SCIENTIFIC REPORT

Spectral transmission of intraocular lenses expressed as a virtual age

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Aim: Currently available intraocular lenses (IOL) have widely different spectral filters. This study aimed to calculate the virtual age of IOL with regard to photoprotection and photoreception, i.e. the age of the natural lens that has similar effects on these aspects.

Methods: With diffuse solar radiation as a light source blue light damage was calculated for natural lenses at all ages, commercially available IOL and Schott steep cut-off filters in the wavelength range 300–600 nm. Similarly, the input to the short wavelength sensitive cone system was calculated for the range 380–600 nm.

Results: The virtual age for photoprotection of IOL and steep cut-off filters varied from under 0 to 66 years. Most IOL had similar ages for photoreception, and thus show a reasonable resemblance to the spectral properties of the natural lens. Two IOL and all steep cut-off filters had a lower age for photoreception than for photoprotection, and thus outperformed the natural lens.

Conclusion: The virtual age of an IOL relates its spectral filtering properties to what happens in the healthy crystalline lens. Many older IOL types offer less protection than the lens of a newborn. Middle age seems a reasonable choice for an IOL.

All intraocular lenses (IOL) have a spectral filter for absorbing short wavelength radiation. When IOL were first introduced they only mimicked the refractive properties of the crystalline lens. Later it was realized that the unhampered transmission of ultraviolet radiation might harm the retina.[1] Only recently it was suggested that visible short wavelength radiation might also cause acute or chronic damage. In the past few years new IOL were therefore introduced with spectral filters extending far into the visible. Available IOL now range in colour from fully transparent to light yellow up to orange.

The cataract surgeon faces the problem of how to choose the spectral filter. Several papers have recently been published on this subject,[2–10] emphasising the uncertainty about the effects of chronic damage through optical radiation, and thus the wavelengths that should be cut, violet and/or blue.

The aim of the present paper was to offer practical help by introducing two numbers for an IOL, a measure for photoprotection, the virtual age Ap, and a measure for photoreception, the virtual age Ar. The idea is based on the fact that the spectral filter in the natural lens changes significantly with age. At birth the lens is perfectly transparent and nearly colourless; in old age a (healthy) lens is yellowish brown. In the (invisible) ultraviolet the changes are even greater. The optical density at 320 nm increases from approximately 2 at birth, to 18, i.e. virtually opaque, at the age of 80 years.[11] With increasing age more potentially dangerous short wavelength radiation is thus absorbed, although at a cost of some reduction in photoreception. We calculated at what age of the natural lens a specific IOL has an identical effect for photoprotection. Similarly, we derived a virtual age for photoreception.

METHODS

The mean spectral characteristics of the human ocular media were obtained from van de Kraats and van Norren.[11] The spectral characteristics of diffuse sunlight, IOL, Schott cut-off filters, blue light damage, and (peripheral) short wavelength sensitive (SWS) cones were taken from another paper by the authors.[10] A number for photoprotection was derived by taking the integral from 300–600 nm of (spectrum of sunlight) * (spectrum of media transmission) * (spectrum of blue light damage at the retinal level). A number for photoreception was obtained by integrating the spectral products of sunlight, media transmission, and SWS cones over the range 380–600 nm. Relating the numbers for an IOL to those of the natural lens led to the virtual ages Ap and As. An IOL has similar spectral characteristics to the natural lens when Ap = Ar.

RESULTS

The calculated virtual ages for photoprotection and photoreception are summarized in table 1. A high age for photoprotection should be interpreted as desirable, but for photoreception the reverse is true. Several IOL had such high transmission that the virtual age was below that of a newborn (Ap, Ar <0). In those cases the difference Ap–Ar could not be calculated. Other IOL ranged from 14 to 60 years. To show what is in principle possible with commercial dyes, we also calculated the ages of hypothetical IOL that have the concentration of dye in a series of 3 mm Schott cut-off filters. These ages ranged from 5 to 66 years. The differences in age for photoprotection and photoreception were generally small. The Bausch & Lomb Sofport,

Table 1 Virtual ages of intraocular lenses for photoprotection (Ap) and photoreception (Ar)

IOL	Ap	Ar	Ap–Ar
Eyeonics AT45	<0	<0	
Alcon Acrysof UV only	<0	<0	
PhysIOL YellowFlex	<0	<0	
AMO Clariflex	<0	<0	
Bausch & Lomb Sofport	14	<0	>14
Alcon Acrysof Natural	34	37	−3
Hoya AF-1 UY	42	44	−2
AMO OptiBlue	42	35	7
Ophtec Orange PC440Y	60	61	−1
Cut-off filters			
Schott GG420	5	<0	>5
Schott GG435	40	33	7
Schott GG455	66	64	2

IOL, Intraocular lens.

Abbreviations: IOL, Intraocular lens; SWS, short wavelength sensitive the AMO OptiBlue and all Schott steep cut-off filters had Ap–Ar >0.

DISCUSSION

The virtual age of commercial IOL differed enormously, from ''younger'' than a newborn, to 60 years old. It was revealing to see that the older types of IOL have such high transmission at short wavelengths that they offer less protection than the lens of a newborn. Newer IOL types successfully imitate natural lenses in the range 14–60 years, with the notable exception of the recently introduced PhysIOL Yellowflex that falls into the group with an age less than 0. Most IOL provide a reasonable imitation of the spectral characteristics of the natural lens, although the balance is a little less optimal than in the natural lens. The Bausch & Lomb Sofport, the AMO OptiBlue (not commercially available) and the Schott cut-off filters have an improved balance between photoprotection and photoreception compared with the natural lens. The Schott cut-off filters also illustrate the flexibility in virtual age that can in principle be achieved.[10]

The limits of the virtual age calculation become obvious in an IOL with an age less than 0. Among these is the Eyeonics AT 45 with much higher transmission in the ultraviolet than the Alcon Acrysof ultraviolet only and the AMO Clariflex.[10] These details were lost in the virtual age calculation. On the other hand, an Ap less than 0 clearly conveys the message that the IOL offers limited protection against short wavelength radiation.

What should the virtual age of an IOL preferably be? Are patients better off with rejuvenation of their vision after a cataract operation, or should the IOL mimic the older lens that it replaces? At present the age choice is between either less than a newborn or at least 14 years. For unhampered vision a very young IOL is fine, but to prevent chronic and acute light damage a safer course should be steered. To give an example, the time allowed for reaching the damage threshold by staring into the sun with an unprotected eye at the age of 80 years is more than four times longer than for a newborn. The average middle-aged individual has good vision in the blue range of the spectrum, no problems with night vision, does not suffer from sleep problems that might be related to problems with melatonin suppression or lesser stimulation of melanopsin,[8] but at such an age substantial protection against acute damage and against possible chronic damage exists. We are thus of the opinion that the middle-aged IOL offers a good compromise between photoprotection and photoreception.

For photoreception we only calculated the input to the SWS cone system. The spectral absorption curve of the SWS cones is closer to the blue light damage spectrum than that of any other system that plays a role in human photoreception. The rod system, for example, has an absorption spectrum that is shifted approximately 70 nm towards longer wavelengths and is thus far less influenced by IOL filters.

In conclusion, we propose a novel system to characterize the spectral properties of IOL. The virtual age of an IOL relates its spectral filtering properties to what happens in the healthy natural lens, and the difference in age for photoprotection and photoreception provides information about the degree of resemblance with the natural lens. The filter in an IOL can, in principle, be designed so that it outperforms nature.

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