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Visual Accommodation and Advances in Management of Presbyopia

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Accommodation is the process by which the eye changes its focus to obtain a clear image on the retina. In this mini-review, we will discuss the main mechanisms of visual accommodation and recent advances in management of presbyopia. What mechanisms are involved in accommodation? Hermann von Helmholtz was the first person to propose the theory of accommodation [1,2]. Helmholtz described the theory of accommodation that the ciliary muscle is relaxed when the eye is focused at the far point [1,2]. This theory is still widely used as a main mechanism of accommodation today. The eye accommodates by changing the curvature of the lens so that it can focus on both near and far objects. The lens is soft and its curvature can be altered by the action of the ciliary muscles through the zonules. When we wish to view near objects clearly, the circular ciliary muscles contract and cause the lens zonules to relax, which squeezes the lens into a more convex shape. To look at distant objects, the ciliary muscles relax and allow the zonular fibers to tighten, which causes the lens to flatten and increases its focal length [3]. The intraocular pressure exerts a tension via Bruch´s membrane onto the lens via the zonular fibers and the ciliary muscle takes over the tension while contracting like a sphincter allowing the lens to go back into their rounded primary shape. The accommodation process is controlled by various factors that alter the shape of the lens, including the iris, cornea, ciliary muscles, lens zonular fibers, and vitreous. Corneal wave front aberration also contributes to apparent accommodation in pseudo phakic eyes [4]. Additionally, the posterior zonular fibers anchored to the anterior hyaloids membrane have an important effect on the mechanics of accommodation [5].

Other vertebrates such as birds have quite different accommodation mechanisms from that of humans [6-8]. Interestingly, ancient animals, such as birds, turtles, and lizards, share many ocular structures and accommodative mechanisms, including striated intraocular muscles, bony plates in the sclera, a lens annular pad, corneal accommodation and iris-mediated lenticular accommodation [1,2,9-12]. The extent of accommodation differs considerably among vertebrates [2]. Birds have ~50 diopters (D) [11], and ducks have 70-80 D [13]. Among mammals, raccoons have approximately 20 D [14], vervets and cynomolgus monkeys also have about 20D [15-17], and young rhesus monkeys have 40 D [18]. In humans, young children display maximum accommodative amplitude of 10-15 D measured subjectively [19] or 7-8 D measured objectively [20], while young adults have amplitude of approximately 4 D [21]. Accommodation decreases with age and is considerably impaired by about the age of 50 years because the ciliary muscles stop working properly in older people and the lens becomes harder due to cataract formation. From 50-55 years of age, the amplitude of objective accommodation declines about 2.5 D per decade until it reaches zero [2,22,23].

Presbyopia is the age-related loss of accommodation that is commonly seen in people over 40 years old. Presbyopia occurs because the lens loses its elasticity and the ability to focus on near objects [2]. What are the options for treating presbyopia? There are now numerous treatments, including spectacles or contact lenses, undergoing corneal refractive surgery, or implantation of multifocal intraocular lenses. Spectacles with bifocal or progressive lenses represent the most common method employed to correct presbyopia. Bifocal and trifocal lenses contain lenses with two or three different powers to help restore reading ability that has been lost due to presbyopia. Progressive addition lenses avoid discontinuity of vision and are also more cosmetically attractive, but are generally more expensive than bifocal lenses and single-vision spectacles. Middle-aged contact lens users are more active than their counterparts living several decades ago and tend to choose bifocal or multifocal contact lenses instead of bifocal spectacles or reading glasses for cosmetic reasons. Otherwise contact lens users over the age of 40 who have presbyopia wear reading glasses on top of their contact lenses.

New surgical procedures are also evolving as a solution for people who do not want to wear glasses or contact lenses. Scleral expansion bands increase the space between the ciliary body and lens, but have not proved to be effective for the treatment of presbyopia [24]. A new corneal surgery technique for the correction of presbyopia, known as Intra Cor (Technolas Perfect Vision), has now been approved in Europe [25,26]. The IntraCor procedure uses a femto second laser to reshape the interior of the cornea without penetrating the outer surface. Ruiz et al. reported that all 83 (100%) eyes had improved uncorrected near visual acuity (UCNVA), with minimal or no change in uncorrected distance visual acuity at six months after Intra Cor surgery [25]. In this surgery, the corneas were clear within a few hours after surgery [26] and no corneal structural complications were observed during a follow-up of 12 months [25]. Corneal inlays and onlays, which are small plastic rings that are implanted in the corneal stroma, are also worth considering. Corneal inlays are typically implanted in the non dominant eye to correct presbyopia [27]. The rings can be removed from the edge of the cornea and the surgery is minimally invasive. At 1 year after corneal inlays, the mean UCNVA improved from Jaeger (J) 6 (preoperatively) to J1+ using Jager Reading Card [27]. All eyes with an inlay had an UCNVA of J3 or better and 85.3%, of J1 or better. No inlay was explanted and or recentered during the reported follow-up. No postoperative complication were reported during the reported follow-up [27,28]. In addition, presbyopia-correcting intraocular lenses (IOLs) have been found to be fairly successful for the treatment of presbyopia [29-37]. These lenses can be inserted at the time of conventional cataract surgery, which means that cataract patients have a chance to simultaneously correct presbyopia and thus become able to see both near and distant objects without reading glasses. At 1 year after transplantation of presbyopia-correcting IOLs, the mean UCNVA was 20/40 and uncorrected distance visual acuity was 20/25 [35,36].

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Thepostoperative complications after the lens implantations, such as glare and halos are very low during the 12-month follow-up [35-37].

Femto second laser systems can create precise and reproducible surgical incisions under computer control. Thus the femto second laser allows for rapid visual recovery, and reduces the wound healing response. But laser corneal surgery cannot restore accommodation. Corneal in lays are difficult technique to master and surgeon experience and variations in surgical technique may affect postoperative complication rates. Multifocal or accommodating IOLs are now a commonly accepted treatment for cataracts and presbyopia, but a patient without cataract is not candidate for these premium IOLs.

The practical clinical application of these surgical techniques is only just starting to be explored. By selecting the optimal surgical approach, patients have a better chance of undergoing refractive surgery for presbyopia, thereby improving their vision and the quality of life. Additionally, the development of topical therapies that increase accommodation would also be desirable as a non-surgical option for the management of presbyopia in the future.

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