ISPUB.COM

The Internet Journal of Ophthalmology and Visual Science
Volume 9 Number 1

An Accidental Finding and Implications for the Etiology of Myopia

R McCollim

Citation

R McCollim. *An Accidental Finding and Implications for the Etiology of Myopia*. The Internet Journal of Ophthalmology and Visual Science. 2012 Volume 9 Number 1.

Abstract

Purpose. To investigate the role of the oblique muscles in axial elongation.Method: A viewing device was constructed consisting of two identical images depicting a visually rich pattern. When the subject (a high myope) looked through the device, each eye viewed one of the images. The images were then tilted, i.e. as seen by the subject, the right-side image was tilted counterclockwise and the left side clockwise. To maintain fusion of the two images, each eye must then rotate in the same direction as the image it is viewing, i.e. the upper end of the vertical meridian of each eye leans nasalwards.The movement of incyclorotation is opposed by the check ligaments and other fascial structures of the orbit. If an effort is made to maintain fusion, the contraction of the obliques, which wrap part way around the globe, will exert pressure in the general area of the equatorial meridian.Results: The existing myopia increased by some 5 D. An unexpected result was that the uncorrected acuity became nearly emmetropic (20/25). The subjective vision consisted of a nearly sharp image superimposed on a highly blurred image. This dual mode of vision could be interpreted as a combination of high myopia and near emmetropia in each eye.Discussion. A possible cause was pressure from the obliques transmitted through the sclera to the vitreous, forcing it forward against the posterior surface of the lens and flattening its periphery. This may have been merely an extreme case of the normal negative spherical aberration that occurs when the eye accommodates. The dual vision persisted for more than a year, which suggests that a highly deformed lens is extremely slow to revert to its original state.

INTRODUCTION

It is almost universally agreed that axial elongation of the globe is the most significant factor in the etiology of myopia. According to Hirsch (1967) vitreous chamber elongation is the structural change producing almost all myopia [1] ”Three variables, then, the axial length, the shape of the cornea, and the power of the crystalline lens, exert the greatest effect upon refraction. There is relative agreement among authors as to the relative influence which each of these exerts, the axial length being the greatest, followed by the cornea and lens in that order.”

T he hypothesis that the extraocular muscles play a role in axial elongation is certainly not new. It has been suggested by numerous investigators over the years, but the mechanism is unclear. Two of the most prominent proposals are elevated intraocular pressure and scleral weakness.

O f the six extraocular muscles that control the movement of each eye, two, the superior and inferior obliques, would be the most capable of compressing the eyeball. According to Curtin, (1985) [2] “With the eyes converged and depressed, the SO [superior oblique] muscle is in a position to exert considerable pressure on the globe” (my emphasis).

A situation in which this situation occurs is the act of reading, probably the most common form of nearwork. With the eyes converged, most people read with the gaze depressed; in this situation the continuous horizontal scanning movement of the eyes from left to right and back produces continual rotation of the eyes, which is effected in great part by contraction of both the superior and inferior obliques.

METHODS

In order to elucidate the role of the obliques in axial elongation and to determine if they could be a significant factor in the etiology of myopia, an experiment was devised to produce contraction of these muscles by the following means:

Because the eye muscles are not subject to individual voluntary control, it was necessary to devise some means to make only the obliques contract while maintaining relative relaxation of the others. The natural tendency of the eyes to fuse two disparate images was utilized for this purpose.

Aviewing device was constructed which consisted of two identical images on a white background. When the subject looked through the device, each eye viewed one of the images; the visual cortex then fuses the two images to form a single view.

The images were then tilted, i.e. as seen by the subject, the right-side image was tilted counterclockwise and the left-side image was tilted clockwise. In order to maintain fusion of the two images, each eye must then rotate in the same direction as the image it is viewing, i.e. the upper end of the vertical meridian of each eye leans nasalwards.

Although the movement of incyclorotation is effected principally by the obliques, there is a limit as to how far the globe can rotate, since this is opposed by the check ligaments and other fascial structures of the orbit. If an effort is made to maintain fusion, the traction of the obliques will exert pressure on the eyeball in the general area of the equatorial meridian, and it would be expected that any alteration in the shape of the globe would consist mainly of stretching in the posterior area (or, less likely, anteriorly).

This is not to say that if the images are rotated, say, 8 degrees, each eye will also rotate exactly 8 degrees; eye rotation can be as much as 2 degrees less. This is because of Panum's fusional area, which in stereopsis allows the image to be pulled apart by some 2 degrees before being broken up into two separate images (Fender, 1967)[3].The images are actually pulled apart on the retina, but a supra-retinal function maintains perception of a single image.

The device was later modified for portable use to facilitate long-term viewing. Instead of viewing graphic images, the subject looked through a device consisting of two pairs of mirrors, one pair for each eye. By adjusting the angle of the mirrors relative to each other, the image presented to the eye can be rotated around its axis.

The mirrors were adjusted so that each set produced incyclorotation of the image, In order to eliminate any stimulus to accommodation, distance fixation of at least six meters was maintained.

The amount of tilt (incyclorotation) varied between 6 and 12 degrees. Since I was unable to find an emmetrope willing to risk becoming a myope, the subject of the experiment necessarily had to be myself.

In order to determine if the device had produced any change in eyeball dimensions, I had to rely on changes in visual acuity. Thus, if in the course of the experiment I noted increased blur for distance vision, this would indicate that the eye had elongated.

RESULTS

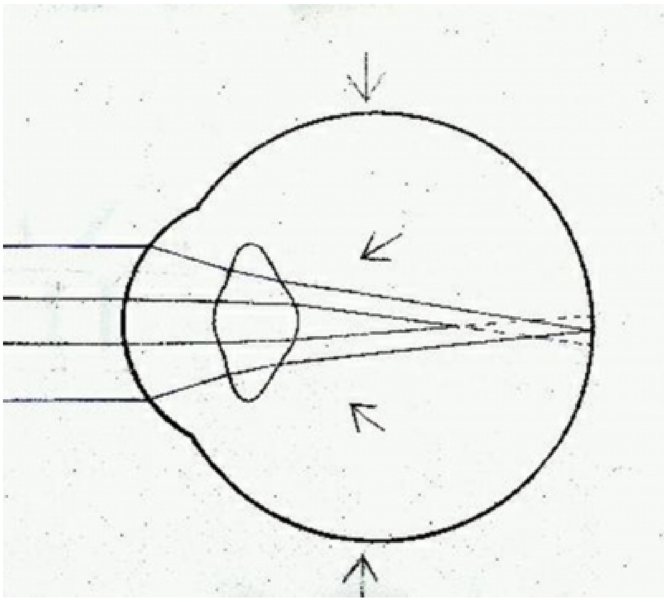
After using the device intermittently for a total of some three hours, I noticed a change in my vision. However, what I saw was completely unexpected. Instead of an increase in blur that would have resulted from increased axial length, my vision improved dramatically.

This improved acuity, however, was not the same as normal acuity but was mixed: it consisted of both sharpness and blur. For example, an object viewed at a distance was seen as highly blurred, yet within it was seen a nearly sharp image of the same object.

It could be said, then, that the experiment was a success, since it indicated that the eyeball had elongated, as evidenced by the increased degree of blur for distance vision with the subject wearing his original corrective lenses. The most significant point, however, is that these changes in acuity must have come not solely from elongation of the globe, but also from changes in the shape and power of the crystalline lens, as visualized in Figure 1.

Figure 1

Figure 1. Lens shape and focal points



The monocular diplopia was so pronounced that the uncorrected acuity improved to the extent that I had become almost emmetropic--I could read the 20/25 line of a Snellen chart.

The only rational explanation of these dual images is that they had to come from two separate focal points. I further reasoned that what had happened was that compressing the eyeball had forced the vitreous against the back of the lens, flattening its periphery, which created a new focal point, located close to the retina.

SPHERICAL ABERRATION AND ITS RELATION TO ACCOMMODATION

The presence of two separate focal points suggests an extreme form of spherical aberration. Spherical aberration is almost certain proof that the lens had accommodated. Many studies have demonstrated that the two go together. Ivanoff (1956) [4]and others have shown that when the eye is at rest the spherical aberration is positive, which means that the rays passing through the periphery of the lens come to a focus in front of rays passing through the axial region of the lens.

As the lens accommodates to view a near object and begins to change its shape, the spherical aberration decreases, and at around 3 diopters there is almost no aberration at all, i.e. all the rays come to a focus at the same point.

If the eye accommodates further, the aberration begins to reverse, in which case the peripheral rays come to a focus at a point behind the axial ray focal point. Apparently this condition had reached an extreme degree, as visualized in Figure 1.

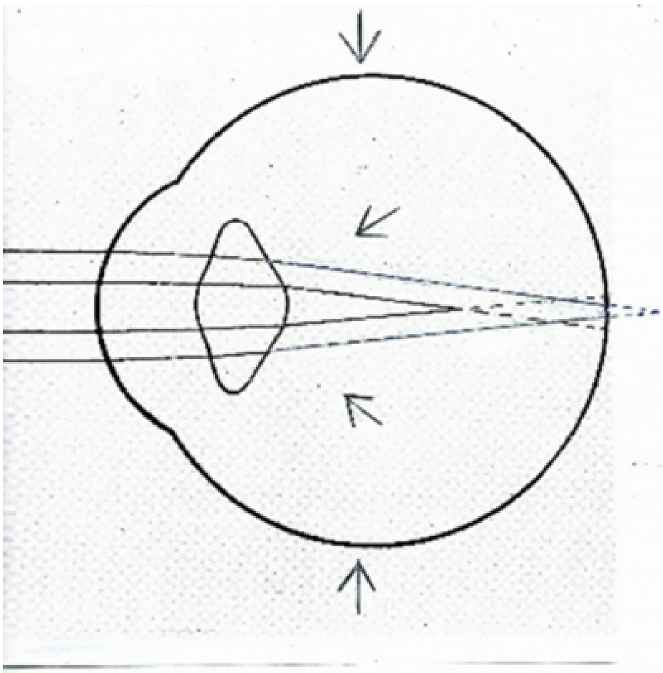
Rays passing through this outer region of the lens came to a focus at a point very close to the retina, which produced the secondary image (nearly clear vision), while the rays passing through the central region of the lens came to a focus in front of the retina, which produced the primary image, which was severely blurred. A subsequent eye examination revealed that my existing myopia had increased by about 5 diopters: At the start of the experiment the refraction was O.D. -7.5 -1.25; O.S. -5.50 -1.50. After the experiment the refraction was O.D. -11.75 -2.25 ; O.S. -9.0 -2.00 (unfortunately, figures for axis are not available).

The approximately 5 diopter increase in the degree of myopia suggests that the vitreous pressure had accommodated the lens to an extreme degree. It is important to note that I was 35 years old at the time, far beyond the age at which myopia increases normally occur.

Because the secondary focal point had produced an almost clear image, it was thought that increasing wearing time of the device might move the focal point even closer to the retina and consequently produce a further improvement in visual acuity. The result was too successful. Apparently, further compression had moved the secondary focal point not just to the retina, but to a position behind the retina, as visualized in Figure 2.

Figure 2

Figure 2. Lens shape and focal points after further accommodation



This is suggested by the fact that I was able to perceive nearly sharp images at a distance with a +4 lens. It could be said then that I had become the world’s only high myope/hyperope.

DISCUSSION

The remarkable finding of the creation of two focal points shows that the eye can accommodate without ciliary contraction. This suggests that in nearwork that involves certain eye movements, e.g. reading, the normal degree of accommodation is augmented by vitreous pressure on the lens caused by SO contraction.

Based on these findings, I propose the following hypothesis: The principal cause of myopia is that the crystalline lens is permanently accommodated for near vision, and that a contributing factor in accommodation is vitreous pressure on the lens resulting from contraction of the oblique muscles. This is not to dismiss the contribution of axial elongation, which obviously is important.

THE PERSISTENCE OF ACCOMMODATION

It is significant that the results noted above were not momentary, but persisted after each viewing session ended: both the increased blur and dual vision remained. Eventually, after the experiment was terminated, the 5 diopter increase in myopia began to reverse, i.e. the visual acuity gradually improved over the course of a year (but never returned to its original degree). This confirms that when an eye is accommodated for long periods of time, the lens does not completely revert to its focus for distance viewing when the nearwork task is completed.

The persistence of accommodation is well documented in studies of nearwork-induced transient myopia (NITM). If, after a period of near focus, the gaze is then shifted to a distant object, the result is a temporary myopia (typically 0.25 - 0.30 D), because the eye requires a certain period of time to re-focus for distance viewing. The time required is related to the amount of time spent on the nearwork task: the longer the period of nearwork, the longer the decay time, i.e. the more time is required for the eye to relax its accommodation.

THE CASE AGAINST THE LENS HYPOTHESIS

Study after study has shown that the principal cause of myopia is increased axial length, not increased lens power.

If, in myopic eyes, the lenses are accommodated, they would tend to be thicker than the lenses of emmetropes. Not only is this not true, but, in general, myopic eyes tend to have even thinner lenses than emmetropes.

If accommodation of the lens were true, then myopia could be cured by simply instilling a cycloplegic. This would allow the ciliary muscle to relax and so enable the eye to re-focus for distance vision.

Evidence In Support of the Lens Hypothesis

The hypothesis presented here is based on three claims:
1. Contraction of the oblique muscles can elongate the globe.
2. Compression of the globe moves the vitreous in the direction of the lens.
3. Pressure by the vitreous can alter lens shape and refractive power.

THE OBLIQUE MUSCLES AND AXIAL ELONGATION

That external pressure on the globe can cause it to elongate is supported by an inadvertent finding from a procedure used to treat retinal detachment. Rubin (1967) [5]reported that "…when silicon bands are placed about the equator and tightened to reduce vitreous traction in retinal detachment work, the eyeball becomes longer axially and thereby increases myopia (or lessens hypermetropia). This increase in length is permanent as long as the band remains in place. It apparently does not harm the eye unless it is cinched up too tight, but I have noted up to 5 diopters of change in extreme cases; most average about 1.5 diopters over the prior existing state."

The role of the obliques might elucidate the question of why the crystalline lens fails to compensate for axial elongation Mutti et al (2012)[6]. In children who later become myopic, the lens flattens and loses power to compensate for the lengthening of the globe, i.e. in order to maintain emmetropia. Stated another way, the eye becomes myopic when an independence develops between the anterior segment, the crystalline lens, and the posterior segment, axial growth. The anterior surface radius of curvature averages 7.2 mm in early infancy and flattens by approximately 4.5 mm, reaching 11-12 mm by age 14 years, equal to 18-19 D. A possible answer as to why the lens interrupts this process: compression of the globe by the obliques might release tension on the zonule, allowing the lens to cease flattening and become more spherical. This might be especially true as children start to increasingly engage in nearwork. However, this might be true only for the early stages of myopia onset.

THE EFFECT OF PRESSURE ON THE VITREOUS

That external pressure on the globe can affect the vitreous is supported by an experiment performed by von Pflugk (1935)[7]. He cut windows in the equatorial region of bovine eyes and injected a drop of dye into the anterior vitreous, midway between the ciliary body and the posterior pole of the lens. Pressing against the ciliary body from the outside in a radial direction made the dye move toward the lens capsule.

Luedde (1940) [8]in a study of subluxated lenses, reported that "The demonstration of the fact that there was a concentric impact of the periphery of the vitreous against the zonule and posterior surface of the equatorial zone of the lens when the ciliary contracted…"

VITREOUS EFFECT ON THE SHAPE AND

REFRACTIVE POWER OF THE LENS

Numerous studies confirm that ciliary muscle contraction pulls the vitreous against the lens.

Araki (1965) [9] reported that in experiments on pig, dog and cat eyes, “...it is suggested that tension of the ciliary muscle/zonules stretching from the posterior surface of the lens was increased by forward movement of the ciliary body and consequently it resulted in pressure to the posterior peripheral part of the lens...the increase in pressure of the vitreous body due to contraction of the accommodative muscle is considered to be the most important factor for the transformation of the lens.” (my emphasis).

Suzuki (1971) [10]performed an experiment in which he injected radiopaque material into the vitreous of a cat's eye, which during accommodation moved in a direction indicating that the vitreous was forced against the back of the lens and also somewhat toward the posterior pole of the lens.

An experiment by Koke (1942) [11]produced a similar result. He injected cat eyes with radiopaque material and took X-rays during miosis and mydriasis, which showed that during accommodation the vitreous moved toward the lens and inward toward the optic axis.

LENS NOT SPHERICAL

The lens shape proposed by this hypothesis is supported by a number studies. The common belief that the lens becomes more spherical with accommodation is probably due to the classical experiment by Fincham (1937) [12]

An eye was made to accommodate for distance viewing by the instillation of atropine and then removed from the orbit upward after dissection of the cornea and iris. The profile of the lens can then be photographed and in this condition demonstrates the characteristic shape of the lens when the eye is looking at a distance. He then cut the fibers of the zonule all around and observed that the curvature of the anterior surface of the lens increased markedly and, as he put it, “assumed the shape that it has under maximum accommodation”, i.e. the lens becomes thicker, and this is clearly seen in the photographs taken by Fincham.

This appears to be an invincible argument, conclusive proof of the relaxation theory of accommodation.

Fincham’s error was to assume that cutting all the fibers of the zonule produced the same effect on the lens that occurs in accommodation in a living eye, i.e. complete relaxation of zonular tension.

It is now known that there are three sets of zonules and that in accommodation they do not relax uniformly.

An experiment by Araki (1965) [13]showed that “electric recordings of the changes in tension of the ciliary zonules suggested relaxation of the zonules which was (sic) stretched to the anterior surface of the lens and on the contrary, increased tension of that stretching to the posterior surface (cat and dog eyes)”.

Fincham’s experiment is misleading in another way: it deals only with momentary accommodation. I propose that long periods of accommodation repeated over months or years produces a lens with a different shape: a convex central region and a somewhat flat periphery, as shown in Figure 1.

In an extensive search of the literature I found four papers (there are undoubtedly more) that describe precisely such a lens shape:

In a study of accommodation in the rhesus monkey, Bito et al [14] state that “A possible iridial contribution was also observed during carbachol-induced accommodation in young animals: development of full miosis was prevented by occlusion of the pupil by the anterior-central portion of the lens. Thus it appears that the pupillary margin and/or the sphincter muscle can apply a force to the lens which may steepen the curvature of its anterior-lenticular central portion thus increasing total dioptric power”.

Lowe (1972) [15]reported that “During examination of a large series of eyes that had pupils dilated after peripheral iridectomy...I was struck by the marked curvature of the anterior lens surface within the enlarged pupil. The lens frequently appeared as though it were herniating through the enlarged pupil, with the pupillary margin of the iris seeming to grip the lens.”

Jampel and Mindel (1967) [16]in a report on stimulation of the oculomotor nucleus in monkeys, observed changes “... characterized by a conspicuous forward bulging of the pupillary or central portion of the iris which produced a marked convexity of the iris diaphragm and a marked increase in the depth of the anterior chamber...On observation of the eye from the side during iris-bulge, the central portion of the lens appeared to become conoidal and to move forward into the anterior chamber.”

It is interesting that the researchers themselves seem surprised by their findings.

Even today, the belief that accommodation simply makes the lens more spherical is widespread. According to Roorda and Glasser (2004) [17:]

“The prevailing view is that the lens becomes more spherical with accommodation due to the molding force of the capsule. ‘Spherical’ does not adequately describe the shape of the accommodated lens because the peripheral area of the posterior surface of the lens is quite different from the anterior surface.”

“The increasing negative spherical aberration of the accommodating lens arises from a more pronounced increase in the optical power near the central region of the lens compared to the peripheral region….this is different to the generally accepted notion that the lens simply becomes more spherical with accommodation….The increase in negative spherical aberration is likely due to the effect of the structure of the lens substance…but may also be due in part to accommodative variations in gradient refractive index of the lens”.

SPHERICAL ABERRATION

The fact that accommodation produces negative spherical aberration is well-established, and a number of studies, including one by Hu, et al, (2004) [18]have shown that spherical aberration is more common in high myopia. Collins et al (1995) [19] report that “A high proportion of the aberroscope grids photographed in myopic eyes were too highly distorted to permit analysis. This was not the case for emmetropic subjects”.

The phenomenon of spherical aberration seems to be widely ignored. Even in basic works such as Adler's Physiology of the Eye, The Myopias (Curtin), Visual Optics and Refraction (Michaels) and The Physiology of the Eye (Davson), the question of spherical aberration is little discussed.

The conventional wisdom that the principal changes occur in the anterior lens was challenged by Patnaik (1967) [20]who wrote that “...the often stated and commonly accepted statement, that it is the anterior lens surface which moves forward while the posterior surface remains stationary and that it is only the anterior surface which changes its curvature during accommodation seems not to be correct.”

Patnaik also commented on the possibility of nuclear changes: “Our observations strongly indicate that during accommodation the increase in the thickness of the anterior cortex is minimal, and that the change in the posterior cortex is greater, and that in the nuclear thickness change is greatest”.

THE PERSISTENCE OF ACCOMMODATION

One of the first to study this phenomenon was Lancaster (1952), [21]

who stated that “When the eye, after an intense effort of accommodation, is shifted to a distant object, although the ciliary muscle may promptly relax, it takes time (a few seconds to a few minutes depending on how long the near effort was continued) for the lens to regain its normal shape adapted to a distance”.

Ong and Ciufredda (1995) [22]in their studies of NITM state that after Lancaster “little was done in this field for the next seven decades, until computer display terminals became commonplace, and symptoms related to their use became prevalent”. However, these more recent studies have attributed this slow recovery time only to the ciliary muscle in the form of changes in tonic accommodation; the possible role of the viscosity of the lens has not even been considered.

They state that “with the continuous high level of accommodative effort necessary to maintain accurate focus, the accommodative hysteresis that was reflected in the (presumed) increased level of tonic accommodation developed as a consequence of increased innervation due to gradual fatiguing of the accommodative system. This myopic increase would then be carried over to distant viewing”.

They go even further: they make the case for the very hypothesis proposed here: “It has been suggested that that these effects might be cumulative over time following successive periods of near tasks, with the transient myopia perhaps evolving into a more permanent form of myopia. For example, it is conceivable that prolonged and repeated periods of nearwork over extended periods of time would result in NITM that failed to decay in some susceptible individuals”.

It is interesting that lens viscosity is widely accepted as an explanation of presbyopia. yet this factor is ignored in theories of myopia.

The slowness of lens changes has been studied by other investigators, not as due to ciliary fatigue, but to lens viscosity.

According to Kikkawa and Sato (1963) [23]Application of an external force to the lens caused a rapid deformation followed by a second phase of slow deformation. On removal of the force, a rapid partial reversal of the deformation occurred and was followed by a gradual restoration; complete recovery was not achieved (my emphasis).

Kabe (1967) [24]reported a similar result from his investigations. He showed that when accommodation is increasing, the change in the apparent curvature of the anterior surface of the lens is slow and continuous, but when accommodation is decreasing, there is a prompt, followed by a slow phase.

Retinal Defocus as a Cause of Elongation

The connection of nearwork with myopia is well established. However, because myopia researchers believe that of the three major determinants of refractive power, the lens is the least important, they have tried to explain the nearwork/myopia connection by claiming that nearwork causes the eye to elongate, and one of the mechanisms they propose is retinal defocus.

It is thought that if a lag of accommodation occurs during nearwork, the amount of accommodation is less than required for a given distance and, with a reduced accommodative response, the retinal image will be defocused, i.e. the target will be focused behind the retina, and a supranuclear mechanism causes the eye to elongate.

The rationale for this theory is derived from animal studies that show that degraded retinal images produce substantial myopia in a variety of different species. For example, when negative lenses are worn by monkeys, which produce hyperopic defocus (the retinal blur from a focal point situated behind the retina), the monkeys' eyes elongate.

It is difficult to understand belief in this theory because the only direct evidence that retinal defocus produces myopia in humans comes from cases of severe image degradation caused by conditions such as vitreous hemorrhage, corneal opacity and traumatic cataract.

In addition, contrary evidence is found in cases of ocular pathology such as albinism and maculopathies, which impair foveal vision in children and is frequently associated with hyperopia.

In any case, even the animal studies are not entirely consistent. In studies of kittens, Ni and Smith (1989) [25]showed that minus lenses did produce axial elongation, but so did plus lenses.

Amore recent view by Hung, G.K. and Ciufredda, K. J. (2002) [26]is that the detection mechanism does not depend on the sign of the blur, but rather on the change in blur magnitude during genetically-programmed ocular growth.. In any case, the retinal defocus hypothesis refers to the period of ocular growth of the eye, which ends at about the age of 17. Consequently, it does nothing to explain adult-onset myopia.

It is almost inconceivable that tens of thousands of studies in physiological optics could have missed the significance of the lens in myopia. There are three possible reasons:

1) The difficulty of determining internal changes in the lens.

2) Excessive trust in the reliability of many of the most basic assumptions about the eye.

3) Researchers have apparently assumed that a thin lens must necessarily be of low power.

Otsuka (1970) [27] commented on the difficulty of studying the posterior surface of the lens: "...the exact radius of the posterior lens surface is impossible to determine because of the lack of knowledge regarding the internal change of the lens substances."

He also suggested the possibility of a thin, yet high power, lens: "the thicker the lens became during accommodation, the thinner the lens became annually." This is intriguing, but unfortunately he did not elaborate.

Smith, G. (2003) [28]confirms the difficulty of such measurements: "It is now possible to accurately measure the aberrations of the whole eye using the Hartrnann-Shack aberrometer and the corneal aberrations via the anterior surface shape. Missing are the shapes of the posterior corneal surface and the anterior and posterior lenticular surfaces'.

FAULTY DATA

Textbooks of ophthalmology give the impression of a solid edifice of knowledge built on firm foundations. Yet at least one researcher, Ludlam, (1967) [29]suggests that some of the most basic facts about the eye are based on faulty data and should be re-evaluated: These include invalid mathematical assumptions, mixed sampling, inadequate experimental technique, and oversimplified models of the refractive system, some of these dating from the nineteenth century:

Nevertheless, the analyses and conclusions drawn from such studies can be no better than either the methods of acquisition of the basic data or the validity of the assumptions underlying the mathematical formulation of the ocular model. It is well to note that in all of these studies the model of the ocular system utilized has consisted of:

Spherical refracting surfaces (my emphasis), causing a systematic under-estimation of the paraxial refracting power of each surface.

Schematic refractive indices, invariant in the population--which assumes that all variability in the ocular refracting system derives only from differences in curvature and spacing of the ocular elements, thus again underestimating both the number of variables in a given eye and the true variability for each component actually existing in the population Ahomogeneous monoindicial lens (my emphasis).This places a high order of importance on the accuracy and precision of the measures of curvature of both the anterior and posterior surfaces of the lens and concomitantly increases the potential effects of spherical assumption.

In addition, in none of these studies have all the refractive components of any given eye been measured. There has always been at least one component whose value was calculated from the other measured elements, so that the measurement errors would all tend to accumulate in the non-measured element.

Since the measurement errors have not always been stated with sufficient clarity to enable the effects of these errors to be assessed, the probability exists that measurement errors have contributed substantially to spurious correlations of measured and calculated elements, as for example between the lens and axial length.

FURTHER EVIDENCE FOR THE LENS HYPOTHESIS

A device was constructed for the purpose of applying vibration to the eye in order to see if it had any effect on the lens. Application was through a soft rubber tip placed on the upper eyelid and vibrated at a rate of 60 Hz and amplitude of 1 mm. The vibrated eye was abducted as far as possible and the other eye was occluded

The result was that initially the visual acuity improved significantly. This suggests that the lens had been accommodated, and that vibration had “softened” the lens, allowing it to revert to a less accommodated state. However, since the subject, the author, was then in the early stages of presbyopia, it was assumed that further improvement was prevented by lack of flexibility of the lens substance.

It could be argued that a different mechanism was operating, e.g. that vibration shortened the globe. However, the evidence that it was the lens is provided by a phenomenon that appeared early in the experiment: increased color brightness and the perception of blackness. It never occurred to me to question what black looks like, but with vibration of the eye there was a marked intensification in the appearance of black objects.

The explanation may be that because in a high myope, light rays are dispersed on the retina in the form of blur circles; as lens power decreases, the blur circles shrink, and the rays are concentrated in a progressively smaller area, resulting in increased density of color or blackness. This phenomenon suggests strongly that vibration produced a decrease in lens power.

DISCUSSION

PRACTICAL CONSIDERATIONS

The role of the obliques and long-term accommodation shown in this experiment lends support to the recommendation that the development of myopia, especially in the young, can be mitigated by frequent rest periods from nearwork, especially reading, by looking at a distance. Some ophthalmologists and optometrists now recommend this, but it should be more widely advocated.

THE FAILURE OF THERAPEUTIC MEASURES

The lens/vitreous hypothesis provides a possible explanation for the failure, or at least disappointing results, of therapeutic measures aimed at preventing or slowing the progress of myopia, such as cycloplegics, and progressive addition spectacle lenses. In both cases, they undoubtedly reduce ciliary muscle contraction, but for only a few hours at a time, while the lens may require far more time for a significant reduction in the degree of accommodation.

More importantly, in both these regimens the subjects are permitted to continue doing nearwork, so that even if complete relaxation of the ciliary muscle were achieved, accommodation could still have been maintained, at least partly.

It would be difficult to replicate the experiment because of the ethical problem of potential harm, e.g. causing a subject to become myopic.

A possible alternative would be to replicate the vibration experiment, not with a human subject, but by using the enucleated lens of a myope, subjecting it to vibration and measuring changes in shape or structure of the lens and/or globe that might mimic the changes that occur with relaxation of accommodation in a living eye.

Another possibility is to apply external pressure to an enucleated eye and then use x-rays, computerized tomography or ultrasound to look for any alteration in lens shape or power.

Needless to say, acceptance of the hypothesis proposed here would require an almost complete reversal of opinion.

References

1. Hirsch, M. Refractive Anomalies of the Eye. Public Health Service Publication No. 1687, National Institute of Neurological Diseases and Blindness. 1967. Page 4.
2. Curtin, B. The Myopias. Philadelphia. Harper and Row. 1985. p.104
3. Fender, D. Extension of Panum's fusional area in binocularly stabilized vision. J Opt Soc Am 1967; 57:819-830.
4. Ivanoff, A. Au Sujet de l'Aberation spherique de l'oeil. Optica Acta 1956 3:47-48.
5. Rubin, M. In Refractive Anomalies of the Eye 1967 Public Health Service Publication No. 1687, National Institute of Neurological Diseases and Blindness.
6. Mutti, D.O. Corneal and Crystalline Lens Dimensions Before and After Myopia Onset. Opt Vissci 2012;
7. von Pflugk. New ways in the study of accommodation. The vitreous in the accommodating eye. Graefes Arch Clin Exp Opthalmol 1935;33:545-558.
8. Luedde, W.H. What subluxated lenses reveal about the mechanism of accommodation. Department lof Ophthalmology, St. Louis University School of Medicine. Presented at the Sectional Meetingof the American College of Surgeons, Detroit. Michigan, April 2, 1940.
9. Araki, M. Changes of the ciliary region and the zonule in accommodation, Jpn J Ophthalmol 1965;9:50-58.
10. Suzuki, H. Observations on the intraocular changes associated with accommodation. Jpn J Ophthalmol 1971;15:47-48.
11. Koke, M. Mechanism of accommodation. Arch Ophthalmol 1942;27:950-968.
12. Fincham, E F. The Mechanism of Accommodation. Br J Ophthalmol Ophthalmology 1937 (Supplement).
13. Araki, M. Changes of the ciliary region and the ciliary zonule in accommodation. Jpn J Ophthalmol 1965; 9:50-58.
14. Bito, L.Z., Kaufman, P.L., Neider, M.W. and Miranda, C.O. The Rhesus Monkey Eye as a Model for the Mechanism of Accommodation, and the Etiology of Presbyopia and Other Aspects of Ocular Aging. Proceedings of the International Society for Eye Research, Volume III.
15. Lowe, R F. Anterior lens curvature. Comparison between normal yes and those with primary angle-closure glaucoma. Br J Ophthalmol.1972; 56:409-413. 16
16. Jampel, R S. and Mindel, J. The nucleus for accommodation in the midbrain of the macaque. Invest Ophthalmol Vis Sci 1967 6: 40-50.
17. Roorda and Glasser. Wave aberrations of the isolated crystalline lens, J Vision 2004; 4:250-261.
18. Hu, JR, Yan, ZH, Liu, CF, Huan, LM, Higher order aberrations in myopic and astigmatism eyes. Zhongua Yan Ke Za Zhi, 2004 Jan. 40:(1):13.
19. Collins, M.J., Wildsoet, C.F. and Atchison, D.A. Monochromatic aberrations and myopia. Vision Res 1995;35:1157.
20. Patnaik, B. A photographic study of accommodative mechanisms, changes in the lens nucleus during accommodation. Invest Ophthalmol Vis Sci 1967;6:601-611.
21. Lancaster,W. Refraction and Motility. Springfield, Charles C. Thomas.1952
22. Ong, E, Ciufredda, KJ Nearwork-induced transient myopia. Doc Ophthalmol 1995;91:57-85.
23. Kikawa, Y. and Sato, T. Elastic properties of the lens. Exp Eye Res 1963;2:210-215.
24. Kabe, S. Dynamic aspects of accommodation. Photographic records of the 3rd Purkinje-image showing changes in size associated with accommodation. Rincho Ganka (Jpn J Clin Ophthal) 1967;21:341-352.
25. Ni, J. and Smith, E.L. Effect of chronic optical defocus on the kitten's refractive status. Vis. Res.1989;29:929-938.
26. Hung, G.K. and Ciufredda, K.J. A Unifying theory of Refractive Error Development. Bulletin of Mathematical Biology 2002;62:1087-1108
27. Otsuka, J, Hirano, S, Suzuki, K, and Imagawa, N. A new approach to the theory of accommodation. Excerpta Medica International Congress Series No. 222 1970.
28. Smith, G. The optical properties of the crystalline lens and their significance. Clin Exp Opt 2003 86.1 Jan. 2003.
29. Ludlam, W. Refractive Anomalies of the Eye. Public Health Service Publication No. 1687, National Institute of Neurological Diseases and Blindness, Monograph No. 5, U.S. Department of Health, Education and Welfare. (1967)

Author Information

Richard McCollim