Source: Contamac Ltd.
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Evolution and Benefits of Materials Containing Blue Light Absorbers

An increasing number of surgical procedures are employing intraocular lenses that contain a blue light absorber. Such lenses are characterised by their yellow appearance and are designed to reduce the transmission of light, which potentially can be hazardous. However the use of such color additives is not a new concept and this article will highlight the evolution of this type of lens, and the potential benefits that these lenses may offer.

Cataract surgery is amongst the most commonly performed surgical procedures with over 300,000 operations carried out last year in the UK alone. The removal of the crystalline lens followed by the implantation of an intraocular lens is now a relatively short procedure that has evolved considerably in recent years. PMMA was long regarded as the material of choice for the fabrication of intraocular lenses, however the development of phacoemulsification was a catalyst for the development of foldable materials. Such materials enable the finished IOL to be inserted or injected through a small incision and examples include hydrophilic, silicone and foldable acrylic, also known as hydrophobic.

PMMA was initially implanted as a clear material without any light absorbing components. For many years however, it has been common for this material to contain an Ultraviolet (UV) light absorber and this trend continued in the materials that evolved for small incision surgery procedures. The inclusion of a yellow colour additive to absorb blue light is a much more recent proposition.

As well as the visible spectrum, the light that emits from the sun also contains UV and Infrared (IR) radiation. A proportion of this light is absorbed by the earth's atmosphere but light of various wavelengths also passes through this layer and can penetrate the eye. This includes UV-B radiation (230-300nm,) UV-A radiation (300-400nm) visible light (400-700nm) and near IR radiation (700-1400.)

The different parts of the eye absorb light of specific wavelengths, although this also depends greatly on age and previous exposure to sunlight. The cornea will absorb light of wavelengths below 300nm (UV-B,) however light of greater wavelength will pass through freely. At infancy the crystalline lens will transmit all light of wavelength greater than 300nm, however increased exposure to light results in the production of yellow pigments. The crystalline lens turns yellow and absorbs light below 400nm with the transmission of blue light between 400-500nm also being greatly affected. Many IOLs contain a UV absorber that will absorb some light between 300-400nm like the crystalline lens, however these compounds do not absorb blue light. The light transmission properties of a typical clear IOL are shown in Figure 1, together with the transmission profile of the crystalline lens.

The first suggestions to use a yellow color additive in an IOL can be found in various patents filed in the 1980s. One such example is US patent 5,374,663 assigned to Hoya, which describes the use of yellow colour additives for use in intraocular lenses to correct for Cyanopsia. This condition relates to the increase in blue light reaching the retina when a cataract is replaced with a standard clear intraocular lens. This condition can result in objects looking more blue than when seen through normal eyes and also makes distinguishing between blues and violets difficult. This patent suggested the incorporation of a yellow colour additive in the IOL, so that its light transmission properties would mimic that of the crystalline lens of a person around the age when a cataract operation would likely be required. Figure 2 shows the change in light transmittance properties achieved by the addition of a yellow colour additive. The patent discusses a wide variety of yellow/orange compounds suitable for this application. Unfortunately, the overall success of yellow IOLs produced from PMMA was relatively limited at this time. A possible reason may be that color perception was not a serious clinical issue that required a resolution.

In recent years there has been increased interest for inclusion of a yellow color additive in an Intraocular lens and Figure 3 shows examples of commercially available products. A wide range of potential benefits have been described, although clinical evidence for some of these has not been conclusive. The potential benefit that stimulates the most discussion, is that blue light absorbing IOLs reduce the risk of age related macular degeneration. A detailed overview of the various theories on this subject is not appropriate here, however some background information is important to consider. The inclusion of the blue light absorber may have negative effects and these can include reduction of scotopic vision, interference with circadian rhythm and problems with perception of colours and contrast sensitivity.

A number of large population studies have been conducted, but only a small number have suggested a link between light exposure and macular degeneration. Although it has been proven that acute exposure to blue light causes retinal damage, a link between longer-term chronic exposure and age related macular degeneration, has not been determined.

...acute exposure to blue light causes retinal damage...

The most recent topic of discussion on this subject is the actual wavelengths of light that should be absorbed. It has been suggested that a lens should absorb only violet light and the majority of blue light should be transmitted by the IOL. Blue light blocking lenses will absorb blue and violet light and some researchers argue this is not ideal. They consider violet light to be more harmful than blue light and transmission of blue light improves scotopic vision and is important for circadian photoreception. One study has found that Lipofuscin may be responsible for the majority of damage to the retinal pigment epithelium. This substance is sensitive to blue light that results in the formation of reactive oxygen species or radicals that damage the epithelium cells. Light of wavelength of 440nm activates this process, so blocking only violet light may not prevent this process.

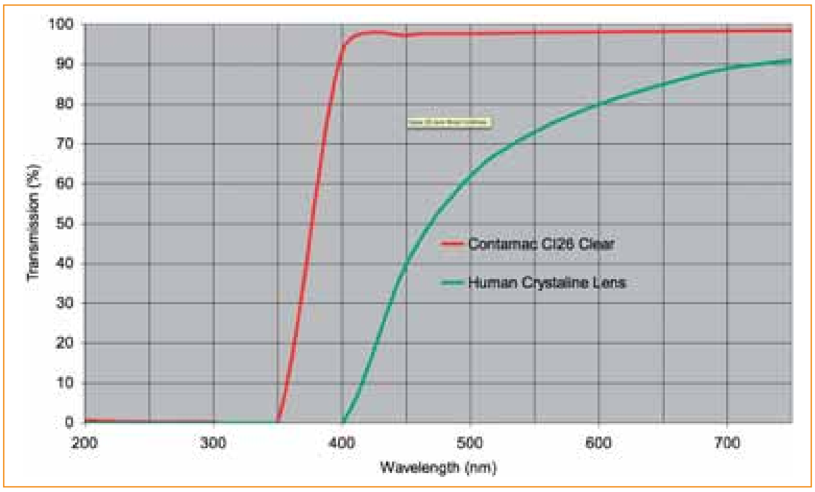

Figure 1 - Transmission of Clear IOL and Crystalline Lens

Most researchers would agree that blocking certain wavelengths of visible light is beneficial, however there is continued debate on the precise wavelengths that would provide the optimum balance between protection and visual performance. Until definitive clinical results are obtained and published, it seems likely that the use of both blue and violet blocking IOLs will increase.

If the yellow IOLs that block blue light have no perceived drawback, then they surely provide the greatest level of protection.

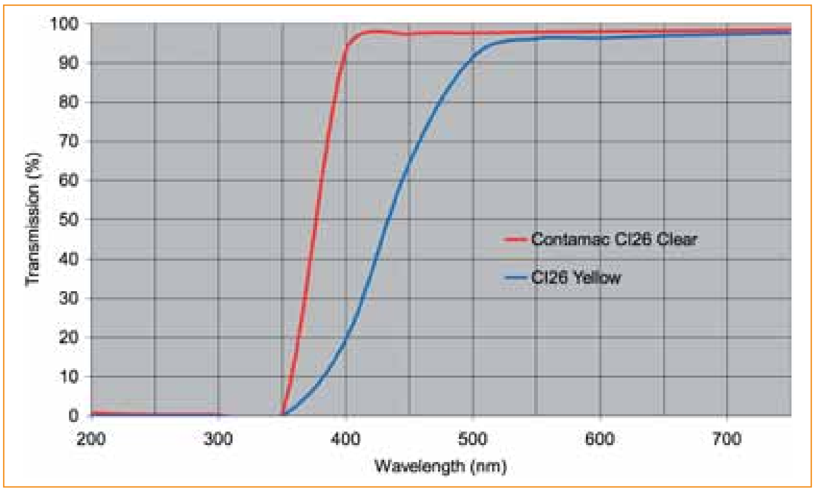

Figure 2 - Transmission Properties of Clear and Yellow IOL

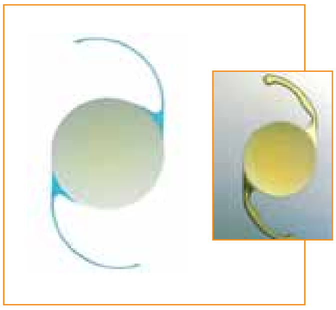

Figure 3 - Examples of Blue Blocking IOLs

Contamac's Yellow Hydrophilic Acrylic IOL Material

There has been much debate about the relationship between blue light and macular degeneration in patients who have had cataract surgery. Some studies conducted have found a correlation and many surgeons are opting to use blue blocking lenses in favor of clear intraocular lenses. In response to this trend in the market, Contamac has developed a yellow version of its market leading CI26 hydrophilic intraocular lens material. This material has excellent blue light absorbing properties that compare well with the crystalline lens.

The use of blue light absorbers in the fabrication of intraocular lenses (IOLs) was first suggested in a number of patents that were filed in the late 1980s. These patents discuss the benefits of yellow IOLs, since they provide a visual outcome that replicates more accurately the natural crystalline lens. The subject matter of such patents was the incorporation of yellow coloring agents in IOLs that were fabricated from PMMA. Unfortunately, such yellow IOLs met with limited commercial success.

More recently, IOL manufacturers have suggested the use of yellow lenses to help prevent age related macular degeneration in patients who have had cataract surgery. The re-introduction of this concept with greater perceived clinical benefits has resulted in these types of lenses gaining favor in recent years. Blue light absorbing IOLs are now available in a number of molded products including silicone and foldable acrylic materials. However, hydrophilic materials have to date not been available with a blue light absorber, resulting in many manufacturers not being able to provide these lens types.

Since PMMA is a hard glassy material, the coloring agents are not able to leach from the material. This is an important consideration since almost all the coloring agents, suggested in early patents, did not contain a polymerisable group. With the development of IOL materials suitable for small incision surgery, it becomes vital for additives to be chemically bound to the polymer material. For quite some time, UV absorbers, which contain polymerisable groups, have been used in the production of IOL materials. Yellow color additives to be used in such materials also need to contain a polymerisable function, to ensure that the yellow color does not migrate from the material.

The development of a blue light absorber for hydrophilic materials has presented a range of challenges. It is vital that a color additive for such materials is chemically bound to the polymeric backbone of the material. Otherwise, the additive can leach out of the material when it becomes swollen with water in its hydrated state. It is also important that the lens absorbs light of correct wavelength. Although a lens may be yellow in appearance, it may not actually be absorbing the light as would be expected.

Contamac has developed a yellow color additive that meets these criteria and is suitable for use in hydrophilic IOLs. The additive contains a polymerisable group that ensures it can be fully incorporated as part of the polymeric backbone. As a result, the yellow color does not leach from the material when the lens is hydrated. The resulting lens will also absorb light of suitable wavelength, closely matching the transmittance spectra of other commercially available, blue light absorbing IOLs.

It is important to ensure that the yellow color is stable, particularly with respect to long term exposure to sunlight. The long term photosensitivity of the blue light absorber can be evaluated by conducting an accelerated aging study. This will replicate the equivalent of 20 years of exposure for an average person and condense it into a relatively short term experiment by use of light with a greater intensity than the sun. Such studies are performed according to a specific ISO standard for the photostability of IOLs. This standard estimates the actual amount of light of potentially damaging wavelengths, which reaches the IOL on a daily basis. The duration of the study is largely dependent on the intensity of the light source used for the experiment. The light transmission properties of the lens are evaluated before and after the testing, and the lens is also examined by microscope to determine if there have been any changes to the material.

Figures 1-3 show the light transmittance curves for three different blue light absorbing IOLs, that have been subjected to photostability testing. Figure 1 shows the light transmission properties of an IOL produced from the yellow version of CI26. The graph shows

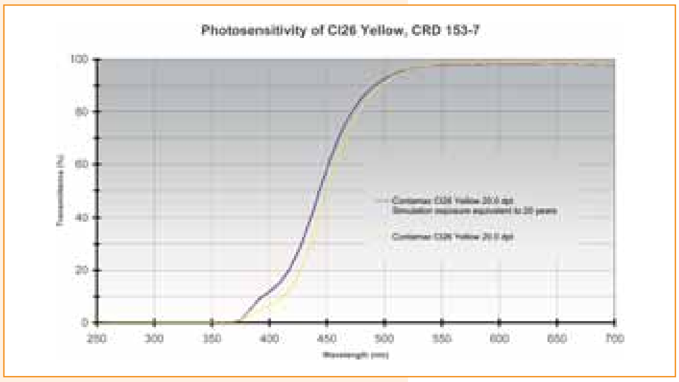

Figure 1 - Light transmission properties of CI26 Yellow

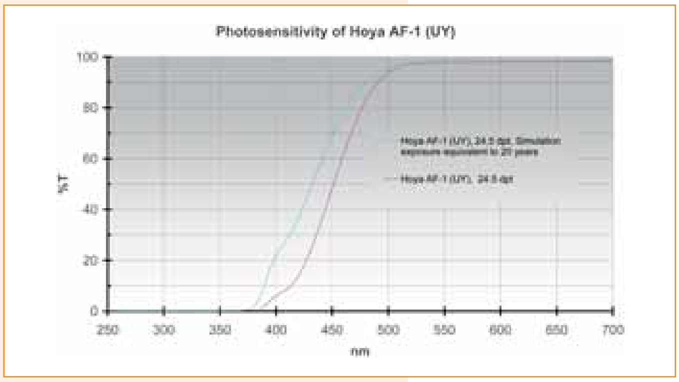

Figure 2 - Light transmission properties of Hoya AF-1 (UY)

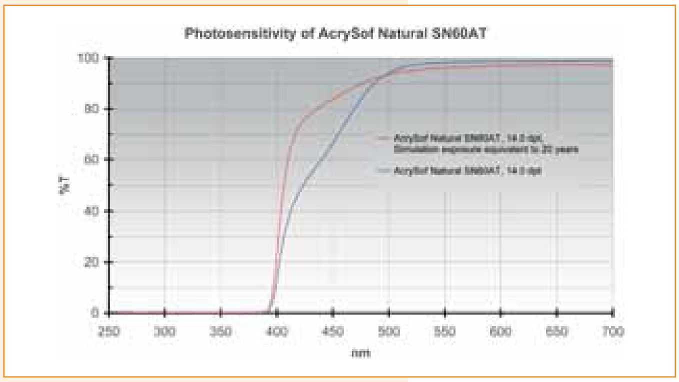

Figure 3 - Light transmission properties of Acrysof Natural SN60AT

a relatively slight change in transmission properties of the lens after simulation of 20 years' wear. Figures 2 and 3 show the light transmission properties of other commercially available blue light absorbing IOLs. For both of these products there is a decrease in the blue light absorbing properties, after the simulation of 20 years' wear and this is greater than the change seen in the Contamac material.

The development by Contamac of a yellow version of its hugely successful CI26 material, represents a major step forward for IOL manufacturers. A range of IOL designs can now incorporate protection against age related macular degeneration, without compromise on the quality of the underlying hydrophilic material.

For further information on this material please contact: sales@contamac.co.uk ■