Ageing and the crystalline lens

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Ageing leads to gradual loss of the crystalline lens's three main functions due to changes in the transparency and rigidity of the latter, and following various biochemical and ultra structural alterations. Opacification causes the appearance of senile cataract, which is the main cause of vision loss worldwide. Hardening of the crystalline lens gradually restricts accommodation, leading to presbyopia, which is the most frequent eye condition since it is permanent from a certain age. The loss of the UV ray filter function increases phototoxic lesions of the retina.

The crystalline lens is a transparent, biconvex biological lens located in the eye's posterior chamber. It is attached to the sides of the eye by the zonule of Zinn or suspensory ligament of the crystalline lens, which extends from the equator of the crystalline lens to the ora serrata. Morphometry of the crystalline lens varies according to a person's age: its diameter and weight increase constantly over the years and its gradually loses its transparency as from the age of 30. It is made up of two main elements: the capsule and the fibres, which are themselves arranged in concentric layers organized in two areas, one supple exterior area known as the cortex and one internal, firmer area, the nucleus. The crystalline lens is a structure without nerves or vessels (blood or lymphatic), it is supplied by diffusion from the aqueous humour and the vitreous body [1].

But what are its main functions and how much are they affected by ageing?

The crystalline lens fulfils an important optical function and, with the cornea, the aqueous humour and the vitreous body it is one of the eye's optical mechanisms. It actually contributes up to approximately 15 dioptres (D) of the total dioptric power of the eye, which is around 58D. Its transparency in visible light results in good vision. Its refractive index varies between 1.386 at its periphery and 1.406 in the centre.

It is also responsible for the accommodation process by which the image of objects located at various distances comes to a focus on the retina. Several theories have been put forward concerning the changes to which the crystalline lens is subject during accommodation. The most generally accepted, put forward by Helmholtz, is the idea that accommodation results from contraction of the ciliary muscle originating in a range of changes to the crystalline lens: 1) an increase in its anterior and posterior curve (mostly anterior), 2) anterior movement of the centre and anterior pole of the crystalline lens, 3) increase in the size of the nucleus, 4) reduction in its equatorial diameter.
The crystalline lens’s third function is to filter UV rays (UVA) of wavelength 320-400nm, which penetrate into the eye with a maximum absorption peak of 365 nm. This filter function protects the retina against UVA.

As with other organs and tissues, the crystalline lens is subject to changes over a lifetime. Consequently, its three main functions are subject to major changes during the course of the ageing process [2]. From a very young age two important characteristics are changed. A gradual loss of transparency is accompanied by a fall in the amplitude of accommodation. Numerous biochemical and cellular changes lead to occurrence of these two phenomena during continuous evolution in structural and functional modifications. This evolution can be modified genetically and amplified by environmental risk factors such as temperature, tobacco and alcohol consumption and by systemic diseases such as diabetes [3]. The loss of transparency of the crystalline lens, whose fundamental mechanism is an increase in the dispersal of light, is a permanent phenomenon over the years, which leads to the appearance of senile cataract (Fig.1).

Senile cataract is the most common cause of vision loss worldwide [4] and the main cause of invalidity in old people. According to the Framingham demographic study, 53% of people aged between 65 and 74 years suffer from opacity of the crystalline lens and this percentage increases to 80% for people aged 75 to 85 [5]. Cataract surgery, in most cases performed by corneal incision and phacoemulsification of the crystalline lens, with the insertion of an intraocular implant (Fig.2), is by far the most commonly practised surgical intervention in the world today [6].

Several risk factors have been put forward to explain the appearance of cataracts [7], but the main one, particularly in the case of nuclear cataracts, is age. The loss of ocular transparency over the years is the result of numerous causes. It would appear that the main cause is oxidative stress in the crystalline lens [8], which would explain the higher incidence of nuclear cataracts, because the nucleus is the area of the crystalline lens furthest from the antioxidant protection of the capsular epithelium and the cortex [9]. Other authors claim the existence of modification in the crystalline lens proteins (which are not necessarily due to oxidative stress) and which could lead to a change in their conformation and therefore functional and structural insufficiency [10]. In the end the two theories can be taken together since oxidation could take over from the opening of the proteins [11]. In any case, it is clear that the crystalline lens is subject to a large number of modifications with age [12]. An accumulation of fluorescent chromophorous pigments produces the characteristic colour of a crystalline lens with a cataract and crystalline autofluorescence, the scale of which is correlated to the colour and opalescence of the crystalline lens [13]. Also, as indicated above, a large number of biochemical changes happen in the crystalline lens proteins and they are accelerated by the reduction in the crystalline lens's antioxidant power [14]. This oxidising "attack" leads to crossing over of the crystalline lens proteins, with the formation of high molecular weight aggregates. These aggregates increase the dispersal of light and the loss of transparency, whilst leading to hardening of the crystalline lens. The increase in light dispersal, or scattering can appear even in the absence of cataract [15]. Finally, ageing is also accompanied by metabolic changes in the crystalline lens, such as the fall in activity of numerous enzymes and the increase in levels of Na+ (sodium) and Ca++ (calcium) with a reduction, later, of K+10 (potassium).

The second essential function of the crystalline lens, accommodation, is also altered during the ageing process. Maximum accommodation amplitude, 10 or 12 D, is reached during the second decade of life, after which it begins to decrease gradually. When this ability to increase the dioptic power drops to around 3.75D, presbyopia occurs, with a loss of the ability to see close objects clearly. In addition to this alteration to vision, a range of symptoms known as accommodative asthenopia may also appear; these are due to prolonged efforts with near vision. The symptoms include headaches,
feeling of eye heaviness and redness and a burning sensation. Presbyopia occurs at around the age of 
45, although this varies depending on existing ophthalmic conditions, such as ametropia (it appears 
first in people with hypermetropia) and the position in terms of latitude and altitude. Whatever the 
reduction in accommodation capacity, until the age of 60-65 years optical correction required for 
presbyopia (usually 1 to 3 D convex lenses) varies over the same period. Although it would appear 
that certain extra-crystalline lens factors are involved in the etiopathology of presbyopia, hardening of 
the crystalline lens, combined with the biochemical and structural changes referred to [16], is the 
main reason for gradual loss of accommodation during the ageing process [17], since the ciliary 
muscle is no longer capable of changing the shape of the crystalline lens [18]. Some authors have 
identified presbyopia as the first sign of nuclear cataract [19].

The last function of the crystalline lens is to act as a filter, to protect the retina against UVA rays. This 
important function is also altered on ageing since the quantity of ultraviolet filters in the crystalline 

References
05. Sperduto R, Seigel D. Senile lens and senile macular changes in a population-based simple. Am J 
07. West SK, Valmadrid CT. Epidemiology of risk factors for age-related cataract. Surv Ophthalmol 
1995;39:323-34.
09. Beebe DC, Holekamp NM, Shui YB. Oxidative damage and the prevention of age-related cataracts. 