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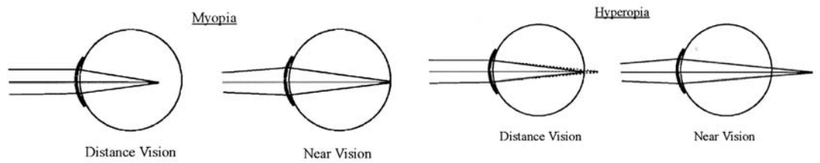
REFRACTIVE ERRORS AND DIVING

IN THE LAST ARTICLE WE LOOKED AT HOW THE NORMAL EYE WORKS UNDERWATER. UNFORTUNATELY, MOST OF US DO NOT HAVE NORMAL EYES! IN THIS ARTICLE WE WILL LOOK AT SEVERAL COMMON REFRACTIVE PROBLEMS AND HOW THEY AFFECT OUR DIVING.

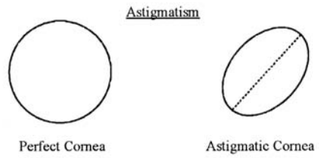
MYOPIA (near-sighted)
In the perfect relaxed eye, light from distant objects will be 'bent' just enough by the cornea and lens to be focused on the retina.
The most common refractive error is when the focusing power of the cornea and lens is too great; causing light from distant objects to be focused in front of the retina (the eye is functionally too long).
Light from near objects will be focused on the retina (more focusing power is required for light from near objects as it is diverging at the eye). People with these kinds of eyes will see clearly up close but distant vision will be blurry. Therefore, this refractive error is called myopia or near-sightedness. The power of a lens (the amount light is bent when it passes through the lens) is measured in 'diopters'. To correct myopia, glasses that cause the light to diverge will be required. Therefore, the power of a lens for myopia will always be 'negative'.
People with myopia will need glasses to see at distance but will be able to focus up close without their glasses. If the error is relatively mild (only a few diopters), the 25% magnification caused by a dive mask will allow them to dive safely without visual correction in clear water. If the visibility during the dive is poor, divers with relatively bad vision will do OK without correction (divers with perfect vision won't be able to see much either!). In general, the greater the degree of myopia, the more important it is for the diver to correct their vision while diving, and the greater the increase in enjoyment and safety that will result from correction.

HYPEROPIA (far-sighted)
The second most common visual problem is when the focusing power of the cornea and lens is too weak; causing light from both near and far objects to be focused behind the retina (the eye is functionally too short). Far-sighted individuals see objects clearly at a distance by contracting the ciliary muscles and increasing the focusing power of the lens, moving the focal point forward onto the retina. Even when the ciliary muscles are maximally contracted, light from near objects will still be focused behind the retina.
People with this kind of eye will see clearly at distance but near vision will be blurry. Therefore, this refractive error is called hyperopia or far-sightedness. Near-sighted individuals see best when the ciliary muscles are relaxed (the focusing power of the eye at rest is too strong and any contraction of the ciliary muscles will move the focal point even further in front of the retina).
To correct hyperopia, glasses that cause the light to converge will be required. Therefore, the power of a lens for hyperopia will always be 'positive'.
People with hyperopia will need glasses to read but will have normal vision at distance. Therefore, as long as the 25% magnification caused by the dive mask allows them to read their gauges, they will have no problems with their vision while diving.



ASTIGMATISM (squished corneas)
Another common visual problem is astigmatism. The cornea should be perfectly spherical but all too often it is more elliptical in shape. The easiest way to understand this is to think of a contact lens. When it is not stressed, it will be a perfectly spherical shape (like a piece of the surface of a ball). Light passing through any part of the contact lens will be bent to focus on one spot. However, if you hold the contact lens by the edges between two fingers and gently squeeze, the lens will bend and become elliptical. When this happens, the light is bent more when it passes through the part of the lens that has a higher curvature. Therefore, light passing through the lens will be focused in a line, not a spot. When the front of the cornea is shaped this way, the person is said to have astigmatism.
Designing a lens to correct for astigmatism is a bit complicated. Conceptually, it has to be sort of 'trough shaped' to counteract the error in the shape of the cornea and the 'hollow' of the trough has to be aligned in the same direction as the long axis of the cornea. Therefore, a lens to correct for astigmatism needs to have a 'power' and a 'direction'.
Small amounts of astigmatism are common and cause few visual problems.

	SPHERE (diopters)	CYLINDER (diopters)	AXIS (degrees)	SPHERICAL EQUIVALENT (diopters)
Right eye	-5.25	+3.50	85	-3.50
Left eye	-5.00	+2.50	90	-3.75
OR				
Right	-1.75	-3.50	175	-3.50



Larger amounts of astigmatism cause distortion in your vision. Straight lines will appear to bend. Larger amounts of astigmatism need to be corrected to have good vision, both in and out of the water.

CORRECTIVE PRESCRIPTIONS
Now that you understand the three most common visual problems, you should be able to understand what the numbers mean when you get a prescription for a pair of glasses. The table shows the prescription for my glasses (before I had laser eye surgery). The 'Sphere' is the correction for myopia and hyperopia. The number is negative and therefore you know that I was myopic. More than 6 diopters of correction represents a 'high' myope or someone with severe visual problems. I had 'moderate' myopia but 25% of people in the western world have more 6 diopters of myopia.

The 'Cylinder' represents the correction for astigmatism and the 'Axis' represents the direction of the correction. This can be written two ways. The direction can be along the ridge of the curve, or it can be across the ridge (90 degrees difference). The 'power' of the correction is the same but it is either convergent (positive) or divergent (negative). When the cylinder is switched from positive to negative (or the reverse) the cylinder must also be added to the sphere. The two prescriptions in the table are for the same pair of glasses but the correction for astigmatism has been written one way in the first and the other way in the second. Obviously, I also had moderate astigmatism.
The 'Spherical Equivalent' represents the combined sphere and cylinder and is calculated by adding 1/2 the cylinder to the sphere. Notice that the Spherical Equivalent is the same no matter which way you right the correction for astigmatism. Spherical Equivalent is important. If you are only going to correct for the sphere and not for the astigmatism, the spherical equivalent is the correction you should use.

PRESBYOPIA (reading glasses)
During normal distant vision the power of the glasses (if required), cornea and relaxed lens combined cause the light to be focused on the retina. When looking at a near object, light from the object will be diverging at the eye and the refractive power of this system must be greater. This is accomplished by contracting the ciliary muscle to take the strain off the lens. The natural elasticity of the lens causes it be

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become 'rounder' thereby increasing its' refractive power. The closer the object is to the eye, the greater the refractive power required to focus the image on the retina.

As we get older, the lens capsule becomes less elastic and the closest point at which we can focus moves away from the eye about one cm per year (some children can actually see the tip of their nose clearly). Most people will have trouble reading sometime after age 40. The nearest point that they can focus becomes so far from their eyes that either their arms become too short to hold the object, or by the time the object is far enough away from the eye to be in focus, the print is too small to read. The only solution is to use a plus lens to increase the refractive power of the system (reading glasses). Sometimes the correction is only ground into the bottom area of the lens so that the person can see clearly at distance by looking through the top part of the lens (really just glass) and can read by looking through the bottom part of the lens.

If the person already needed glasses to see clearly at distance, they will need two pairs of glasses, one for distance and one for up close (reading). These two different lenses are often combined into one pair of glasses with the correction for distance in the top part of the lens and the correction for close in the bottom (bifocals).

In even older people whose lens capsule can become so stiff that the lens has very little ability to change shape and three pairs of glasses may be required. One for far distance, one for middle distance and one for close. If all three corrections are ground into one pair of glasses, they are called 'trifocals'.

A common alternative to bifocals and trifocals is to graduate the correction in the glasses from distance at the top to close at the bottom. The person can then see clearly at any distance without changing the shape of the lens by finding the area of the glasses with the correct refractive power and looking through that area.

The problem with presbyopia is that the diver will not be able to read their gauges! The forearm really can not be moved very far away from the eyes. One solution is to attach the gauges to a retractor so that they are normally held near the chest. When you want to read them you simply grab them and hold them at arms length from your eyes. When you let go they are pulled back in tight to the front of your chest. I have used this trick for many years with the consoles of my rebreathers (as I write this I am 53 years old). I have also been pretty well limited to Cochran dive computers for several years as they have large easy to read numbers and I can still read them on my forearm (barely).

CONCLUSION

There are even more complex types of visual problems (I also need prismatic correction in my lenses) but very few divers have these problems and they are beyond the scope of this article.

We have reviewed several common refractive errors that often result in people needing to wear glasses. We have seen how some people can dive safely without their glasses but others will require some form of visual correction while diving to optimize their vision and safety while diving. In the next article I will look at the ways in which divers can correct their vision while diving, including wearing contact lenses.

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