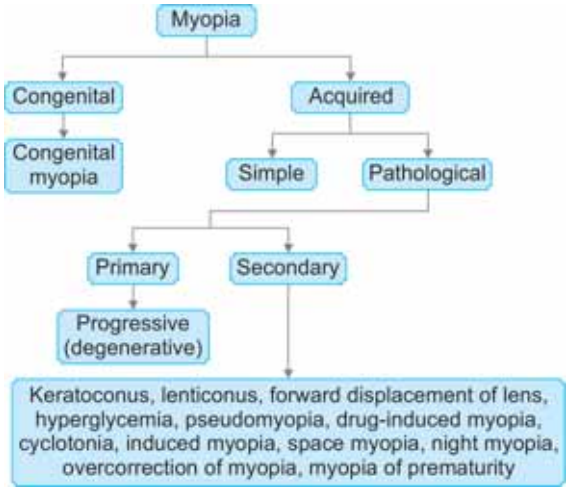


Fig. 3: Emmetropia when accommodation is at rest.



Figs. 4A and B: Myopia with or without active accommodation. (A) Myopia without accommodation (small circle of blur); (B) Myopia with active accommodation (large active of blur).

Flowchart 2: Classification of myopia.



tendency to the coming generations. It is common to see many of the siblings to have myopia.

Clinical Types of Myopia/Classification of Myopia

Myopia has been classified variously. The most comprehensive classification is shown in **Flowchart 2**.

Congenital myopia: Congenital myopia is rare. The exact cause, especially in unilateral cases, which is otherwise more common than bilateral, is not well understood. In bilateral cases, the cause may be some unknown factors, which influence the growth of the sclera in utero. The congenital myopia, unilateral or bilateral is present at birth, but missed unless fundus has been examined for some reason. In bilateral cases, its presence becomes obvious by 2–3 years when parents become aware of poor vision in the child. Unilateral cases go unnoticed unless the child starts squinting. Squint is generally esotropia, as the eye converges to see clearly at far point that may be as short as 12–15 mm in front of the eye. The eye in unilateral myopia may be large enough to draw parent's attention. The congenital myopia is generally 8–10 diopters, which invariably does not progress much. The fundus changes are similar to that seen in progressive myopia. In unilateral cases, the eye with myopia is generally amblyopic due to prevailing anisometropia and changes in the fundus. The congenital myopia may be associated with other congenital anomalies such as cataract, aniridia, megalocornea, Marfan's syndrome, and homocystinuria.

Management—The management of congenital myopia consists of:

- Early diagnosis
- Full cycloplegic refraction with special reference to associated astigmatism, which is common.
- Little under correction to give comfortable near correction.
- Management of amblyopia when present by usual antiamblyopic treatment.
- Contact lenses are given when the child is old enough to manage the contact lenses.
- Refractive surgery after 21 years of age
- Regular yearly examination of fundus under full mydriasis by indirect ophthalmoscope for any degeneration
- Peripheral degenerations when present should be managed by the standard procedures.
- These patients are prone to develop rhegmatogenous retinal detachment in spite of fairly good visual correction.
- The best corrected vision in congenital myopia is seldom better than 6/12.
- Clear lens extraction is a viable option.
- The eyes are prone to develop posterior subcapsular opacity, open angle glaucoma, macular degeneration, and macular hemorrhage.

Acquired myopia: Acquired myopia is difficult to classify satisfactorily. It can roughly be divided into primary myopia where no specific causative factor can be found to correlate with the condition and secondary where, the condition can be attributed to some ocular or systemic cause.

Primary myopia—Primary myopia can be divided into two classes:

1. Simple myopia
2. Progressive myopia

Features of the two may overlap.

1. *Simple myopia*: Simple myopia is the most common type of myopia. There are two age groups that are inflicted by this refractive disorder. They are:
   i. Simple myopia in children
   ii. Simple myopia in young adults

The etiopathogenesis is same in both. The former is more frequent than the latter. As the former is seen between 6 and 12 years that corresponds to school age, it is also called school myopia **(Table 1)**.

It has been amply proved that near work in school has no effect on progress of school myopia.

The latter is seen between 15 and 20 years of age when a person reaches high school or college, so it is called college myopia, **(refer Table 1)**. It is less in diopters as compared to school myopia, but is more often associated with moderate amount of astigmatism. The glasses required to give best vision, rarely exceeds –2D to –2.5D. Prognosis in both is good and vision can be improved to 6/6 with correction. Both the conditions stabilize after few years. The school myopia stabilizes in about 5–6 years with increment of 0.5D–1.00D every year. The college myopia stabilizes in about 2–3 years with little increase in power.

The most common cause of simple myopia is disparity between dioptric power of the eye and the axial length.

TABLE 1: Comparison between school myopia and college myopia.

Features	*School myopia*	*College myopia*
Type of myopia	Simple	Simple
Age of onset	First decade	Second half of second decade
Increment in power	0.5D–1.00D yearly	Not much
Final power after stabilization	–5D to –6D	–2D to –2.5D
Associated astigmatism	Less common	Frequent
Stabilized by	17–18 years	22–25 years

The axial length in simple myopia is in excess to axial length of an emmetropic eye. The exact cause of simple myopia is not well elucidated. It is thought to be a condition of overshooting the physiological limits of growth of the eyeball. At birth, all eyes except congenital myopia have short axial length, hence are hypermetropic. As the child grows, over next years the axial length increases reducing axial hypermetropia. By the age of 5–6 years, the axial length becomes almost 24 mm that is equal to axial length in adult and the child becomes emmetropic. Only about 10–15% of the eyes will keep on growing beyond stipulated 24 mm and become myopic. Like all primary myopias, simple myopia too has genetic predisposition. Exact mode of inheritance is not clear. There are two theories, one feels that it is autosomal dominant and the other feels it to be recessive. The exact genetics behind the condition can only be reached by mapping the myopic gene marker, which is being awaited.

Symptoms: The symptoms are mostly visual, which manifests as diminished distant vision, with normal near vision, hence, it is also called nearsightedness. The term nearsighted is relevant when referred to myopia in contrast to farsightedness used for hypermetropia because myopia is always associated with diminished distant vision and normal near vision, while hypermetropia may have diminished distant vision need not have diminished near vision.

The child may not be aware of diminished vision, but the parents realize that the child does not recognize far objects as other children. The child moves too close the television or the teacher complains that the child does not comprehend writings on the blackboard. The diminished vision is gradual, painless, and almost equal in both eyes. It rarely causes headache or asthenopia.

Signs: There are hardly any external signs in simple myopia of moderate degree except deliberate narrowing of the interpalpebral aperture, phorias that may break into tropias. The child narrows the interpalpebral aperture to produce a pinhole effect that increases the vision by few lines.

Fig. 5: Autorefractometer.

The fundus changes are minimal that include:

- Disk larger than emmetropia and hypermetropia
- Paleness of disk
- Temporal crescent (rare)

Complications: In simple myopia are few under 40 years of age. The complications become evident by fourth to fifth decade and include:

- Early development of central nuclear sclerosis
- Chronic simple glaucoma
- Lattice degeneration of the peripheral retina
- Rhegmatogenous retinal detachment
- Rhegmatogenous detachment is more frequent in simple myopia as compared to emmetropia and hypermetropia, but less common than in progressive myopia.

Diagnosis:

- History of bilateral, gradual, diminished distant vision in a child is strongly suggestive of simple myopia.
- Positive family history of myopia in parents and siblings point toward presence of myopia.
- Narrowing of interpalpebral aperture—improvement of vision by pinhole to almost 6/6
- Subjective improvement with minus glasses
- The confirmatory diagnosis is reached by retinoscopy under cycloplegia that automatically eliminated pseudomyopia in the child.
- The retinoscopy reading can be arrived at either by mirror retinoscope or streak retinoscope.
- Autorefractometers are handy tools in screening myopia in large number of children.

Autorefractometer ***(Figs. 5 and 6)***—It is a computerized digital instrument that is used to find out the error of refraction quickly as is required in mass screening of errors of refraction or in noncommunicative, nonverbal, or illiterate persons. It can be done under both cycloplegia or without cycloplegia. One eye at a time is examined. The machine

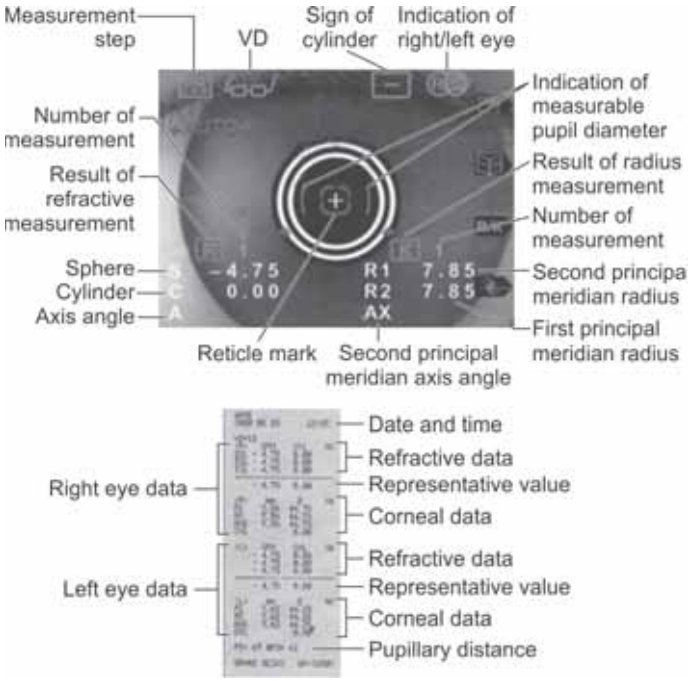
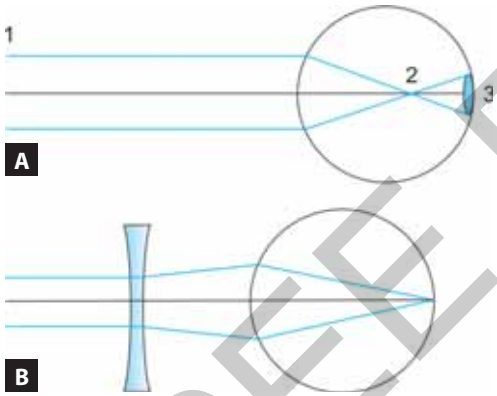


Fig. 6: Autorefractometry. (A) Various readings that can be taken by an autorefractometer; (B) A typical reading.
[*Courtesy:* Appasamy Associates (with permission)].



Figs. 7A and B: Correction of myopia. (A) Myopic eye; and (B) Myopic correction by concave lens, it brings the posterior focal plane on the retina, eliminating the circle of blur (1—parallel rays brought to focus in front of the retina; 2—it is posterior focal plane of the myopic eye; 3—circle of blurred vision).

contains a picture that moves in and out of focus when the patient looks at it and multiple readings are taken, which are computerized to give an average power along with its axes.

Treatment ***(Figs. 7A and B)***:

- There is no medical treatment available for myopia.
- Diets do not have any role to play in improving vision.
- No vitamin can stop the progress of myopia.
- Exercise and yoga have no role in management of myopia.
- The definitive treatment is optical by spectacle.
  - There is a recent trend in medical management of progressive myopia by weak solution of atropine in dose of 0.01–0.025% once a day in children between 6 and 10 years. The myopia should be more than one diopter with at least 0.5D yearly progress for 2 years. It is claimed to be effective in 70% of eyes. Atropine in such strength does not interfere with papillary size and accommodation. The exact mode of action of atropine in retarding myopia is not well understood.
  - *Optical treatment is not curative, it is only palliative. Optical treatment does not stop progression of myopia; neither does it reduce the power.*
- The optical treatment consists of prescribing full correction in children and young adults and under correction over 30 years.
  - *Myopes over 40 years do require near correction. They develop habit of removing the spectacle to do near work. This has led to misconception that presbyopia does not develop in myopes.*
- Older children who can manage contact lenses will prefer contact lenses over spectacles due to cosmetic reasons. Contact lenses in no way lead to reduction of myopia. The hypothesis that constant use of contact lens reduces or stabilizes myopia is called orthokeratology.
  - *Orthokeratology:* This is a technique used in myopia where a flat hard contact lens is prescribed for constant use. The contact lens should be flatter than the corneal curvature. The reduction of progression, if at all, is transient. This method is no more in vogue.
- Refractive surgery is not indicated unless the patient has reached the age of 20 years and there is no increase in the power for at least 1 year.
- The aim of treatment of myopia is not only improving vision, but also to bring back disparity between accommodation and convergence within physiological limits to make an eye orthophoric for distance and near. This will also eliminate any asthenopia when present.

2. *Progressive myopia*: Progressive myopia is also known as degenerative or pathological myopia. The optics involved in progressive myopia is same as simple myopia, i.e., increased axial length that brings the far point nearer than infinity, very close to eye forming a large circle of blur on the retina. It may be considered as exaggerated form of simple myopia with rapid progression and degenerative changes in posterior segment. Progressive myopia may begin at birth or first few years of life and increase relentlessly. The age of first presentation is little less than found in simple myopia. The extent of myopia at the first presentation may be as much as –3D or –4D, which progresses faster than in simple myopia. The progression may be as much as –1D to –2D per year and reach the maximum by age of 12–15 tears. The maximum power may be as much as –20D to –25D. This fast progression differentiates it from congenital myopia, which rarely progresses beyond 8D–10D. Progressive

Manual of
Optics and Refraction

Salient Features

- Errors of refraction form a major part of teaching of ophthalmology in undergraduates, postgraduate training and optometry
- The present book in meant for students appearing for first part of final MBBS that includes both theory and practical in optics
- Refraction forms a major part of practical examination in postgraduate evaluation. Students undergoing training for MS, MD, DO, DOMS, FRCS, DNB and degree in optometry will find the book handy for practical and viva. The paramedical ophthalmic assistances will be much benefited from the book
- Divided in two parts, i.e., basics of optics and application of optics in clinical ophthalmology. The book is profusely illustrated with diagrams, charts and photographs
- Written in English that is comprehendible and practiced by students of medicine in commonwealth countries.

PK Mukherjee MS (Ophth) is a Practicing Consultant and Counselor in Ophthalmology. He is Retired Professor and Head, Department of Ophthalmology, Pt Jawahar Lal Nehru Memorial Medical College, Raipur, Chhattisgarh, India. He has experience of 40 years as clinical teacher in various medical colleges in states of Madhya Pradesh and Chhattisgarh. He had been examiner in undergraduate and postgraduate examination in various universities. Along with teaching assignment he has been administer as well, i.e., superintended of medical college and hospital, Principal of Medical College, Dean, Faculty of Medicine; Pt Ravishankar Shukla University, Raipur, Chhattisgarh, India. He had been Incharge of Mobile Unit of Medical College, Raipur and performing numerous eye camps all over state of Chhattisgarh. He specializes in community and pediatric ophthalmology. He has three innovation to his credit, i.e., corrections of cicatricial entropion from conjunctival surface, correction of spastic entropion and nasolacrimal duct intubation. He has published many postgraduate books in ophthalmology and published papers in national and international journal. He has been awarded Professor Wagle Oration award for his work on ocular leprosy. He is a recipient of Dr RK Mishra, Gold Medal for his contribution towards ophthalmology by Madhya Pradesh State Ophthalmological Society, he is also recipient of Dr MR Pandey, Gold Medal for his contribution in the field of community ophthalmology. In the year 2011–2012, he was honored by Dr Kummud Joshi Oration award of NSPB (MP). He received lifetime achievement award from Chhattisgarh State Ophthalmic Society in 2009 and from AICON in 2013. He is the President Emeritus of Chhattisgarh State AICON. He is lifetime member of AIOS, MP State Ophthalmological Society, Chhattisgarh State Ophthalmological Society, and Ocular Trauma Society of India.

Printed in India

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