Literature Review

1. **Erratum in** 1987/Questioning our classical understanding of accommodation and presbyopia

The development of precise instrumentation, electron microscopy and enhanced analytical capabilities have renewed interest in understanding the mechanisms of accommodation and presbyopia. The properties of the ciliary muscle, the zonule, the lens capsule and the crystalline lens are being reevaluated, suggesting, for example, that these components' elasticities change significantly with age and that the biochemical properties of the crystalline lens may be altered as the lens ages. The recent findings, mainly during the past decade, are contrasted with or incorporated into our classical understanding of the accommodative mechanism and presbyopia as stated originally by Helmholtz and Fincham.

2. **Nishida S**, 1990/Aging changes in ocular tissues and their influences on accommodative functions.

It is a Japanese article to compare the reliability between two instruments. Age-dependent deterioration of the subjective amplitude of accommodation obtained by an accommodometer (VDT Accommodometer NP-200, Toyo-Medical, Nagoya) and the objective amplitude by an autorefractometer with a built-in infrared optometer (NIDEK AA 2000 Accommodometer, NIDEK, Gamagori, Japan) were compared. The objective amplitude was 2-3 dptr less than the subjective amplitude for all ages, but change of both curves with aging were parallel. The crystalline lens measured by an ultrasonic A-scan instrument, Alpha 20/20 (Storz, U.S.A.), showed continuous increase in thickness with aging and by accommodative contraction. The crystalline lens in the fifties was as same in thickness as the accommodatively contracted lens in the twenties but the increasing ratio of lens thickness in accommodative contraction decreased with aging and it reached a minimum in the sixties.
3. **Schachar RA** 1993/Experimental support for Schachar's hypothesis of accommodation.

This study was experimental in nature which contradicts Helmholtz’s hypothesis. The experiment determined the physical effect of a change in the equatorial lenticular diameter on optical power. Sclera-ciliary bodies of bovine eyes were stretched radially. The effective optical power and lenticular equatorial diameter were measured. It was found that an increase in the equatorial diameter of the bovine lens produced an increase in its effective optical power. These results support Schachar's hypothesis of accommodation, which states that there is increased zonular tension during accommodation.

4. **Schachar RA** 1993/Mathematic proof of Schachar's hypothesis of accommodation.

This was the experimental study to evaluate whether there is increased or decreased zonular tension during accommodation. They developed a qualitative small displacement model using Rayleigh's method to determine the characteristics of the human lens changes that occur during accommodation. They found that the optical power of the human lens increased linearly with zonular tension. Their results definitely prove Schachar's hypothesis of accommodation.

5. **Schachar RA** 1994/ A physical model demonstrating Schachar's hypothesis of accommodation.

This study was based on the hypothesis of accommodation. It states that there is increased zonular tension during accommodation and the observed in vivo changes in
lenticular curvature that occur during accommodation are the result of zonular forces. It was demonstrated by steepening of the central curvature of the lens with increased zonular tension. Profile photographs of an equatorially unstretched and stretched gelatin-filled balloon and profile photographs from the literature of an unstretched and equatorially stretched human lens were digitized. Their radii of curvature were determined. They found that equatorial stretching of both the gelatin-filled balloon and the human lens produced central curvature steepening that was consistent with Schachar's hypothesis of accommodation.


This study was done on the basis of hypothesis, assuming the change in lens matter should change the velocity of sound through the lens with ultrasonography. The physiological change in the lens with age contributes for the change in cytoskeleton and membranes. The velocity of sound confirmed that prebyopia is not due to change in lens matter and soluble salts but its due to the cytoskeleton of lens fibre and the membrane enclosed.


This is the review article to support Fincham's theory of presbyopia. It would require maximum ciliary muscle contraction to produce maximum accommodative response at all ages. The Hess- Gullstrand theory, however, would allow a maximum accommodative response with a decreasing ciliary muscle contraction as age increases leaving a reserve ability of ciliary muscle to contract with age. If Fincham's theory is correct, a mild parasympatholytic drug would produce a decrease in the amplitude of accommodation, a mild parasympathomimetic drug would produce an increase in the amplitude of accommodation and the AC/A ratio would increase with age. The results of this study indicate that all three of these do occur and therefore support the Fincham concept of the cause of presbyopia.
Atchison DA, 1995/Accommodation and presbyopia.

This is the review of the postulated theories. The state of presbyopia is reached when accommodation has declined sufficiently to interfere with close tasks requiring acute vision. One of the lenticular theories, the Hess-Gullstrand theory, is distinguished from other theories by its claim that as age increases there is an increasing excess amount of ciliary muscle contraction beyond the ability of the lens and capsule to respond to it. For all other theories, the maximum possible amount of ciliary muscle contraction is always necessary to produce maximum accommodation, at least beyond the age at which it reaches its peak. From this review of the present understanding of the mechanisms of accommodation and the theories of the development of presbyopia, the conclusion is that there is overwhelming evidence against the Hess-Gullstrand theory and that it is unlikely that changes in the ciliary muscle contractility contribute significantly to the development of presbyopia.

Gilmartin B, 1995/The aetiology of presbyopia: a summary of the role of lenticular and extralenticular structures

This paper presents a summary of issues, past and present, which have figured in the literature on the physiology of accommodation and presbyopia, and confirms that the pathophysiology of presbyopia is likely to result from deterioration in structure and function of a number of inter-related tissues. Changes in crystalline lens dimensions with age, the associated change in geometry of zonular attachments and changes in viscoelastic properties of the lens capsule and lens matrix would, however, appear to be the principal correlates for the onset of presbyopia. Recent models of the biomechanics of accommodation have drawn attention to the feasibility of extralenticular contributions to presbyopia and have examined properties of the elasticity and leverage provided by posterior, anterior and tensile fibre systems.

The crystalline lens of the eye is structurally a biological tissue, it functions as an optical element providing one third of the refracting power of the human eye, and a variable focus in younger years. Throughout a life-time, the optical properties of the eye-lens alter, resulting in changes in function: there is a gradual depletion of the focussing amplitude from infancy to middle age, and a loss of transmittance in the later decades of life. The optical properties of the lens depend on its power, which in turn is determined by its physical dimensions (curvatures and thickness) and its refractive index as well as transmissivity and the organization of its internal components. The power of the functional lens is, however, modifiable by virtue of the lens being attached via the zonule to the ciliary muscle. The contraction and relaxation of the latter respectively increases and decreases lens power in accordance with innervations determined by the physical distance of external objects to be imaged on the retina. This review will consider many of these features and how alterations in any of them may lead to changes in lenticular function.

11. Heron G, Schor C, 1995/ The fluctuation of accommodation and ageing

Optometer is an instrument to measure refractive state of eye. Two groups were taken with mean age 22 and 42 yrs. Both the groups were subjected to high and low contrast target. Reduction in the magnitude of the fluctuation was consistent with a general diminution in accommodation dynamics as the accommodation ages.

This was the objective finding which confirmed the reduction in accommodation with progression of age.

This study was done to establish the relationship between far to near and near to far point accommodation and the dynamics of lens change during accommodation. There was significant decrease in lenticular changes, approx 20 fold lens dampening was observed from the age 15 to 55.

So, presbyopia causes decrease in amplitude of accommodation due to lens dampening and its only the lens function and it is independent of ciliary body


In this study scanning laser technique was used to measure focal length and spherical aberration of the lenses. The lenses were subjected to stretching forces applied through the ciliary body/zonular complex. The focal length of all outstretched lenses increased linearly with increasing age. Younger lenses were able to undergo significant changes in focal length with stretching, whereas lenses older than 60 years of age showed no changes in focal length with stretching. There are substantial optical changes in the human lens with increasing age and during accommodation, since both the magnitude and the sign of the spherical aberration change with age and stretching. These results show that the optical properties of the older presbyopic lens are quite different from the younger, accommodated lens.


This is the biometric study where the lens spacing and the refractive index of emmetropic human eyes were combined with lens shape and placement within the globe to generate paraxial models of image formation as a function of age. The Gullstand’s model of lens was taken with different refractive indices of cortex and nucleus. Lenticular paraxial
gradient was found 2D less by the age of 50. The change in refractive index and the anterior placement of lens was the cause of reduction of total power of the lens.

15. **Marc C Westcott et al.** 2001, Failure of accommodation in patients with HIV infection. This study was done on the basis of hypothesis that amplitude of accommodation decreases for the HIV patients. 43 HIV positive patients were taken; with ART aged 25 to 39. The study concluded that there was significant failure of accommodation.

It was clear from the study that there is reduction in the amplitude of accommodation. The study was limited to the age of 35yrs as the sample size was too small for ages between 35 to 39 yrs.

16. **Svetlova OV.** 2003/Morpho-functional characteristics of lens ciliary body as a key mechanism of accommodation in human eye.

This is the review from Russian Journal which supports Helmontz’s accommodative mechanism. With the aid of ophthalmological, morphological, biomechanical and regulation theory methods, the inconsistency of prevalent concepts on the functional interpretation of morphological structure of ciliary zonule was demonstrated and the scheme of functioning of its elements matching clinical and physiological observations was proposed. The role of anterior and posterior portions of ciliary zonule appears to be functionally essential and consistent with accommodation mechanism proposed by Helmholtz, while the role of cilioequatorial fibers of ciliary zonule is functionally auxiliary.

This study was literature based using new geometric information on the shape of the lens that has recently become available. A finite element model has been developed in order to estimate the forces that act on the lens during accommodation for a typical 29-year-old human eye. To investigate the influence of the anterior, posterior and central zonular fibres insertion regions, three models with different configurations were built. All three configurations appeared to be capable of inducing the required accommodative changes in the lens. Based on material properties from the literature, the estimated summed net force for each of the three models was approximately 0.08 N.

Here the Neuton force exerted was assumed to be from the ciliary complex and lens matter,

18. Chien CH, 2006/Analysis of human crystalline lens accommodation

This study was analytic. The human crystalline lens behavior was observed during accommodation. The lens is modeled as a closed asymmetrical membrane shell of varying thickness enclosing an incompressible liquid. To simulate zonular tension associated with lenticular accommodation, an asymmetrical radial force or displacement was imposed around the shell equator. Two second-order, simultaneous, nonlinear governing differential equations were derived. When zonular traction within the physiological force range of the ciliary muscle is exerted, both central lens thickness and central optical power increase. Qualitatively, these increases are independent of lens shape. However, the magnitude of these changes is dependent on the initial profile of the lens and is enhanced by the "natural" variation in capsular thickness. Only when a pulling force significantly exceeds the force capacity of the ciliary muscle does the lens flatten and its central thickness and optical power decrease.

This study was done to measure changes in human eye lens dimensions and refractive index with age and state of accommodation. The results validated the Helmholtz theory of accommodation.


This study was done to determine the age-dependence of the accommodative force on the lens in order to make it clear whether the causes of presbyopia are due to lenticular or extralenticular changes. A finite element model of the lens of an 11, 29 and 45-year-old human eye was constructed to represent the fully accommodated state. Subsequently, the force that was needed to mould the lens into its unaccommodated state was calculated. The force on the lens appeared to be preserved with age, with only a slight increase to a value of approximately 0.06 N. In conclusion, the preservation of the net force delivered by the extralenticular ciliary body indicates that the causes of presbyopia must be ascribed to lenticular changes.

21. Sophia pathai, Hendren Bajillan, Alan L.Landay and Kevin P High, 2013, Is HIV a model of accelerated or accentuated aging

This study was done on extensive literature review. ART reduced the morbidity rate by reduced adverse effect of the drug like cardiovascular disease, diabetes, cancer, liver disorder and neurocognitive impairment which was found more prevalent in HIV infected than non infected.

Limitation of this study was the need for validated biomarkers of aging in the context of HIV. Despite these differences, well designed studies of HIV-infected participants are likely to provide new opportunities to better understand the mechanisms that lead to aging and age-related diseases.
22. **Sophia Pathai, et-al** 2013/ HIV infected individuals in South Africa: Relationship between chronological age and systemic biomarker of ageing

This study established cellular biomarkers as leucocyte telomere length and the gene expression CDKN2A. It was observed that with increasing age, telomere length decreases whereas CDKN2A was not associated with ageing process.

23. **Sophia Pathai, et-al** 2013/ Increased ocular lens density in HIV-infected individuals with low nadir CD4 counts in South Africa: evidence of accelerated aging

The increase in lens density is regarded as biomarker of ageing. In this study low nadir CD4 count less than 200 were more likely to get increased cell density. The age of participants were 30 yrs but higher limit was not mentioned. This study did not give any clear conclusion of increased lens density in HIV. The values were almost equal in terms of case control and HIV.

24. **Kröger RH** 2013/Optical plasticity in fish lenses.

This study is the clue to think about the plasticity in the vertibrates which may cause accommodation. In a typical fish eye, the crystalline lens is the only refractive element. It is spherical in shape and has high refractive power. Most fish species have elaborate color vision and spectral sensitivity may range from the near-infrared to the near-ultraviolet. Longitudinal chromatic aberration exceeds depth of focus and chromatic blur which is compensated for by species-specific multifocality of the lens. The complex optical properties of fish lenses are subject to accurate regulation, including circadian reversible adjustments and irreversible developmental tuning. The mechanisms optimize the transfer of visual information to the retina in diverse and variable environments and allow for rapid evolutionary changes in color vision. Active optical tuning of the lens is achieved by changes in the refractive index gradient and involves layers of mature, denucleated lens fiber cells. First steps have been taken toward unraveling the signaling
systems controlling lens optical plasticity. Multifocal lenses compensating for chromatic blur are common in all major groups of vertebrates, including birds and mammals. Furthermore, the optical quality of a monofocal lens, such as in the human eye, is equally sensitive to the exact shape of the refractive index profile. Optical plasticity in the crystalline lens may thus be present in vertebrates in general.

25. **Croft MA** 2013 / Extralenticular and lenticular aspects of accommodation and presbyopia in human versus monkey eyes

This was the study done on the human and rhesus monkey to investigate the connection between the vitreous zonule posterior insertion zone and the posterior lens equator. It also determined which components-muscle apex width, lens thickness, lens equator position, vitreous zonule, circumlental space, and/or other intraocular dimensions are most important in predicting accommodative amplitude and presbyopia.

All the patients were on ART and the age chosen were too young to cause change in lens density

26. **Arcinue CA, et.al.** 2015 Retinal thickening and photoreceptor loss in HIV eyes without retinitis

The photoreceptor density was significantly reduced in HIV sero positive. When imaged with adaptive optics camera, the cone density was found less than case control HIV sero negative patients.

Retinal thickness was assessed with SD –OCT scan. There was significant retinal thickening from Inner limiting membrane to ganglion layer[ inner retina].The oedema is thought to be due to inflammation in HIV retinae

According to the biomarker for retina, thinning of retinal layer is suggestive of ageing,

27. **Demirkaya N et al** 2015./ Neuroretinal degeneration in HIV patients without opportunistic ocular infections in the cART Era
Patients infected with HIV are given combination Anti Retroviral Treatment (cART). This treatment is known to cause Neuro Retinal Disorder (NRD) without any infectious retinitis, The fundus findings too did not reveal any abnormalities.

HIV is a chronic disease and the patient is on ART for long duration which can lead to loss of colour vision, sensitivity loss visual function and visual field loss, bilateral visual impairment and blindness.


Presbyopia is the result of senile change but to date, there is no uniform explanation for presbyopia and many factors have been proposed as contributors including continuous enlargement of the lens, loss of power of the ciliary muscle and hardening of the lens fibers. This study was done to experiment on the hypothesis of decrease in the permeability of aquaporin zero (AQP-0) also known as major intrinsic protein (MIP). An age-related loss in lens water permeability could reduce fluid fluxes during the shape changes of accommodation potentially contributing to presbyopia.

29. Nankivil D, 2015/The zonules selectively alter the shape of the lens during accommodation based on the location of their anchorage points.

This was the study done to determine the role of anterior and posterior zonular tension on the opto mechanical lens response during accommodation simulation. The zonular fibers attached to either the posterior or anterior lens surface were then carefully transected and the experiment was repeated. Zonular transection was confirmed in four eyes via laser scanning confocal microscopy after immunostaining. The effect of zonular transection on the tissue response to stretching was quantified. The anterior or posterior zonules alone are capable of changing the shape of both lens surfaces, the anterior zonules have a
greater effect on the anterior lens surface, and the posterior zonules have a greater effect on the posterior lens surface.


This study was done to evaluate the change in lens volume during accommodation in cynomolgus monkey. This result supports a hypothesis that the change in lens shape with accommodation is accompanied by a redistribution of tissue within the capsular bag without significant compression of the lens contents or fluid exchange through the capsule.