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# CAUSES AND CORRECTION OF PRESBYOPIA: A REVIEW

Christoph Ortner, Ognjen Marković

Department of Ophthalmology,University of Vienna, Medical School

ABSTRACT – Presbyopia is the progressive inability of the eye's lens to change shape and focus clearly on near objects. This review gives a comprehensive overview of the symptoms, influencing factors in the progression of presbyopia, age-related changes of the eye, optical correction and surgical approaches to presbyopia. The age-related changes of the lens, the capsule, the ciliary muscle and the vitreous are well examined; however, a distinction whether those changes are a cause or a consequence of presbyopia cannot be made.

The optical correction of presbyopia reaches from monovision, bifocals, trifocals to progressive lenses and contact lenses. Approaches to surgical techniques for correcting presbyopia include scleral expansion bands, radial sclerotomy, anterior ciliary sclerotomy, polymer injectable lenses, photodisruptive laser and accommodative IOLs. Milestone innovations can only be expected in the surgical field as the optical correction of presbyopia using spectacles and contact lenses has already reached extremely high quality levels and is limited by optical laws.

Key words: presbyopia, physiopathology; presbyopia, therapy; presbyopia, surgery; review

## Introduction

Presbyopia is the condition in which a patient's amplitude of accommodation has decreased to the point where clear or comfortable vision at the desired nearpoint is not obtainable (Figure 1). Presbyopia generally occurs if the amplitude of accommodation is less than five to two diopters.[1] Throughout the literature the point at which presbyopia starts varies due to different definitions.

The word presbyopia finds its origin in Greek,. where the prefix „presby" means old and the suffix „opia" refers to eyes. Therefore, presbyopia is sometimes referred to as the „old age vision".

Due to the demographic development of the world's population the prevalence of presbyopia will increase from about 590 million today to one billion by the year 2020. It is an inevitable part of aging and should therefore get the proper attention from all the people working in the field of ophthalmology.

Correspondence to: *Christoph Ortner, M.D., M.P.H.* Kienmayergasse 29/ 18 A-1140 Vienna Austria

Even though presbyopia is an extraordinary public health issue and makes up a major part of the work in an ophthalmologist's office comprehensive information about the very topic is hard to find. This review will describe the most common assumptions about presbyopia and different solutions including the latest developments for possible surgical interventions.

The review summarizes age-related changes of the human eye and their possible influence on the development of presbyopia. However, a distinction whether those changes

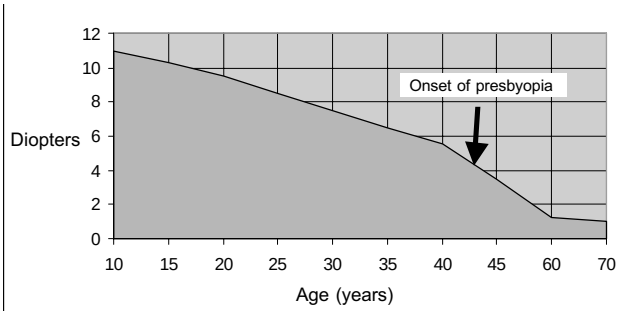


*Fig. 1. Decrease in amplitude of accommodation with increasing age*

are a reason or a consequence of presbyopia cannot be made with the literature and research available today.

A major reference for this review is "Presbyopia", International Ophthalmology Clinics, 2001, 41, a collection of several presbyopia articles edited by Mitchell H. Friedlaender.

## Symptoms of Presbyopia

The age of onset of presbyopia is slightly variable, but the majority of patients will need near correction by the age of 45.

General symptoms of presbyopia include:

- Vision at the patient's normal near point becomes blurred.
- Patients get the need to hold reading material or other up-close objects further away in order to gain clarity or see details.
- The patients need brighter light for example when reading. Bright light constricts the pupils, which then increases the clarity of words.
- Eye discomfort, fatigue or drowsiness when doing close work because of the strain of the eye muscles working to change the lens shape.

Many factors in addition to distance refractive error and amplitude of accommodation determine when the patients require a correction for presbyopia. Some of these factors include:

- Occupation
- Pupil Size (depth of field)[1]
- Reading Habits, Hobbies, other near vision demands
- Stature (length of arms)

## Age-Related Changes of the Eye the Lens

The crystalline lens grows continuously throughout the whole life span.[2] Mitosis in the lens epithelium produces the so called lens fiber cells that compose the lens substance. The newest fibers are laid down closest to the lens surface, the older fibers shrink, lose their nuclei and become incorporated into the central part of the lens.

Lens wet weight also increases throughout the whole life span. The weight of the isolated human lens increases linearly at a uniform rate of 1.33 mg per year.[2]

There is also an age-related change of the lens diameter. In vivo measurements with MRI technology show no age change in the diameter of an unaccommodated lens. However, the lens diameter increases with age in an accommodated lens.[3]

The gradient refractive index of the lens increases from the cortical surface to the center of the nucleus. According to empirical studies this gradient becomes relatively flatter in the nucleus of older lenses which could decrease the optical power of the lens by 2 D.[4] This decrease in optical power might be compensated by the increase in thickness and the development of a steeper surface curvatures in older lenses.

Also the degree of hardness of the lens increases over the years. This increase in hardness can reach up to a 4 times higher level than in young lenses. This continued increase in hardness suggests that the age at which accommodation is lost may simply represent the time point when the capsule can no longer mold the hardened lens with the remaining ciliary muscle contraction.[5]

## The Capsule

The elastic capsule ensures that the lens can reach a maximally accommodated state. However, this primarily works with younger lenses. Removing the capsule of an isolated, young lens shows that the lens substance undergoes a change towards a more unaccommodated configuration. This alteration in shape occurs to a lesser extent with increasing age. Older lenses show no alteration in shape after removal of the capsule.[5]

In addition to the age-related changes of the lens, the capsule itself becomes less elastic[6], less extensible, thicker, and more brittle with age.[7]

## The Ciliary Muscle

The ciliary muscle shows a reduced mobility in elderly people. MRI studies show that during accommodation the decrease in the ring diameter of the ciliary muscle is reduced in older eyes. Also in an unaccommodated state the ciliary body ring diameter is reduced as well.[3] Therefore circumlenticular space is reduced with increasing age.

Furthermore the posterior attachment of the ciliary muscle becomes increasingly inelastic which contributes to the progressive age-related restriction of the muscles motility.[8] This loss of ciliary muscle excursion is probably involved in the pathophysiology of presbyopia. In how far those changes are a cause or a consequence of presbyopia has so far remained undetermined, but they represent age changes that could effect the amplitude of accommodation.

## The Vitreous

The vitreous becomes progressively more liquid with age, which might affect the peripheral compression of the lens. However, when comparing the eyes of people with unilateral performed vitrectomy there was no difference in amplitude of accommodation found.[9]

## Optical Correction of Presbyopia

Optical correction of presbyopia can be achieved through wearing either spectacles or contact lenses. In addition to the refractive correction at distance the correction of presbyopia requires the application of plus lenses. The goal is to reach clear and comfortable vision at the near point. There are several methods for the determination of add power. The most simple and sufficient way to determine the add power is to add plus lens power +0.25D at a time until the patient can comfortably read at his/her preferred reading distance.

The following kinds of spectacles can be proposed:

*Single Vision lenses*

Monofocal spectacles are convenient for work that requires good close up vision for an extended time. When trying to see far away or intermediate distance objects these reading glasses can sometimes give a vertigo sensation since images may be out of focus.

*Bifocals*

Bifocals are a good option for people that need to alternate between near and far vision. Following a common, initial inconvenience practically everybody will get used to bifocals. When looking automatically through the proper segment a comfortable use of those glasses is granted. This is possible when the difference between the near and distance segments is at least +1 D. Side-effects of bifocals could be object displacement, chromatic aberration, image jump or marginal astigmatism.

*Trifocals and Progressive Lenses*

Trifocals have an intermediate segment of one half of the reading add power and are tolerated as easily as bifocals. Trifocals are not indicated if the reading add is less than +1.75 D as there is generally no intermediate problem with such lower adds.

Multifocals allow focussing on objects no matter the distance. They also provide a better aesthetic result as there is no dividing line in the middle of the lens such as in bifocals. Some patients need more time adapting and learning how to use them. However, progressive lens technology has highly developed and satisfies most patients, especially first timers.[10]

The following contact lens solutions are available for correcting presbyopia:

*Monovision*

Monovision lenses correct one eye for distance vision and the other eye for near vision. The advantages of monovision are simpler fitting and less expensive lenses; however, the loss of binocular vision is a major disadvantage.

*Modified Monovision*

A variant of monovision is modified monovision where you either put a bifocal contact lens in one eye and a single-vision contact lens in the other eye; or a bifocal lens set for better near vision and a bifocal contact lens in the other eye set for better distance vision.

Monovision contact lenses are used if simultaneous vision and segmented bifocals do not work properly.

*Simultaneous Vision*

Simultaneous vision lenses allow both distant and near objects to be in focus at the same time. Near and distance vision correction is placed in concentric rings on the lens. Related lens types include aspheric - in which the lens power changes gradually from the center to the edge of the lens - and diffractive, which uses a series of grooves - cut into the back surface of the lens - to provide near vision correction. It is important that the lens centers properly and proper movement is obtained. Simultaneous vision should be tried especially with patients who experience presbyopia for the first time.

*Segmented Contact Lenses*

They have a small bifocal or trifocal embedded into the lens. The embedded segment needs to be below the pupil center when the patient is looking at distance. While reading the lower lid needs to push the lens up into the center. These lenses tend to be used more when presbyopia is advanced.

## Surgical Correction of Presbyopia

In general, most of the surgical procedures described below are in an early state of investigation and testing.

Future will show whether any of them will develop to a generally accepted and scientifically and statistically proven method for correcting presbyopia.

*Scleral Expansion*

SRP (Surgical Reversal of Presbyopia) is probably the most publicized technique. The technique relies on Schachar's theory of accommodation[11] which assumes that presbyopia is due to slackening of the equatorial zonules attached to the lens. This is the consequence of a continuous equatorial growth of the lens throughout the life and a therefore decreased distance to the ciliary muscle. By enlarging the distance between the ciliary muscle and the lens equator by different techniques those equatorial zonules should be tightened again and accommodation should be restored.

Scleral expansion restoration of accommodation relies on the premise that the crystalline lens retains the capacity to accommodate with age. Scleral expansion whether through relaxing radial incisions (radial sclerotomy or anterior ciliary sclerotomy) or through the use of scleral expansion bands[5] does not restore accommodation as assessed by an objective infrared optometer.[12]

Another technique for tightening the zonules involves applying an infrared laser to strategically thin the sclera. Similar restrictions as with the techniques mentioned above are likely to exist with this procedure.

*Polymer injectable Lenses and Photodisruptive Laser*

Those two emerging techniques assume that presbyopia is primarily due to lens hardening and loss of elasticity. After phakoemulsification with a special instrument through a small capsulorrhexis a silicone polymer lens could be injected into the capsular bag. The polymer would restore the elasticity needed to change focus.[5] However, studies with rabbits have reported complications and proved to be a problematic procedure.[13]

The second technique involves using a photodisruptive laser to soften the inside of the crystalline lens to restore elasticity. Both techniques are far from clinical use.

*IOL*

Companies in Germany and the US have designed accommodative IOLs which are placed in the capsular bag so that they move with the ciliary muscle and change focal power due to a vertex vergence effect. Currently clinical trials are conducted with such lenses. It will be interesting to see how those accommodative lenses will function once the capsule has hardened over time after surgery.

## Conclusion

Even though there is a lot of information from experimental studies, observations and analysis of the age-related changes of the eye, the reasons for the occurrence of these physiological changes remain fairly uncertain. The main question that has to be answered is whether these optical and physical changes of the human eye with increasing age are a cause or a consequence of presbyopia.

The optical correction of presbyopia has reached already a very high standard and a lot of different top quality products are available on the market. Despite continuous research and development from industry leaders in this segment space for innovation seems to be limited as optical laws have to be obeyed and the optical correction of presbyopia is just dealing with the symptoms not with the causes of the old age vision.

As the world's population ages and more and more people get effected by presbyopia researchers and industry all over the world put extensive resources into finding new approaches to treat presbyopia. Especially the surgical correction of presbyopia is in the focus of research. All different techniques that are examined are in early stages of their development and it is impossible to foresee which approach is the most promising one.

However, in order to develop an optimal surgical technique a holistic understanding of presbyopia is necessary. It will be very interesting to follow upcoming studies and experiments in the field of surgical correction over the next years. Until then the conservative correction of presbyopia by using spectacles and contact lenses remains to be the only way for risk adverse treatment of the old age vision.

We know a lot about how the eye ages and when the symptoms occur but there is still a lot of space for further and innovative research in order to come closer to a complete understanding of presbyopia.

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Sažetak

UZROCI I KOREKCIJA PREZBIOPIJE: PREGLEDNI ČLANAK

*C. Ortner, O. Marković*

Prezbiopija je progresivna nesposobnost leće da promjeni oblik i jasno fokusira bliske predmete. Ovaj članak pruža iscrpan pregled simptoma, čimbenika koji utječu na napredovanje prezbiopije, promjene oka povezane sa starenjem, optičku korekciju i kiruruške pristupe prezbiopiji. Promjene leće, kapsule, cilijarnog mišića i staklastog tijela povezane sa starenjem su dobro dokumentirane, ali se ipak ne može sa sigurnošću utvrditi da li su te promjene uzrok ili posljedica prezbiopije.

Optička korekcija prezbiopije uključuje monofokalne, bifokalne, trifokalne progresivne leće, te kontaktne leće. Kirurške tehnike za korekciju prezbiopije uključuju trake za skleralnu ekspanziju, zatim radijalnu sklerotomiju, prednju cilijarnu sklerotomiju, polimerne leće za injiciranje, fotodisruptivni laser i akomodativne intraokularne leće.

Veći napredak na ovom području može se očekivati samo kod kiruruških tehnika jer je optička korekcija prezbiopije sa naočalama i kontaktnim lećama već dosegla izuzetno visoki stupanj i ograničena je zakonima optike.

Ključne riječi: *prezbiopija, patofiziologija; prezbiopija, terapija; prezbiopija, kirurgija; pregled*