

DOES THE LENS DIAMETER INCREASE OR DECREASE DURING ACCOMMODATION? HUMAN ACCOMMODATION STUDIES: A NEW TECHNIQUE USING INFRARED RETRO-ILLUMINATION VIDEO PHOTOGRAPHY AND PIXEL UNIT MEASUREMENTS*

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ABSTRACT

Purpose: To describe a new technique for viewing and measuring the lens diameter during accommodation.

Methods: The accommodative lens activity, in a young female carrier of ocular albinism, was evaluated using retro-illumination infrared video photography and pixel unit measurements.

Results: Right and left lens diameter measurements were 498 pu and 501 pu, respectively, during natural accommodation. In pharmacologic non-accommodation (Tropicamide), the average lens diameter was 524 pu (range 518-528) while in accommodation (Pilocarpine), the average lens diameter was 485 pu (range 479-491).

Conclusions: Right and left lens measurements were essentially identical. All measurements were reliable, repeatable and extremely accurate. The lens diameter consistently reduced during accommodation and enlarged during non-accommodation.

The theories, similar to Tscherning's, which imply that the lens diameter increases in accommodation, are clearly disproven.

INTRODUCTION

The mechanism of accommodation of the human lens continues to be a subject of intense debate. Recent interest in refilling the lens following cataract surgery has heightened research on accommodative mechanisms.

Recently, a number of articles modifying Tscherning's theory, which in his lifetime he could never prove, have been resurrected and repropounded.¹⁻³ In short, such a theory postulates an active mechanism of accommodation

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where the central lens becomes more convex while the peripheral lens becomes flattened (ie, the lens diameter increases and the central lens anterior and posterior distance increases). This is proposed in spite of a vast body of contradictory information in the literature which implies that the lens diameter (whether measured vertically, horizontally, or in any degree from peripheral edge to peripheral edge) is reduced during accommodation and not enlarged.⁴⁻¹¹ Unfortunately, since many of the observations which show the lens diameter to decrease were made indirectly, or in deformed, diseased, injured, surgically altered, or postmortem eyes, the proponents of the Tscherning's theory quickly discount their validity.

The question then is simply, Does the lens diameter increase or decrease during human accommodation?

Unpublished reports of ultrasound and magnetic resonance imaging by Coleman and Glew have implied a lens diameter reduction (D.J. Coleman, personal communication, 1996).¹² Except in injured or congenitally deformed eyes, such as in aniridia, the lens periphery is not visible and has never been seen to be recorded in "normal" eyes owing to masking of the iris.

This report describes a new technique for dynamically viewing the lens periphery and measuring, with extreme accuracy, the lens diameter in varying degrees of accommodation, naturally as well as under pharmacologic influence. To my knowledge, this technique of unmasking the iris has never been used as a tool for study of the lens and accommodation.

METHODS

The accommodative lens activity in a young female carrier of ocular albinism was evaluated using retroillumination infrared video photography. Two studies, 1 month apart, were conducted following a pilot study to work out equipment and mechanical details.

The subject, a healthy 27-year-old woman, is a carrier in a large family of ocular albinism that has been under study for many years. With the exception of lack of normal iris pigment, seen only in retro-illumination, all other aspects of her ocular examination were normal. Vision was 20/20 uncorrected, and the irides appeared normal (brown-grey) with brisk pupillary responses. Near point of accommodation and amplitudes were consistent with her age. There was no nystagmus. Retinal pigment epithelial pigmentation was within a normal range. The subject is highly intelligent, and she cooperated fully with all aspects of the studies.

The physical equipment is similar to that used in infrared pupillography. Equipment components were the ZEISS slit-lamp with a photoadapter and infrared filter (Wratten 87) coupled to the IKEGAMI CCD

camera imaging system and Sony VCR SVO1610 with a Boeckler on-screen cursor. Pixel unit (pu) measurements of the changes were recorded (and photographed) using the NEWTEK VIDEOTOASTER and JVC BR-S822U and SVHS tape deck. Pixel unit measurements were used because they are far more accurate than metric.

Fixation cards were run between near point to infinity, and control of the angle created by convergence was eliminated by always directing the camera parallel to the lens-iris diameter plane. In addition, measurement was taken only in frames where the circular light was concentric with the pupil, guaranteeing no angle deformity. Use of crossover techniques of evaluating 1 eye and then the other under similar studies eliminated the variables between the 2 eyes. Infrared lighting precluded light as a variable.

The subject's lenses were easily seen in retro-illumination. The diameter was recorded during stages of natural accommodation as well as pharmacologic extremes using pilocarpine 2% and tropicamide 1%. The pupillary response always corresponded to the direction of accommodation, that is, constriction with accommodation and dilatation with nonaccommodation.

RESULTS

The results are recorded in Table I and illustrated in Figures 1 through 4. Right and left lens diameter measurements were 498 pu and 501 pu, respectively, during natural mild to moderate accommodation. In pharmacologic nonaccommodation (tropicamide), the average lens diameter was 524 pu (range, 518 to 528), while in accommodation (pilocarpine), the average lens diameter was 485 pu (range, 479 to 491). There was a distinct refractive circumferential line at the lens periphery, which seemed to become stronger with accommodation. There was absence of such a concentric circle around the center of the lens, which one would expect if the Tscherning theory were correct.

DISCUSSION

The proponents of Tscherning's theory (which basically states that owing to increased vitreous pressure, the zonular fibers become tightened, enlarging the peripheral lens and increasing the central lens thickness) have tried to show with ultrasound (UBM) that the lens edge and the ciliary body distance are shorter during accommodation.² Unfortunately, their data are based on unreliable echoes, and only one edge of the lens is examined.

Grossmann,⁴ Story,⁵ and Fincham⁶ studied and/or photographed the

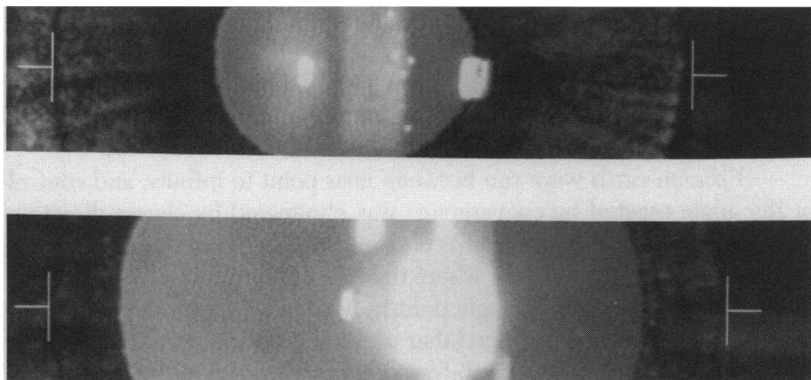


FIGURE 1

Comparison of accommodation (above) and nonaccommodation (below). Cursors mark lens edge.

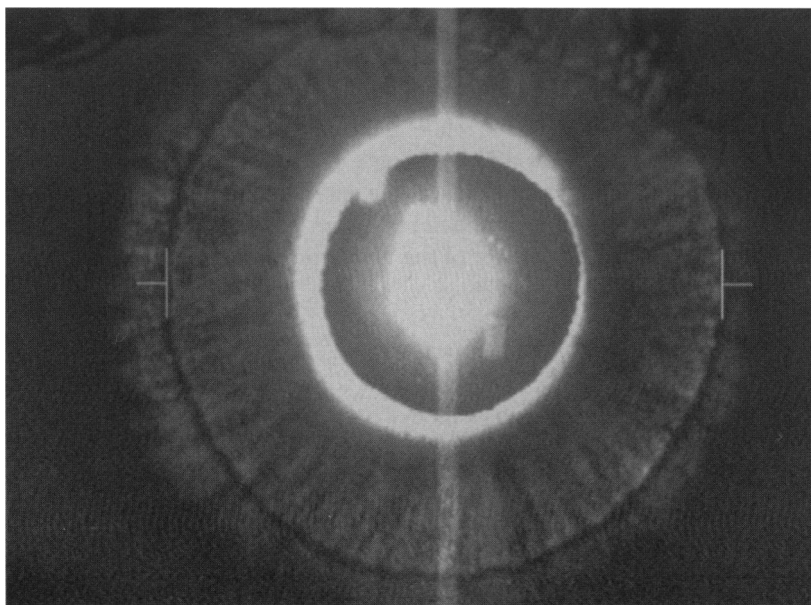


FIGURE 2

Normal mild-moderate accommodation (diameter 500 pu).

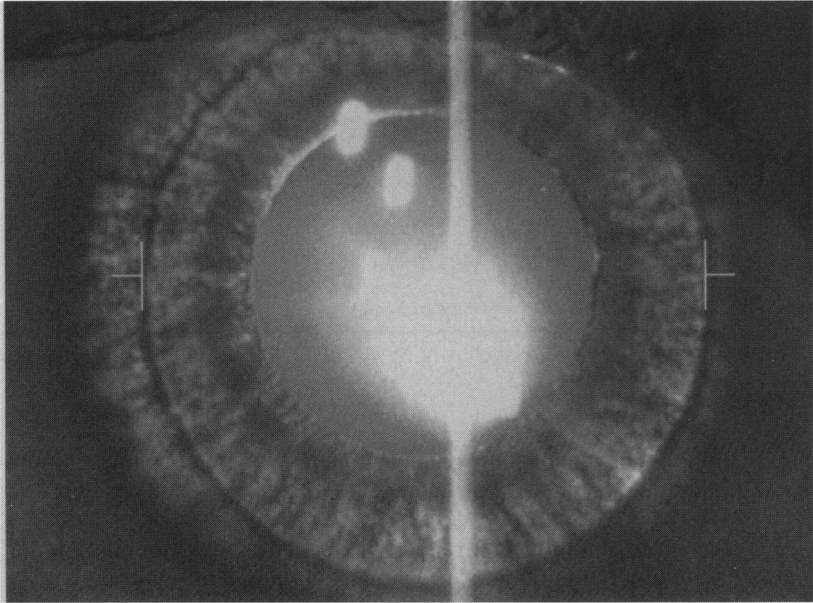


FIGURE 3

Nonaccommodation (tropicamide 1%) (diameter 525 pu).

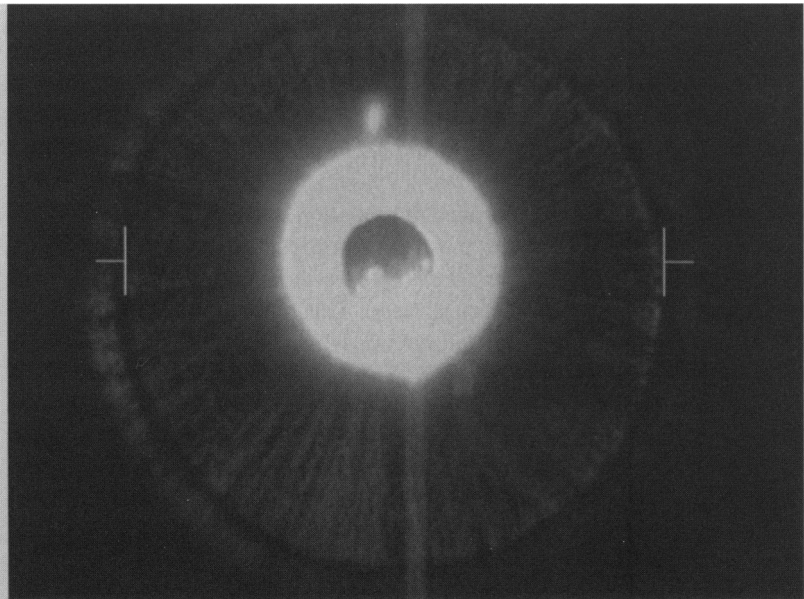


FIGURE 4

Accommodation (pilocarpine 1%) (diameter 486 pu). Concentric circle of light to pupil guarantees alignment. Vertical line is a video artifact known as "vertical smear," not slit beam.

TABLE I. ACCOMMODATIVE LENS ACTIVITY

NONPHARMACOLOGIC (MILD-MODERATE ACCOMMODATION)	TROPICAMIDE 1% (NONACCOMMODATION)	PILOCARPINE 2% (ACCOMMODATION)
OD - 498 pu	OD - 525 pu	OD - 479 pu
OS - 501 pu	OS - 518 pu	OS - 491 pu
(Range 491-501)*	OS - 528 pu	OS - 486 pu
	(Average 524 pu)	(Average 485 pu)

*5 measurements.

lens diameter in aniridia. All confirmed that the lens diameter was less in accommodation (12.25 to 10.25 mm). Libby studied an albino in which the accommodation decreased from 10 mm to 9 mm.⁷ Fisher's histology of monkey eyes in pharmacologic accommodation and nonaccommodation showed a similar reduction in diameter.⁹

The present investigation uses the most accurate method of measurement—pixel units. It also measures the lens from edge to edge, which was not done by proponents of Tscherning's theory in their experiments. The reproducibility and accuracy of the method used in this paper make it a valuable tool to study more dynamically the nature of accommodation.

Right and left lens measurements were essentially identical. All measurements were reliable, repeatable, and extremely accurate. The lens diameter consistently reduced during accommodation and enlarged during nonaccommodation. There was a 7% constriction between pharmacologic accommodation and nonaccommodation, consistent with the percentage necessary to produce maximal anteroposterior convexity seen in accommodation of the human lens. No refractive circle was seen anywhere on the lens except at its periphery. This technique might be applicable for dynamic (time measurement) of lens changes during accommodation.

The theories similar to Tscherning's, which imply that the lens diameter increases in accommodation, are clearly disproven with infrared retroillumination video photography measurements of the lens.

ACKNOWLEDGEMENTS

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DISCUSSION

JACKSON COLEMAN, MD. Dr Wilson has presented unique and important observations on the equatorial changes of the lens during accommodation.

The major aspects of accommodation have generally been agreed on over the seven score years since Helmholtz presented his capsular theory; even though several areas of disagreement remain. Agreement generally exists as to the shape of the lens and position of the lens in the accommodated state, i.e. the lens rounds up and the anterior surface of the lens is more steeply curved centrally. The posterior surface of the lens changes only slightly as to position and curvature.

Disagreement exists as to the mechanism of producing the lens change in shape. Capsular elasticity (Helmholtz); vitreous support of lens with iris flattening of the anterior lens periphery (Tscherning); vitreous support with catenary-like shaping of the anterior lens (Coleman); zonular compression of the lens equator (Wilson).

Other theories have been proposed and recently a radical view that surgical intervention may be possible to strengthen accommodation in the aging eye (Schachar). This theory proposes that the equator of the lens is

actually pulled closer to the ciliary body by equatorial zonular fibers and high frequency ultrasound was used to purportedly demonstrate this feature. The ultrasound analysis is not accurate in that the measurements are of very small segments of the lens and do not properly utilize the acoustic velocity variation produced by transit through the ciliary body. Dr Wilson's analysis with optical methods demonstrates the spurious nature of the Schachar analysis in a most succinct and forceful manner - better perhaps than pointing out the physical misinterpretations of the Schachar analysis.

Dr Wilson is to be congratulated on his clear demonstration of the equatorial reduction in lens diameter during accommodation. It may help prevent un-beneficial surgery.

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DOUGLAS D. KOCH, MD. Thank you Dr Spencer, and I would also like to congratulate Dr Wilson for his paper. The correction of presbyopia is a topic of great interest in refractive surgery. There are 2 types of clinical studies underway that are based on the Schachar theory. One of them consists of making radial scleral incisions, somewhat akin to radial keratotomy. In this instance, the incisions are made transconjunctivally into the sclera in order to permit circumferential scleral expansion. There have been some anecdotal data suggesting that these incisions can increase accommodative amplitude, but I have not seen any data from long-term studies. In the other studies that have been alluded to, I have had the opportunity to see 2 postoperative patients. This technique consists of placing a plastic band through scleral loops in the anterior sclera in the region of the ciliary body. By expanding the scleral band, one can allegedly increase scleral diameter and thereby increase the space between the lens and the ciliary body. This approach is based on the hypothesis that growth of the lens is the major cause of presbyopia. These studies are being conducted by Dr. Richard Yee of the University of Texas in Houston. One patient whom I saw had markedly increased accommodative ampli-

tude. However, what was equally striking was that this patient had an increase in accommodative amplitude in the eye that did not undergo surgery. The investigators were puzzled by this finding. I believe that these studies have been, for the time being, terminated in the United States, but are about to be reinstated in Europe. Dr Wilson's work is therefore very timely. A question for Dr Wilson is, based on your study, what is your feeling with regard to the likelihood of success of procedures that involve some form of scleral expansion? Also, have you studied eyes with aniridia, which might also serve as an excellent model for your methodology?

PAT WILKINSON, MD. Dr Wilson, congratulations on a terrific paper. I have been interested in the relationship between miotics and retinal detachment. For years, as you well know, it has been proposed that miotic agents induce vitreous changes that cause retinal tears. Even though no proposed mechanism has ever really satisfactorily explained this, the polls have shown that a majority of ophthalmologists still believe the relationship exists. So, my question is, Did you see anything or learn anything or do you know anything about the possible relationship between changes in the lens shape, subsequent vitreous changes, and the production of retinal tears?

SLOAN WILSON, MD. Thank you for your comments. I appreciate once again, Dr Coleman, the nice summary of your theory and confirmation that the lens diameter does decrease during accommodation.

Related to Dr Koch's question - I'm certainly familiar with Dr Schachar's work to which Dr Coleman also alluded. I think it is a rather unusual procedure, to say the least. Of course, it's not up to me to decide its merits or whether it should be funded in continued studies. I have no basis to assume that Dr Schachar's Theory is correct considering what we've seen experimentally or what the literature shows. In relation to your question about aniridia the answer is yes. Some of the earliest studies, which show the lenses decrease in diameter were done in patients with aniridia but their measuring techniques were not accurate like the pixel unit measurements which I used. Nevertheless, they showed quite clearly a diameter decrease in accommodation. While I have seen patients with aniridia I have not had an opportunity to study one with infrared video photography. Some have questioned that because of the aniridia deformity, it may not represent what happens in an otherwise normal human eye's accommodation.

Related to Dr Wilkinson's question about miotics and retinal detachment, I can only say, that I have no more experience than any other surgeon. However, I certainly agree that there appears to be a temporal rela-

tionship between eyes which receive miotics and retinal detachment. It's easy for me to conceive that what we see only as miosis of the iris is actually a sustained effect of the accommodative mechanism and the ciliary body. If my theory is correct, compression of the peripheral lens and the moving of the vitreous in this area could pull tears in certain eyes. I can't discount the accommodative mechanism as being a major part in these rare cases, even in aphakia. The ciliary muscle is very powerful and does not lose power with age.