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ABO Study Guide
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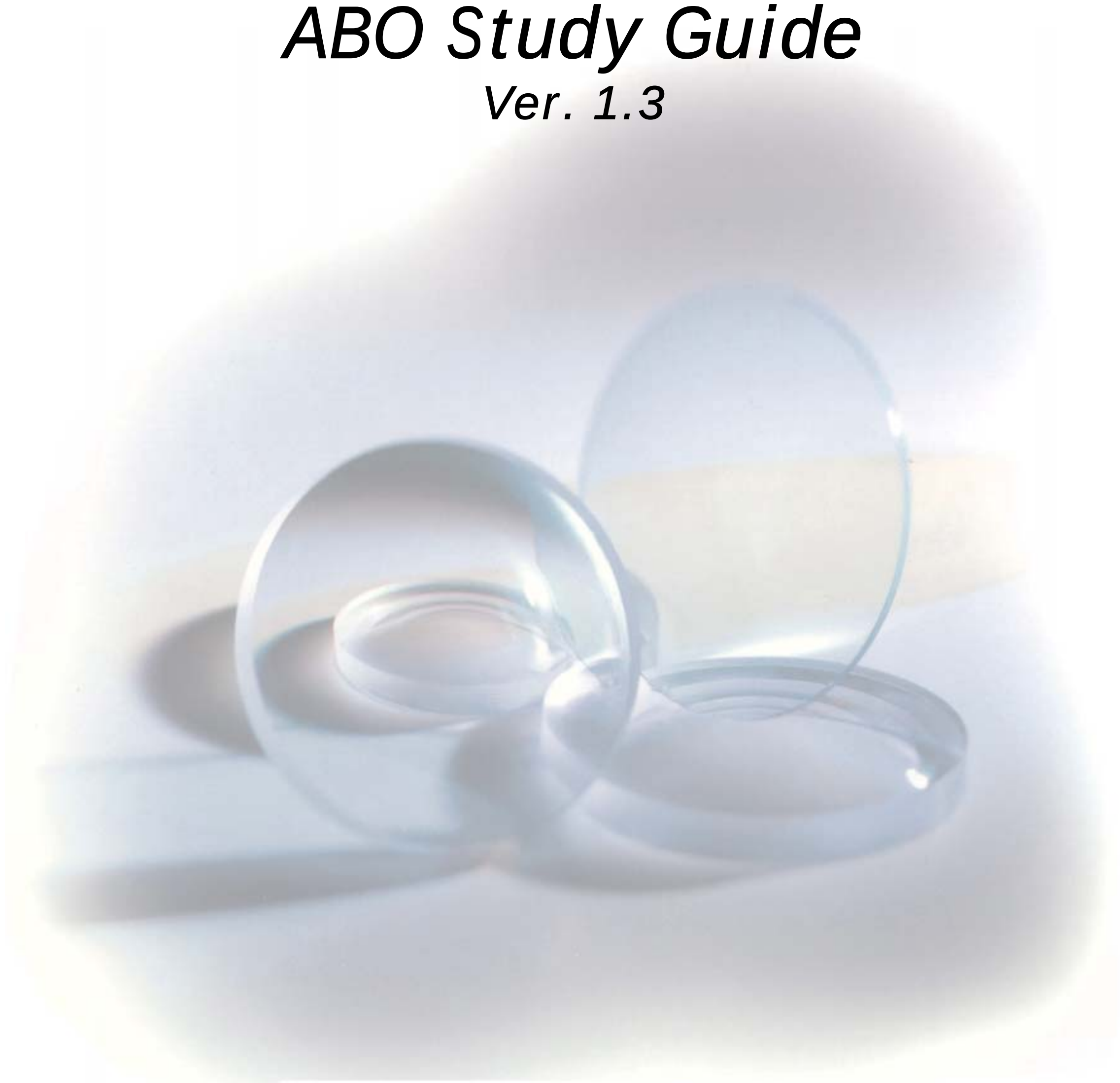

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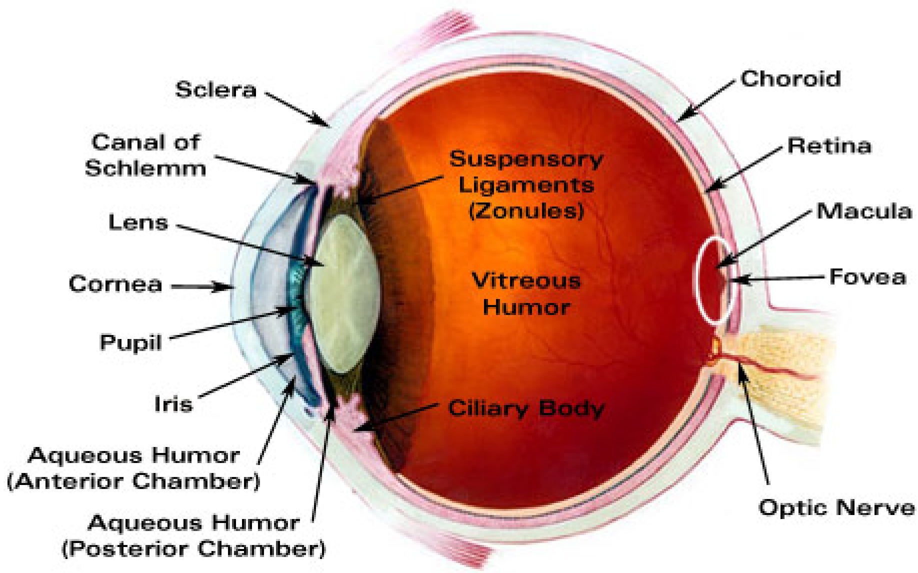
Chapter 1: OCCULAR ANATOMY

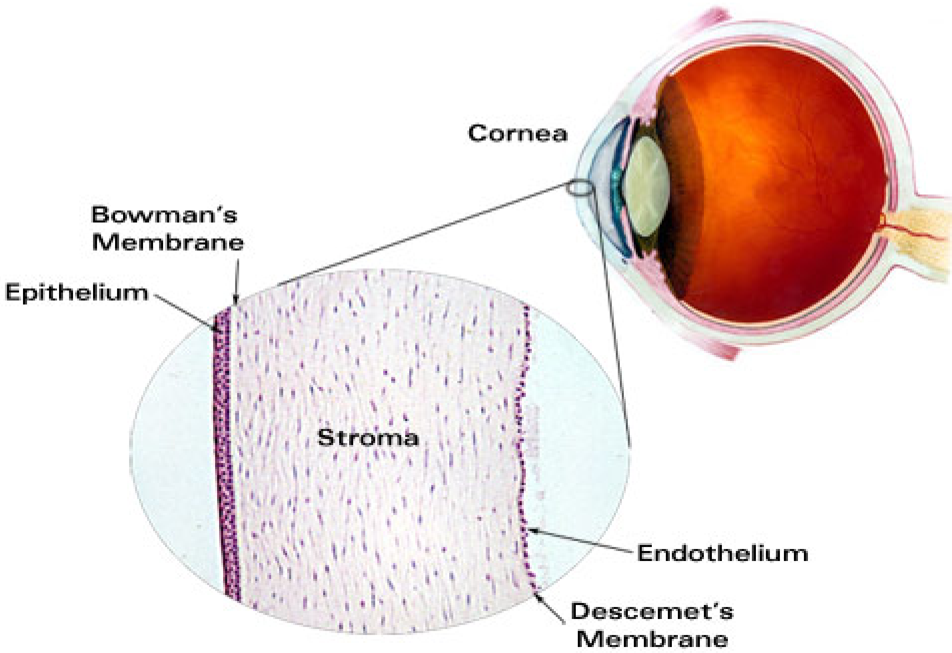
Major Ocular Structures

The eye is made up of three layers: the outer layer called the **fibrous tunic**, which consists of the **sclera** and the **cornea**; the middle layer responsible for nourishment, called the **vascular tunic**, which consists of the **iris**, the **choroid**, and the **ciliary body**; and the inner layer of photoreceptors and neurons called the **nervous tunic**, which consists of the **retina**.



The eye also contains three fluid-filled chambers. The volume between the cornea and the iris is known as the **anterior chamber**, while the volume between the iris and the lens is know as the **posterior chamber**, both chambers contain a fluid called **aqueous humor**. Aqueous humor is watery fluid produced by the **ciliary body**. It maintains pressure (called **intraocular pressure or IOP**) and provides nutrients to the lens and cornea. Aqueous humor is continually drained from the eye through the **Canal of Schlemm**. The greatest volume, forming about four-fifths of the eye, is found between the retina and the lens called the **vitreous chamber**. The vitreous chamber is filled with a thicker gel-like substance called **vitreous humor** which maintains the shape of the eye.

Light enters the eye through the transparent, dome shaped **cornea**. The cornea consists of five distinct layers. The outermost layer is called the **epithelium** which rests on **Bowman's Membrane**. The epithelium has the ability to quickly regenerate while Bowman's Membrane provides a tough, difficult to penetrate barrier. Together the epithelium and Bowman's Membrane serve to protect the cornea from injury. The innermost layer of the cornea is called the **endothelium** which rests on **Descemet's Membrane**. The endothelium removes water from cornea, helping to keep the cornea clear. The middle layer of the cornea, between the two membranes is called the **stroma** and makes up 90% of the thickness of the cornea.



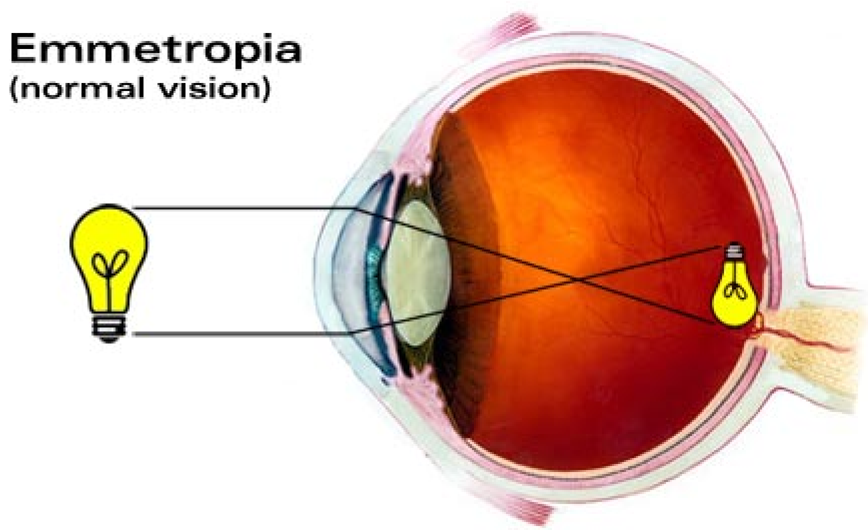
From the cornea, light passes through the **pupil**. The amount of light allowed through the pupil is controlled by the **iris**, the colored part of the eye. The iris has two muscles: the dilator muscle and the sphincter muscle. The dilator muscle opens the pupil allowing more light into the eye and the sphincter muscle closes the pupil, restricting light into the eye. The iris has the ability to change the pupil size from 2 millimeters to 8 millimeters.

Just behind the pupil is the **crystalline lens**. The purpose of the lens is to focus light on the retina. The process of focusing on objects based on their distance is called **accommodation**. The closer an object is to the eye, the more power is required of the crystalline lens to focus the image on the retina. The lens achieves accommodation with the help of the **ciliary body** which surrounds the lens. The ciliary body is attached to lens via fibrous strands called zonules. When the ciliary body contracts, the zonules relax allowing the lens to thicken, adding power, allowing the eye to focus up close. When ciliary body relaxes, the zonules contract, drawing the lens outward, making the lens thinner, and allowing the eye to focus at distance.

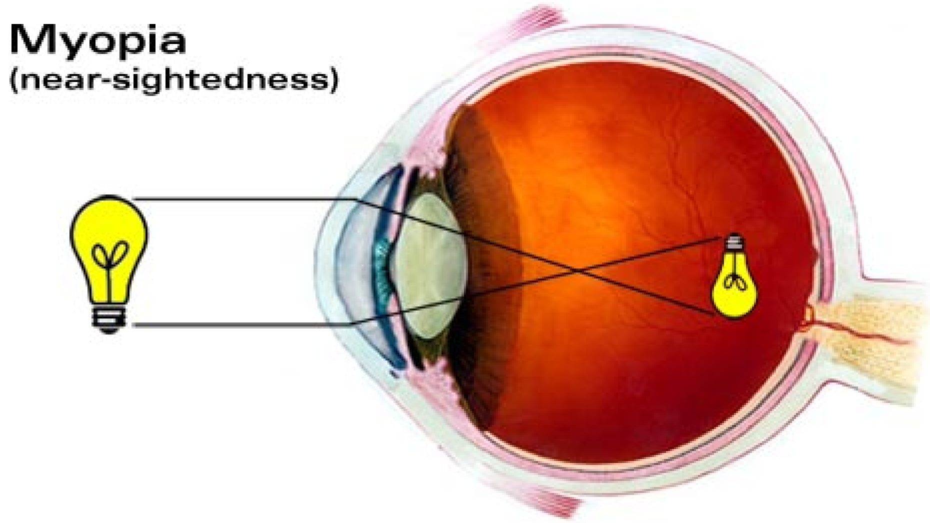
Light reaches its final destination at the **retina**. The retina consists of photoreceptor cells called **rods** and **cones**. Rods are highly sensitive to light and are more numerous than cones. There are approximately 120 million rods contained within the retina, mostly at the periphery. Not adept at color distinction, rods are suited to night vision and peripheral vision. Cones, on the other hand, have the primary function of detail and color detection. There are only about 6 million cones contained with in the retina, largely concentrated in the center of the retina called the fovea. There are three types of cones. Each type receives only a narrow band of light corresponding largely to a single color: red, green, or blue. The signals received by the cones are sent via the **optic nerve** to the brain where they are interpreted as color. People who are color blind are either missing or deficient in one of these types of cones.

Refractive Errors

Refractive errors occur when abnormalities of the eye prevent the proper focus of light on the retina. **Emmetropia** refers to an eye free of refractive errors.

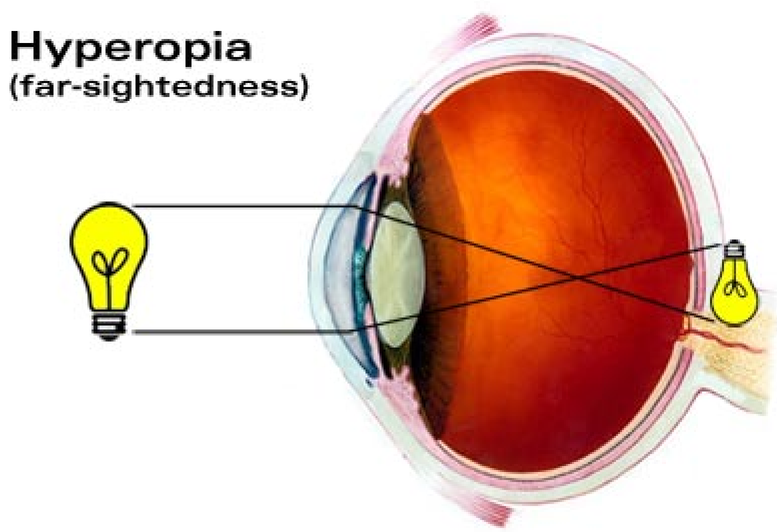


Two common types of refractive errors are **myopia** and **hyperopia**.



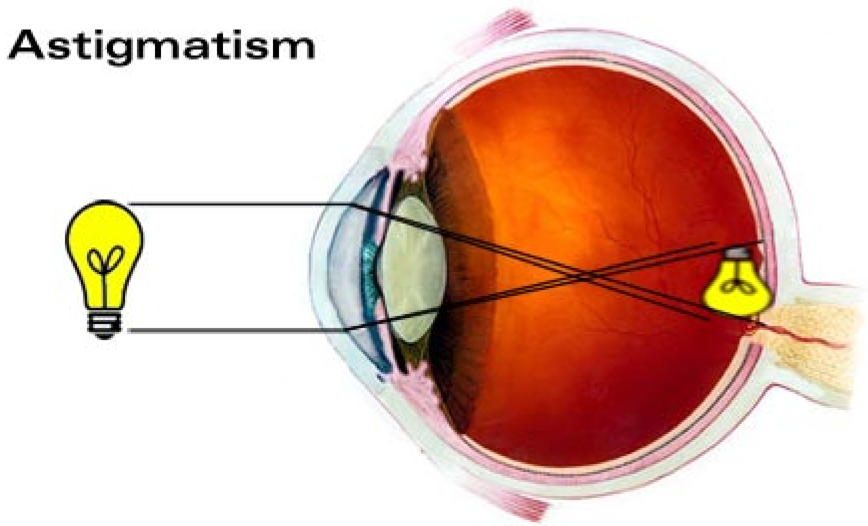
Myopia

Myopia, also known as near-sightedness, occurs if the eye is longer than normal or the curve of the cornea is too steep, causing light rays focus in front of the retina. Patients with myopia are able to see objects at near, but distant objects appear blurred. Clear vision can be restored to most myopes through the use of minus-powered lenses.



Hyperopia

Hyperopia, also known as far-sightedness, occurs if the eye is too short or the curve of the cornea is too flat, causing light rays to focus behind the retina. Patients with hyperopia are able to see objects at distance, but near objects appear blurred. Mildly hyperopic patients may be able to see clearly at near without correction by using accommodation to compensate. Clear vision can be restored to most hyperopes through the use of plus-powered lenses.



Astigmatism

An even more common type of refractive error is **astigmatism**. Astigmatism occurs when the cornea has an oblong, football-like shape in one or more directions (or axes) causing light rays to focus on more than one point on the retina. Astigmatism is compensated for using cylinder powered lenses along the appropriate axis.

Presbyopia

As eyes age, the crystalline lens begins to lose elasticity. With the loss of elasticity, the eye loses the ability to accommodate or focus at near. This typically becomes noticeable around 40 years of age. This condition where the crystalline lens is unable to add sufficient power to focus at near is known as **presbyopia**. The loss of elasticity in the crystalline lens continues until somewhere around the age of 65 when all the elasticity is gone from the lens as is all ability to accommodate. Presbyopia can be compensated for through the use of plus-powered lens segments, reading glasses, or magnifying devices.

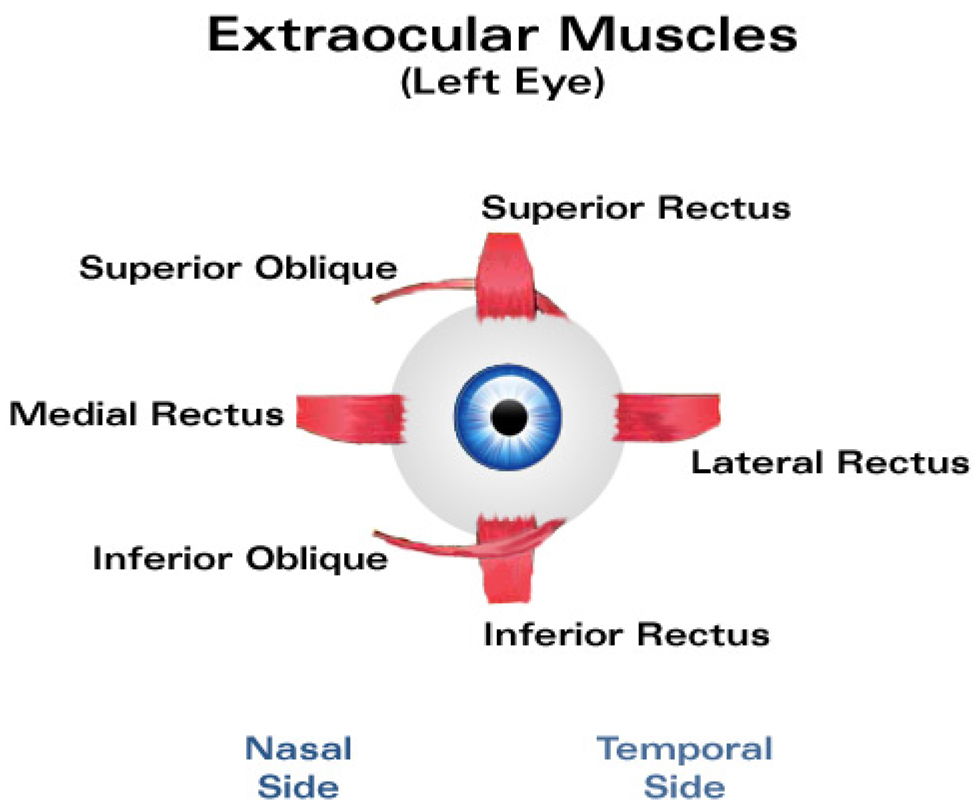
Anisometropia is a condition in which the two eyes have unequal refractive power. A**ntimetropia** is an extreme case of anisometropia where one eye is myopic and the other is hyperopic. The unequal refractive states can often lead to diplopia (double vision) or asthenopia (eye strain).

Anisometropia can adversely affect the development of binocular vision in infants and children, if there is a large difference between the two eyes. The brain will often suppress the vision of the blurrier eye in a condition called amblyopia, or lazy eye (a condition often mistakenly confused with phorias and tropias discussed later in this section).

Extraocular Muscles

The stabilization of eye movement is accomplished by six extraocular muscles attached to the eye via the sclera. The six muscles and their function are:

Lateral rectus - moves the eye outward, away from the nose
Medial rectus - moves the eye inward, toward the nose
Superior rectus - moves the eye upward and slightly outward
Inferior rectus - moves the eye downward and slightly inward
Superior oblique - moves the eye outward and downward
Inferior oblique - moves the eye outward and upward



In addition to movement and tracking, extraocular muscles maintain alignment between the eyes. When the eyes are properly aligned, the brain is able to fuse the disparate images received by each eye into a single image. If any of the extraocular muscles are stronger or weaker than they should be, eye alignment can be affected making fusion difficult or impossible. Difficulty with fusion can cause double vision, also known as **diplopia**, or can cause the brain to "turn off" one image in an effort to eliminate diplopia. The latter is a condition known as **suppression**.

When the eye has a tendency to turn from its normal position (such as when the patient is tired), it is called a **phoria**. When the eye has a definite or obvious turning from its normal position, it is called a **tropia**. Phorias and tropias are further described by the direction of the turning: exo meaning outward or in a temporal direction (e.g. exotropia); eso meaning inward or in a nasal direction (e.g. esotropia); hyper meaning upward (e.g. hyperphoria); and hypo meaning downward (e.g. hypophoria).

Chapter 2: BASIC OPTICAL PRINCIPLES

Light and the Electromagnetic Spectrum

Produced by the nuclear cauldrons of stars and all matter in the cosmos, energy in the form of electromagnetic radiation permeates our entire universe. Every second of every day we are bombarded with and surrounded by electromagnetic radiation; some bounces off of our bodies, some passes through us, and some we absorb, but most goes undetected and unperceived.

Electromagnetic energy travels at the speed of light (approx. 2.9x10^8 m/s or 186,000 miles/sec) in the form of a wave. In fact, we classify electromagnetic energy according to its wavelength. Wavelength is defined as the distance between two corresponding points on two consecutive waves. Electromagnetic wavelengths range in scale from that of an atomic nucleus (gamma rays) to that of a small planet (radio waves).

A tiny fraction of electromagnetic radiation is visible to the human eye. Only the portion of the electromagnetic spectrum that makes it through our corneas and is absorbed by our retinas is perceived as color and light. Often expressed in nanometers (nm) or one billionth of a meter, the wavelengths of the visible spectrum lie between 400 and 700nm, with red light at the longer end of the spectrum and violet light at the shorter end. A common acronym used to remember the order of colors in the visible spectrum is ROY G BIV (red, orange, yellow, green, blue, indigo, and violet). Just below the visible spectrum from 1 to 400nm lies ultraviolet (UV), while just above from 750nm to 1mm lies infrared (IR).

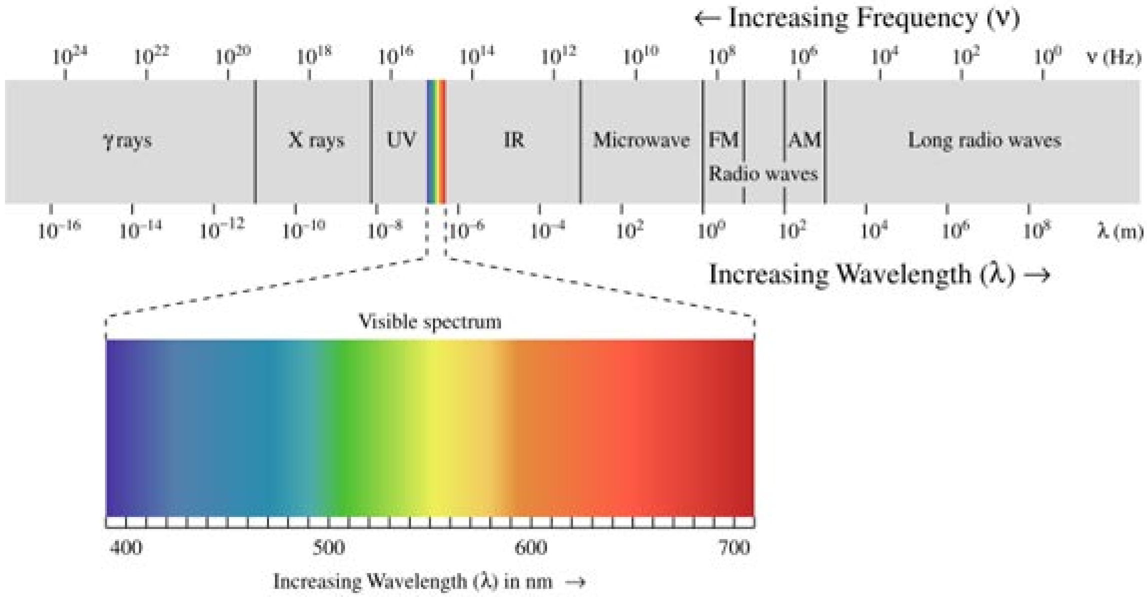


Figure 1: Electromagnetic Spectrum – Image source: Wikipedia

Index of Refraction

Light waves travel through transparent media at different speeds. As light moves from one transparent medium to another, at any angle other than perpendicular to the material surface, the change in speed will also result in a change in direction. This change is direction is called refraction. The greater the change in speed, the greater the magnitude of refraction becomes. Refraction is principle that allows the creation of optical lenses that alter the path or focus of light.

The straw seems to be broken, due to refraction of light as it emerges into the air. Image source: Wikipedia

The index of refraction is a measure of how much the speed of light is altered as enters a given media relative to the speed of light in air. The index of refraction (*n*) can be calculated using the following equation:

n = speed of light in air / speed of light in selected material

The following are examples of *n* in various media:

Air:	1.00
Aqueous Humor:	1.33
Vitreous Humor:	1.33
Cornea:	1.37
Crystalline Lens:	1.42
CR-39 Plastic:	1.49
Crown Glass:	1.52
Polycarbonate:	1.58
High Index Plastics:	1.60 to 1.74
High Index Glass:	1.60 to 1.80

Lens Power

As light rays pass through a lens with power, the rays are bent or refracted. In a lens with a plus power, the light rays converge or are refracted toward one another. The point at which the light rays converge is called the focal point and in a plus lens, is behind the lens surface. In a lens with a minus power, the light rays diverge or are refracted away from one another. If these rays are extrapolated or traced back toward the light source, the lines will converge and form a focal point in front of the lens surface.

The lens power is relative to the focal distance or the distance between the focal point and the lens. More specifically, lens power is the reciprocal of the focal distance in meters. Lens power is expressed in diopters (D).

Power = 1 / Focal Distance

As explained above, if the light rays converge, the focal distance is expressed with a positive value resulting in a positive or plus power. If the light rays diverge, the focal distance is expressed with a negative value resulting in a negative or minus power.

Example:

Light rays pass through a lens and converge 0.50 m from the lens. What is the power of the lens?

Power = 1 / Focal Distance

Power = 1 / 0.50 m

Power = 2.00 D

Prism

Prism can be used to correct vision for an individual whose eyes are not perfectly aligned as with, for example, a patient with strabismus. When the eyes are not aligned, the right and left eye see different images resulting in blurred or double vision. Sometimes the brain can even "shut off" one eye, in an attempt to remedy the vision, resulting in monocular vision and loss of depth perception. Prism can sometimes be used to align the images seen by both eyes, so the eyes can fuse or see the same image, restoring visual clarity and depth perception.

Prism, like lens power, is also measured in diopters (Δ), but measured differently. One diopter of prism is equal to the prism required to divert a ray of light 1 cm from its original path, measured at a distance of 1 m from the prism.

As important as the amount of prism, is the direction of prism. The prism must displace viewed objects in the proper direction to achieve the desired visual correction. Prism direction can be specified in two ways, either using the prescriber's method or the 360° method.

The prescriber's method specifies the direction if the prism in terms of the base, using base-up, base-down, base-in, and base-out (base-in referring to the direction of the nose and base-out referring to the direction of the temple). Often prescriptions will include a combination of directions to achieve the proper resultant prism. For example: 2 Δ base-in and 1 Δ base-up.

Labs however, use a 360° or 180° method of describing base direction. Using the 360° method, when a lens is viewed from the front, a prism with a base direction to the right (base-in for the right eye and base-out for the left) becomes 0°. Likewise, a prism with a base direction to the left (base-out for the right eye and base-in for the left) becomes 180°. Base-up then becomes 90° and base-down 270°. Using this method, prism directions other than base-in, base-out, base-up, and base-down can be specified at a single angle e.g. 2.7 Δ base 64°. The 180° method is similar, however, as the name suggests, only 180° are used, consequently, an up or down direction must also be specicfied.

Prism specified in using the presciber's method consisting of multiple base direction components can easily be converted to the 360° or 180° methods by using a prism chart or simple trigonometric formulae.

360° resultant prism can be calculated with the following equation:

$$R = Sqrt(V^2 + H^2)$$

Where V is the vertical prism and H is horizontal prism.

The resultant angle can be calculated using this equation:

$$Tan(\Delta) = V/H$$

Prism by Decentration

To better understand why there is induced prism, the cross-section of a plus lens can be likened to two prisms base-to-base, as the lens is thicker in the middle and thinner at the edges. Likewise, a minus lens can be likened to two prisms apex-to-apex, thinner in the middle and thicker at the edges.

This induced prism can actually be used to the advantage of the lab when prism is called for in a prescription. If the lens power is sufficient, to induce the prescribed prism, the lens can simply be cut off-center to achieve the required results. This is known as prism by decentration. If the power is insufficient, however, the prism must be cut into the surface of the lens.

A simple equation can be used to calculate the prism induced by decentration. Prentice's rule states that prism in diopters (Δ) is equal to the decentration distance (c) in centimeters multiplied by the lens power (D).

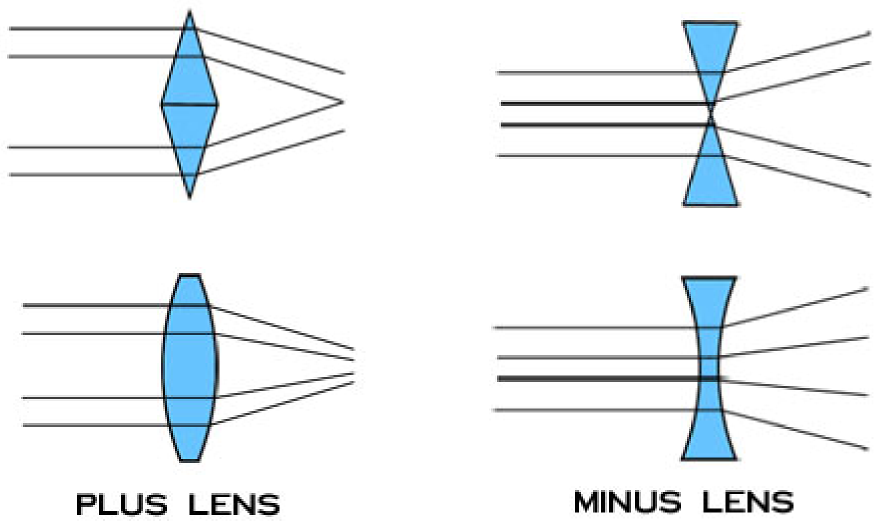
Prentice's Rule

$\Delta = cD$

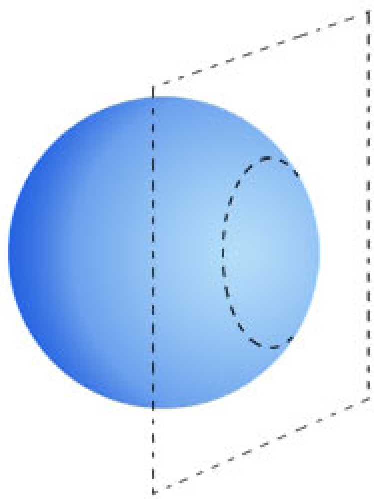
Chapter 3: LENS FORM

Sphere

It can be helpful to think of very basic lens forms in terms of prisms. Recall, as light passes through a prism it is refracted toward the prism base. Minus lenses therefore resemble two prisms apex to apex spreading light rays outward as they pass through the lens, while plus lenses resemble two prisms base to base converging light rays as they pass through the lens.

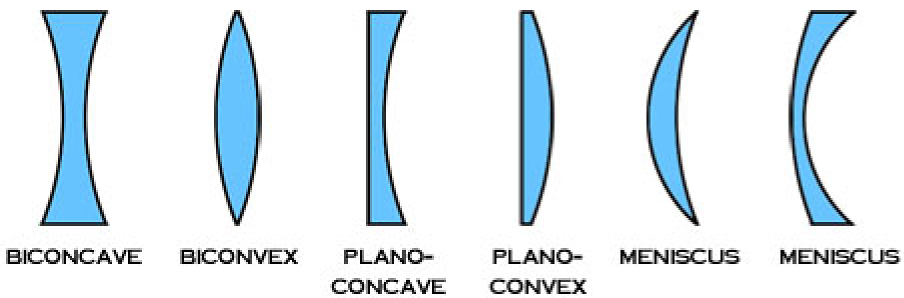


Of course, most lenses are not comprised of angular prismatic surfaces but consist of curved surfaces. The most basic of these curves is a sphere. The curve on the surface of a spherical lens, if extrapolated in all directions, would form a ball or perfect sphere. The sphere would vary in size based on the steepness of the curve. A steeper, higher power curve would form a smaller sphere with a smaller radius, while a flatter, lower power curve would form a larger sphere with a larger radius.



In addition to being described by their power or radius, spherical curves also have a direction. An inward curve is called concave, while an outward curve is called convex. Thinking back to the prism example, a minus lens that diverges light would require a concave spherical surface, while a plus lens that converges light would require a convex surface. Therefore, we use the minus (-) sign to denote concave curves, the plus (+) sign to denote convex curves, and the term "plano" to describe a flat or zero curve.

A lens has two curved surfaces of consequence to the vision of the wearer: the front surface and the back surface. Common lens shapes based on front and back curves are described in the figure below.



The corrective power of a lens is determined by adding the front curve to the back curve. This is expressed by the equation: $F_1 + F_2 = F_{Total}$. As you can see from this equation for any given corrective power, an infinite number of curve combinations may be used to achieve the same result.

Example:

+6.00 D + -2.00 D = +4.00 D

+4.00 D + 0.00 D (plano) = +4.00 D

+2.00 D + +2.00 D = +4.00 D

Practically speaking, the laboratory has a limited number of curve combinations with which to work. Lens blanks come from manufacturers with a limited selection of front curves, also known as base curves, with suggested power ranges for each. Furthermore, since aberrations occur as the eye moves away from the optical center of the lens, the lab will choose curves that minimize aberrations. Lenses with curves chosen to minimize aberrations are called "corrected curve" or "best form" lenses.

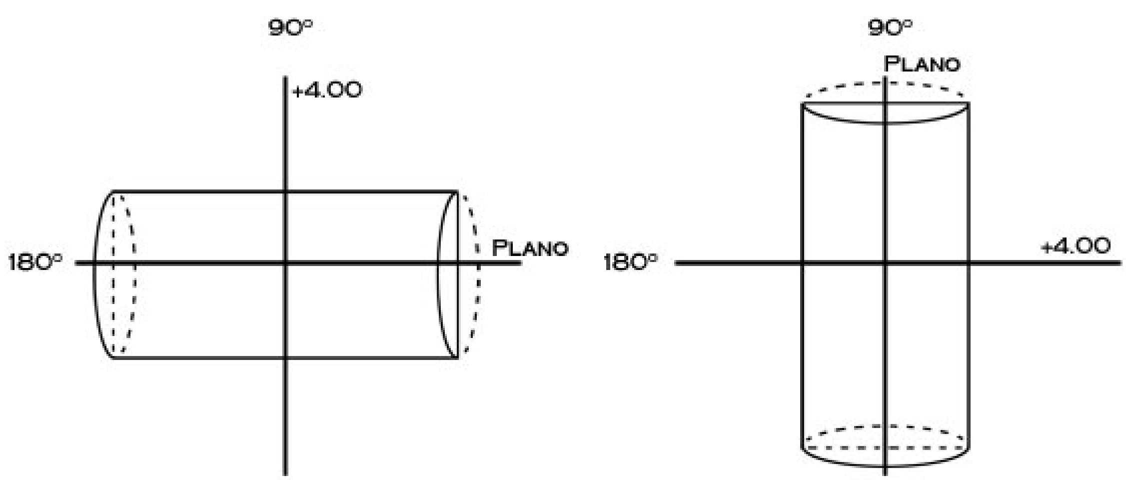
The following chart shows basic guidelines for selecting base curves to minimize peripheral aberrations.

Sphere Power	**Base Curve**
> +12.25	+16.00 D
+10.75 to +12.25	+14.00 D
+9.00 to +10.50	+12.00 D
+5.50 to +8.75	+10.00 D
+2.25 to +5.25	+8.00 D
-1.75 to +2.00	+6.00 D
-2.00 to -4.50	+4.00 D
-4.75 to -8.00	+2.00 D
-8.00 to -9.00	+0.50 D
< -9.00	plano or minus

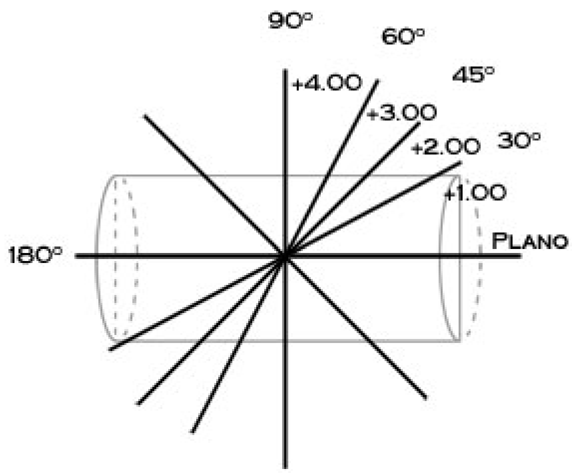
Remember, these are only guidelines for selecting base curves, there are typically many more factors involved in base curve selection including: manufacturer recommendations, frame selection, aesthetics, lens material, and patient history.

Cylinder

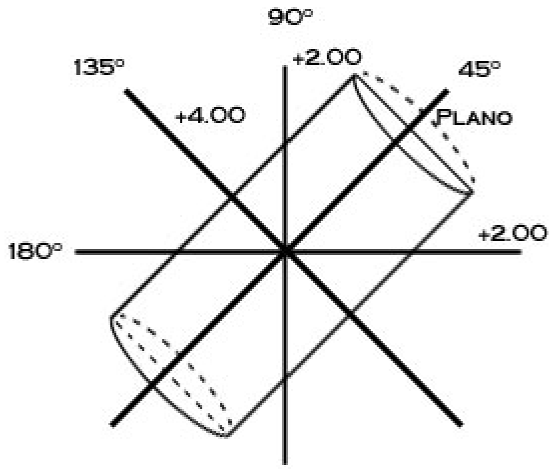
In addition to the spherical curve, many prescriptions call for a cylinder curve to correct for astigmatism. A cylinder curve is curved along a single axis and flat along the perpendicular axis. Furthermore, while the focus of a spherical curve is a single point, the focus of a cylinder curve is a line. The meridian along which there is no cylinder power in the lens and consequently the meridian of the cylindrical focus is the cylinder axis. The cylinder axis is expressed in degrees between 0 and 180.



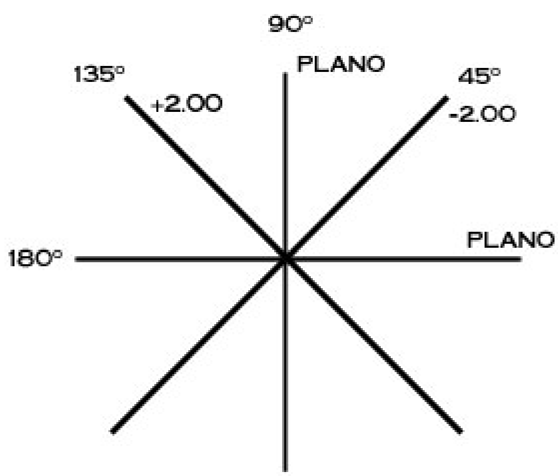
Most prescriptions have some combination of spherical and cylinder curves. A lens that combines spherical and cylinder curves is called a *compound lens* or *toric*. The convention of the power cross helps conceptualize the compound lens. The power cross is a representation of the two major meridians of the lens surface. The simplest combination to visualize is a plano with +4.00 D cylinder. The above examples show the cylinder curve at right angles. Note how the power in the meridian of the cylinder axis is plano, while the power of the meridian perpendicular to the cylinder axis is +4.00 D. To fully understand the cylinder curve, however, it is important to consider the lens form at meridians other than 90º and 180º from the cylinder axis.



The figure above shows the +4.00 D cylinder curve at 45º. Note, the curves at the 90Âº and 180º are now +2.00 D and the +4.00 D curve is now at 135º. As the meridian is rotated away from the cylinder axis, the curve gradually changes from 0 to the full power of the cylinder curve (+4.00 D in this example) once the meridian is perpendicular to the cylinder axis. A simple equation can be used to determine the amount of cylinder power in any meridian: $F = F_{cyl}*(SIN(Î))^2$ where F_{cyl} is the cylinder power and Î is the angle between the cylinder axis and the new meridian. It is also easy to remember the major angles 30º, 45º, 60º, and 90º as 25%, 50%, 75%, and 100% of the cylinder power respectively.



Since a spherical curve is the same in all meridians, if a -2.00 D spherical curve is combined with a +4.00 D cylinder at 45º, we end up with a compound lens described by the power cross below.

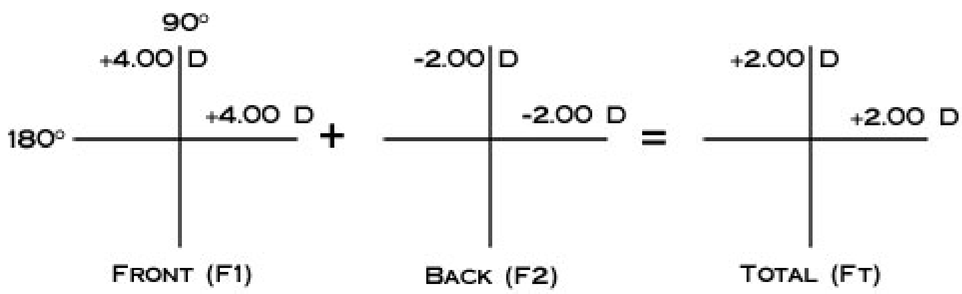


These curves on the lens surface can easily be measured with an instrument called a *lens measure* or *lens clock.*

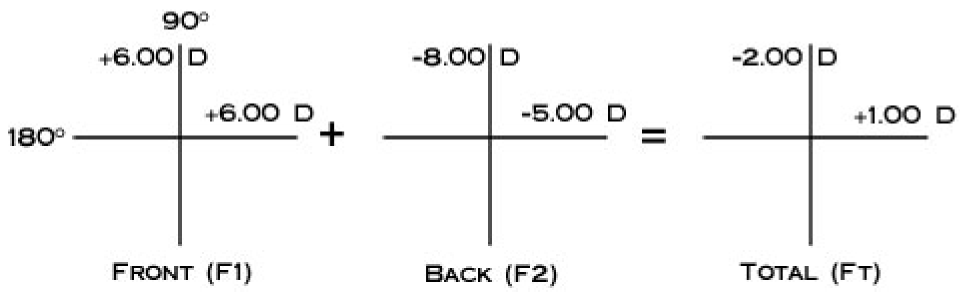
A lens measure has three points of contact which are placed on the lens surface to measure its curve. The outer two points are stationary while the inner point moves in or out to measure the sagittal depth of the lens. From the sagittal depth the instrument indicator displays the curve in diopters, with plus (+) curves shown in one direction and minus (-) curves in the other. The lens measure can also be used to determine whether a lens surface is spherical or toric by placing the lens measure on the optical center of a lens and rotating the instrument about the center. If the indicator does not move while rotating, the surface is spherical. If the indicator changes when the lens measure is rotated, the lens surface is toric, with the minimum and maximum readings corresponding to the meridians of power.

When using a lens measure, keep in mind the instrument is calibrated to read powers of lens materials with a refractive index of 1.53, therefore higher index materials will have a true power greater than the indicated measurement.

With a lens measure, the power cross, and the total power equation ($F_1 + F_2 = F_{Total}$) it is possible to determine the nominal power of spherical and toric lenses. For example, if we use the lens measure to find the curve on the front surface of a lens to be +4.00 D in all meridians and the curve on the back surface of the same lens to be -2.00 D in all meridians, we know the curves are spherical and can determine the total power of the lens as follows:



Now, if we find the curve on the front surface of the lens to be +6.00 D and determine the back surface to be toric with a measurement of -8.00 D in the 90º meridian and -5.00 in the 180º meridian our power determination would look like this:



Aspheric Lenses

Aspheric lenses are defined as lenses that are non-spherical. This non spherical surface encompasses all kinds of lenses from aspheric, atoric, progressive, and aphakic.

Aspheric lenses are defined as lenses that are non-spherical. This non spherical surface encompasses all kinds of lenses from aspheric, atoric, progressive, and aphakic. So if all these lenses fall in the definition of an aspheric lens, how do we further define and differentiate aspheric lenses in all their forms.

Aspheric

Generally aspheric in the ophthalmic industry defines a lens surface that varies slightly from a spherical surface. This variation is known as the eccentricity of the lens and can further defined as conic sections. Sections of a cone represent various curves that are used in ophthalmic surfaces, for instance circle, ellipse, parabola, and hyperbola.

Curve	Eccentricity
Circle	e = 0
Ellipse	0 < e < 1
Parabola	e = 1
Hyperbola	e > 1

To get a good idea of what an aspheric looks like, the theorem $\sin^{-1}(e)$ gives you the angle at which to tilt a cone to view from above the shape the curve will represent. If you were to take a coffee mug and tilt it by any degree you would see that the shape of the perfectly circular top changes when it is tilted, this same shape represents the curves of the lens. Why are aspheric lenses used? Aspheric lenses are used in their various forms to correct aberrations in a lens that are produced from changes to best form curves. For instance in a CR-39 lens a lens with power -2.75 calls for a 4.63 base lens, if that lens were to be made up in a 6 base the consequences would be that the lens would change power as the wearer were to view further off the visual axis of the lens. This change in power can be compensated for by allowing the form of the lens to vary as it goes further from the axis, this eccentricity would allow the lens to correct the condition in which it was prescribed as well as fit the individual frame or curve necessary to make a cosmetically appealing lens.

Atoric

In the previous example we used a power of -2.75 for a CR-39 lens, if we were to give an example of a -2.75 -2.00 sphero-cylindrical lens the best form curve would differ for the two meridians (sphere and cylinder). Using a spherical lens you would have to determine the meridian in which you would want to provide the best base for either, sphere or cylinder, or spherical equivalent and split the error between the two meridians. The solution to this is an atoric lens which can be defined as having differing eccentricities for the separate meridians. This allows the user a wider area of the lens with the correct power and minimal aberrations.

Progressive

Progressive's lenses are a category in and of themselves; however the progression of power is accomplished with the use of asphericity in the corridor to create a lens without power. Progressive lenses differ from many aspheric surfaces because they are not fashioned after conic sections, but would be better defined as deformed conicoids. To get an idea of what a deformed conicoid would look like take a pebble and drop it into a pond, the waves would ripple and the surface could not be defined with a simple curve, but depending on where in the pond you look the curves would vary, this variation could be defined with an expansion of the saggital equation:

$z= Ay^2+By^4+Cy^6+Dy^8+Ey^{10}$

$A=1/2r$

$B=p/8r^3$

$C=p^2/16r^5$

$D=5p^3/128r^7$

$E=7p^4/256r^9$

This expansion allows the shape to be manipulated to varying degrees as it gets further from the axis without directly affecting the axis. This expansion can also be used to define a more simple conic section by setting the B, C, D, and E variable to 0, therefore only the a value remains and defines the conic.

Aphakic

Aphakic lenses use aspherics because plus power lenses higher than +8.00 are outside of the Tersching ellipse and do not have a best form curve. This means that in order to provide the best vision the lens designer has no choice but to use aspherics. Usually you will find that the aphakic lens not only uses asphericity to optically improve the performance of the lens, but often the lens uses again deformed conicoids to provide cosmetic appeal to the lens as well since often times high plus powers will be thick.

Keep in mind that aspherics when referred to in ophthalmics can be placed on both the front or back surface of the lens and as free form technology takes a hold in our industry we will be seeing varying degrees of eccentricity on both the front and the back of all lenses to improve cosmetics and optics.

Transposing Prescriptions

Transpose a prescription written in plus cylinder form to minus cylinder form as follows:

1. Add the sphere and cylinder powers to determine the new sphere power.
2. Change the sign of the cylinder.
3. Change the axis by 90 degrees.

Example:

Transpose -3.00 +2.00 x 30

1. Add the sphere and cylinder powers to determine the new sphere power.

(-3.00) + (+2.00) = -1.00

2. Change the sign of the cylinder

-2.00

3. Change the axis by 90 degrees.

120

The transposed prescription is:
-1.00 -2.00 x 120

Chapter 4: LENS OPTIONS

Lens Materials

Material Properties

Refractive Index

The refractive index of a lens material indicates how much the material will refract or bend light as it enters the material from air, by comparing the speed of light in a given material to the speed of light in air. The higher the index number of a given material, the more the light will refract as it enters the material. If a material has a greater ability to refract light, less of a curve is required to obtain a specific power, resulting in a thinner lens. Plastic (CR-39) and Crown Glass are considered base index with indices of 1.498 and 1.52 respectively. Materials with an index between 1.53 and 1.57 are sometimes considered mid-index, while 1.58 and greater is considered high-index. More frequently, however, anything over 1.53 is called high-index.

Specific Gravity

Specific gravity describes the density of a lens material by comparing its density to the density of water. The higher the specific gravity of a lens material, the higher the density, and consequently, the heavier a lens of that material will be for a given power and size.

Abbe Value

White light is composed of the visible spectrum of wavelengths each corresponding to a different color. When light enters a prism it is bent toward the base of the prism. Shorter wavelengths (e.g., violet) are bent at a greater angle than longer wavelengths (e.g., red). Since a lens can be likened to two prisms (apex to apex for a minus lens and base to base for a plus lens), light passing through a lens has a tendency to separate into its respective colors as its varying wavelengths are focused at differing points. The tendency to of a material to separate light in this manner is called chromatic aberration and is measured by its Abbe value. The Abbe value of a material is inversely proportional to the chromatic aberration induced as light passes through it. In other words, the higher the abbe value, the lower the amount of chromatic aberration. Generally speaking, the higher the index of a lens material, the higher the chromatic aberration, and the lower the Abbe value.

Reflectance

The reflectance of the material describes the percentage of incident light reflected from a highly polished surface of that material and is calculated from the refractive index of a material. When light hits a lens surface in air normally, the percentage of light reflected at each surface is given by:

R = (n - 1)2/(n + 1)2 * 100%

Thus a material of refractive index 1.5, has a reflectance of

(0.5/2.5)2*100 = 4% per surface

Transmittance

The transmittance of a lens material describes the amount of light (usually specified for a given waveband) that will pass through that material.

Glass

Glass has historically been the material of choice for ophthalmic lenses. Glass is most stable, scratch-resistant, and provides the best optical quality of all lens materials. However, since glass is more brittle than most materials, lenses made of glass must be tempered or heat-treated to give them more strength and make them safer to wear. Glass is available in a number of indices of refraction. As mentioned above, the higher the index, the thinner a lens will be for a given power. However, the specific gravity also increases dramatically with the index making high-index glass lenses much heavier. Chromatic aberration is also more pronounced in high-index glass.

Index: Crown 1.52; High index 1.60, 1.70, 1.80

Pros
Superior optics
Stable material
Scratch resistant

Cons
Does not accept tint
Not impact resistant
Heavy

CR-39

Developed by PPG during WWII, CR-39, also known as plastic or hard resin, serves as a much lighter lens material (approximately 50% lighter) than glass. CR-39, however, is far less scratch resistant and often must be coated to improve its scratch resistant characteristics.

Index: 1.498

Pros
Lighter than glass
Readily tintable
Less likely to fog

Cons
Susceptible to scratching (correctable by coating)
Lower index of refraction makes it less suitable for higher powered prescriptions

Polycarbonate

While its optical characteristics are less than ideal, polycarbonate, the same material used for bullet-proof glass, is the most impact resistant of lens materials. Consequently, polycarbonate is the material of choice for safety and children's eyewear. With an index of 1.59, polycarbonate also produces thinner, lighter lenses than glass or plastic. These factors along with polycarbonate's inherent UV protection and pricing make it a popular material.

Index: 1.59

Pros
Thinner and lighter than glass and plastic
Highly impact resistant (used for safety glasses)
Inherent UV protection

Cons
Poor optical quality
Susceptible to scratching (correctable by coating)
Susceptible to stress fractures in drill mounts
Does not readily accept tint

Hi-Index

High index lenses polymers typically refer to products with an index higher than 1.58. High index lenses require flatter curves than their lower index counterparts, resulting in thinner and lighter lenses. Furthermore, aspheric curves come standard in many high index products, particularly 1.66 and 1.70 products, and are available in 1.60. Asphericity reduces spatial distortion, reduces magnification or minification, and further helps maintain a thin and flat lens profile. High index material, however, tends to have a lower Abbe value which could potentially affect patients who are sensitive to chromatic aberration. Also higher index and flatter curves tend to result in more backside and inner-surface reflections. AR coatings are usually recommended for high index lenses to eliminate these reflections.

Index: 1.60, 1.66, 1.70

Pros
Thinner and lighter than glass and plastic
Better optical quality than polycarbonate

Cons
Susceptible to scratching (correctable by coating)
Susceptible to backside and inner-surface reflections (correctable with AR)

Trivex

Developed in 2001 by PPG, Trivex combines impact resistance of polycarbonate, exceptional optical clarity, and a specific gravity of 1.11 (the lightest available). Trivex's tensile strength makes it ideal for drill mount frames. Trivex is available from Younger as Trilogy and from Hoya as Phoenix. All Trilogy products are aspheric and guaranteed for life against stress fractures and drill mount cracking. Some Phoenix products are now available with aspheric curves.

Index: 1:53

Pros
Impact resistance of polycarbonate
Better optical quality than polycarbonate
Tintable
Lightest material on the market
Inherent UV protection
High tensile strength (ideal for drill mounts)

Cons
Susceptible to scratching (correctable by coating)

Lens Material Properties Summary

Lens Material Properties						
Material	Index	Specific Gravity (g/cm3)	Abbe	Reflectannce	Transmittance UVA (286 - 320 nm)	Transmittance UVB (320 - 380 nm)
CR-39	1.50	1.32	58	4.0	10.3	0.0
Poly	1.58	1.21	29	5.2	0.0	0.0
1.60 (MR6)	1.60	1.22	42	5.3	0.0	0.0
1.66 (MR7)	1.66	1.35	32	6.2	0.0	0.0
Trivex	1.53	1.11	46	4.4	0.0	0.0
Crown Glass	1.52	2.54	59	4.3	84.3	30.5
1.60 Glass	1.60	2.60	42	5.3	39.1	0.1
1.70 Glass	1.71	3.20	35	6.7	24.6	0.0
1.80 Glass	1.81	3.66	25	8.2	19.5	0.0

Principles of AR Coatings

As light passes through a lens, it experiences a change in index of refraction. Subsequently, some of the incident light is transmitted through the lens medium and refracted while some of the light is reflected. This reflected light is not only perceived by others as glare, but also represents a loss of light transmitted through to the eye.

As the refracted light continues through the lens medium and reaches the back surface of the lens, there is another index change and again refraction and reflection occur. Reflected light here can bounce off the internal surfaces of the lens and be seen by the patient as blurred or ghost images. Others may see internal reflections as multiple rings inside the lens (most prevalent in high minus powers). Blurred or ghost images can become intensified at night around bright lights common in dusk or night time driving conditions, and can significantly impair vision. Also, this backside reflection represents further loss of light transmitted through to the eye.

Light incident upon the back surface of a lens will also undergo a certain amount of reflection. Light here can be reflected directly back to the eye. The resulting images can be a distraction to the wearer or can, in certain conditions, impair vision. For example, bright sun light hitting the back surface of a sun lens that is not AR coated, depending on the angle, can either be reflected directly back into the eye or can "fill" the lens with reflected light. Either case can result in significant vision impairment.

AR coating can minimize lens surface reflections, significantly reducing or eliminating the problems discussed above, reducing eye strain, while allowing more light to reach the eye, improving contrast and clarity.

How AR Works

AR coating reduces lens surface reflections by actually generating reflections of its own. The index of refraction of the AR layer is in between that of the lens medium and that of air. Light incident upon an AR coated lens experiences reflection at both the AR layer and the surface of the lens. However, the thickness of the AR layer is such that the light waves reflected from the AR surface are 180° out of phase with light waves reflected from the surface of the lens. Consequently, the reflected light waves undergo destructive interference and effectively cancel each other. The Law of Conservation of Energy states that energy can neither be created nor destroyed. So, what happens to the energy from the cancelled light waves? It is transferred through the lens medium to the patient's eyes improving contrast and clarity!

Photochromic Lenses

Photochromic is a generic term to define a lens with a characteristic of changing state from clear to sunglass dark when exposed to light. Over the years this option has been available in many different chemical, material, and color combinations; as well as offered by many different manufacturers with varying methods for application. Below is a list of the most popular flavors of photochromic lenses and a brief overview of the technologies and the companies that produce them.

Transitions

Transition lenses were created by PPG Industries (Pittsburgh Plate Glass Company). Transitions lenses use a technology called imbibing to place the photochromic dye photosol a few microns below the front surface of the lens. The advantage is that the lenses can be surfaced to a very thin center thickness without worry of the photochromic properties being changed. This technology also allows for uniform color in cases where the thickness between right and left lens varies. Transitions is available in a CR-607 monomer 1.5, a CR-424 UV curable monomer 1.55, and a urethane 1.67.

PGX/PBX

Photo Grey Extra and Photo Brown Extra are the original glass versions of a photochromic lens. These lenses used an en masse technology which had the dye mixed throughout the entire lens. A large disadvantage to en masse technology s the fact that with varying thicknesses the lenses would have a slight variance in color, this is apparent in plus lenses with darker centers and minus powers with lighter centers. The chemical commonly used in these lenses is silver halide which is also a popular dye used in photography for film and paper.

Sunsensors

Sunsensors are an en masse plastic technology created by Corning. Corning offers this lens in a 1.56 material. Sunsensors use an en masses technology yet lenses will match one another even with varying thicknesses and powers, the idea behind this is that only the surface dye is activated so no matter the variation in thickness the UV light is absorbed and activates the same amount of chemical in the surface of the lens.

LifeRx

LifeRx lenses were created by Vision Ease to fill a niche for polycarbonate FT photochromics. The technology used to create theses lenses is a dye film that is applied to the lens similar to a polarized film. The advantage is that FT polycarbonate photochromic lenses are finally available for sale, however the disadvantage is the same disadvantages polarized lenses face; delamination which the earlier version experienced and contra indications for use in nylor mounts. None of these disadvantages have stopped the LifeRx line of photochromics from being widely accepted and heralded in the ophthalmic community. Especially among pediatric dispensers who were until LifeRx were limited to Trivex FT transitions.

Polarized Lenses

Photographers often use polarized lenses on their cameras to obtain bolder colors and deeper contrast in their photos. In the same way polarized lenses remove the glare and improve the visual quality of a photograph, polarized ophthalmic lenses improve the vision and comfort of those wearing them, in addition to playing an important safety role for drivers, particularly in morning and late afternoon sun.

Imagine standing on the shore in the early morning, the bright sunlight reflecting off the surface of the water into your gaze. There is a boat in the water, but you can barely see it because the intense reflected sunlight fills your eyes. You put on your polarized sun glasses. The intense reflected sunlight is replaced with a scene full of detail, color, and contrast. That is what polarized lenses do. Next, imagine a similar scene where instead of standing on the shore, you are driving your car and the sun is reflecting off the wet pavement. Instead of a boat being obscured by the glare, a child is crossing the road - now consider the important safety role polarized lenses can have in everyday life.

How It Works

Light waves coming directly from the sun vibrate in all directions and are considered non-polarized. When vibration is restricted to a single direction or plane, the light is considered polarized. When non-polarized sunlight is reflected by surfaces, it can become polarized as light of all but a single angle is either absorbed or scattered. Bright, flat surfaces such as water, wet roads, sand, snow, car hoods, and windshields are major sources of reflected polarized light. The intensity of this reflected light can obscure useful information about the color, texture, and other properties of the underlying surface and can be visually uncomfortable or constitute a safety hazard. The good news is this reflected light can be virtually eliminated by using polarized filters.

The principle behind polarized lenses is perhaps best illustrated by thinking of the lens containing a microscopic Venetian blind. The blind blocks the transmission of light from certain angles while allowing it from other angles. The blinds are aligned horizontally to absorb the reflected light that degrades vision. The horizontal alignment can be demonstrated by taking a pair of polarized sunglasses outside on a sunny day. Find a reflection of sunlight on the hood or windshield of a car. Hold the sunglasses in front of your eyes and view the reflected sunlight through the polarized lenses. Notice the intensity of the reflection drop dramatically. Now rotate the sunglasses 90Â°, just as if you were to tilt your head to one side or the other, and notice the intensity of the reflection return illustrating how the horizontal alignment of the polarizing filter interacts with the reflected polarized light. This horizontal alignment makes correct placement of the polarized lenses in the wearer's frames imperative.

Polarizing filters are created by stretching sheets of polyvinyl alcohol (PVA) so its molecules align in long directional chains. The PVA is then passed through an iodine solution where the light absorbing iodine molecules attach to the molecular chains forming the microscopic blinds. The film is then incorporated into the lens blank as it is poured, creating polarized lenses.

Tinted vs. Polarized

Although tinted sunglasses may reduce brightness and improve wearer comfort, they do not remove glare like a polarized lens. Moreover, dark sunglasses without UV protection can potentially do more harm than good as the darkness of the lens can cause the pupil to dilate, allowing damaging ultraviolet rays into the inner parts of the eye. Polarized lenses provide the comfort of darkened lenses, eliminate uncomfortable and often dangerous glare, and filter harmful ultraviolet light.

Stressed Out

There is an interesting visual phenomenon associated with polarized lenses, one that allows stress patterns in certain materials to become visible to wearers of polarized lenses. The effect can most often be seen in the car windows as a cross hatch pattern in the glass. Auto glass is tempered for safety. This tempering induces stress that becomes visible when viewed through polarized lenses. Similarly, ophthalmic lenses can be checked for stress by holding them between two polarized lenses with light shining through. Any amount of stress in the lens material becomes evident. The process works for lenses of any material and is the only way to detect unwanted stress that could ultimately result in a broken lens. This unusual feature of polarized lenses has no effect on acuity or vision, but it may help to explain this characteristic of polarized lenses to anyone purchasing or considering polarized sunwear.

Dispensing Polarized Lenses with AR

Something else to consider when dispensing polarized lenses; most high-end sunwear manufacturers, in addition to using polarized lenses, add an AR coating to at least the back surface of the lenses. While polarized lenses reduce reflected light from external surfaces, AR coatings reduce reflected light both in and on the lens itself. Reflections on lens surfaces, most significantly back side reflections are far more noticeable in dark lenses and can sometimes even dramatically impair vision. An AR coating eliminates these reflections and improves visual clarity. While it can be argued that the most benefit is derived from back side AR coating, front side AR coating carries the same benefits outdoors as it does indoors.

Scratch, UV, and Mirror Coatings

Scratch Resistant Coating

The purpose of adding a scratch resistant coating to lenses is to protect the lens from abrasions and scratches. The majority of lenses used in today are some form of plastic. These lenses tend to be rather soft materials. The SRC hardens the lens surface and makes them much more abrasion resistant.

SRCs are made from many different materials. The manner in which the hard coat is applied to the lens can affect the overall abrasion resistance and ability to tint the lens.

The main types of coatings are:

Dip-Coating - These type of coatings are produced relatively cheaply. They can be done in-house by most offices, laboratories, and lens manufacturers. This coating is applied by dipping the lens into a chemical solution and curing the lens in an oven.
Spin-Coating -These coatings are applied to a spinning lens. The lenses must be cured after the hardcoat chemicals are applied. The curing can be done in an oven or by ultraviolet light.
In-mould Coating -These coatings are made by adding the hardcoat chemical at the time that the lenses are being formed. Most lens manufacturers are using this type of coating process. This process is generally used on semi-finished lenses only. These coatings tend to be non-tintable.
Vacuum Coatings -This is a process that is becoming more popular with the rise in anti-reflective coating use. The cost is generally much higher than the other methods. When this type of hard coat is produced at the same time and in conjunction with an anti-reflective coating, the costs difference is not as prohibitive.

UV Coating

An ultra violet coating is added to CR-39 lenses to increase the absorption of harmful UV rays. This type of coating can easily be done in-house. It is applied by dipping the lens into a solution for a period of time so that the lens can absorb the UV blocking chemical. The majority of new lens materials have UV filtering properties inherent in the material.

Mirror Coating

Mirror coatings are highly reflective and are used to reduce the light transmission through a lens. They are produced in a vacuum process. The chemicals used vary greatly depending on the color and density of the mirror desired. The coating generally will have a combination of various metal oxides that when combined will result in the specified color. Mirror coatings are available as a solid, gradient, double, and triple gradients.

Multifocal Lenses

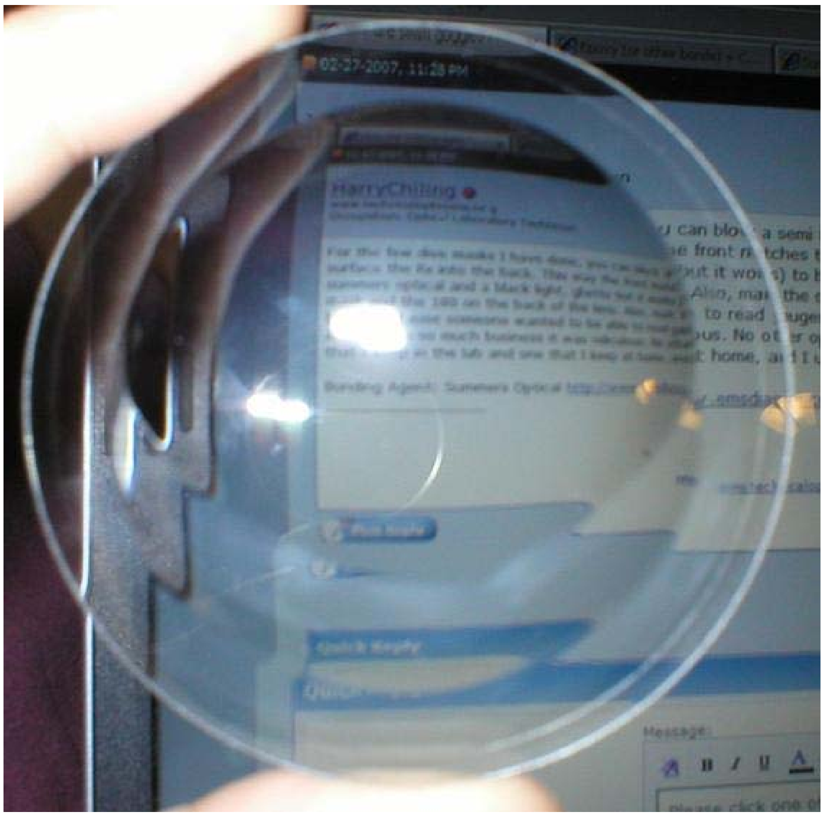
A multifocal lens can be thought of as two lenses on one. The larger lens is sometimes referred to as the carrier, while the smaller lens is typically called the segment. The power of the segment is always a plus and is also commonly referred to as the reading add. The add power is used to correct presbyopia, compensating for the lack of accommodation, and allowing the wearer to clearly view objects at near.

The first multifocal lens was created by Benjamin Franklin out of necessity. Mr. Franklin had a hard time viewing distances and when he had his distance spectacles on he had a hard time seeing up close. So, around the 1750s Benjamin Franklin had two pairs of spectacles one for distance and one for near cut in half and placed in one frame together to create what was referred to as "double spectacles". Although there is no evidence, many credit Samuel Pierce as the optician who made the first multifocal lenses for Benjamin Franklin. The term multifocal in it's earliest sense was a bifocal however the term can be used for any lens with multiple focal lengths from trifocals and double D segments to blended and round segments. There are cemented, fused, and one piece construction methods for creating multifocal lenses. Cemented multifocals are worked as two separate lenses with the multifocal section being worked to the equal but opposite curve of the surface it is being glued to. Cemented lenses used to be constructed with balsam as the adhesive. However, balsam is susceptible to heat and shock. It also tends to discolor over time. Although not as common, newer methods include using epoxies to bond the lenses. One of these cements is Summer Optical's lens bond. Fused construction is made in glass where sections of higher index glass are fused using heat into a countersunk corresponding curve in the lens blank. The addition of a fused multifocal is created by the following relationship:

n = index of the main lens
n_s = index of the segment

$(n - 1) / (n_s - n)$

This formula gives the ratio of the base curve to the addition created. One piece construction can be described as molding. One piece construction also includes lenses made by grinding various curves onto the back of a single vision lens blank as in the case of a Myoter Bifocal.



Another distinct lens design that fits one piece construction yet doesn't resemble the traditional lenses seen today is the Younger Seamless bifocal. This lens is a 22mm round bifocal with a 2-3mm transition zone which blends the two curves together. This allows the lens segment to be nearly invisible. Recently, a few labs have offered a variation of the Younger seamless bifocal by placing a blended round segment on the back surface of a single vision lens blank. This allows the design be offered in more materials and options then in the past.

Multifocals types:

- Flat Top – 25mm, 28mm, 35mm, 45mm, 7x28mm, 8x35mm, Double D 28mm, Double D 35mm, Quadrifocal 28mm
- Curved Top – 28mm
- Round – Achromat, Kryptok, Ultex, 22mm, 25mm, Double Round
- Panoptik
- Ribbon
- Executive – Bifocal, Trifocal, ED Trifocal

Fitting Multifocals

A good procedure to follow for the fitting of multifocal lenses is:

1. Adjust the frame and nosepads so that the frame fits the patient comfortably and the frame is fit closely to the patients face roughly 10mm - 14mm vertex distance.
2. Position yourself in front of the patient so that you are looking directly at the patient with your eyes on the same plane as the patient and parallel to the floor.
3. For FT, Executive, or Round bifocals, mark the lower lid margin on the demo lenses or a piece of tape placed from the top to the bottom eyewire of the frame, for FT, Executive, or Round Trifocals mark the position of the lower pupil margin, For Seamless bifocals place your mark at the lower lid margin then add a mm to the segment height.

Image Jump

Many multifocals have the optical centers placed some distance from the segment top, which creates an effect called "image jump". This is the abrupt change in the position of the image due to the change in power and corresponding prism. Certain multifocal designs for instance FT45 and Executive styles have their segment optical centers situated on the top of the segment creating no image jump. To determine the amount of jump created by a segment the following formula applies:

To find the optical center of the segment:

FT Designs (below top of segment):

Seg_{OC} = (width – height) / 2
For Round Designs (below top of segment):

Seg_{OC} = width / 2 = height / 2

Jump = amount or prism or image jump
Add = multifocal add power
Seg_{OC} = from above the measure in mm of the optical center from the top of the segment

Jump = Add x Seg_{OC} /10

In certain cases this image jump can be used to offset the amount of prism created when a patient looks down through the NRP of the lenses. For instance when the power along the 90 meridian or the vertical meridian differs by a large degree, it causes problematic amounts of prism on down gaze in some cases leading to double vision. Different segments with different image jumps can be used to neutralize the difference in prism on down gaze. The only other way to eliminate this effect is by supplying two separate pairs; one for reading and one for distance or with the use of slab off prism which can be costly.

Progressive Addition Lenses

Progressive addition lenses (PALs), commonly referred to as no-line bifocals or varifocals, are a gradient power lens used to treat presbyopia. PALs allow the viewer to avoid image jump caused by the abrupt change in power found in bifocal and trifocal lenses. The power in a PAL gradually changes from the top of the lens, which corresponds to the distance power of the lens, and the bottom portion of the lens which corresponds with the near power of the lens. However, this gradual change in power comes at a cost. The vision outside of the optimal viewing areas of the lens suffers from distortion, although the problem is more accurately referred to as aberrations with distortion being one of the aberrations induced.

History

The first patent for a PAL was filed in Britain in 1907 by Owen Aves (Patent 15,725); the design was for a conical back surface with a cylindrical front surface. The sum of the two surfaces of Owen Aves' lens created a progression in power; however the design had one major flaw: it was difficult to include any cylinder power in the lenses so ultimately the design was never produced commercially. The first commercially available PAL was designed by Duke Elder in 1922 named the "Ultrifo". This design utilized aspheric surfaces to create a progression in power. The next commercially available PAL was a lens called the Varifocal. Created by Offcine Galileo di Milano out of Italy in the 1950's, the design was inspired by Aves' design. Milano's design is referred to as an "elephant trunk" design and utilizes only the front surface to create the progression in power. It wasn't until 1959 that the first modern day progressive was born; the Varilux. The Varilux was developed by Bernard Maitenaz and produced by the Societe des Lunetiers (Essel) known today as Essilor. The first Varilux used a spherical near and distance section with an aspheric intermediate corridor that gradually changed in profile from the distance to the near. This design was crude but effective and is the basis for many of the modern designs seen today.

Fitting Method

Many manufacturers have fitting criteria available for their lens designs, however a good technique to follow is outlined below:

1. Have patient chose frame, making sure the frame is fit close to the face with 10mm -14mm of vertex distance.
2. Adjust the nose pads to the patient's nose. Apply 5°-10° of face form, and 10° – 15° of pantoscopic angle to the lenses.
3. Sitting directly across from the patient, aligned so that your eyes and the patients eyes meet on a plane parallel to the floor, mark the centers of the pupils on the demo lenses or a piece of clear tape placed across the frame.
4. Measure the distance from the pupil center on the lens to the inside bevel of the bottom most portion of the eye wire. This is the segment height to specify for the lens.
5. Use the manufacturers cut out chart to verify that the DRP, NRP, PRP are properly placed and within the confines of the frame.
6. Take monocular IPD with a corneal reflex pupilometer. It is important to take an accurate measure for correct placement of the optics.

Soft vs. Hard Design

Progressive lens designs have been classified as hard or soft in the past with the newer generation of lenses exhibiting characteristics of both. Soft lenses are described as lenses where the astigmatism from the corridor is allowed to creep into the top distance portion of the lens or the bottom near portion of the lens. This allows the corridor to appear wider and less distorted making it easier for first time progressive lens wearers to adapt. Hard designs have clear peripheries in the top distance portion and bottom near portion which moves the peripheral distortion to the middle corridor section of the lens. Hard designs are more difficult for first time patients, however they provide wide near and distance areas which often make them a good choice for advanced presbyopes. Today's lenses often employ multiple designs across a range of add powers varying from soft to hard. Most even combine characteristics to come up with hard distance and soft near sections or vice versa allowing multiple combinations to fit the patients particular needs.

Manufacturing Process

Progressive surfaces are described mathematically as deformed conicoids, these surfaces present certain problems in the traditional sense of ophthalmic molded lenses. Single visions and aspheric single vision lens molds exhibit rotational symmetry which means when a glass mold is created, the surface can be polished by rotating a tool of the opposite curvature at high speeds to polish the surface. However, with progressive surfaces the lenses do not exhibit this same rotational symmetry, so polishing in this manner would warp the surface and destroy the intended design. So to make a progressive mold the process used is called slumping. Slumping requires a clay mould to be created to the exact standards of the lens design and then a highly polished piece of glass is heated to just above flowing and allowed to slump or rest upon the clay mould until it takes on the profile of the clay mould. The mould is then tested to ensure that the accuracy. This process is not easy and requires precise temperature control and other metrics to ensure adequate reproduction of the intended design. In some cases the mould manufacturer will incorporate a vacuum assisted technique to suck the glass into the clay mould. Using this method the subtleties of the design can be lost just like the details of a photocopy of a photocopy to the original.

The most recent manufacturing techniques incorporate CNC grinding of the design directly to the surface of the mould instead of using clay moulds. This allows more subtleties of the designs to remain. This is done with Computer Numerically Controlled generators and floating pad polishers. The generators use a single point diamond which leaves a smooth surface that requires little polishing and the floating pad system allows for minimum stock removal. This eliminates the issue of degradation from making a copy of a copy.

The individual PAL designs utilize the same CNC process as the updated digital molding process except the progressive surface is directly scribed to the lens blank eliminating the molding process of the progressive surface. This allows any number of single vision semi finished lens blanks to be utilized in any number of material and treatment combinations.

Prism Thinning

Because of their design, the powers of a progressive lens vary from the top of the lens to the bottom of the lens, leading to differences in thickness. To reduce the difference in thickness, when the lenses are ground to specification, the lab will often incorporate prism. This process is referred to as equi-thinning, prism thinning, or yolk prism. The rule of thumb is to use 2/3 the add power in base down prism, however many labs employ more sophisticated software that can take into account the frame size, power, astigmatism, and segment height when making a determination for the amount of prism. It is a good idea to establish your preferences for equi-thinning with your lab up front then make alternate specifications should circumstances dictate. When changing one lens it is also important to inform the lab of the amount of prism present in the current lens so no imbalance is produced.

Progressive Design Generations

The Varilux design is the basis of all modern designs and as such we use their generation to describe all progressives.

1st Generation Designs: Outlined above; spherical distance zone, using a progression of conic sections to arrive at a spherical near. The lenses were rotated nasally to allow for inset. Sometime between the first and second generations the ideas of splitting the intermediate zones into nasal and temporal to create asymmetry was employed.

2nd Generation Designs: This generation moved away from spherical distance and near zones to aspheric zones which allowed the aberrations to be managed slightly better by moving some of the intermediate zone abberations into the distant periphery and some of the aberrations down into the near periphery. This created a wider intermediate zone that was more useable. This generation also focused on a concept called orthoscopy. Orthoscopy is minimizing distortion, mainly in this case along horizontal and vertical lines. This was accomplished by focusing on keeping the horizontal prismatic effect from varying along the periphery both nasally and temporally, as well as keeping the vertical prismatic effect from varying along the distance and near zones.

3rd Generation Designs: This generation of progressive lenses was the first to employ multi design principles in a series of progressive lenses. In the past the design was fixed for the entire progressive series. This meant that the design was chosen to be either soft, aberrations distributed throughout the entire lens, or hard, aberrations kept in the periphery of the progression zone. At this time there were different designs on the market with each manufacturer focusing their attention towards eliminating or managing certain aberrations better than others. These design philosophies can be thought of and seen as signatures which continue through modern designs (examples include the VIP which focused on wider distance and near zones keeping the astigmatism in the lens periphery of the intermediate zone, Truvision Omni which focused on reduced astigmatism by spreading it out over the entire surface of the lens, and the Zeiss Gradal HS which focused on more comfortable binocular vision). From these various designs came the concept of going from soft and easy for an early presbyope to hard with wider areas of vision for an advanced presbyope. The new design philosophies were combined into one progressive lens series with the design being a function of add power.

4th Generation Design: This generation employed a soft periphery combined with a short corridor. Previous designs had been plagued with the choice of a short corridor which allow the viewer a more comfortable posture when reading with the periphery being difficult to use, or a longer corridor with better dynamic vision through a softer periphery. This design also included variable insets which were based upon the add power.

5th Generation Design: This design focused on improvements in peripheral and binocular vision. This generation improved and enlarged the horopters (corresponding points on the retina where the two images viewed through the right and left lens form a single image) and peripheral vision. This was accomplished by varying the inset based not only upon the add power but also upon the distance vision through the base curve.

6th Generation Design: This is the current generation of lens design. These lenses incorporate all the design characteristics of the past while using beam tracing instead of ray tracing the lenses. In essence instead of focusing on the characteristics of one ray through one point on the lens the designer now focuses their attention on a beam the size of a pupil through the lens. This helps to reduce the effects of the lesser aberrations, coma, and spherical aberration. In the past these two aberrations have been ignored and for good reason since they provide only negligible improvements when corrected. However, with the technology of computers today it is possible and feasible to account for these aberrations. This generation of lenses is often referred to as high definition or high resolution lenses.

Individual Designs: These designs are not necessarily a generation but they are the next step in the evolution of progressive lenses and follow chronologically after 6th Generation Designs, individual lenses use digital or free form surfacing techniques along with sophisticated PAL design software and incorporate the patient's biometric data, prescription, and frame attributes into the design of the lens. In the past, designs have used global variables for things such as back vertex, center of rotation, pantoscopic tilt, dihedral or face form angle, as well as insets. The individual designs take the patient's correct metrics into account and factors them into the design. This means the patient gets a truly custom lens with minimal compromises due to manufacturing constraints. One manufacturer even goes as far as incorporating a metric for the amount of head tilt as compared to eye movement to vary the designs hardness for a more comfortable feel given the patient's viewing habits. This stands out from the average individual design in that the variable becomes the research behind what makes the design comfortable rather than the designs and patient related parameters.

Example of a 1st Generation Design

The distance can be described as a spherical surface with power (F_D) corresponding to the distance front surface measured in diopters and the near described as a sphere of power (F_N) corresponding to the near front surface power, then the corresponding radius of the lenses can be described as:

$r_D = 1000/F_D$
$r_N = 1000/F_N$

With the corresponding points fitting into the spherical equation:

$$x^2 + y^2 + z^2 = r_D^2$$

these equations make the assumption the point (0,0,0) is the point at which the radius originates to wards a point on the corresponding spheres. Our domain for the distance could be easily described as above the prism reference point or $y>0$, and our domain for the reading could be easily described as $y<$minimum fitting height, leaving the domain for the intermediate or progressive zone as $0<y<$minimum fitting height, and since our progression zone would follow along a tangential plane our equation to create a change in tangential power equal to the add (A) along a path equal to the corridor length (y_1) with the use of a conic section would be described as having a aspheric p-value of:

$$p = 1 + (r_D/y_1)^2 * \{1 - [F_D/(F_D + A)]\}^{2/3}$$

This would be used in our conic equation:

$$x^2 + y^2 + pz^2 - 2r_D z = 0$$

Combined these formulas can be programmed to create a point file that would be introduced into a digital generator that can create deformed conicoids and a digital polisher that would use soft laps to polish the surface to create a digital progressive.

Occupational Lenses

In the broadest sense of the term, an occupational lens is any lens designed for a specific task aside from everyday, “general-purpose” lenses. This can be something as simple as a single vision computer lens with only one viewing area or as complex as a “double-D” trifocal lens with 5 separate viewing areas or anywhere in between.

This section will help you to understand the different types of occupational lenses and how to determine which lenses will help your patient accomplish the tasks encountered in their daily life.

Occupational lenses can be broken down into two main categories; single vision lenses with a set focal length for a specific task or multifocal lenses which will allow the patient to focus at two or more distances with the same lens. The multifocal category can be further broken down into lined and progressive addition lenses.

Single Vision

The single vision category of lenses includes those specifically for work done at a fixed distance. A computer lens will be set so the patient can see the computer monitor and keyboard easily, normally around 20-24 inches (50-60 cm). A reading lens will likewise be set so that the patient can comfortably read for long periods of time in their preferred position. This is usually set around 14-18 inches (35-45 cm). These will be the most common single vision occupational lenses that you will encounter. However, a lens can be made for viewing at any distance required by the patient. Using this information, we can also consider a jeweler’s loupe to be an occupational lens, though the focal length would be much shorter, around 8-12 inches (20-30 cm).

Multifocals

Lined multifocal lenses can cover a much wider area of application than the single vision variety. The most common lined multifocal occupational lens is the “Double-D” lens. This lens offers correction for distance vision as well as near just as a traditional bifocal. The added benefit of this type of lens is the addition of a second near vision segment on the top of the lens. This will allow someone such as a plumber, electrician, or mechanic to read information that is above the normal line of vision without having to tilt their head back to an uncomfortable or impractical angle to use the reading segment on the bottom of the lens. This type of lens is also available in an “executive” style (the segments stretch across the entire width of the lens), trifocal segments on both top and bottom, trifocal on the bottom and bifocal on top, or even with different addition powers in the top and bottom segments.

A standard style bifocal or trifocal may also be made into an occupational lens. By changing the distance portion of a bifocal lens to the patient's intermediate prescription and reducing the add power accordingly, you will allow your patient to see the computer monitor comfortably while still being able to read while working. A 14x35 mm trifocal set slightly higher than normal will give the same effect while also allowing distance vision through the top of the lens. You can also adjust the placement of the reading segment to allow your patient much more comfortable vision during certain sports. A golfer may prefer to have his reading segment set around 5 mm; just enough to see the scorecard without interfering with his swing. A shooter may want the segment of his glasses rotated nasally for a better view of the gun's sights. These as well can be considered occupational lenses.

Progressives

The progressive type occupational lenses differ somewhat from the lined versions. A progressive lens being worn in an office environment may have distance vision set higher in the lens than normal and adjusted to focus at 10-12 feet (3-4 meters) while dedicating the majority of the lens to computer distance and reading. This will allow the patient to see across the office while seated at a desk while still giving the patient comfortable intermediate and near vision. This type of lens will also work well for concert musicians who need to be able to see the conductor as well as the music in front of them.

Some new technologies also allow a combination of lined and progressive type lenses. It is now possible to have a progressive lens with a lined reading segment on the top of the lens. This would work very well for commercial pilots who not only need to see distance and near/intermediate below the normal line of sight but also need to see instruments located above them to properly do their job.

Safety Lenses

Safety lenses, or industrial lenses, fall into two primary categories: Basic and High Impact. These categories are defined by the American National Standards Institute (ANSI) and have been adopted by the Occupational Safety and Health Administration (OSHA).

Basic impact lenses must:

- Have a minimum center thickness of 3.0mm regardless of lens material; or
- Have a minimum edge thickness of 2.5 mm if it is a+3.00D lens or higher
- Pass a drop ball test of a 1 inch diameter steel ball dropped 50 inches
- Sandblasted with the manufacturer's identification
- be delivered to the wearer bearing a Warning Label indicating that the protector only meets the Basic Impact Standard

High impact lenses must:

- Have a minimum center thickness of 2.5 mm regardless of lens material
- Pass a high velocity test in which a ¼ inch steel ball is shot at a lens at 150 ft/second
- Sandblasted with the manufacturer's identification and a plus (+) sign
- Be manufactured from either polycarbonate, Trivex, or SR-91

All safety lenses, whether they are basic or high impact resistant, must be inserted into a frame that meets the high impact lens standards. In addition, the frame must be marked with the Z87+ mark on the frame front and temple. These frames are able to retain a lens during high impact testing.

The application of occupational lenses is nearly limitless. By determining the needs of your patients, you should be able to recommend a lens that will help to accomplish nearly any task encountered at work or play.

Slab Offs

Slab-off, or bicentric grinding, is a method of correcting vertical imbalance for patients with anisometropia. Anisometropia is a condition in which the eyes have unequal refractive power. Anisometropia may be caused by differing amounts of either myopia or hyperopia between the eyes. In some cases, one eye will be myopic while the fellow eye is hyperopic, a condition known as antimetropia. When this condition exists, unequal refractive powers result in differing amounts of induced prism as the eyes move away from the optical center of the lenses, often causing diplopia or double vision. This may be corrected by adding Base Up prism (slab-off) or Base Down prism (reverse slab-off) to one or both spectacle lenses.

Slab-off is a technique in which the base-up prism is ground on half the lens in either the most minus or least plus lens. The finished lens looks like a portion has been cut from it, hence the name "slab-off." In 1983, Younger Optics developed a pre-molded reverse slab-off lnes. A reverse slab-off adds Base Down prism to the least minus or most plus lens. The reverse slab-off lens was designed to aid in the difficulties of slab-off grinding. Producing a traditional slab-off lens requires great skill and is quite time consuming. By using a pre-molded reverse slab-off lens, cost and production time are both greatly reduced.

Generally, vertical imbalance does not become troublesome for the patient until it reaches 1.5 diopters of imbalance. Some patients are able to tolerate much more imbalance while others much less. To determine which eye will receive the slab-off and how much prism should be ground, you will need to find the lens power at the 90° meridian. This is calculated by using the oblique meridian formula or the table below (you will most likely have to round to the nearest 5°):

Cylinder Axis	% Cylinder Power @ 90°
0 180	100
5 175	99
10 170	97
15 165	93
20 160	88
25 155	82
30 150	75
35 145	67
40 140	59
45 135	50
50 130	41
55 125	33
60 120	25
65 115	18
70 110	12
75 105	7
80 100	3
85 95	1
90	0

Calculate a Slab Off

Example:

OD –5.75 –2.00 X 130
OS –0.50 –1.00 X 025

1. *Determine the power of each lens in the 90° meridian.*

Using the table, you can find that the right eye has 41% of the cylinder power at 90° or -.82 diopters, giving total power at 90° of –6.57. The left eye has a total power of -1.32. Clearly we will be using the right lens for the slab off.

2. *Now we must determine the seg drop for the frame selected.*

This is done by dividing the 'B' measurement of the frame by 2 then subtracting the seg height. Add 5 mm to this to get the reading depth.

'B' of frame = 50mm, seg height = 20
½ of 'B' = 25 – seg height 20 = 5 seg drop
5 + 5 = 10 this is the reading depth

3. *Apply Prentice's Rule to determine the amount of vertical prism induced in each eye.*

To determine the amount of prism needed, we will use Prentice's Rule. Multiply the power by the reading depth and divide by 10.

OD -6.57 X 10 = 65.70 / 10 =6.57 diopters
OS -1.32 X 10 = 13.20 / 10 =1.32 diopters

For the total prismatic effect, we subtract the left from the right.

6.57 – 1.32 = 5.25 diopters of correction needed.

3. *Conventional Slab Offs are always ground base up in the most minus or least plus powered lens in the 90° meridian.*

The process of bicentric grinding is very involved and will not be covered in this section.

Cataract Lenses

Prior to the introduction and prominent use of IOL's (intra-ocular lenses) in the early eighties, Cataract lenses were regularly dispensed by opticians. Increasingly rare today, there is still a need for cataract lenses. While this section covers the topic of cataract lenses much of the information also applies to high plus lenses.

A cataract is an opacity in the crystalline lens of the eye; a cloudiness that occurs in some of us as we age. To restore clarity, cataract surgery is performed to remove this natural lens from the eye. Without the crystalline lens, the eye loses its natural ability to focus and is referred to as aphakic. Most cataract surgeries today are followed by the insertion of an intra-ocular lens, also known as an IOL, which helps restore the eye's ability to focus. An eye with an IOL implant is called pseudo-phakic.

There are many things to consider when helping a patient with cataract lens needs. The first thing to consider is frame selection. Lens size and fit are particularly important since material availability is limited. Cataract lenses generally fall in the +12.00 D to +16.00 D power range (sometimes higher) which means the finished glasses will have considerable weight.

The ideal frame will have a relatively small eye size and a frame PD very close to the patients PD. The more the lens is decentered, the thicker it will be, particularly at the nasal area. A good rule of thumb is to select a frame PD within 4 mm of the patients PD.

A round shape is also a good choice for cosmetic reasons. If the B measurement is significantly smaller than the A measurement, the lenses will have a thick shelf on the top and bottom. Once again, a good rule of thumb is to keep the A and B measurement within at least 6 mm of each other.

Metal frames allow some latitude in customizing the fit. However, a well fitting plastic frame can often offer the patient more comfort and improved appearance. Plastic frames also tend to sit closer to the eye which reduces magnification contributing further to improved vision and appearance.

With higher powers, vertex distance is another important consideration. The prescribing Dr. should indicate on the Rx the refracted distance. The refracted and worn vertex distances should match otherwise, vertex compensation must be performed. If the lenses are worn closer than the refracted distance, the lens powers need to be made stronger. Likewise, if the lenses are worn further from the eye than refracted distance, the lens powers need to be made weaker because of the additional magnification.

Lens selections and designs

Cataract lenses are available in single vision, but this category is seldom used for an aphakic unless the patient wants near only or distance only. Once again, when a patient losses his natural crystalline lens, he also loses the ability to naturally focus on near and distance objects. Therefore, if a patient wants to see both far and near out of one pair of glasses, he will need a multi-focal lens of some type.

The first multi-focal lens type we will discuss is the lenticular. Lenticular cataract lenses have a similar shape to an egg sunny side up. The outside of this design (the white of the egg) is called the carrier. The carrier is a flat, non-specific powered area which serves to support the central viewing area of the lens.

The central viewing area of a lenticular design (the yoke of the egg), also known as the aperture, is much steeper and holds the base curve upon which the back curve is calculated for the desired lens power. The aperture can be either spherical or aspheric.

Lenticular design cataract lenses are best used when the patient's frame chooses a large frame or the desired power is high (greater than +15.00 D). The carrier region of a lenticular improves cut out options and edge thickness. Higher add powers also are generally more available in this type design.

Cataract lenses are also available in full field designs. Full field designs have no carrier and are most often aspheric. Asphericity in these high powered lenses greatly improves optics and cosmetics. Most patients will notice wider, more natural vision wearing a full field design. They will also look better cosmetically since there is no carrier.

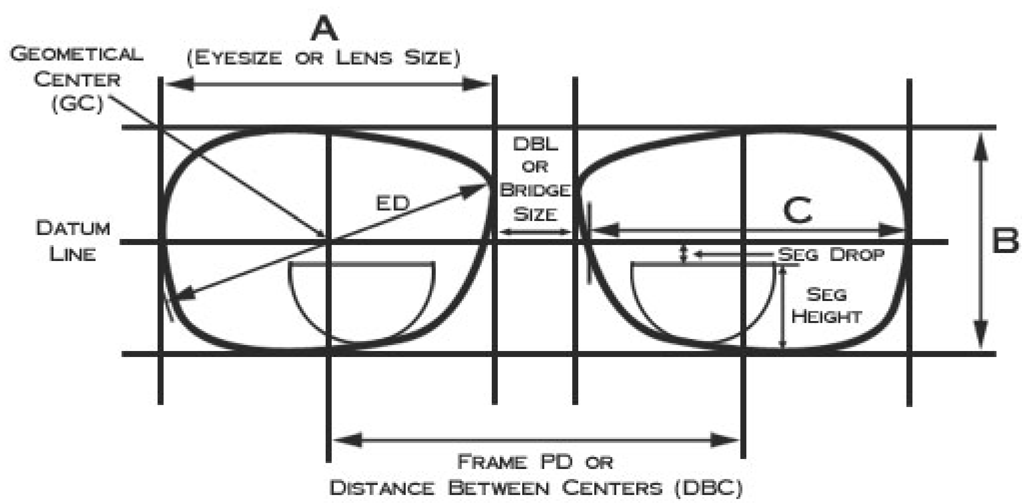
The last lens to discuss is called the Super Modular. This is an aspheric designed lens that is a cross between a lenticular and full field. Rather than a distinct carrier, this lens utilizes a rapid aspheration on the outer edges, making the transition from the aperture to the carrier seamless. This lens availability often allows for higher power than full fields. This lens is best used when high correction is required with better cosmetics than a lenticular.

Chapter 5: FRAMES

The Boxing System

In 1962 the Optical Manufacturers Association adopted the **boxing system** to provide a standard for frame and lens measurement that greatly improved upon the accuracy of previous systems. The boxing system is based upon the idea of drawing an imaginary box around a lens shape with the box's sides tangent to the outer most edges of the shape. The system uses the sides of the boxes as reference points for the standard system of measurements.

Boxing System



"A" Measurement - The horizontal distance between the furthest temporal and nasal edges of the lens shape or the distance between the vertical sides of the box. The A measurement is also commonly known as the **eyesize**.

"B" Measurement - The vertical distance between the furthest top and bottom edges of the lens shape or the distance between the horizontal sides of the box.

Datum Line - The horizontal line that runs through the vertical center of the frame.

Geometric Center (GC) - The intersection of the Datum Line and horizontal centers of each lens shape.

Distance Between Lenses (DBL) - The shortest distance between the nasal edges of each lens or the distance between boxes. DBL is also commonly referred to as **bridge size**.

Distance Between Centers (DBC) - The horizontal distance between the geometric centers of the lenses. DBC is also know as the **Geometric Center Distance (GCD)**, but more commonly referred to as the **frame PD**. In theory the DBC can be calculated by adding the "A" Measurement to the DBL as marked on the frame, however in practice the calculation may differ from the actual measurement.

Note: Frames are typically marked for size, for example: 54-18, where 54 is the "A" Measurement and 18 is the DBL.

Effective Diameter (ED) - Twice the distance from the geometric center of the lens furthest edge of the lens shape. The ED can also be defined as the smallest diameter lens that would cutout, if the frame's geometric center matched the lenses optical center. ED is used in combination with decentration distance to select the minimum lens blank size required to fit a given frame.

Seg Height - The vertical distance between the bottom edge of the box and the top of the bifocal or trifocal segment

Seg Drop - The vertical distance between the Datum line and the top of the bifocal or trifocal segment Overall

Temple Length (OTL) - The running distance between the middle of the center barrel screw hole and the end of the temple.

Length to Bend (LTB) - The distance between the center of the barrel and the middle of the temple bend.

Front to Bend (FTB) - The distance between the plane of the front of the frame and the temple bend. Used if there is a significant distance between the frame front and the beginning of the temple.

Frame Styles and Materials

What makes up a frame?

It is very important to know what components make up various frames. You will need to know which specific part you are talking about when ordering replacement parts, when describing a frame for a manufacturer or sales representative, when conveying information to a fellow optical dispensing professional, or when speaking with lab personnel. Failing to accurately describe the part you need could create delays, cause increased shipping costs, and create waste.

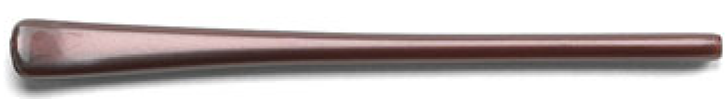
Some frame parts may be called different names by different people, some terms only apply to plastic frames and some apply only to metal. Some terms do not apply at all when discussing three-piece mounts (see below) made of hinge-less flexible metal. However, here are the generally accepted terms and their meanings:

Chassis (also known as frame front): When connected by a solid bridge of any kind (metal or plastic), the chassis is the combination of eyewires, bridge and the end pieces.

This includes any crossbars above the bridge, and any artful details applied to any of those pieces (like rhinestones).

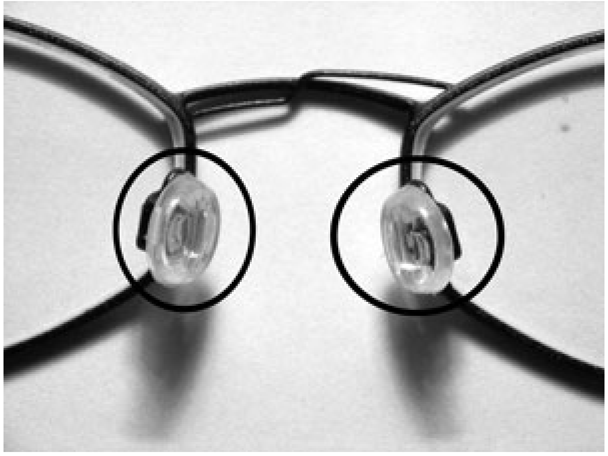
Temples (also known as temple arms or arms): Temples are the pieces that hold the chassis to the head and ears. The temple is the piece that runs from the end piece on the chassis back to behind the ear. The temple also holds half the hinge assembly. (Also, see temple types, below.)

Temple tips: Temple tips are usually removable plastic sleeves that slip over the ends of metal temples to provide comfort for the wearer. On plastic frames, the temple tip is the part of the temple that goes behind the ear. (Also see chapter 11)



Bridge: The bridge is the area between the two eyewires. On a plastic frame, it is the area that touches the nose and the area that connects the two eyewires together. On a metal frame, it is only the area that connects the two eyewires together. On a three-piece mount it is the entire assembly that connects the two eyewires together in the middle.

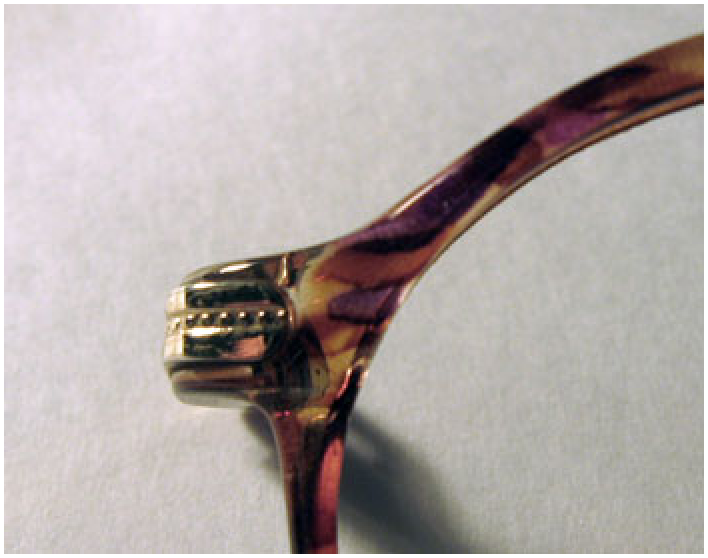
Nose pads: Nose pads are the small pads designed to contact the nose and hold the frame up off the nose and away from the face.



Guard arms: Guard arms are the small wire arms that actually hold the nose pad in place.

Eyewire: The eyewire is the area of the frame that actually surrounds the lens and holds the lens in place.

End piece: The end piece is the area of the chassis that meets the temple or the point where the temple attaches to the chassis. It is where half the hinge is found.



Hinge: The hinge is the point where the temple is connected to the chassis. It allows the temple to fold in and out. The hinge is usually held in place by a screw, but may be secured by a ball-and-socket or other variation. Also see ‘hinges’ below.

Frame Materials

There are two basic kinds of frame materials: metals and plastics.

Metals have four general types:

1. **Monel,** or basic nickel-based metal frames. These are inexpensive and make up the bulk of all low and mid-range metal frames made today. If a frame is metal and not flexible or not marked ‘stainless steel’ or ‘titanium,’ chances are excellent it is a Monel-based frame.

Advantages of Monel-based frames:

- Easy to adjust
- Hold adjustments well
- Very strong
- Relatively light in weight
- Can have a wide range of colors and plating like bright gold and bright silver
- Economical
- Can be repaired by solder.

Disadvantages of Monel -based frames:

- Outermost plating (the layer that touches the skin) can wear off, which can cause skin allergies or reaction to nickel in Monel metal
- Prone to breaking after repeated bending
- Once plating is worn away, metal may erode quickly and create abrasive areas and sharp edges
- Monel is the heaviest of metal frame materials in use.

2. **Stainless steel** is used in many mid-range to high-end frames. If a frame is metal and looks as if it is made of a material just a little thicker than a paper clip, then chances are excellent that it is made from stainless steel. Most frames will be marked on the demo lenses Stainless or Stainless Steel and may be marked on the inside of the temple as well.

Advantages of stainless steel frames:

- Light in weight because of reduced material
- Very strong
- Very little chance of allergic reaction to metal
- Holds color well
- Attractive appearance
- Holds adjustments very well.

Disadvantages of stainless steel frames:

- Limited range of colors
- Colors tend to be matte in finish
- Temples rarely made in any shape other than "paper clip"
- Larger frames can become heavy.

3. **Titanium** is used in many mid-range and many high-end frames. Since it comes in a wide range of colors, plating, and styles, it is not always possible to spot a titanium frame unless it is marked as such. Its extreme light weight may tip you off. A titanium frame of equal size may weigh half as much as an identical frame in Monel.

Advantages of titanium frames:

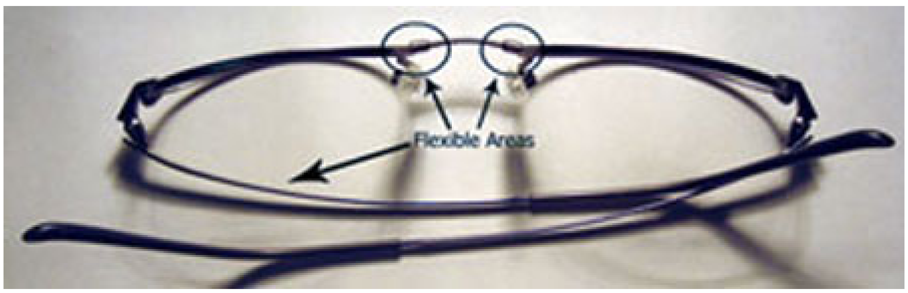
- Titanium is hypo-allergenic: it will not cause reactions with skin
- It is extremely lightweight
- It is 100% corrosion proof
- Extremely durable. A well-made titanium frame can last for years
- Very strong.

Disadvantages of titanium frames:

- Titanium is not easy to manufacturer, and not all companies provide the same quality of production
- Frames can be legally labeled 100% titanium yet contain other metals
- Frame lines may be inconsistent in their quality. Just because a frame is 'titanium' does not mean it is a quality product.

- Adjustments can be tricky. If a frame is 100% titanium, it can break easily at weld points if not well made
- A well-made titanium frame can last for years which might discourage repeat sales

4. **Flexible or memory metals** are metals with flexible properties, and are usually a mix of titanium and other metals. These frames will either be all flex-metal throughout the entire chassis and the entire temple, or a mixture of rigid areas and flexible metal. Flex metal frames are generally high-end and expensive. They are extremely popular for use in children's frames for obvious reasons. Just like titanium frames, not all flex metal frames are created equal. Many lower-end frames offered with memory metal, do not have the same quality of higher-end ones. Brand names for flexible metal frames include, Flexon, Flexolite, Easy Twist, MagicTwist, HyperFlex, etc.



Advantages of flex metal frames:

- Bend instead of break
- Return to original shape after being bent
- Have spring-like quality that helps hold glasses in place on head
- Lightweight.

Disadvantages of flexible metal frames:

- If not well designed with adjustment points built in, frames may be impossible to adjust
- You may find fitting difficult on people with unusual or very asymmetrical face shapes
- Some patients cannot adapt to a flexible frame; they actually need to feel the frame on their nose!
- People (especially children) may incorrectly assume that the frame is indestructible, or that it can be bent repeatedly without damage.

Plastics really have one general category, and then an odd collection of other materials.

1. 'Zyl,' or Zylonite, makes up the bulk of all plastic frames on the market today. If a frame is plastic, chances are excellent that is Zyl.

Advantages of Zyl frames:

- Light in weight
- Huge range of colors
- Strong
- Fairly easy to adjust
- Can be molded in any shape and size

Disadvantages of Zyl frames:

- Can lose shape and even be ruined by high heat (dashboard of car in direct sun)
- Will discolor over time
- Will dry out and become brittle over time
- Will stretch out and lose fit in hot weather.

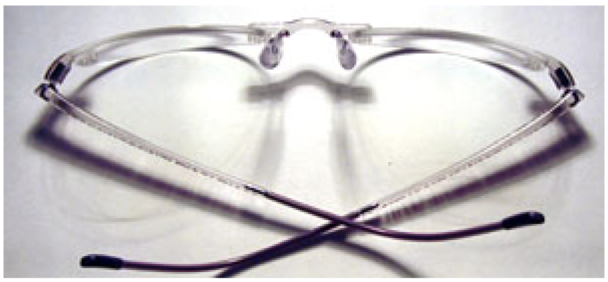
The generic category of plastic frames also includes brand names like SPX, and Grilamide. Which are variations of Zyl that are slightly lighter in weight, slightly more flexible, and have a little greater range of colors available. These Zyl hybrids are prone to heat damage, and can snap or split if over-stressed.

Other materials in the plastic category have included:

- Carbon: These were lightweight and strong but nearly impossible to adjust and never really took any substantial market.
- Nylon: These were strong but quite heavy and also nearly impossible to adjust.
- Rubber: Still found in swim goggles and as parts of frames but not used for complete chassis.

- Optyl: This is one of the few materials that enjoyed a substantial market share for several years. Frames made of Optyl will usually be marked OPT or Optyl on their temple.
- Polycarbonate: Strong and extremely lightweight it is used in sport safety eyewear.
- Kevlar: These were lightweight and strong but nearly impossible to adjust and never really took any substantial market.

A recent addition to the plastic category is **flex plastic**. It has all the advantages and disadvantages of flex metal with the added advantage of even greater weight savings.



Note: Manufacturers will often mix several materials in a single frame. When a frame has a mix of materials – for instance, metal temples and a plastic front -you note the frame material by the chassis or frame front. The lab will need to know the material of the eyewire, in order to set their machines in the correct mode for cutting out the lenses.

Frame Selection

Although being fashionable and looking good are important, nothing is more important when dealing with frames than how they fit. Remember the old snowflake metaphor? "People are like snowflakes…every one of us is different?" Well, you will learn this is true when you start fitting eyeglasses! Frames either fit, or they do not. You cannot make a frame designed for a child fit a grown man. Frames come in a wide variety of sizes. Each manufacturer's different lines will cater to different sizes. Large frame manufacturers will often offer each frame in three sizes, such as 49, 51, and 53. Smaller frame companies and specialty frame makers usually offer their frames in just one size.

We are often asked if the frames on our board are divided by gender, which leads to thinking about what makes a men's frame different from a women's frame. To spot a traditional men's frame look for features like a cross bar over the bridge, traditional gold and silver plating, aviator shapes, sharp angular shapes, and very large eye sizes. To identify a traditional women's frame look for pinks and bright colors, decorative stones, and especially artful details on the temples or chassis. Everything else on the board falls into the unisex category! However even some "unisex" models seem to lend themselves towards one gender or another. Any frame with a cat-eye or accentuate upper temporal corner of the eyewire is definitely feminine.

Frame Shape

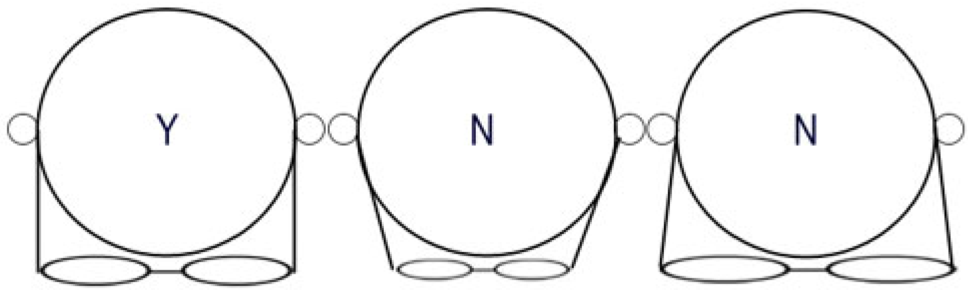
Although fairly self-explanatory frame shapes fall in to three general categories, round, rectangle, and oval. When describing a frame or eyewire as round it is assumed that the eyewire will be an almost perfect circle. When describing a rectangular frame or eyewire it is assumed that the horizontal and vertical lines of the frame will be approximately 90 degrees apart from each other and that they will meet at what could best be described as a corner not a curve. The oval category will be longer across the A than across the B and will not have any distinguishable corners or straight lines. Within the categories you will see and hear frames being labeled as "modified" or as being a variation of one shape or another.

Note: Frames have a base curve just like lenses do. Some prescriptions do not do well in certain frames. The higher plus the prescription the steeper or more curved the lens will be. A minus prescription will have little or no curvature of the lens. Should a frame be very flat (having very little face form) it will not hold a plus lens well. The reverse is true when we consider minus lenses in heavily wrapped shapes like sport sunglasses. One of the primary sources of lab delays is poor prescription – frame matching. If in doubt send the frame to the lab and get approval before promising a customer that it can be done.

Poor Rx - Frame matching is one of the most common reasons for jobs to be delayed at the lab!

Primary Frame Fitting Considerations

The first thing to consider when fitting a frame to a patient's head is the width of the frame. This means how the temples fit the sides of the patient's head. A properly fitting frame will have its temples leave the frame front, or chassis, and go straight back, touching the person's head just before their ear. There is simply NO EXCEPTION to this rule.



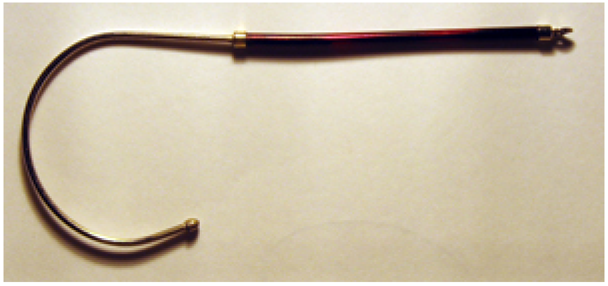
A frame that is too slightly too tight or too narrow may feel quite good to the patient when they first try it on. However, it will shortly begin to give them trouble by sliding down their nose in a short period of time. A frame that is much too loose or too wide will slide down their nose immediately.

Note: One good clue that a frame is too small is when a frame has spring hinges and they are partially open when the frame is on. Spring hinges are only there to provide flex when taking the glasses on and off or when they are struck. SPRING HINGES HAVE NOTHING TO DO WITH THE FIT OR COMFORT OF A PAIR OF GLASSES!

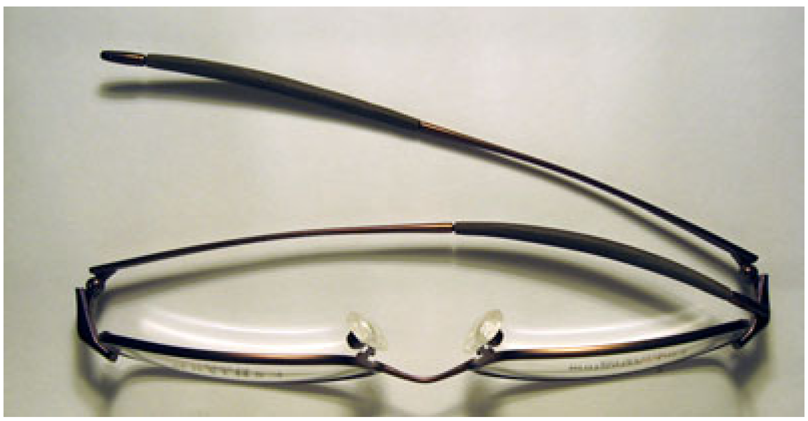
Temples should never be bent to curve around a person's head (unless provided by the manufacturer as part of the design of the frame), and they should never angle out from the chassis to reach the ear. Temples that are bent in or out mean that the frame DOES NOT FIT. This is where frame size comes into play: Should your frame be just a little too small, and it is marked 46 – 19, then check your catalog or call the manufacturer and see if it comes in a 48 – 20. If larger size is not available, then find another frame that fits!

Temples come in three types, with the "skull" temple being the most prevalent found on 95% of all glasses. It has a temple end that bends around the back of the ear, ends approximately mid-ear, and then bends in slightly towards the head, hugging the skull.

The second type is a cable temple, found on shooting glasses, glasses for infants, and some safety glasses. It has temple ends that are sprung and that wrap around the entire ear, holding the glasses firmly in place. Because they are springs, they can and will weaken over time, and can also break.



The last temple type was once called a “library” temple. This temple goes straight back, hugging the skull above the ear, never curving down at all. Originally these were popular for reading glasses, before progressive lenses made it unnecessary for people to take their glasses off frequently. Now, many modern designs have returned to this style of temple for fashion, but they are not given a special name. Many modern sport sunglasses also use a straight back design without any special designation. Frames designed for use under a helmet may also make use of a temple that goes straight back.



Many temples are offered with “spring hinges” which are built into the temple end near where it meets the chassis. Placing the spring in the hinge allows it to be forced open several millimeters without damaging or bending the frame. Spring hinges are an excellent addition to a frame however they increase weight, they can freeze and break, and they should be lubricated from time to time with a very light oil.

Second, we must consider how the frame fits the patient's nose. Consider whether the frame is a plastic one with a molded solid bridge, or a metal one with adjustable nose pads. If the frame is plastic and has a solid bridge (almost all do), then the frame either fits, or it does not. There is simply NO EXCEPTION to this rule. Look at the patient's nose, and see how the frame fits it. If the frame contours the nose well and has great contact across the entire bridge, then it fits. If you can see gaps or light showing between the nose and the bridge then it does not fit, and the patient must choose another frame. If the patient loves the frame, this may put you in an uncomfortable position, but remember that you are the optical dispensing professional and should be able to explain your reasons that the frame does not fit and the problems that will cause.

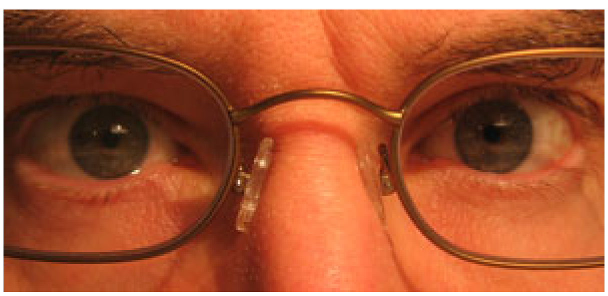
NO! This plastic frame makes very little contact with the patient's nose. In fact because of its design it actually only touches at the two sharp points of the "keyhole" and would be uncomfortable to the wearer.

YES! This is a much better plastic frame fit. Notice how the curve of the frame matches the curve of the patient's nose. You want maximum contact and do not want to see gaps or "daylight" between the nose and frame bridge.

If the frame is metal and has adjustable nose pads, be sure the pads are sitting comfortably on the nose, are not too far apart or too close together. Simply look at the pads and be sure they are touching the nose as much as possible. If they are not, you will need to adjust them.

Watch your frame manufacturers for designs that have narrow or wide bridges. Many manufacturers will develop their entire line, or one of their individual lines, for people with very wide or very narrow noses. You may find a line with consistent DBL measurements of 20, 21, and 22, and another with consistent DBL measurements of 15, 16, and 17. Keep this in mind as you learn your frame boards, so you will be able to quickly guide your patients towards great-fitting frames. It is a fine line between adjustability and a frame with a bridge that is simply too wide or too narrow.

NO! In this figure the nose pads are spread much too wide apart or flat for the patient's bridge or nose. Notice that the bridge is actually resting on the patient's nose. Also note how low the frame sits and high the eye is within the eyewire opening.



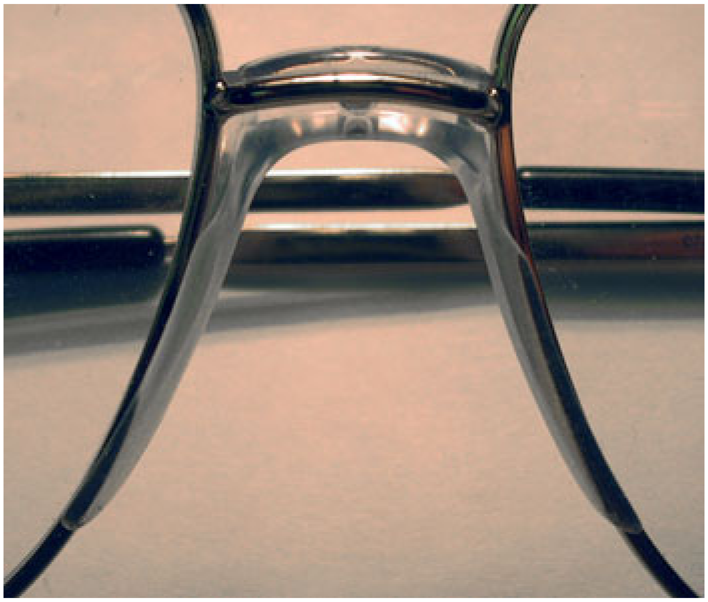
NO! In this figure the pads are pulled too close together or are angled to straight for the patient's bridge or nose. Overall contact with the patient's nose is quite poor and they would have a sore spot in no time at all.

YES! In this figure the pads are making good contact with the patient's nose. In particular look closely at the pad for the right eye (left eye in the picture) that is EXACTLY what you want to see, including the exposure of the pad and guard arm when viewing the patient.

Nose pads come in a huge variety of shapes, materials and sizes (more in Chapter 11). Guard arms are provided so you can adjust the fit of the frame on the patient via the nose pads. You can change nose pad types to accommodate frame fit, but a frame that requires a lot of work to achieve a good fit is probably not the right frame to begin with.

Rarely, will plastic frames will come wth nose pads. There is nothing special about these plastic frames, treat them as you would a metal frame with nose pads.

Some metal frames have solid bridges with plastic inserts that either screw in or snap into place, covering the entire bridge area of a metal frame. These solid bridges eliminate nose pads and guard arms while they mimic the fit and feel of a plastic frame while providing the advantages of a metal one. Check fit of metal frames with solid bridges as you would a plastic frame.



Third, check that the temples are long enough to curve over the ear properly and hold the glasses in place. This is often overlooked by even the most seasoned optical dispensing professional. For some reason, we seem to forget to check behind the ear and see if the temples are too short. If we sell a frame with temples that are too short, and a longer version is not available from the manufacturer, then we risk remaking a pair of glasses. Many temples can be shortened (see Chapter 11) but few can be lengthened. You may be able to slide a temple tip approximately 5 millimeters off the temple and maintain a normal bend effectively creating a longer temple.

Develop the habit of performing these checks now, and remember the rule of three:

One -- Width

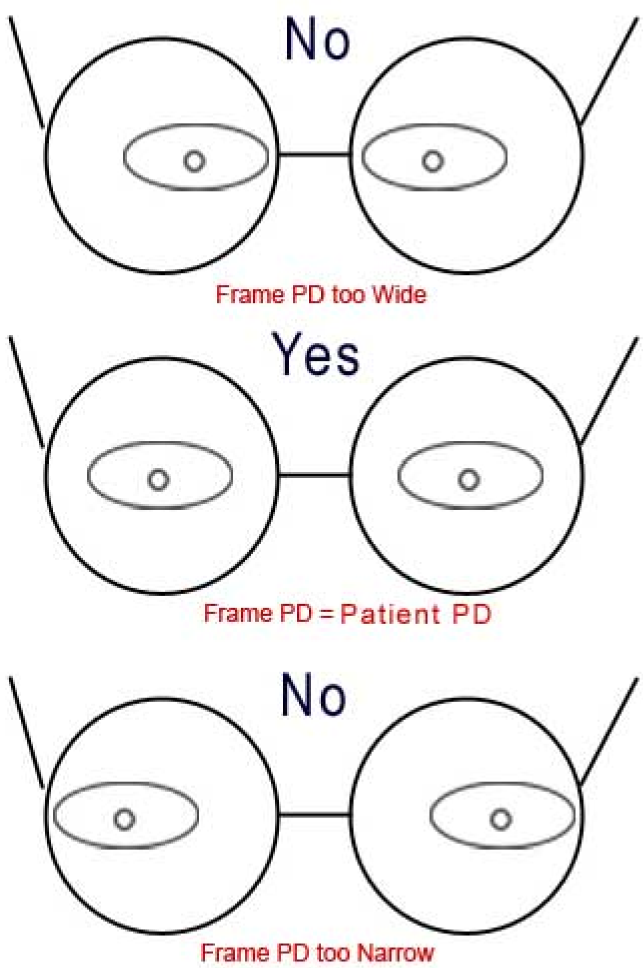
Two -- Nose

Three -- Temple length

Secondary Frame Fitting Considerations

After determining that the frame is the appropriate width, has a good fit on the nose, and that the temples are long enough, we need to consider a few other things.

For cosmetic appearances, it is best to choose a frame with a frame PD (A + DBL) as close to your patient's PD as possible. Try to keep your patient's eyes well centered in each eyewire opening.



Also keep in mind the smaller the eyesize, the thinner and lighter the lens will be.

For cosmetic reasons, when a prescription is high plus or minus avoid round shapes and go towards frame shapes with more angular dimensions or traditional ovals. This helps diminish the “bug-eye” appearance created by plus lenses’ magnifying power, and it helps reduce the appearance of myopic rings (visible distortions) in highly minifying lenses (greater than - 5.00). Also see chapter 3 on lens materials. Using the proper lens material and aspheric base curves will greatly reduce the cosmetic appearance of high powered lenses.

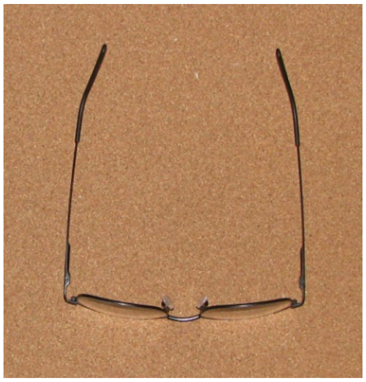
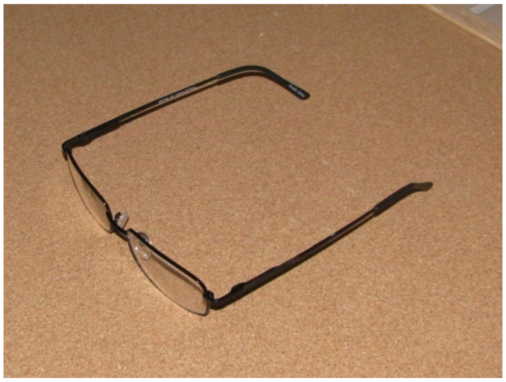
Fitting and Adjustment

As optical professionals, there are two distinct times when we fit and adjust a patient’s eyewear. The initial dispense when the patient is putting on their glasses for the first time and when the patient returns because their glasses are no longer fitting properly due to routine wear or damage. The tools and techniques we use are the same for both cases. Let’s begin with the initial dispense.

Standard or Bench Alignment

Four Point Touch

When a frame comes out of the lab for final inspection, it should be in standard or bench alignment.

Standard frame alignment – four point touch

This means that when the frame is placed on a flat surface upside down, both eyewires and the crest of each temple should rest on the surface. When the frame is turned over, both eyewires and temple tips should touch the surface. The temples should be near parallel and the frame should have slight face form and pantoscopic tilt.There should be no X-ing of the eyewires (twisting of the bridge).
The lenses should be in the same plane and the same height.

Frame Misalignment


X-ing


Skewed out of coplanar alignment


OD skewed higher than OS


Improper temple fold alignment

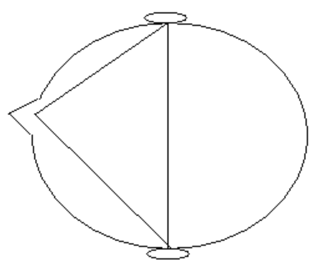

Proper temple fold alignment - When the temples are closed, they should overlap and be near parallel with the top of the frame.

If the frame has nose pads they should be symmetrical and have slight frontal, splay and vertical angles (complete descriptions to follow). The width should be slightly narrower than the contours of the eyewire.

Proper standard nose pad alignment

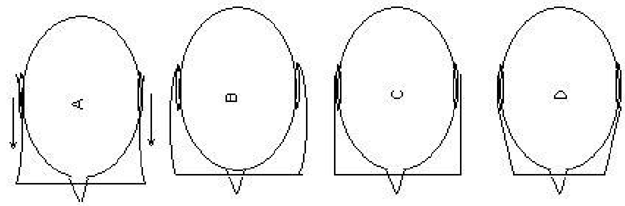
The price sticker should be removed and the residue cleaned. This is a good start on the way to the final adjustment and will give the patient confidence that we are professionals. An out of alignment and unclean frame put on the patient's face can give them doubts about the quality of our work and the value they are receiving for the money they spent.

The Fitting Triangle



When the frame is put on the patient's face, it touches at three points: The junction of each ear and the skull and the bridge of the patient's nose.

Temple Fit

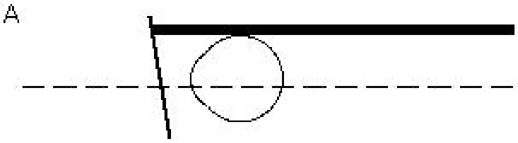


Ideally, the temples should go straight back, touching the sides of the patient's head as in example C above. They should not put pressure on the sides of the head as in example A. Nor should they bow out from the patient's head as in example B. With today's smaller frame sizes particularly on patients with larger heads, sometimes it is necessary to angle the endpieces of the temples out and curve them around the head as in example D.

Pantoscopic Tilt

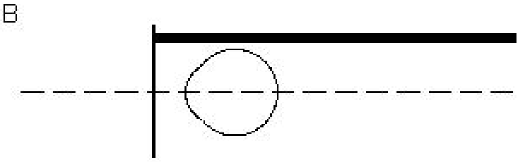
Ideally, for good cosmetics and optics, there should be about 8 - 10 degrees of pantoscopic tilt for most frames.

A



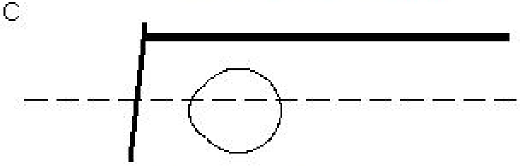
Pantoscopic Tilt or Angle

B



Orthoscopic Tilt or Angle

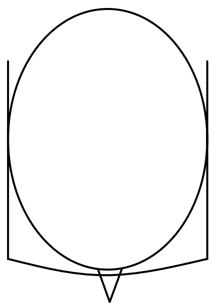
C



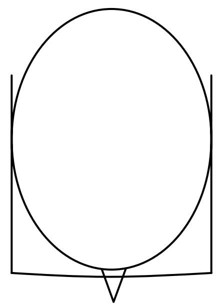
Retroscopic Tilt or Angle

Face form

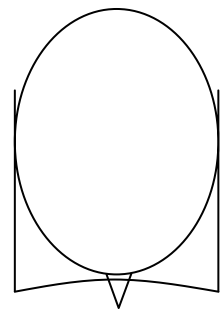
There should also be slight positive face form, particularly if the patient's PD is narrower than the frame PD (A measurement + dbl), the most common situation.



Positive face form



No face form



Negative face form

Fitting the bridge

With a plastic frame only minimal adjustments can be made to the bridge. Care should be taken during frame selection to ensure a proper fit. The sides of the bridge should come in contact with the length of the nose. A frame that has a wider bridge than the patient's nose rests on the top of the nose and will be uncomfortable and will slip.

Adjustable nose pads should be adjusted so the frame sits comfortably on the patient's bridge with the pupils falling slightly above the vertical center of the frame.

There are four basic adjustments that can be made to adjustable nose pads. In every case, adjustments should be made to bring the maximum surface area of the pad in contact with the patient's nose. Use the nose pad pliers for these adjustments

Width – The horizontal distance between the pads when viewed from the front.

Frontal angle – The angle of the pads when viewed from the front of the frame. The tops of the pads should be slightly closer together than the bottoms of the pad following the contours of the nose as it gets wider from top to bottom.

Splay angle – The angle of the pads when viewed from the top of the frame. The front edges of the pads should be closer together than the back edges.

Vertical angle – The angle of the pads when viewed from the side of the frame. Since most frames will have some amount of pantoscopic tilt, the bottoms of the pads should be slightly closer to the frame front than the tops.

There are two other adjustments that aren't used nearly as often. The first of these is the cal height of the nose pads relative to the vertical center of the frame. This is a much more difficult adjustment and should only be used to raise or lower multifocal segments and or optical center heights. The second of these is the distance between the nose pads and the frame front. Occasionally this distance should be decreased to optimize the keyhole effect and decrease peripheral distortions.

Fitting around the ears

When fitting temples, it is necessary to touch the patient's face and ears. Always let the patient know that you are about to touch them. If they are surprised, it can make them uncomfortable. Say something like "I need to check the fit of the frame around your ears."

The temple bend should occur just behind the junction of the top of the ear and the skull. The temple should then follow the contour of the bone behind the ear (the mastoid), touching, but not putting pressure there. There should also be no pressure on the soft tissue on the back of the ear. With a proper temple bend, the end of the temple should fall about one half to two thirds down the length of the ear.

When checking the fit of the temples, you should manually feel the fit behind the patient's ears. It is also helpful to have the patient turn their head and bend the top of the ear forward to see the fit. Gently pull forward on the front of the frame while it is on the patient's face to check for slippage.


PROPER TEMPLE FIT


TEMPLE TOO SHORT


TEMPLE TOO LONG


TEMPLE BEND SHORT


TEMPLE ANGLED OUT


TEMPLE ANGLED IN

Commonly Required Frame Alignments

Left lens is higher -	Bend left temple up, or right temple down.
Right lens is higher -	Bend right temple up, or left temple down.
Left lens is lower -	Bend left temple down, or right temple up.
Right lens is lower -	Bend right temple down, or left temple up.
Left lens is farther in -	Bend left endpiece in or right endpiece out.
Left lens is farther out -	Bend left endpiece out or right endpiece in.
Right lens is farther in -	Bend right endpiece in or left endpiece out.
Right lens is farther out -	Bend right endpiece out or left endpiece in.

Use whichever adjustment will bring the fit the closest to standard alignment.
Increase pantoscopic angle - Bend both temples, or endpieces down.
Decrease pantoscopic angle - Bend both temples, or endpieces up.

Adjusting the endpieces is preferable, but can't always be done, particularly if the endpieces are thick.

A simple method to remember these rules is: "in with in, out with out, up with up, down with down." If a lens is in, bend the temple in. If a lens is out, bend the temple out. If a lens is up, bend the temple up. If a lens is down, bend the temple down.

Common Complaints and Solutions

"My frames slip down my nose."
Temples may be too wide – adjust temple angle
Temples may be too short of long or the bend behind the ears may be too loose or too tight – check for proper adjustment
A fit that is too tight will make the temples ride up and then slip down
Temples may not follow the contour of the mastoid
Nose pad fit may need adjustment
Hard or slick nose pads may cause slippage. Change to silicone pads.

"My nose hurts."
Pads may be too close together
Pad angles may need adjustment
Unequal temple spread angles may put pressure on one side of nose
Hard pads can be replaced with soft silicone pads
Larger pads can distribute weight better

"My ears hurt."
Temples bend may be bent too soon
Temple bend angle is too steep putting pressure on soft tissue on back of ear
Unequal temple spread angles puts pressure on one ear
Temple touches only one point concentrating pressure – contour temple curve
Temple tips may be angled too much putting pressure on mastoid

"My glasses sit too high."
Widen the distance between the nose pads
Bend the nose pad arms up

"My glasses sit too low."
Narrow the distance between the nose pads
Bend the nose pad arms down

"My eyelashes touch the lenses."

Increase pantoscopic tilt
Bring nose pads closer together
Increase distance between nose pads and frame front

"My frames rest on my cheeks."
Decrease pantoscopic tilt
Bring nose pads closer together
Increase distance between nose pads and frame front

"My frames leave creases on the sides of my head."
Widen temple spread angle
Slightly bow temples

Chapter 6: TOOLS

Lensometer

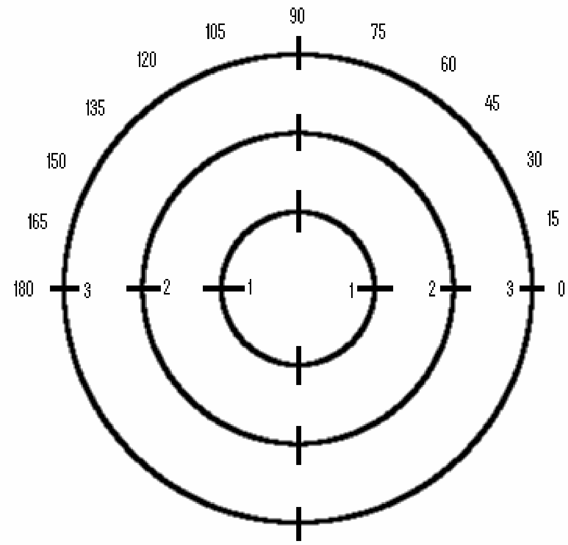
Known by many names, the lensometer, lensmeter, or vertometer is a microscope used to measure the back focal length of a lens. A lensometer allows the opticians to align a prescription lens for edge grinding, allows verification or neutralization of a prescription, as well as various other tasks related to ophthalmic optics. A lensometer is the back bone of all optical shops and labs, although there are automated lensometers on the market that read lenses to a more sophisticated scale than any manual lensometer many opticians still prefer to use manual lensometers.

Part Identification

1. Eyepiece	7. Magnifier
2. Reticle Adjustment Knob	8. Axis Adjustment Knob
3. Prism Compensator	9. Filter Control
4. Lens Marker	10. Inclination Control
5. Gimbal (Lens Holder)	11. Power Drum
6. Eyeglass Table	12. Eyeglass Table Control

Part Descriptions

1. Eyepiece – The eyepiece is the most overlooked and arguably the most important part of a lensometer, many state practicals require that the optician show that they understand that the eyepiece must be adjusted to zero out the lensometer for their Rx. This is done by turning the eyepiece counterclockwise to the most plus setting and then slowly turning the eyepiece clockwise towards the minus until the reticle comes into focus. It is important to go slowly and repeat this process at least twice to make sure that no accommodation is being stimulated leading to off power readings through the lensometer. The eyepiece allows the operator to adjust the reticle so that no matter what the refractive condition of the operator, the mires will always come into focus on the correct power.



2. Reticle Adjustment Knob – The reticle is the series of scales on the inside of the lensometer. This scale is often composed of a series of concentric rings to denote prism and has an axis scale from 0 to 180 to allow the operator to align the prism with a line often running through 180 degrees. The reticle adjustment knob is used to turn the reticle so that the scale lines up with the prism. The measurement is read by where the mires fall on the concentric rings and at what angle they fall. The prism measurement is easily read here in compound form. The prism can be deconstructed with the use of equations into their resultant form.

3. Prism Compensator – The prism compensator is a relatively new development. Most new model lensometers have attached a Risley prism or rotary prism that allows the operator to dial in 0 to 25 diopters of prism anywhere from 0 to 360 degrees. Some older model lensometers do not contain a prism compensator, but do have a ledge that allows the use of auxiliary prisms usually in increments of 3, 6, and 9 prism diopters to help neutralize high amounts of prism.

4. Lens Marker – The lens marker is a simple device consisting of three spring loaded pins that dip into a water soluble ink to mark the lens horizontally with the center pin marking the direct point being read through the lensometer. Of course the most common uses are to mark the optical center, and the 180 degree meridian for edge grinding.

5. Gimbal (Lens Holder) – The lens holder is the arm that swivels into place to hold the lens or frame stable while taking a reading. The circular piece on the end that swivels and has legs that touch the lens is referred to as a gimbal.

6. Eyeglass Table – The eyeglass table is used to keep a frame mounted and lens aligned properly for measuring the correct axis of the lens. The table often bisects a scale mounted on the lensometer body used to measure height of the optical center.

7. Magnifier – Some lensometers have this optional component which allows the operator an easier view of the axis wheel by magnifying the scale.

8. Axis Adjustment Wheel – The axis adjustment wheel allows the operator to align the primary and secondary power meridians in the lensometer. This is done by spinning the mires inside of the lensometer body.

9. Filter Control – The filter control is a small knob used to apply a green filter to the lensometer lamp for a more comfortable view through clear material while allowing this same filter to be removed for a brighter view of filtered lenses.

10. Inclination Control – The inclination control is used to loosen the lensometer body from the base, this allows the operator to adjust the viewing angle of the lensometer for easier viewing.

11. Power Drum – The power drum is the wheel attached to a long screw on the inside the lensometer body that moves the optics so various powers can be neutralized. This wheel is usually incremented in steps of 0.12 diopters, with higher powers being incremented in steps of 0.25 diopters. Some lensometers are built so the power drum can be controlled from the left or the right of the lensometers body to accommodate left or right handed individuals.

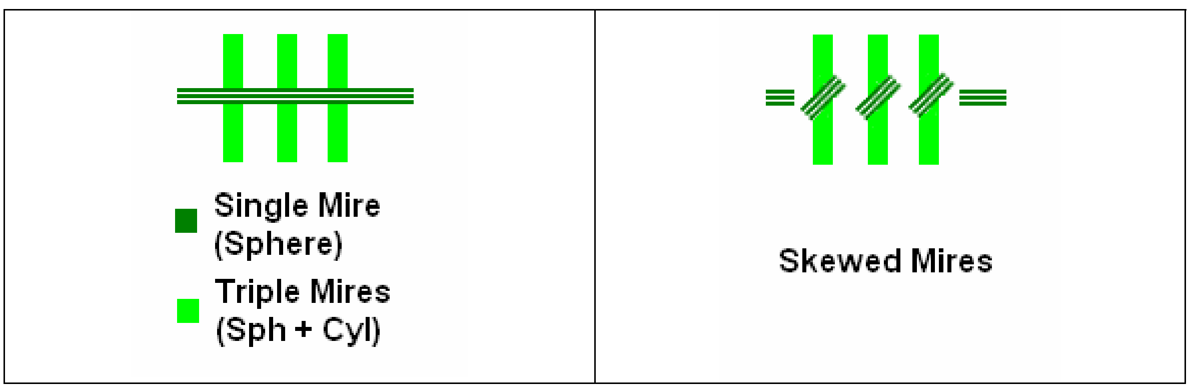
12. Eyeglass Table Control – The eyeglass table control is used to move the eyeglass table to align the frame mounted optics.

A firm understanding of the various parts of a lensometer is crucial to understanding the full potential of this instrument. Once an operator has been familiarized with all the parts of a lensometer, it is important to learn the proper steps in utilizing the lensometer to neutralize lenses.

Operation

Step 1 – The first step is to calibrate and reset the lensometer to make sure that the lensometer reads properly. This is done by setting the power drum to zero, the prism compensator to zero prism and aligned along the 180 degree line, the reticle to the 180 degree line, and then calibrating the eyepiece. The eyepiece is again calibrated by turning the eyepiece counterclockwise all the way and then slowly turning it clockwise while viewing the reticle through the eyepiece. The eyepiece should be turned clockwise until the reticle first comes into sharp focus. It is recommended to repeat this process at least twice to eliminate any accommodative effects. Tips: Make sure the lensometer is turned off when calibrating to make sure the reticle and mires do not affect accommodation; Keep your other eye open and focused on a distant spot.

Step 2 – Turn the lensometer on. If the lens is clear, the green filter should be utilized and if the lens is a sun lens, the filter should be removed. Swivel the lens holder out of the way so to allow a lens to be mounted. If the lens being measured or marked is a loose lens (unmounted) then the eyeglass table should be lowered to its lowest position to avoid interference with the lens. The lens should be placed on the lens stop (the opening on the lensometer body where the lens rests). While viewing through the lensometer, position the lens so it is centered in the reticle or intersects the proper concentric prism rings, if being marked with prism. The lens holder and gimbal should then be swiveled in place to stabilize the lens. Any adjustments to the lens position should be done only after loosening the lens holder to eliminate friction between the gimbal, the lens, and the lens stop preventing scratches while neutralizing or marking. Once properly aligned, mark the major reference point or point being viewed by depressing the pins of the lens marker on the lens so all three pins come into contact with the lens. This will mark the lens along the 180 line with the center mark as the major reference point. If the lens is mounted the same steps should be followed except instead of moving the eyeglass table to its lowest position, the lens table should be adjusted using the eyeglass table control until the reference point is centered or properly aligned within the reticle.



Step 3 – Rough adjustments are often necessary. The power drum should be rotated from the most plus towards minus until the single set of mires come into focus. The mires may come into focus with sections skewed. At this point, the axis wheel would be rotated until the mires are no longer skewed. Once this is completed the power drum can be fine adjusted to get the mires into focus. This first reading is the primary power reading

which should be documented along with the axis. From here the power drum should be rotated again towards the minus until the second set of three mires comes into focus. This second reading is the secondary power reading and lies perpendicular (90 degrees) from the first set of mires. This power should be also documented. These powers are in a form commonly referred to as drum readings. They can be graphically displayed on an optical cross. From here the first power meridian is noted as the **sphere**, the difference between our first and second power meridian is the **cylinder,** and the axis our first power is noted as the **axis**.

This is a simplified 3 step process to help novice opticians learn to utilize the lensometer. Another tip to add would be the correct neutralization of add powers. This is a common task on many opticianry licensure practicals. Although the powers read through a lensometer are often back vertex powers the addition is given by the difference between the front vertex powers of both the distance and reading sections of the lens. This is because the thickness of the lens has an effect on the two powers that can cause enough error to get a false reading. To measure the front vertex power, a lens should be mounted in a lensometer so the front of the lens is placed against the lens stop with the gimbal placed on the back of the lens. Even if the reading recorded from the back vertex differences is correct, many practicals would fail this task as the procedure is what is being tested. This little tip can help one to avoid retaking any practicals.

Hand Tools and Instruments

Hand tools can be grouped into several categories, the most common being: drivers (screwdrivers and hex drivers), pliers, files, drills and calipers. When it comes to hand tools, function comes first. There is no substitute for a flat head screwdriver nor is there an easy replacement for a nylon gripping plier. There are also subtle differences between like tools that may address more specific issues.

1. Drivers
    a. Screwdrivers
        i. Flat Head
        ii. Phillips Head
        iii. Pick-up
    b. Hex/Star Nut Drivers
    c. Screw Extractors

2. Pliers
    a. Bending pliers
    b. Shaping pliers
    c. Angling pliers
    d. Gripping pliers
    e. Nose pliers
    f. Axis pliers
    g. Cutting pliers

Key elements in frame adjustment are bracing, gripping, bending and cutting. For this purpose there are many different types of tools: angling pliers, pad arm adjustment pliers, snipe nose pliers and trimming pliers, to name a few. Varying the design of a plier to the required task greatly increases its efficiency.

The forces that cause bent frames are sometimes tremendous, i.e. someone stepping on a dropped pair of glasses. Because of this, great strength is often required to realign a frame. The repetition of motion and exertion takes its toll on an optician's hands. Thankfully, some hand tools are more ergonomically designed than others and some even have rubberized handles to further prevent hand fatigue.

Aside from design, perhaps the most important consideration when selecting a plier is its ability to make the adjustment without causing or further damaging the frame's finish. Many pliers use a partial if not total nylon jaw intended to protect the lacquer that coats the frame. These are especially important when handling outwardly visible parts of the frame and often help prevent the "crimping" that sometimes occurs with metal jaws.

1. Files
2. Drills
3. Calipers

Ultimately it is the skillful hand of the optician that will make the adjustment. Even with the most basic tool, an experienced optician can turn a tangled and twisted mess into a wearable, functional and even comfortable frame. That said, selecting a hand tool specific to the task can help you perform your job more efficiently, saving energy and time.

Common Handtools for Frame Adjustments

Nylon Jaw Pliers
Commonly used on endpieces, bridges, and brow bars. *Image courtesy of Hilco.*

Double Nylon Jaw Pliers
Multipurpose adjusting tool for frames with delicate finishes. For bridge, endpiece and temple adjustment. *Image courtesy of Hilco.*

Angling Pliers
Pantoscopic angle adjustments, heavy bridge and endpiece corrections. *Image courtesy of Hilco.*

Snipe Nose Pliers
Fine adjustments of curved areas of pad arms, endpieces and eyewires. *Image courtesy of Hilco.*

Cutter Pliers
For cutting screws. *Image courtesy of Hilco.*

Nose Pad Pliers
For screw-on, push-on, and clip-on type nose pad assembly adjustments. *Image courtesy of Hilco.*

Axis Pliers
For lens axis aligning. *Image courtesy of Hilco.*

Hot Air Frame Warmer
For warming plastic frames. *Image courtesy of Hilco.*

Common Handtools for Rimless Frame Adjustments

Compression Pliers
For assembling compression mount frames. *Image courtesy of Hilco.*

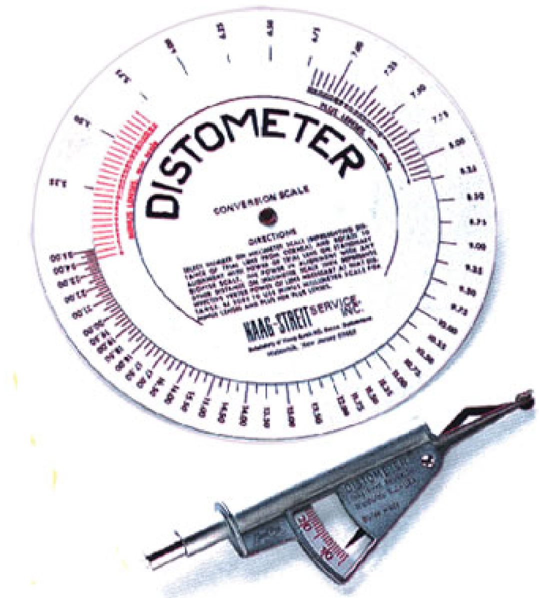
Compression Sleeve Cutters
For trimming compression sleeves. *Image courtesy of Hilco.*

3-Piece Frame Adjusting Pliers
For adjustment of drill mount frames. *Image courtesy of Hilco.*

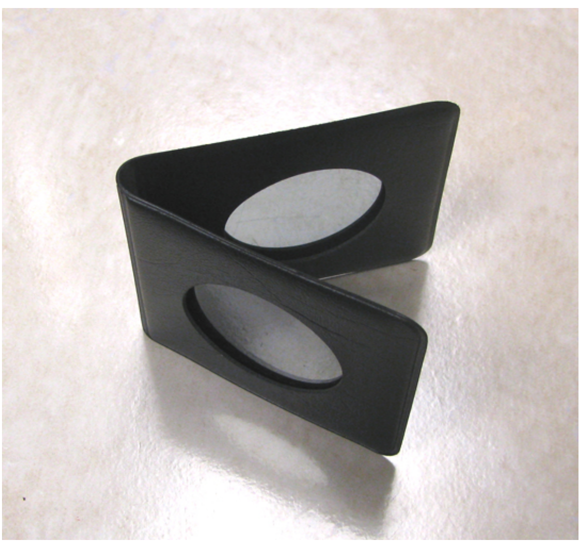
Hex Wrenches
Image courtesy of Hilco.

Other Tools and Instruments

Pupilometer
Instrument used for measuring pupillary distance (PD). *Image courtesy of Hilco.*



Distometer
Instrument used for measuring vertex distance. *Image courtesy of Hilco.*



Polariscope
Instrument used for visualizing and measuring lens stress.

Chapter 7: REGULATIONS AND STANDARDS

Regulatory Agencies

ASTM –The *American Society for Testing Materials* sets standards for sports-related products. Standard F803 sets standards for safety eyewear used in sports.

ANSI – The *American National Standards Institute* is a private agency who purpose is to set commercial and industrial standards. Standard Z80.1 sets standard Recommendations for Prescription Ophthalmic Lenses.

OSHA – The *Occupational Safety and Health Administration* is a federal government agency established for the purpose of reducing deaths, injury, and illnesses in the workplace.

FDA – The *Food and Drug Administration* is a federal government agency whose function is to enforce laws related to the production and labeling of food, drugs, and cosmetics. Contact lenses and eyeglasses are considered medical devices and fall under the jurisdiction of the FDA.

Standards Publications of Interest to Opticians

ANSI Z80.1 - 2005	*Ophthalmics - Prescription Ophthalmic Lenses - Recommendations*
ANSI Z80.3 - 2001	*Ophthalmics - Non-Prescription Sunglasses and Fashion Eyewear - Requirements*
ANSI Z80.5 - 2004	*Ophthalmics - Requirements for Ophthalmic Frames*
ANSI Z80.9 - 2004	*Ophthalmics - Devices for Low Vision*
ANSI Z80.10 - 2003	*Ophthalmic Instruments - Tonometers*
ANSI Z80.12 - 2007	*Multifocal Intraocular Lenses*
ANSI Z80.17 - 2001	*Ophthalmics - Focimeters*
ANSI Z80.18 - 2003	*Contact Lens Care Products: Vocabulary, Performance, Specifications and Test Methodology*
ANSI Z80.20 - 2004	*Ophthalmics - Contact Lenses - Standard Terminology, Tolerances, Measurements, and Physicochemical Properties*
ANSI Z80.21 - 1992	*Ophthalmics - Instruments - General-Purpose Clinical Visual*

(R2004)	*Acuity Charts (R2004)*
ANSI Z80.25 - 1996 (R2002)	*Ophthalmics - Instruments: Fundamental Requirements and Test Methods*
ANSI Z87.1 - 2003	*Occupational and Educational Personal Eye and Face Protection*

ASTM F513 - 00 (2007)	*Standard Safety Specification for Eye and Face Protective Equipment for Hockey Players*
ASTM F659 - 06	*Standard Specification for Skier Goggles and Faceshields*
ASTM F803 - 06	*Standard Specification for Eye Protectors for Selected Sports*
ASTM F910 - 04	*Standard Specification for Face Guards for Youth Baseball*
ASTM F1045 - 07	*Standard Performance Specification for Ice Hockey Helmet*
ASTM F1587 - 99 (2005)	*Standard Specification for Head and Face Protective Equipment for Ice Hockey Goaltenders*
ASTM F1776 - 01	*Standard Specification for Eye Protective Devices for Paintball Sports*

ANSI Standards are available for purchase from:
American National Standards Institute, Inc.
25 West 43rd Street, 4th Floor
New York, NY 10036
212/642-4900 (Sales Department)
212/398-0023 (Fax)
www.ansi.org

ASTM Standards are available for purchase from:
ASTM
100 Barr Harbor Drive
P.O. Box C700
West Conshohocken, PA 19428
610/832-9585
www.astm.org

ANSI Z80.1 Prescription Ophthalmic Standard

The American National Standards Z80 committee was organized in 1956 and sponsored by the Ophthalmic Manufacturers Association. The committee was reorganized in 1961 under the sponsorship of the Optical Society of America. The new committee took the three original drafts and came up with the original Z80.1 standard which was approved on April 1st 1964. The standard was designed to meet the needs of the ophthalmic laboratories and dispensers and has been revised 5 times since the original standard was approved.

1st – 1964
2nd – 1972
3rd – 1979
4th – 1987
5th – 1995
6th – 2005 (most recent)

The draft is composed of definitions to many of the most common terms used in ophthalmic optics, as well as tolerances, and procedures for the measurement of various metrics. This document is not a mandatory standard but a guideline for an accepted minimum quality in spectacle manufacture. As new technology becomes available the standard will need to be updated to keep up with the times so this standard should be thought of as a work in progress and as such if any discrepancies are noticed the committee can be notified at the following address:

Optical Laboratories Association
Z80 Secretariat
11096 Lee Highway
A101
Fairfax, VA 22030-5039

ANSI Z80.1 - 2005 Summary

	Power Range	**Tolerance**
Highest Meridian For SV and MFs	$\geq$ 0.00 D, $\leq \pm$6.50 D $> \pm$6.50 D	± 0.13 D ± 2%
Highest Meridian For Progressives	$\geq$ 0.00 D, $\leq \pm$8.00 D $> \pm$8.00 D	± 0.16 D ± 2%
Cylinder Power For SV and MFs	$\geq$ 0.00 D, $\leq$ 2.00 D $>$ 2.00 D, $\leq$ 4.50 D	± 0.13 D ± 0.15 D

	> 4.50 D	± 4%
Cylinder Power For Progressives	≥ 0.00 D, ≤ 2.00 D > 2.00 D, ≤ 3.50 D > 3.50 D	± 0.16 D ± 0.18 D ± 5%
Cylinder Axis	> 0.00 D, ≤ 0.25 D > 0.25 D, ≤ 0.50 D > 0.50 D, ≤ 0.75 D > 0.75 D, ≤ 1.50 D > 1.50 D	± 14° ± 7° ± 5° ± 3° ± 2°
Add Power	≤ +4.00 D > +4.00 D	± 0.12 D ± 0.18D
Prism		≤ 0.33 PD
PRP Location		≤ 1.0 mm
Base Curve		± 0.75 D
Vertical Prism	≥ 0.00 D, ≤ ±3.37 D > ±3.37 D	≤ 0.33 PD ≤ 1.0 mm
Horizontal Prism	≥ 0.00 D, ≤ ±2.75 D > ±2.75 D	≤ 0.67 PD ≤ ± 2.5 mm
Segment Tilt		± 2°
Vertical Location		± 1.0 mm
Vertical Difference		≤ 1.0 mm
Horizontal Location		±2.5 mm
Vertical Prism (PAL imbalance)	≥ 0.00 D, ≤ ±3.37 D > ±3.37 D	≤ 0.33 PD ≤ 1.0 mm
Horizontal Prism (PAL imbalance)	≥ 0.00 D, ≤ ±3.37 D > ±3.37 D	≤ 0.67 PD ≤ 1.0 mm
Vertical Location PAL		± 1.0 mm
Vertical Difference PAL		≤ 1.0 mm
Horizontal Location PAL		± 1.0 mm
Horizontal Axis Tilt		± 2°
Center Thickness		± 0.3 mm
Segment Size		± 0.5 mm
Warpage		≤1.0 D

Impact Resistance Testing

The FDA requires all ophthalmic glass lenses be individually tested for impact resistance according to 21CFR801.410.

> *In the impact test, a5/8-inch steel ball weighing approximately 0.56 ounce is dropped from a height of 50 inches upon the horizontal upper surface of the lens. The ball shall strike within a5/8-inch diameter circle located at the geometric center of the lens. The ball may be guided but not restricted in its fall by being dropped through a tube extending to within approximately 4 inches of the lens. To pass the test, the lens must not fracture;*

With the following exemptions:

> *Prism segment multifocal, slab-off prism, lenticular cataract, iseikonic, depressed segment one-piece multifocal, bioconcave, myodisc and minus lenticular, custom laminate and cemented assembly lenses shall be impact resistant but need not be subjected to impact testing.*

Liability and Duty to Warn

In 1987 the OLA (Optical Laboratories Association) reminded offices about their duty to warn patient about the impact resistance of various lens materials. The dispensing optician has a legal responsibility or liability for the products, services, and information they provide to the public. The term "Duty to Warn" has been used in our industry to inform the patient of the safety aspects of polycarbonate or trivex lenses compared to other lenses. This duty to warn covers the professional from negligence torts involving injury resulting from broken lenses or eyewear. If the optician has knowledge of a product better suited the to the safety requirements of a customer, it is his/her duty to warn the patient so they can make an informed decision. This duty to warn not only applies to ophthalmic lenses. Duty to warn is a common part of negligence torts. The OLA provides a duty to warn kit to help your office comply with informing your patients of the differences in impact resistance of various materials.

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