part two

INTRODUCTION

In the first part of this article we described the principal refractive errors, that is, myopia, hyperopia, astigmatism and presbyopia. We then discussed the types of masks that are currently available as well as their advantages and drawbacks. We shall now outline the main types of corrective lenses used in diving masks.

CORRECTIVE LENSES FOR DIVING MASKS

1. CORRECTIVE LENSES FOR GLASSES AND CORRECTIVE LENSES FOR OPTICAL MASKS

The majority of lenses for use with masks are made from glass. In rare cases mask lenses are made from polycarbonate (for example the "dome port" mask). Lenses are made from material (either glass or plastic) that has a higher refractive index than that of air. They have curved surfaces; the convex surfaces are positive (they converge rays of light) and concave surfaces are negative (they diverge rays of light). The change in direction of the rays of light in this case is called refraction. A useful method for differentiating plus lenses from minus lenses without special equipment is to check the thickness in different points. Plus lenses are thicker at the centre than at the edge. The opposite is true for negative lenses. Standard lenses for glasses cannot be used instead of the masks windows. One important reason is that common lenses for spectacles have convex front surfaces. This is not suitable for masks, because water would leak into the mask where the skirt lies over the side arms. The second reason is due to refraction. Normal lenses for glasses usually have a convex front surface and a concave back surface (meniscus lenses). The power of the front surface of the lens is added algebraically to that of the back surface to get the total power of the lens.

Lenses of this type have some advantages in air because they have less optical aberrations. If, however, the same meniscus lens is used instead of the normal standard flat glass in a diving mask, the total power of the lens will no longer be the same as that in air. In fact the front surface in contact with the water would have a lower refractive power, while the refractive power of the back surface in contact with the air would remain unchanged. The diver using the mask would see well on the boat but would see very badly underwater. In order to avoid this problem and to ensure that the lenses have the same power in air as in water, diving mask lenses have flat front surfaces (that is, without refractive power) and all of the refractive power of the lens is on the back curved surface (concave, convex or toric). There is also a refractive problem with the dome port mask as will be described in more detail later. Dome ports have zero power in air. However, in water the negative power is greater the smaller the radius of the dome port.

2. THE DIFFERENT TYPES OF CORRECTIVE LENSES FOR MOUNTING IN MASKS

a. Ready-made Lenses for Inserting Instead of Standard Mask Glass

Companies that produce masks that are designed for corrective lenses generally refer to a manufacturer of ophthalmic lenses and order a stock of spherical monofocal lenses for the correction of the most common visual errors. These lenses are made of pre-moulded tempered glass with a flat front face **(Fig. 16)**. All of the power (plus or minus) is due to the curvature of the back face. The flat glass normally supplied with masks for people without visual errors is removed and the lenses are then mounted instead of the standard glass.

fig.16 Spherical pre-ground lens

Advantages:

-Low cost

-They can be fitted by the retailer or user without the requirement to have a vision prescription.

-They come in a single piece without glue-on parts

Disadvantages

-They can only be used with certain specially designed masks.

-They only correct spherical errors (myopiaand hyperopia)

-The lens power is fixed, usually in increments of .5 dioptres. A person with myopia of 2.75 dioptres would be unable to get an exact lens to suit him/herself.

-The distance between the optical centre sof the two lenses is fixed. It corresponds to the average distance between the two pupils of normal subjects. In some cases - in actual fact rare - where the diver has an interpupillary distance that is considerably above or below average, with increased lens power the prism effect caused by decentration of the lens can cause visual fatigue or even double vision.

-They do not correct presbyopia (they are neither bifocal nor progressive) and they cannot correct astigmatism.

-The lenses have to be moulded for a particular type of mask only and cannot be reused on another mask.

b. Prescription Lenses Bonded to the Mask Glass

These lenses can correct myopia, hyperopia, astigmatism and presbyopia. They are made of tempered glass. The front face is flat and all of the power comes from the curvature of the back face. For this reason they are made by very few companies since they are not used for normal glasses. They are bonded to the inside of the mask glass with special transparent epoxy glue that has the same refractive index as glass. The layer of glue between the two surfaces of glass ends up being only a few tenths of a millimetre thick.

Advantages:

-They can be bonded onto masks with a single front window (for example full-face masks) and theoretically onto the glass of any diving mask (with the exception of masks that have particular technical peculiarities).

-They correct both spherical errors (myopia and hyperopia) and spherocylindrical errors (astigmatism associated with myopia or hyperopia) as well as simple astigmatism.

-The lens power corresponds exactly to the power for correcting the error according to the prescription.

-The distance between the optical centres of the two lenses can be adjusted to suit the individual. The prism effect caused by decentration of the lenses and the potential vision disturbance that could result can be avoided in this way.

fig.17 Bifocal glue-on lens (courtesy Proteye)

-They can be mounted like bifocals to correct presbyopia **(Fig. 17)**. In actual fact, in

this instance two lenses are applied for each eye; one at the top and one at the bottom on the inside face of the mask glass. The upper lens is for distance vision and the lower lens is for near vision.
- If the scuba diver is presbyopic and 20/20 for far vision, a small crescent-shaped positive lens can be glued to the back face of any mask to enable near vision.

Disadvantages

-High cost
-They must be obtained from an optician based on a prescription.
-In some cases the glue (at least that of old types) can with time become yellow or cause iridescence.
-Once moulded for a particular type of mask, the lenses cannot be reused on a different type of mask, unless special reversible glues are used.
-Currently progressive focal lenses with a flat front face are not currently produced therefore this type of lens cannot be stuck on.

c. Mask Lens Holding Inserts

Some companies make inserts that rest on the inside part of the mask glass **(Fig. 18)**.

fig.18 Mask with a removable lens holding mask insert. At the side is the detached insert (courtesy Sportspectacles, UK)

Other inserts have a support that can be stuck onto the glass of the mask **(Fig. 19)**.

fig.19 Lens holding inserts fixed to the mask glass (courtesy Scubaspec)

SCUBASPEC IN SCUBA MASK

Others still are fixed to the side part of the mask **(Fig. 20 A, B)**. In theory, all standard lenses for glasses can be mounted on these mask-lens holding inserts. In fact, the lens holding insert is completely surrounded by air in the mask so there are no other refractive problems caused by contact with water.

Advantages:

-They can correct spherical errors (myopia and hyperopia), spherocylindrical errors (astigmatism associated with myopia or hyperopia) as well as simple astigmatism.
-They are relatively inexpensive. In addition, standard lenses made for glasses can be used.
-They can also be used in masks with a single front window (for example full-face masks).
-The lens power corresponds exactly to the power for correcting the error according to the prescription.
-The distance between the optical centres of the two lenses can be adjusted to suit the individual. The prism effect caused by decentration of the lenses and the potential vision disturbance that could result can be avoided in this way.
-Common bifocals can be mounted on them to correct presbyopia. Also, progressive focal lenses can theoretically be mounted on these supports.
-The mask-lens holding insert can be detached and reused on another mask whenever a different mask is used.

Disadvantages

-The clutter caused by the inserts inside the mask can be annoying.
-Some types of inserts can shift inside the mask
-There are additional reflections on the front and back faces of the insert that degrade the quality of the images.
- For each eye there are three surfaces that are subject to fogging (i.e., the internal surface of the mask glass and the front and back surfaces of the lens).
- The lenses are difficult to clean.
-There is a reduction in the field of vision as a result of the insert frame.
-They are available in very few shops.
-They must be obtained from an optician based on a prescription

d. Press-on plastic lenses for presbyopia attached to the mask glass

Some companies make thin lenses of flexible plastic that can be pressed on to the inside of the mask glass **(Fig. 21)**. These lenses are applied to the lower part of the mask glass (on the inside surface) and can correct presbyopia, as with bifocal glasses. They are held in place by a weak electrostatic charge. They are generally made in the shape of a crescent. They can also be applied to pre-moulded lenses for the correction of spherical refractive errors (i.e., so-called “ready-made lenses”).

Advantages:

-Low cost
-They can be applied to any mask glass including pre-moulded spherical corrective lenses by the diver him/herself by following the manufacturer’s instructions.
-The lens can be positioned on the point of the mask glass that the diver finds most suitable for close vision.
-The distance between the optical centres of the two lenses can be adjusted for the individual. The measurement must, however, be made by an ophthalmologist or by an optician.

Disadvantages

-The optical quality of the images is not as good as that obtained with of glass.
-The lenses can easily move when water enters the mask.
-They are only useful for presbyopia

e. Glass lenses for presbyopia in separate windows of the mask

A mask with six windows (Mares ESA) has two separate windows for lenses for close vision, positioned at the bottom of the front window. The front windows can be substituted for lenses for distance vision.

Advantages:

- Low cost
- Easily repairable

Disadvantages

- The near vision lenses cannot be used for close objects in front of the diver
- The mask is relatively high volume
- The interpupillary distance is fixed

f. Polycarbonate Spherical Dome Port Lenses

We shall mention this solution even though they have not yet been introduced on the European market. It involves a solution that is very promising in theory, even though there are some disadvantages. Dome port masks give a much wider field of vision than standard diving masks, without distortions or peripheral aberrations. This is due to the fact that the rays of light coming from all

fig.20 A Lens holding inserts fixed to the side of the mask (courtesy Oceanreef)

fig.20 B Details of the preceding figure (courtesy Oceanreef)

fig.21 Press-on crescent shaped plastic lenses for presbyopia (Optix 20/20)

points in the space surrounding the dome port can reach the glass itself at a normal angle, and they are not therefore subject to the phenomenon of total reflection **(Fig. 22).** Dome ports have been used for many years in underwater photography to increase the available visual angle of photographic lenses. They are indispensable for wide-angle lenses. Underwater photographers who use such dome ports with curved front surfaces however know that it is often necessary to mount an accessory plus lens in front of the photographic lens. Underwater the air/glass/water interface of the dome port becomes transformed into a negative power lens, the same one that corrects myopia **(Fig. 23).** On the other hand dome ports don't have optical refractive power in air. For this reason many people with myopia should be able to use this type of mask with two dome ports without additional lenses. With this mask, however, all the others should use plus lenses inside the mask when diving (in the same way that an additional photographic lens must be used in front of the camera) in the form of plus contact lenses that make the diver temporarily near-sighted.

fig.22 The visual field of the flat glass mask in air and in water and of the dome port mask, like that of the naked eye in air (courtesy Hydrooptix).

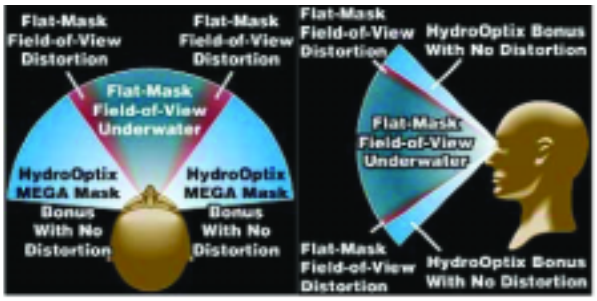

fig.23 Negative lens effect of the dome port (courtesy of Hydrooptix). The curvature of the dome means that the water acts like a concave lens (negative). In order to neutralise this it is necessary to use plus power contact lenses (arrow).

3. COMPENSATION OF THE DISTANCE OF THE LENS FROM THE EYE

Often an ophthalmologist's prescription for normal glasses may be insufficient for diving mask lenses. In fact, another factor needs to be taken into account. Generally the mask lens is further from the eye in comparison to that of glasses. In many cases this difference in distance can affect the correction of the visual error. The power of the lens to be used in the mask should be increased with respect to that of the glasses if the lens is negative (for myopia) and should be reduced if the lens is positive (for hyperopia). The optician can calculate the necessary variation in lens power. For low power lenses no variation is necessary.

CONCLUSION

Not all masks are suitable for the application of corrective lenses.

For masks that are designed for corrective lenses, standard power spherical lenses are usually readily available (for the correction of myopia or hyperopia) usually in increments of .5 Dioptres. On the other hand, lenses need to be made to measure for the correction of spherocylindrical errors, that is, for those that are associated with astigmatism, and for bifocal lenses for presbyopic people. Often it happens that for reasons of cost or difficulty in finding an optician who deals with masks, the diver goes without proper optical correction. We believe that visual errors should be corrected underwater as well as possible, particularly for safety reasons. Currently, there are services available on the Internet for preparation and timely delivery of spherical and spherocylindrical lenses that can be applied to many underwater masks. If the cost of spherocylindrical lenses is excessive or the lenses are difficult to find, in some cases it is possible to substitute spherocylindrical correction (for astigmatism) with spherical correction alone (more easily available and less costly). This substitution must however be approved by an ophthalmologist in order to avoid potential visual fatigue disturbance. In conclusion, the most important thing that we would like to emphasise yet again in this article is that it is possible to correct practically all the common refractive errors of divers in a satisfactory way. There are also correction methods that are inexpensive. We must stress that good vision underwater is a very important safety factor in diving.

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USEFUL LINKS

Prescription Corrective Lenses for Masks:
www.proteye.nl/Eng/hi/Enghi.html
www.rxsportoptics.com
www.olent.it

Mask Lens Holding Inserts:
www.scubaspec.com
www.sportspectacles.co.uk/Diving.asp
www.oceanreefgroup.com

Press-on Plastic Lenses:
www.neoptx.com

Dome Port Masks:
www.hydrooptix.com

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www.sportspectacle.co.uk