# Refractive errors

## Definition

In order to allow us clear vision, light rays reflected from objects towards which we are looking cross four successive eye regions: the cornea, the aqueous humour, the crystalline lens, and the vitreous body. Every time a light ray crosses one of these regions, its path deviates at a certain angle in a phenomenon called refraction. These combined refractions result in the convergence of light rays on the retina, allowing a clear view of the object.[1]

When light rays converge in front of or behind the retina, instead of directly on it, the patient is said to have refractive errors, also called ametropia. As a consequence of this, images are blurred. Possible manifestations of this condition are:

**Myopia:** If you suffer from myopia (near-sightedness), you are not able to clearly see distant objects, though closer objects can still be clearly seen. This condition occurs when the eye is elongated, which is detected using an examination called biometry, or the cornea is too convex, causing the light rays to converge in front of the retina.

**Hyperopia:** The opposite of myopia, if you suffer from hyperopia (far-sightedness), you are not able to clearly perceive close objects. This condition occurs when the eye is too short, detected by biometry, or the cornea is too flat, causing the light rays to converge behind the retina.

**Astigmatism:** In the case of astigmatism, the cornea has an abnormal, ovular shape closer to a rugby ball than a football. Also, the crystalline lens may be abnormally tilted. Light rays crossing the eye focus on different points, both behind and in front of the retina, resulting in a distorted image. If you suffer from astigmatism, your vision is imprecise and blurry at any distance.

**Presbyopia:** The crystalline lens hardens with age, reducing the eye's ability to focus on close objects. Because of this, if you suffer from this condition, your near vision becomes blurred. Accommodation refers to the process which ensures, thanks to changes in the crystalline lens's shape, that objects at different distances can be seen clearly.

## Epidemiology

The number of people worldwide suffering from refractive errors is estimated to range from 800 million to 2.3 billion.[2] Of these, around 153 million cases have not been corrected with contact lenses or glasses.[3] In France, 39% of the population are estimated to suffer from myopia, 15% from astigmatism, 9% from hyperopia, and 26% to 30% from presbyopia.[4]

Myopia seems to be less common in Europe than in Asia, where 84% of the population in Hong Kong and Taiwan appear to be affected. Australian aborigines represent the other extreme, with less than 5% experiencing myopia.[5] Hypermetropia affects 9.9% of Americans, 11.6% of Western Europeans, and 5.8% of Australians aged 40 years or older.[5]

While presbyopia most often begins after 40 years of age in Western countries, studies have shown that it starts earlier and is more severe in Africa compared to Europe and North America.[6] These studies have shown that in developing countries, more than 50% of adults older than 30 years suffer from presbyopia.[6] Furthermore, presbyopia is more common and more severe in women than in men.[6]

## Risk factors

Both genetic and environmental factors appear to contribute to the development of myopia. A primary contributing environmental factor is the frequent performance of work requiring extensive use of close vision.[7] An association between myopia and socio-economic station and education level has also been observed.[8]

Hyperopia and astigmatism both seem to be at least partially genetically determined.[9] Astigmatism is often inborn, but may also develop later in life, for example following cataract surgery or an accident.

The most important risk factor for presbyopia is age, as it occurs mainly after 40.[10] Other factors, such as the presence of uncorrected hyperopia, the performance of work requiring extensive use of close vision, eye conditions and accidents affecting the crystalline lens, and medical diseases such as diabetes or multiple sclerosis, may play a role.[10]

## Symptoms

Refractive errors principally result in visual blurriness at short or long distance. In some patients, headaches may also occur. Occasionally, the eye surface may become dry, resulting in eye irritation, itching, visual fatigue, the sensation of a foreign body, or redness.[11]

## Diagnosis

Ophthalmologists apply a multi-step diagnosis to myopia, hyperopia, astigmatism, and presbyopia. In the first step, you will provide him with a description of your symptoms, permitting him an initial understanding of your condition. For example, those patients complaining of poor near vision will

give their ophthalmologist reason to suspect presbyopia, whereas astigmatism may be suspected if a patient complains of distorted vision.

In order to obtain more precise information, the ophthalmologist will measure your near and distance vision by asking you to read with one or two eyes a series of letters of decreasing size on an illuminated display. Furthermore, in order to determine the precise type and degree of ametropia, the ophthalmologist will employ a refractometer or a skiascope.

Following these examinations, the ophthalmologist will be able to prescribe you the appropriate visual correction.

## Examinations

In order to diagnose your ametropia and determine precisely from which type you suffer, your ophthalmologist will perform either refractometry or skiascopy.

Refractometry is a method of measuring the eye's spherical refraction, which is altered in myopic and hyperopic patients, and its cylindrical refraction, which is modified in astigmatic patients. For this examination, the ophthalmologist employs a computer-assisted instrument called an automatic refractometer. Before the examination, he may apply cyclopegic eye drops in order to block your eye's capacity for accommodation and obtain a more accurate measurement. During the examination, you will be asked to rest your chin on the refractometer's chin rest while the instrument takes three consecutive measurements of each of your eyes. Refractometry is quick, painless, and very accurate.

An alternative method of measuring refraction is skiascopy. Your ophthalmologist, using a portable instrument called a skiascope, will focus a beam of light on your retina and observe the reflected light which then exits through the pupil. If there is no movement at all, it means that there is no refraction error. A movement in the direction of the beam of light indicates hyperopia, and a movement in the opposite direction indicates myopia. The reflection's movement speed is also an important indicator.

The slower the movement is, the more significant the refraction error is. In order to determine the necessary correction power, the ophthalmologist places lenses of varying strength between your eye and the beam of light, until the reflection is neutralised.

## Complications

Myopia generally occurs most frequently during childhood. Vision decreases steadily during adolescence and stabilizes between the ages of 20 and 25.[12] Patients with myopia may suffer certain complications, such as macular degeneration, retinal detachment[13] or glaucoma.[14]

Hyperopia often develops during childhood. In mild cases, it often recedes and disappears before adulthood. However, children suffering from severe hyperopia may develop strabismus or amblyopia,[15] which corresponds to a progressive decrease of visual acuity due to a lack of interaction between the brain and the eye.

Generally, astigmatism is not a progressive condition. Rarely, it progresses rapidly, in which case a keratoconus should be suspected. This condition is characterised by the progressive deformation of the cornea, which becomes conical. As a result, vision is distorted.

Presbyopia and difficulties with close vision normally develop after the age of 40. However, reduction of the eye's accommodation capacity begins as early as childhood. Accommodation capacity is 18.5 dioptres at the age of 6 months, 14 dioptres before 10 years of age, 4 dioptres at 40 years of age, and less than 1 dioptre after 65 years of age,[16] at which presbyopia tends to stabilise.

## Treatment

**Optical correction**
All refractive errors can be corrected either by the use of glasses or contact lenses, whose dioptres are calculated by the ophthalmologist who examined your eyes:

- **Glasses:** Myopia may be corrected using a concave lens, and hyperopia may be corrected using a convex lens. Both lenses focus light rays on the retina, correcting poor distance vision or near vision, respectively. Astigmatism may be corrected using lenses which correspond specially to the patient's corneal deformations.

- For presbyopia, different types of lenses are available. **Bifocal lenses**, whose lower convex portion corrects near vision and whose upper portion permits distance vision. More recently, progressive lenses permit vision at any distance, as bifocals do, but without any lens separation. Convex lenses are used to correct near vision, but they must be removed for distance vision.

- **Contact lenses:** In the cases of myopia, hyperopia, and astigmatism, contact lenses often provide a better correction of both visual acuity and peripheral vision than glasses.[11] If you suffer from myopia or hyperopia, you may use either soft or hard contact lenses. Astigmatism may be corrected either by hard contact lenses or soft toric contact lenses, which operate on the same principles as glasses. However, if you choose to wear contact lenses, you must follow the instructions regarding handling and hygiene provided by your ophthalmologist. Poor lens care, prolonged usage, and the use of tap water rather than the designated cleaning solution may result in inflammation or infections of the cornea.[11]

**Refractive surgery**
Refractive surgery aims to decrease the dependence on glasses and contact lenses. Different laser techniques, which involve the modification of the cornea's shape, are available. In some cases, the placement of an intraocular implant is the preferred solution.

Your ophthalmologist will decide which procedure best suits your treatment needs, depending on the nature of your ametropia, its intensity, and the shape of your cornea.

Photorefractive keratectomy (PRK) consists of the removal of the superficial corneal cell layer, called the epithelium, and the reshaping of the cornea just below with a computer-controlled laser. This procedure flattens the cornea in myopic patients and rounds it in hyperopic patients, permitting light rays to converge on the retina rather than in front of or behind it. Following surgery, around 95 % of patients achieve 20/40 vision and no longer require corrective lenses.[11]

LASIK, or laser-in-situ keratomeliusis, is a technique designed to decrease the cornea's thickness in order to modify its refraction capacity. The procedure involves the creation of a corneal flap which is raised to expose the cornea. The laser then sculpts the cornea to the desired thickness. Following the surgery, visual recovery is quick, and most patients experience a major improvement in their vision within a day.[11] LASIK may be used to treat myopia, astigmatism, and hyperopia.[11]

LASEK, or laser epithelial keratomeliusis, serves as an intermediary technique between PRK and LASIK. It consists of the remodelling of the cornea's surface with a laser. Prior to this, the surgeon creates a flap in the corneal epithelium. To facilitate the detachment of the epithelial flap, he applies a diluted alcohol solution to the eye and uses specialized instruments. After having remodelled the cornea with the laser, the flap is restored to its previous position over the sculpted corneal tissue. The recovery period is similar that of PRK.[11]

Intraocular implants are optic lenses of varying power, made of synthetic material, which are either placed in front of the crystalline lens or used to replace it. They permit the restoration of near or distance vision, depending on the eye condition they are used to correct. After the surgery, the surgeon will use an instrument called an optic biometer to measure the length of your eye and calculate how powerful the implant is. He will also ensure that the capsule surrounding the crystalline lens remains intact. This procedure is generally performed on patients with severe myopia or hyperopia, for whom laser procedures do not yield satisfactory results. Moreover, in patients whose cornea is to thin for laser treatment, an intraocular implant may be the best solution.[17]

The High Frequency Echography, linear 25 MHz probe for example, is perfectly adapted:

- To check, before surgery, if the capsule bag of the lens is intact
- To check, after surgery, if the implant is correctly positioned

## References


1 Albou-Ganem C, Saragoussi JJ. Qu'est-ce que la réfraction. Dans : Chirurgie réfractive. Bash 2008, p. 32-3.

2 Titcomb L. Laser surgery for refractive errors. The pharmaceutical journal 2006;276:511-4.

3 Organisation Mondiale de la Santé. What are refractive errors? October 2006. http://www.who.int/features/qa/45/en/index.html

4 Syndicat National des Ophtalmologistes de France. http://www.snof.org/accueil/epidemio.html

5 Jobke S, Kasten E, Vorwerk C. The prevalence rates of refractive errors among children, adolescents and adults in Germany. Clinical Ophthalmology 2008;2:601-7.

6 Patel I, West SK. Presbytie : prévalence, impact et interventions. Revue de santé oculaire communautaire 2008;5:4-5.

7 Ibay G, Doan B, Reider L, et al. Candidate high myopia loci on chromosomes I 8p and I 2q do not play a major role in susceptibility to common myopia. BMC Medical Genetics 2004;5-20.

8 ANAES. Correction des troubles de la réfraction par laser excimer : photokeratectomie réfractive et lasik. Avril 2000. p.83-4.

9 Hammond CJ, Snieder H, Gilbert CE, et al. Genes and environment in refractive error: the twin eye study. Invest Ophthalmol Vis Sci 2001;42:1232-6.

10 American Optometric Association. Optometric clinical practice guideline - Care of the patient with presbyopia. 1998. p. 5.

11 Beers MH, Porter RS. Erreur réfractive. Dans : Le manuel Merck. Merck Research Laboratories 2006, p. 881-5.

12 Albou-Ganem C, Saragoussi JJ. Comment corriger ma myopie. Dans : Chirurgie réfractive. Bash 2008, p. 40-1.

13 Lai T. Retinal complications of high myopia. The Hong Kong Medical Diary 2007;12:18-20.

14 Mitchell P, Hourihan F, Sandbach J, et al. The relationship between glaucoma and myopia: the Blue Moutains Eye Study. Ophthalmology 1999;106:2010-5.

15 Jeddi Blouza A, Loukil I, Mhenni A, et al. Prise en charge de l'hypermétropie de l'enfant. Journal français d'ophtalmologie 2007;30:255-9.

16 Duncombe-Poulet C. La presbytie : bases cliniques et physiopathologies. Tropique. p. 4-10.

17 Albou-Ganem C, Saragoussi JJ. Comment le chirurgien choisit-il la meilleure technique adaptée à mon cas. Dans : Chirurgie réfractive. Bash 2008, p. 64-5.