National Academy of Opticianry

Continuing Education Course

Approved by the American Board of Opticians

Refractive Status of the Human Eye

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Refractive Status of the Human Eye

By

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Course Description

- This course will present the refractive status of the human eye, discussing the refractive errors of the eye. Included in discussion will be corrections for the various refractive errors. Corrections for muscle imbalances will be presented.

Learning objectives/outcomes

- At the completion of this course, the participant should be able to:
  - Understand the refractive status of the eye
  - Use correct terminology for refractive errors
  - Explain the various refractive errors
  - Identify lenses to correct different refractive errors
  - Be able to explain how different lenses will look based on the patient's prescription
  - Discuss corrections for muscle imbalances

Refractive Status of the Human Eye

Introduction

During this course, we will discuss basic terminology as it relates to the refractive status of the eye. Then we will move on to the descriptions of the various refractive errors of the eye and how to correct them, including presbyopia and muscle imbalances. We will also add to the information presented in earlier chapters on unequal refractive errors, and finally discuss how to visualize the final Rx and be able to discuss it with the patient.

Terminology

Terminology that we will be discussing will begin with what does 20/20 vision mean. We will discuss some of the refraction terminology in order to understand how it relates to a patient's vision.

20/20 Vision

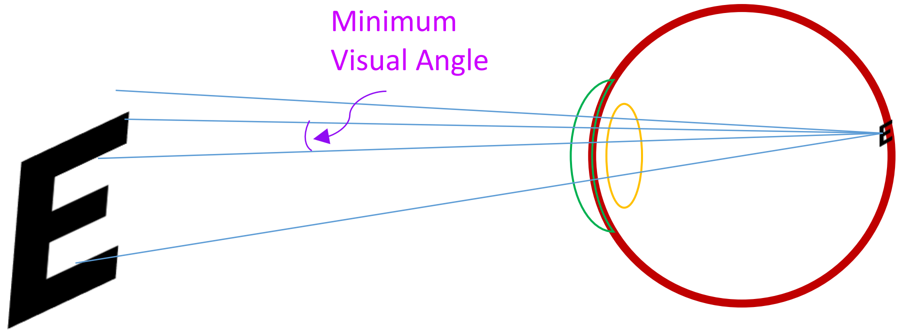
20/20 vision is identified as normal vision. This section will discuss exactly what 20/20 vision means.

Visual Acuity

The Dictionary of Ophthalmic Optics defines visual acuity thusly:

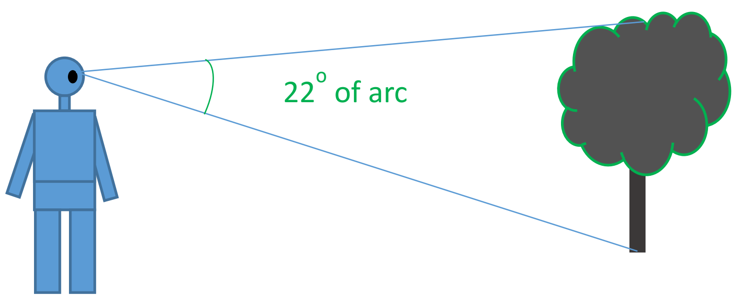
Resolving power or form discrimination dependent upon the sharpness of the retinal image, the sensitivity of the neural elements and the interpretation facility of the brain.

Visual acuity is the measure of the angle subtended by the outer limits of rays of light coming from the minimum detail of an object as they enter the eye. It is a quantitative measure of the ability to identify the smallest elements of a letter (or object) to correctly identify the letter or object. We'll discuss the Snellen letter shortly and identify this just a little more. We refer to normal visual acuity as 20/20 or in metric terms as 6/6. It means that they eye can resolve at 20 feet the elements of the size letter on the chart that would be considered normal resolution at 20 feet. 20/20 vision does NOT mean perfect vision, because it doesn't account for total clarity. In reality, a person may have visual acuity that would be "better" than 20/20.



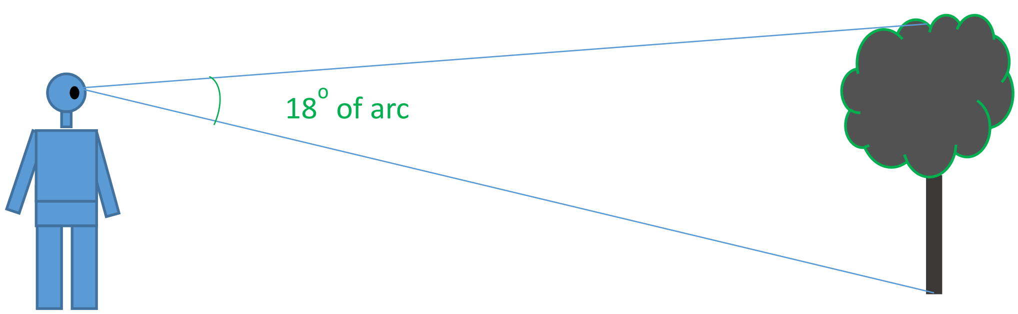
Subtend

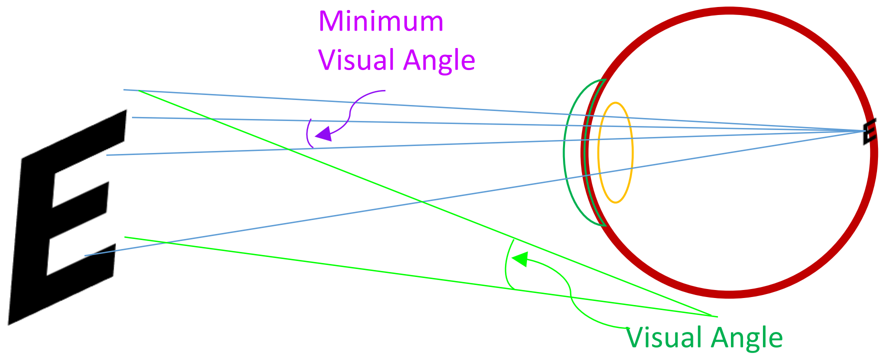
While this course will not be presenting the subject of refraction as related to refracting a patient, it will present some terminology that is common with refraction. We just introduced a word, subtend. Subtend means to extend under or to be opposite to. That means the angle which is opposite the object being observed.



Visual Angle and Minimum Visual Angle

The visual angle is the angle subtended by an object at the lens of the eye; the retinal image size. The visual angle is dependent upon the size of the object and the distance of the object from the eye. An example would be that the same object placed at different distances from the eye would subtend different visual angles. Also, images of different sizes could subtend the same visual angle if placed at different places away from the eye.

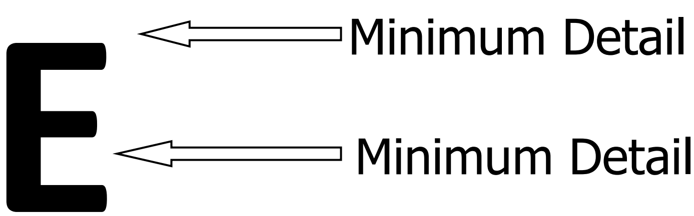




Minimum detail is the detail that must be detected on an object to positively identify or distinguish the object.

Minimum Detail

The detail that must be detected on an object to positively identify or distinguish the object is the minimum detail. For example, it indicates that a person can distinguish the blank spaces between the lines, seeing three horizontal lines and two spaces between. In addition, they can see the vertical line on the left and can tell it is not enclosed on the right.



Resolution

Resolution is the ability to detect minimum detail. The resolving power of the normal eye is a minimum visual angle of 1 minute. The minimum visual angle of the letter is 1 minute. The visual angle of the letter is 5 minutes. An example would be the letter E has three horizontal lines and two spaces between the parts. Each line and each space create a minimum visual angle of 1 minute each, therefore creating a total visual angle of 5 minutes.

Visual acuity is ability to resolve small detail, or the measure of the angle subtended by the outer limits of the rays of light coming from the minimum detail of an object as they enter the eye. The standard definition of normal visual acuity

(20/20 vision) is the ability to resolve a spatial pattern separated by a visual angle of one minute of arc.

Snell's Law of Refraction

We won't be going over Snell's formula just yet, but will present it for future reference. Here is the formula.

$n_1 \sin i = n_2 \sin r$

The Snellen Fraction

The Snellen Fraction is the distance at which the test is made divided by the distance at which the smallest letter read subtends an angle of 5 minutes.

An example would be on the Snellen letter. Each part of the letter E including the spaces must be positively identified in order to identify the letter as an E rather than for example an F or B.

Refractive Errors

Terminology

Some of the terminology that we will be discussing in this section will include emmetropia, ametropia, myopia and hyperopia. Other terminology will include astigmatism. Depending on the location of the principle meridians, there are different types of astigmatism.

While presbyopia is not classified as an ametropia, we will discuss it later in the course.

Four Refractive Mediums of the Eye

The four refractive mediums of the eye include the cornea, the aqueous humor, the crystalline lens and the vitreous humor.

As we begin our discussion on the refractive status of the eye, let's consider the visual system as being a plus (power) visual system. That means that within the visual system there are mediums (components) that contribute plus power that is needed to place an image focus on the retina. If the power is adequate in every medium, the image comes to a point focus on the retina. If some medium is under plussed or over plussed, the image will not come to a point focus on the retina. Too much plus and the image converges too much and the image will be focused in front of the retina. Too little plus and the image does not converge quickly enough and the image will fall behind the retina. This will be discussed more in-depth later on in this course.

The index of refraction of the cornea is 1.37, the aqueous humor is 1.33, the crystalline lens is 1.42, and the vitreous humor is 1.33.

Dioptric Power

While the crystalline lens has the highest index of refraction, the cornea, because of it's radius of curvature has the most power. The power of the average cornea is +42.00 to +45.00 diopters, while the crystalline lens has +12.00 to +15.00 diopters or +20.00 diopters depending on the text that you are studying. I like to use +17.00 diopters as an average for the crystalline lens and +43.00 diopters for an average for the cornea. Combined that will give approximately +60.00 for the total refractive power of the eye. As you can see the cornea performs approximately 70% - 80% of the refraction or bending of light rays within the eye.

Axial Length

In addition to the dioptric power of the lens, the axial length must be within normal range also for light to focus on the retina. The axial length is based upon the average physical diameter of the globe of the eye being about 24.0mm. That is based upon a radius of 12mm. So as you can see the globe is almost round. Added to that, the average cornea protrudes approximately 2.5mm. By combining the length of the globe and the cornea, the axial length of the average eye is about 26.5mm. Of course we know that there are variables in all eyes, but these numbers are averages.

Refraction

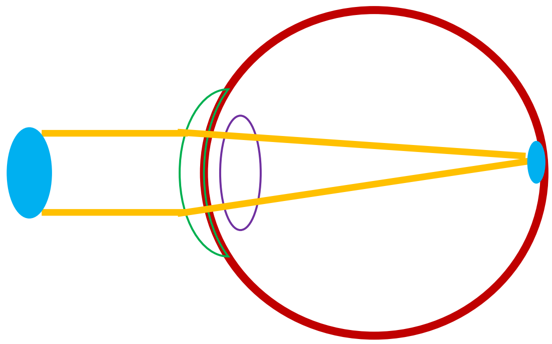
Refraction is defined as the "bending" of light as it passes <u>obliquely</u> between two different refractive mediums

A beam of light that enters a refractive medium perpendicularly is not refracted, but merely slowed down and the path of the beam is unchanged.

Emmetropia

<u>Emmetropia (Emetropia)</u> is defined as the normal ocular refractive condition in which the principal focal point of the dioptric system of the eye lies exactly in the plane of the retina. Theoretically it is an eye with normal refractive status. An emmetropic eye is a non-accommodating eye that refracts light coming from a distant (parallel light = 20 feet) object so that light rays are clearly focused on the retina. There is standard emmetropia and non-standard emmetropia. A standard emmetropic eye has a standard refractive power of both cornea and crystalline lens and a standard axial length. A non-standard emmetropic eye would still be an eye with no refractive error, but would have either excessive refractive power of either cornea or lens or both combined with a shorter than

normal axial length, or deficient refractive power and excessive axial length, canceling out any requirements for refractive correction. A person could have an emmetropic eye and still have muscle imbalance problems or ocular disease.



Ametropia

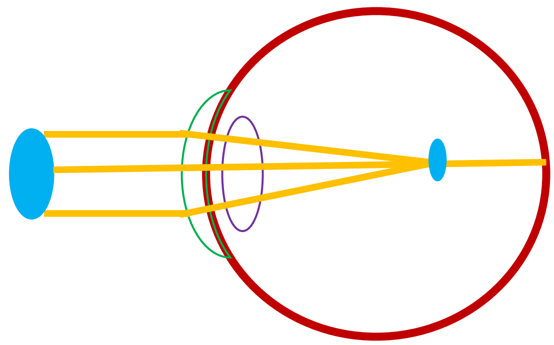
Ammetropia (Ametropia) is a general term for any error of refraction in the eye. An ametropic eye is one that at rest refracts light coming from a distant (parallel light = 20 feet) object so that light rays are not clearly focused on the retina. Let's begin with basic terms. As mentioned earlier, the eye could be classified as a plus visual system. If the visual system were not over plussed or under plussed, it would result in an emmetropic eye.

Myopia

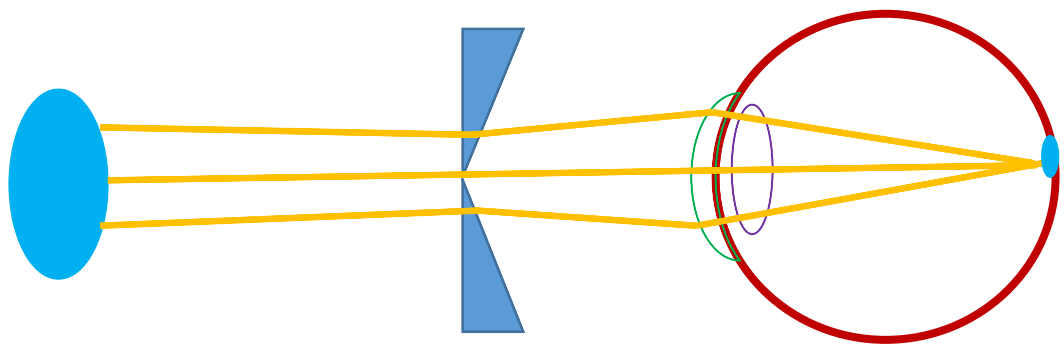
If the eye were over plussed (containing too much plus power) it would result in myopia.

Myopia (hypometropia) also called short sight or nearsighted is defined as a refractive error of the eye in which light rays from infinity focus in front of the retina of an uncorrected eye.

Axial myopia is nearsighted refractive error in which the eye is too long from front to back for its optical power, thereby placing the light rays from infinity in front of the retina. Curvature myopia is an optically overpowered (plussed) eye caused by steeper than normal corneal curvature or a crystalline lens that is too convex for the eye's axial length. Curvature myopia could be due to an over plussed cornea, over plussed crystalline lens or a combination of both. Myopia could also result from a combination of both axial and curvature myopia.



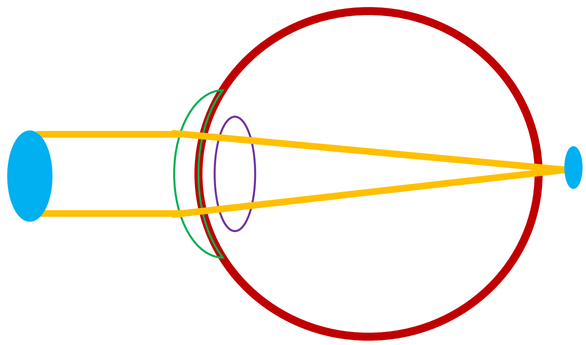
Myopia is generally corrected by minus (-) concave powered lenses. Remember, based upon the characteristics of lenses, minus lenses diverge light rays. In addition, a minus lens reduces the effect of the over plussing of the visual system, allowing the image to focus on the retina.



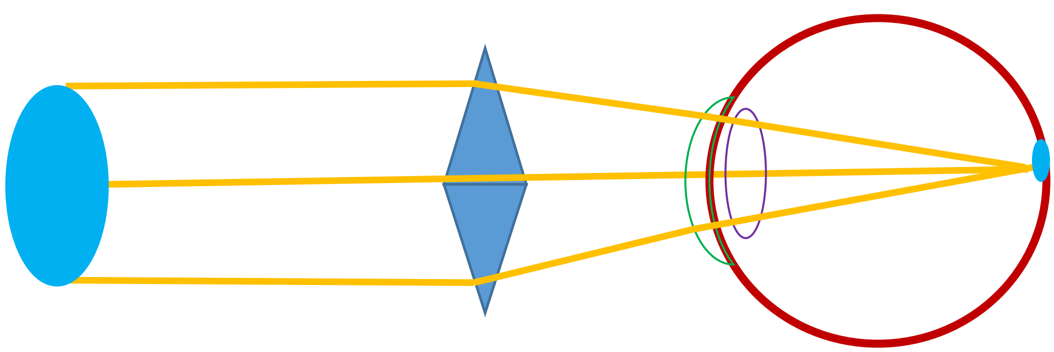
Minus lenses are basically two prisms having the apexes in the middle and the bases on the edge of the lens. Light rays will be bent toward the base so light rays are diverged or spread apart, making the rays further apart upon entering the eye, allowing them to come to a point focus on the retina.

Hyperopia

An eye (visual system) that is underplussed would result in hyperopia. Hyperopia also called Hypermetropia is defined as an eye in which parallel rays of light from infinity strike the retina before coming to a focus, correctable by plus lenses. Axial hyperopia is a farsighted refractive error in which the eye is too short from front to back for its optical power, thereby having light rays from infinity strike on the retina before coming to a point of focus. Curvature hyperopia is an optically underpowered (plussed) eye caused by flatter than normal corneal curvature or a crystalline lens that is not convex enough for the eye's axial length. Curvature hyperopia could be due to an under plussed cornea, under plussed crystalline lens or a combination of both. Hyperopia could also result from a combination of both axial and curvature hyperopia.



Hyperopia is corrected with plus or convex lenses. Because the visual system is under plussed, this additional plus power in the lens allows the image to focus on the retina.



Plus lenses are basically two prisms having the bases in the middle and the apexes on the edge of the lens. Light rays will be bent toward the base so light rays are converged or brought together, bringing the rays closer together upon entering the eye, allowing them to come to a point focus on the retina.

Astigmatism

Astigmatism could be defined as "without point focus". It is an imperfect condition of refraction in which rays emanating from a single luminous point are not focused at a single image point by an optical system, but instead are focused as two line images.

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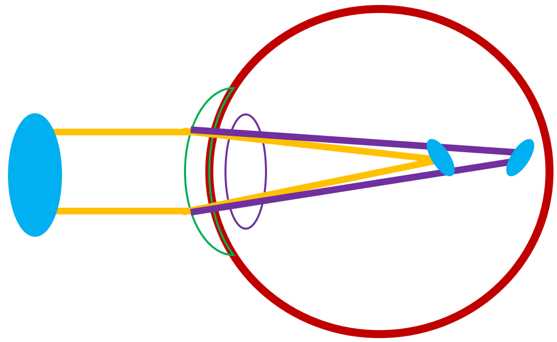
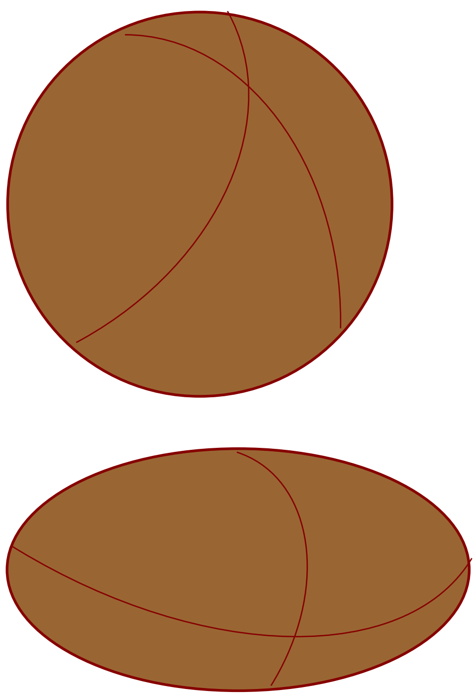


Toricity may be found either on the cornea which would be corneal astigmatism or on the crystalline lens in which case it would be lenticular astigmatism. Corneal toricity is defined as the difference between the vertical and horizontal meridians on the cornea. Likewise, lenticular astigmatism is defined as the difference between the vertical and horizontal meridians on the crystalline lens.



Oftentimes, we explain that corneal astigmatism is when the curvature or power of the cornea is greater in one meridian than in another. We can give an illustration that the surface of the cornea is shaped more like a football than like a basketball or baseball. The length of the football would have a flatter curvature, whereas the curvature on a basketball or baseball would be the same in every direction or meridian.

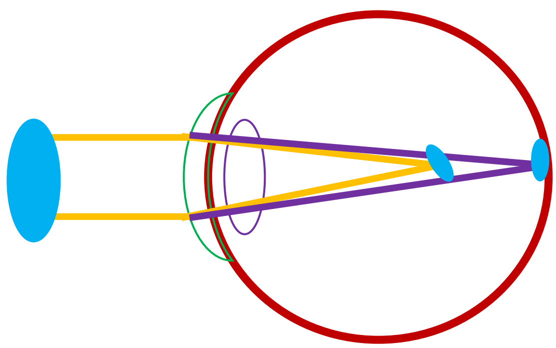
Regular Astigmatism

Regular astigmatism occurs when the principal meridians are at right angles to each other and at different distances from the object point.

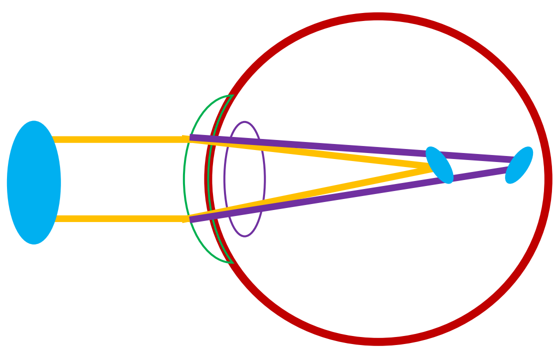
Depending on where the points of focus are located it would be classified as one of the following:

- Simple myopic astigmatism
- Compound myopic astigmatism
- Simple hyperopic astigmatism
- Compound hyperopic astigmatism
- Mixed astigmatism

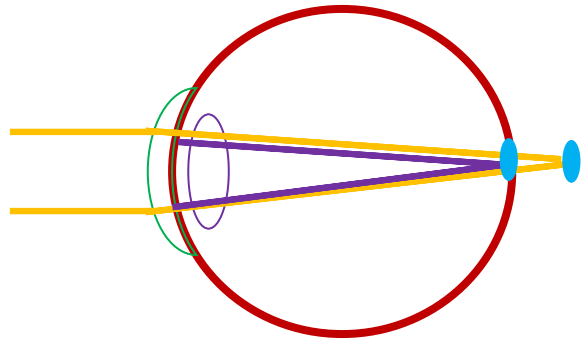
If one focus point is on the retina and the other is in front of the retina, it is classified as simple myopic astigmatism.



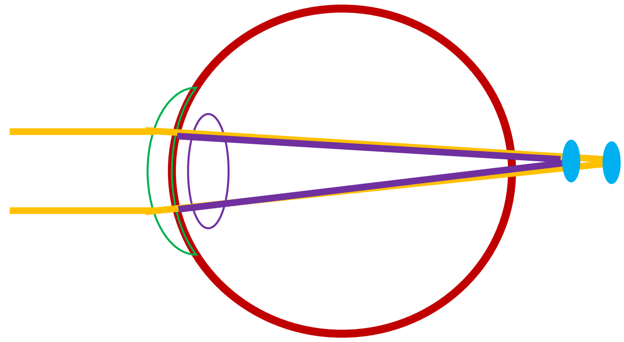
If both light rays focus in front of the retina it is classified as compound myopic astigmatism.



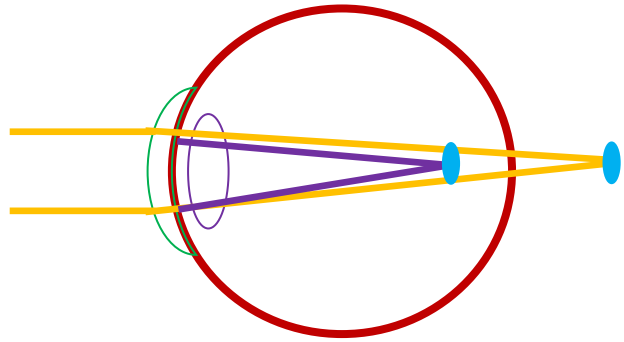
If one light ray is on the retina and the other strikes the retina prior to coming to a point focus, it is classified as simple hyperopic astigmatism.



If both light rays strike the retina before coming to a point focus, it is classified as compound hyperopic astigmatism.



If one is in front of the retina and the other strikes prior to coming to a point focus, it is classified as mixed astigmatism.



Irregular Astigmatism

In irregular astigmatism, the principle meridians are not at right angles to one another and is better corrected with the use of contact lenses. Irregular astigmatism could be caused by disease, trauma, surgery, corneal dystrophy or other reasons.

Correction of astigmatism is with the use of cylindrical lenses. Various types of lenses have been utilized and contact lenses are an option particularly in the case of irregular astigmatism. Soft Toric contact lenses have greatly improved over the years, and there is no reason why they shouldn't be offered as an option to patients.

Presbyopia

Although not classified as an ametropia, presbyopia is an impairment of the visual system due to advancing years. Greek = Presby = Old, opia = sight. Old sight… It includes reduction in accommodative ability, reduction in contrast sensitivity, need for additional light, increased light scattering, and reduced ability to cope with glare. There is also slower visual processing. Since the visual system is a plus system, and accommodation requires additional plus power to be pumped into that system to see clearly at a close range, correction is to increase the plus power with the aid of either readers, bifocals, trifocals or other types of multifocals including progressive addition lenses, or contact lenses in multifocals, monovision, modified multifocal fitting, or combinations of single vision distant lenses with readers, multifocals or others over them. Combining contact lenses and spectacles for managing presbyopia is certainly a successful option.

The cause of presbyopia is the hardening of the crystalline lens. This condition usually occurs sometime around 40 to 50 years old, usually about 45. It could be earlier or later. What causes it? It is an age-related condition. You need to assure your patients that it is not life threatening or sight threatening. It IS irreversible, and at present there is no cure. However, it is manageable.

In addition to presbyopia, as we age our visual system undergoes other major changes. Some of these changes include senile miosis, which is the pupil becoming smaller and responds slower to dilation and constriction, loss of visual acuity, lowered contrast sensitivity, increased lighting sensitivity, and slower speed of visual processing, which means that it takes longer for the brain to interpret the images that it receives. The ability to accommodate can be identified as; the bulging or plussing of the crystalline lens of the eye when looking at near objects (less than 20 feet away).

Corrections for presbyopia include prescription reading glasses, over the counter (OTC) readers, progressive addition lenses (PALs), segmented lenses, contact lenses (soft and rigid) surgery and permanent contact lenses. There is a plethora of choices with contact lens modalities. In addition, there are newer technologies being introduced every year that increase the management options of presbyopia.

Extraocular Muscles

The muscles that control turning the eye include four rectus muscles – Superior rectus, inferior rectus, medial (internal) rectus, lateral (external) rectus, and two oblique muscles, superior oblique and inferior oblique muscles. The medial rectus moves the eye towards the nose (adducts) and the lateral rectus moves the eye away from the eye (abducts). The lateral and medial rectus muscles move the eye only in the horizontal plane. The superior rectus primarily moves the eye upward and secondarily rotates the top of the eye toward the nose. The superior oblique primarily rotates the top of the eye toward the nose and secondarily moves the eye downward. The inferior rectus primarily moves the eye downward and secondarily rotates the top of the eye away from the nose. The inferior oblique primarily rotates the top of the eye away from the nose and secondarily moves the eye upward. Each eye movement is actually a combination of two or more muscles contracting and relaxing to create the fluid movement of the eye. Without this cooperation of muscles, visual imbalances would occur. The superior levator muscle lifts or elevates the eyelid, and the orbicularis oculi muscle, which is a sphincter muscle that forms a circle running through both the top and bottom lids, around the palpebral fissure, close the eyelids.

Muscle Imbalances

For muscle imbalances, we will be discussing terminology, the muscles of the eye and possible corrections.

Muscle imbalances can cause turning in, out, up, down, or tendencies to do all of these. First let's discuss some terms. Eso is a turning in, Exo is a turning out, Hyper (above) is a turning up, Hypo (below) is a turning down. A Phoria is a tendency to turn, while a Tropia is a definite turning. Therefore, esotropia is a definite turning in, while an Exophoria is a tendency to turn out. A Hypotropia is a definite turning down, while a Hyperphoria is a tendency to turn up.

Tonicity is the state of slight contraction of all six extraocular muscles of the eye while at rest in order to hold the eye steady in a fixed position. Fusion is the ability of the brain to form a single image by coordinating the movements of the two eyes so that the visual images fall on corresponding areas of the retinas of the two eyes. Diplopia is a double image caused by a muscular imbalance in one or more muscles of the eye overcoming the brain's desire for fusion.

Orthophoria means eyes that are "carried correctly", and proper extraocular muscle tonicity is maintained. Fusion takes place because an image is formed on corresponding points of each retina. Heterotropia is turning in different directions.

Strabismus is a disorder in which the two eyes are not correctly aligned. It is also referred to as squint, or crossed-eyes. If untreated it can lead to Amblyopia, which is also called lazy eye, a condition in which the vision in one eye deteriorates. Strabismus and Amblyopia are the most common causes of visual impairment in children.

Depending on an ophthalmic surgeon's assessment of the condition, strabismus can be corrected with eyeglasses or the patching of the unaffected eye to strengthen the affected eye. If these methods fail or if the amount of ocular deviation is very large, an operation may be carried out to tighten the affected muscle. Treatment of a child with strabismus should begin as soon as the condition is diagnosed, in order to prevent vision loss.

Unequal Refractive Errors

Anisometropia

Anisometropia is referred to as “unequal measure”. It is a condition where the two eyes require a different degree of correction (1.00 or more) but the same type of correcting lens (+ or -). The condition may cause vertical prism imbalance at near or cause a difference in the retinal image sizes between the two eyes

Here are some examples of anisometropia.

Example Rx:
OD -7.00 D. sphere
OS -3.00 D. sphere

Example Rx:
OD +7.25 sphere
OS +5.25 sphere

Antimetropia

Antimetropia is referred to as “opposite measure”. It is a condition where the two eyes require opposite types of corrective lenses (+ or -). The condition may cause vertical prism imbalance at near or cause a difference in the retinal image sizes between the two eyes.

Here are some examples of antimetropia.

Example Rx:
OD +1.75 sphere
OS -1.00 sphere

Example Rx;
OD -2.25 sphere
OS +1.50 sphere

Anisometropia and antimetropia can cause Aniseikonia, which is “unequal images”. Anisometropia or antimetropia may result in the condition whereby two unequal images are sent by the eyes to the brain. It is more prevalent due to refractive surgeries. Meridional Aniseikonia can be defined as normal or less aniseikonia in one meridian and more in another due to high astigmatism in that meridian.

Iseikonic lenses are used to correct Aniseikonia.   You don’t call the laboratory and just say I want iseikonic lenses. You have to design them yourself.

The following variables are used:

- Base curve
- Thickness
- Vertex distance
- Index of refraction

Because:

- The steeper the base curve, the more magnification.
- The thicker the lens, the more magnification.
- A plus lens moved further away will produce more magnification.
- A lens with lower index of refraction will generally be thicker and produce more magnification.

Digitally produced lenses have added to the Ophthalmic Dispenser’s toolbox for designing iseikonic lenses.

The use of contact lenses for aniseikonia uses vertex distance by bringing the lenses directly to the eye.

Analyze and interpret Prescriptions

In order to fully benefit the patient, we need to be able to analyze and interpret the prescription and determine what type of lenses the patient may require. That may include contact lenses.

What does the patient see/feel?
In reality, what the patient sees when he/she looks at a written Rx is a lot of numbers and symbols. Sometimes they are more knowledgeable and know that the higher the number, the stronger and thicker their lenses will be. Sometimes they are somewhat apprehensive, because of the unknown. Sometimes they are more even more knowledgeable and know to “ask” about certain types of lenses and/or lens options.

What does the dispenser see?
What we should see when we look at a written Rx, is the evaluation from the refractionist/doctor that will maximize the patient's vision for particular visual tasks.   It may be a spectacle Rx or it may be a contact lens Rx or it may be a combination of both.

We should analyze and interpret the prescription, and investigatively question the patient to determine exactly what it will be used for. Then we need to determine whether there will be any special considerations that may need to be determined in order to maximize the patient's visual performance for the visual tasks that they have. Does the lens require special fabrication considerations? Would the patient benefit from having high index, mid index, polycarbonate, Trivex, or any other special lens material? What about multifocal lens options? Should you discuss different Rx's based on the intended use of the eyewear? Distant only, near only, intermediate only, etc. Based on the intended use of the eyewear, should a particular type of frame be considered? What about additional options such as AR or UV or cosmetic or specialty tints? Can you demonstrate the thickness options to the patient?

Make sure that you cover all of the options that should be suggested for the intended use of the eyewear or contact lenses. Don't forget to include multiple pairs of eyewear, in introducing options, because one pair of eyewear won't work for every visual task. Don't forget to include quality sunwear.

In conclusion, there is much to consider in understanding the "Basic Refractive Status of the Eye".   One course couldn't begin to present all of the information needed to make you a super Optician/Technician. However, with the basics introduced here, you should have a better understanding of much of the basics. Well now, maybe it wasn't so basic after all…
Thank you.

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