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# Axial length changes during accommodation in myopes and emmetropes

Scott A Read (PhD)
Michael J Collins (PhD)
Emily C Woodman (BAppSci Optom (Hons))
Shiow-Huoy Cheong (BAppSci Optom (Hons))

Contact Lens and Visual Optics Laboratory
School of Optometry
Queensland University of Technology
Room D517, O Block, Victoria Park Road, Kelvin Grove 4059
Brisbane, Queensland, Australia
Phone: 617 3864 5739, Fax: 617 3864 5665
Email: sa.read@qut.edu.au

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## Abstract:

**Purpose:** To investigate the influence of accommodation upon axial length (and a comprehensive range of ocular biometric parameters), in populations of young adult myopic and emmetropic subjects.

**Methods:** Forty young adult subjects had ocular biometry measured utilizing a non-contact optical biometer (Lenstar LS 900) based upon the principle of optical low coherence reflectometry, under three different accommodation demands (0 D, 3 D and 6 D). Subjects were classified as emmetropes (n=19) or myopes (n=21) based upon their spherical equivalent refraction (mean emmetropic refraction -0.05 ± 0.27DS and mean myopic refraction -1.82 ± 0.84 DS).

**Results:** Axial length changed significantly with accommodation, with a mean increase of 11.9 ± 12.3 μm and 24.1 ± 22.7 μm for the 3 D and 6 D accommodation stimuli respectively. A significant axial elongation associated with accommodation was still evident even following correction of the axial length data for potential error due to lens thickness change. The mean 'corrected' increase in axial length was 5.2 ± 11.2 μm, and 7.4 ± 18.9 μm for the 3 D and 6 D stimuli respectively. There was no significant difference between the myopic and emmetropic populations in terms of the magnitude of change in axial length with accommodation, regardless of whether the data were corrected or not. A number of other ocular biometric parameters, such as anterior chamber depth, lens thickness and vitreous chamber depth also exhibited significant change with accommodation. The myopic and emmetropic populations also exhibited no significant difference in the magnitude of change in these parameters with accommodation.

**Conclusions:** The eye undergoes a significant axial elongation associated with a brief period of accommodation, and the magnitude of this change in eye length increases for larger accommodation demands, however there is no significant difference in the magnitude of eye elongation in myopic and emmetropic subjects.

**Keywords:** myopia, accommodation, axial length, eye biometrics

## Introduction:

Near work has previously been found by a number of investigators to be one environmental factor associated with the development, presence and progression of myopia.[1-4] Whilst the association between myopia and near work has been established by a number of authors, the exact reason underlying this association is still unclear, and there is some debate over the causal nature of these associations.[5] Attempts to establish a causative mechanism linking myopia and near work have been one motivating factor behind previous research investigating ocular changes associated with accommodation.

When the eye accommodates to focus on near objects the dimensions of the anterior eye undergo a number of changes. Accommodation is known to lead to a steepening of the curvature of the anterior and posterior crystalline lens surfaces, an increase in crystalline lens thickness, an anterior movement of the anterior lens surface, and a posterior movement of the posterior lens surface.[6-11] These changes in crystalline lens dimensions lead to a concomitant shallowing of the anterior chamber, and an increase in the anterior segment length (distance from the cornea to the posterior lens surface).[7,10,11] These biometric changes in the crystalline lens have also been shown to be linearly related to the ocular refractive changes associated with accommodation.[10,11]

Whilst changes in the crystalline lens and anterior eye dimensions are the most prominent consequence of accommodation, changes in structures posterior to the crystalline lens have also been found to occur. Moses[12] reported that a stretching of the peripheral retina accompanied accommodation, with 0.05mm anterior movement of the ora serrata noted per dioptre of accommodation. There have also been reports of significant spatial distortions in vision,[13-15] and alterations in the Stiles Crawford function accompanying marked accommodation,[16] which also implies that stretching/distortion of more central retinal elements may also be associated with accommodation, although recent findings suggest changes in the Stiles Crawford effect with lesser amounts of accommodation are small.[17] The introduction of highly precise non-contact, partial coherence interferometric (PCI) methods for assessing axial length has also revealed that small, transient changes in eye length accompany accommodation. Drexler et al[18] reported an increase in axial length of mean magnitude ~5-12 µm associated with accommodation (mean accommodation level of 4-5D) in young adults that was noted to be of larger magnitude in emmetropes compared to myopes. More recently, Mallen et al[19] also reported an accommodative induced elongation of the eye to occur in young adults, but the magnitude of elongation was larger (mean magnitude of ~48 µm change for a 6D accommodation stimulus) and myopes were reported to exhibit significantly greater elongation than emmetropes.

There have been only a relatively limited number of studies examining the influence of accommodation on eye length, and whilst these studies have consistently found eye elongation to accompany accommodation, there are inconsistencies between studies in terms of the reported magnitude of eye length change, and the relative differences in eye elongation between myopes and emmetropes. We therefore aimed in this study to further examine the influence of accommodation on eye length in young adult emmetropic and myopic subjects, utilizing a newly introduced biometer based on the principle of optical low coherence reflectometry (OLCR) that is capable of measuring a comprehensive range of ocular biometric parameters.

## Methods:

Forty young adult subjects aged between 18 and 33 years of age (mean age 25 ± 4 years) participated in this study. Subjects were recruited primarily from the students and staff of our university. All subjects were free of any ocular or systemic disease and no subject reported any history of significant ocular trauma or surgery. Approval from the university human research ethics committee was obtained prior to the commencement of the study and all subjects provided written informed consent to participate. All subjects were treated in accordance with the declaration of Helsinki.

Prior to the study, each subject underwent an eye examination to ensure good ocular health, determine their refractive status and to confirm they exhibited monocular amplitude of accommodation of ≥7D (as measured with the push-up method). All subjects exhibited normal visual acuity of logMAR 0.00 or better and no subject exhibited a cylindrical refraction of >1.00 DC. Subjects were classified as either emmetropes or myopes, based upon their best sphere subjective spectacle refraction, with the emmetropes exhibiting best sphere refraction between +0.50DS and -0.50 DS, and the myopes exhibiting best sphere refraction of ≤ -0.75 DS. Nineteen of the 40 subjects were emmetropes (mean spherical equivalent refraction -0.05 ± 0.27 DS, mean cylindrical refraction -0.17 ± 0.16 DC), and 21 were myopes (mean best sphere refraction -1.82 ± 0.84 DS, mean cylindrical refraction -0.48 ± 0.27 DC). The mean age of both the emmetropic and myopic populations was 25 ± 4 years. The gender balance between the two populations was well matched, with the emmetropic population consisting of 57% and the myopic population 58% female subjects. The two populations were also well matched for ethnic background with subjects having either Caucasian (15 emmetropes, 16 myopes), East Asian (2 emmetropes, 3 myopes), or Indian (2 emmetropes, 2 myopes) ethnic backgrounds.

Following these preliminary ocular measurements, each subject then underwent ocular biometric measures, under three different levels of accommodation. All biometric measurements were carried out on the right eye only (the left eye was occluded for all measurements), using the Lenstar LS 900 instrument (Haag Streit AG, Koeniz, Switzerland). This instrument is a non-contact optical biometer, based upon the principle of optical low coherence reflectometry that provides a range of ocular axial biometric measurements (i.e. corneal thickness, anterior chamber depth, lens thickness and axial length) simultaneously in a single measurement procedure. The ocular biometric measurements from the Lenstar instrument have been shown to be reliable, highly precise and comparable with previously validated instruments.[20-23]

To allow biometry to be performed whilst subjects were accommodating to different accommodative stimuli, we used a similar experimental setup to that of Mallen et al,[19] consisting of a high contrast Maltese cross target viewed through a beamsplitter and a +10 D Badal lens mounted in front of the Lenstar instrument (Figure 1). The plate beamsplitter used exhibited 82% transmittance for the Lenstar's 840nm wavelength. Prior to data collection, we confirmed that introducing a beamsplitter in front of the instrument did not lead to any significant change in biometric measures on the Lenstar test eye or on five human subjects. The mean corneal thickness (531 ± 23 μm without beamsplitter, and 531 ± 23 μm with beamsplitter), anterior chamber depth (3.05 ± 0.34 without and 3.03 ± 0.36 with beamsplitter), lens thickness (3.66 ± 0.28 without and 3.68 ± 0.29 with beamsplitter) and axial length (24.05 ± 0.75 without and 24.05 ± 0.75 with beamsplitter) all showed no significant change when the measurements were taken through the beamsplitter. We performed measurements on five subjects with the Canon R-1 Autorefractor and our Badal system and found mean accommodative responses of 2.4 ± 0.3 D and 5.3 ± 0.3 D for the 3 D and 6 D accommodation demand respectively (findings consistent with a small lag of accommodation).

Prior to biometric measurements being carried out on each subject, care was taken to align the centre of the Maltese cross target as viewed through the beam splitter to be adjacent with the instrument's measurement beam. Subjects were instructed to attain and maintain clear focus upon the Maltese cross target throughout the measurement protocol. Once subjects reported the target to be clear, biometric measurements were carried out. A total of 5 repeated biometric measurements were carried out for each subject for each of three different accommodative stimuli (0 D, 3 D and 6 D). A 2 minute break, during which time the subjects fixated in the distance, was given in between each accommodative task.

**Analysis:**

The mean of each of the following ocular biometric measurements at 0 D, 3 D and 6 D accommodation demand for each subject were derived from the Lenstar's data output: central corneal thickness (CCT, the distance from the anterior to the posterior corneal surfaces), anterior chamber depth (ACD, the distance from the posterior corneal surface to the anterior lens surface), lens thickness (LT, the distance from the anterior lens surface to the posterior lens surface), anterior segment length (ASL, the distance from the anterior corneal surface to the posterior lens surface), vitreous chamber depth (VCD, the distance from the posterior lens surface to the retinal pigment epithelium) and axial length (Axl, the distance from the anterior corneal surface to the retinal pigment epithelium). All results are presented as the mean ± standard deviation (SD). For each of the considered ocular parameters, a repeated measures ANOVA with one within subject factor (i.e. accommodation level) and one between subject factor (i.e. refractive error group), was carried out to investigate the change in each of the parameters with accommodation and to determine any differences between the myopic and emmetropic populations.

The exact method and refractive index used by the Lenstar instrument to calculate axial length is proprietary information, however personal communication with Haag Streit revealed that the instrument, in a similar fashion to the IOLMaster instrument, does use an ‘average ocular refractive index’ to convert from optical length to geometric length in the axial length calculations. There is potential as suggested by Atchison and Smith[24] that measurements collected with the instrument during accommodation may overestimate axial length, because the biometric changes associated with accommodation (i.e. thickening of the crystalline lens) effectively lead to an increase in the eye’s average refractive index (as the higher refractive index crystalline lens takes up a relatively larger proportion of the eye during accommodation). However, as the Lenstar also provides the individual ocular component dimensions for each measurement, a reasonable approximation of the potential error associated with the measurements taken during accommodation can be made for each individual subject. We used the formulae and methods outlined by Atchison and Smith,[24] substituting each subjects’ individual ocular component dimensions to provide an indication of the potential error associated with the change in axial length during the 3 D and 6 D accommodation demands for each subject. These values were then used to calculate a ‘corrected’ change in axial length during accommodation for each subject. It should be noted that as the exact refractive index used by the instrument is not known, this ‘corrected’ change in axial length is an approximation. For this reason we present both the measured axial length changes and corrected changes in the results.

## Results:

Accommodation led to a significant change in most of the ocular biometric parameters measured. Table 1 displays the mean biometric parameters for the 3 different levels of accommodation for the myopic and emmetropic populations, and the p-values from the repeated measures ANOVA investigating for significant change in each parameter. All parameters, except for corneal thickness were found to exhibit a significant change with accommodation.

The measured axial length (AxL) was found to undergo a small, but highly statistically significant increase with accommodation ($p<0.001$). A mean ± SD eye elongation of 11.9 ± 12.3 µm (mean myopic elongation of 11.2 ± 12.2 µm, mean emmetropic elongation of 12.6 ± 12.8 µm) was observed for the 3 D accommodation stimulus and 24.1 ± 19.2 µm (mean myopic elongation 23.1 ± 22.7, mean emmetropic elongation 25.2 ± 15.0) for the 6 D stimulus. The magnitude of eye elongation was significantly greater for the 6 D stimulus ($p<0.001$). There was a significant difference in the average AxL between the two populations of subjects with the myopic subjects exhibiting significantly longer eyes on average (mean myopic axial length 24.40 ± 0.60 mm and mean emmetropic axial length 23.71 ± 0.73, $p= 0.003$) however, there was no significant difference found in the magnitude of axial elongation occurring with accommodation between the myopic and emmetropic groups at either of the accommodative demands ($p>0.05$). Figure 2 illustrates the mean change in axial length with accommodation in the two populations of subjects.

Analysis to estimate the potential measurement error associated with axial length calculations during accommodation due to relative changes in each subject's ocular components revealed a mean error of 6.7 ± 4.5 µm for the 3 D and 16.8 ± 5.6 µm for the 6 D accommodation stimulus. The average change in axial length, accounting for each subject's individual estimated measurement error was 5.2 ± 11.2 µm for the 3 D, and 7.4 ± 18.9 µm for the 6 D accommodation stimulus. Repeated measures ANOVA revealed that the change axial elongation (corrected for measurement error due to ocular component change) due to accommodation was still statistically significant (p=0.007). Similar to the measured values, the 'corrected' axial length changes also demonstrated no significant difference in the magnitude of axial elongation between the myopic and emmetropic groups (p>0.05). Figure 3 illustrates the average change in eye length as measured by the instrument, and the change in axial length corrected for the ocular component error.

The majority of the biometric parameters associated with the anterior segment also showed significant change with accommodation (Table 1). Figure 4 provides an overview of the changes observed in each of the considered anterior segment biometric parameters with accommodation. The crystalline lens thickness (LT) increased significantly in all subjects with accommodation (p<0.001), with a mean increase in LT of 143 ± 97µm (myopes 156 ± 93 µm, emmetropes 128 ± 102 µm) for the 3D accommodation stimulus and a mean increase of 356 ± 118 µm (myopes 346 ± 118 µm, emmetropes 367 ± 120 µm) for the 6 D stimulus. These changes in crystalline lens thickness led to a significant shallowing of the anterior chamber depth (ACD) and a significant increase in the anterior segment length (ASL) with accommodation (p<0.001). A mean change in ACD of -121 ± 102 µm (mean myopic change -139 ± 112 µm, mean emmetropic change -102 ± 90 µm) and -292 ± 136 µm (mean myopic change -285 ± 138 µm, mean emmetropic change -300 ± 138µm) was found for the 3D and 6 D accommodative stimuli respectively. The ASL increased on average by 22 ± 51 µm (mean myopic change 16 ± 55 µm, mean emmetropic change 27± 46 µm) and 64 ± 83 µm (mean myopic change 61 ± 68 μm and mean emmetropic change 68 ± 100μm) for the 3D and 6D accommodative stimuli respectively. The change in ASL is indicative of a small backward movement of the posterior lens surface with accommodation. This posterior movement of the posterior lens surface also led to a significant shallowing of the vitreous chamber depth (VCD). The mean change in VCD was -9.6 ± 52 μm (mean myopic change -5 ± 57 μm, mean emmetropic change -15 ± 47μm) for the 3 D stimulus and -40 ± 85 μm (mean myopic change -38 ± 68 μm and mean emmetropic change -43 ± 103 μm) for the 6 D stimulus. Whilst all of these ocular biometric parameters changed significantly with accommodation, the magnitude of change in each of the parameters with accommodation was not significantly different between the myopic and emmetropic populations for each parameter ($p>0.05$). Central corneal thickness did not change significantly with accommodation ($p=0.65$), with the mean change in CCT being less than 1 micron for both the 3D and 6D accommodative stimuli.

## Discussion:

We have demonstrated that a number of ocular biometric parameters associated with both the anterior and posterior segment undergo significant change with accommodation in a population of young adult subjects. Our findings of a significant eye elongation with accommodation that increases for higher levels of accommodation, are in general agreement with the results of Drexler et al[18] and Mallen et al,[19] who also observed increases in axial length associated with accommodation in young adult subjects using instruments based upon partial coherence interferometry, however there are some differences in the magnitude of axial length change and the relative differences between emmetropes and myopes between our study and these previous reports. Whilst there is a potential for the instrument we used to overestimate the change in axial length occurring during accommodation, we found significant axial elongation to be associated with accommodation, even after accounting for this error in our analysis.

Our mean 'corrected' change in axial length (~ 5 μm and ~7 μm for the 3 D and 6 D stimulus respectively), is of similar magnitude to that reported by Drexler and colleagues[18] (~5-12 μm change for 4-5 D of accommodation), and is substantially smaller than that reported by Mallen et al[18] (mean axial length change ~48 μm for a 6D stimulus). Mallen et al[18] used the commercially available IOLMaster instrument for axial length measurements, and as this instrument does not provide lens thickness estimates were not able to correct for the potential error associated with lens thickness change during accommodation highlighted by Atchison and Smith.[24] Drexler et al[18] on the other hand used a PCI instrument that used individual refractive indices to calculate eye length, and reported significant axial length changes that approximate our reported 'corrected' values closely.

We found no significant difference in the magnitude of change in axial length (or in the change in the other measured ocular biometric parameters) with accommodation between our myopic and emmetropic populations, whereas Drexler et al[18] reported a greater change in axial length with accommodation in emmetropes compared with myopes. It should be noted however, that Drexler et al[18] measured the change in axial length associated with accommodation to each of their subject's near point, which lead to slightly unequal accommodation between the two refractive error groups (on average the myopic subjects were accommodating by ~1D less), which may account for some of the difference noted in their study. In our current study, the use of a Badal system allowed equal accommodation demands to be provided to all subjects. Furthermore, the fact that the change in anterior eye parameters (i.e. lens thickness and anterior chamber depth), also exhibited no significant difference between emmetropes and myopes suggests that both populations of subjects were accommodating to the same level for each of the different accommodative demands.

In contrast to our findings, and those of Drexler et al[18], Mallen et al[19] reported a significantly greater eye elongation in their myopic subjects compared to their emmetropic subjects. The difference between our results and Mallen's findings may reflect the characteristics of the specific populations of myopes tested in the two studies. The myopic subjects used in Mallen's study were all early onset myopes (i.e. reported onset of myopia prior to fifteen years of age), whereas our subjects were a mixture of early onset (n=9) and late onset myopes (n=12), which suggests that EOM's may exhibit a larger eye elongation with accommodation. However, when we stratified our subjects according to age of onset of myopia we found no evidence of the early onset myopes exhibiting a significantly greater axial elongation with accommodation than the late onset myopes (mean elongation for the 6 D stimulus was 24 ± 14 μm for our early onset myopes and 23 ± 28 μm for our late onset myopes, which was not a statistically significant difference). Additionally, Mallen et al's[19] myopic population exhibited substantially greater amounts of myopia compared to our myopic population (mean best sphere refraction from our myopic population was -1.8 ± 0.8 DS versus -3.59 ± 0.75 DS from Mallen et al[19]), which leaves open the possibility that higher amounts of myopia are associated with a greater accommodation induced eye elongation. This suggests that structural ocular changes associated with higher amounts of myopia (e.g. changes in scleral biomechanical properties[24]) may also be associated with the eye being more susceptible to accommodation induced transient axial elongation.

The transient increases in eye length accompanying accommodation could potentially provide a link between near work and longer term axial elongation of the eye, and it has been suggested that these changes may therefore be important in the development of refractive error.[18,19] We found consistent eye elongation associated with accommodation across our young adult subjects tested. Whilst the emmetropic and myopic populations examined in our current study did not demonstrate significant differences in the magnitude of change in axial length with accommodation, this does not necessarily preclude the involvement of accommodative induced eye elongation in longer term eye growth in myopia. If these axial length changes are involved in myopia development, then larger amounts of near-work, performed at closer working distances, might potentially be expected to lead to prolonged short term eye length changes of greater magnitude which could potentially predispose a patient to greater amounts of eye elongation in the longer term. It should also be noted, that our findings (and those of others) relate to the change in eye length occurring during a relatively short duration accommodation task. The influence of longer periods of accommodation upon eye length and the time-course of recovery from these accommodation induced eye length changes, and the relative differences in these characteristics between myopic and emmetropic subjects, are areas of research that have not been explored and may help to shed further light upon the potential importance of these axial length changes in refractive error development.

In addition to the changes in axial length, we also found a number of significant changes in anterior segment ocular biometric parameters with accommodation. The changes that we have found in anterior chamber depth, lens thickness and anterior segment length parallel those of previous investigators.[10,11] The use of high resolution measurement techniques has allowed us to confirm the relatively recently established finding that a small backward movement of the posterior lens surface occurs with accommodation.[10,11] We also confirm our previous finding that no significant change occurs in central corneal thickness with accommodation.[26]

In conclusion, this study confirms that significant change in eye length accompanies accommodation in young adults. No significant difference was noted in the magnitude of change in eye length (or the change in biometric parameters associated with the anterior eye), between emmetropes and myopes. Further research investigating the characteristics of these eye length changes associated with near work in more detail may shed light on longer term eye growth and refractive error development.

## Acknowledgements:

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## References:

1. Kinge B, Midelfart A, Jacobsen G, Rystad J. The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. Acta Ophthalmol 2000;78:26-29.

2. Hepsen IF, Evariklioglu C, Bayramlar H. The effect of reading and near-work on the development of myopia in emmetropic boys: a prospective, controlled, three-year follow-up study. Vision Res 2001;41:2511-2520.
3. Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K. Parental myopia, nearwork, school achievement, and children's refractive error. Invest Ophthalmol Vis Sci 2002;43:3633-3640.
4. Saw S-M, Chua W-H, Hong C-Y, Wu H-M, Chan W-Y, Chia K-S, Stone RA, Tan D. Nearwork in early-onset myopia. Invest Ophthalmol Vis Sci 2002;43:332-339.
5. Mutti DO, Zadnik K. Has near work's star fallen? Optom Vis Sci. 2009; 86:76-78.
6. Garner LF, Yap MKH. Changes in ocular dimensions and refraction with accommodation. Ophthalmic Physiol Opt 1997;17:12-17.
7. Drexler W, Baumgartner A, Findl P, Hitzenberger CK, Fercher AF. Biometric investigation of changes in the anterior eye segment during accommodation. Vision Res 1997;37:2789-2800.
8. Kirschkamp T, Dunne M, Barry J-C. Phakometric measurement of ocular surface radii of curvature, axial separations and alignment in relaxed and accommodated human eyes. Ophthalmic Physiol Opt 2004;24:65-73.
9. Dubbelman M, Van der Heijde GL, Weeber HA. Change in shape of the aging human crystalline lens with accommodation. Vision Res 2005;45:117-132.
10. Ostrin L, Kasthurirangan S, WinHall D, Glasser A. Simultaneous measurements of refraction and A-Scan biometry during accommodation in humans. Optom Vis Sci 2006;83:657-665.
11. Bolz M, Prinz A, Drexler W, Findl O. Linear relationship of refractive and biometric lenticular changes during accommodation in emmetropic and myopic eyes. Br J Ophthlamol 2007;91:360-365.
12. Moses RA. Accommodation. In: Moses RA, Hart WM, eds. Adler's physiology of the eye 5th ed. St Louis: Mosby; 1970.

13. Blank K, Enoch JM. Monocular spatial distortions induced by marked accommodation. Science 1973;182:393-395.
14. Hollins M. Does the central human retina stretch during accommodation? Nature 1974;251:729-730.
15. Enoch JM. Marked accommodation, retinal stretch, monocular space perception and retinal receptor orientation. Am J Optom Physiol Opt 1975;52:376-392.
16. Blank K, Provine RR, Enoch JM. Shift in the peak of the photopic Stiles-Crawford function with marked accommodation. Vision Res 1975;15:499-507.
17. Singh N, Atchison DA, Kasthurirangan S, Guo H. Influences of accommodation and myopia on the foveal Stiles-Crawford effect. J Modern Opt 2009;1-4. First published online 15 June 2009.
18. Drexler W, Findl O, Schmetterer L, Hitzenberger CK, Fercher AF. Eye elongation during accommodation in humans: Differences between emmetropes and myopes. Invest Ophthalmol Vis Sci 1998;39:2140-2147.
19. Mallen EAH, Kashyap P, Hampson KM. Transient axial length change during the accommodation response in young adults. Invest Ophthalmol Vis Sci 2006;47:1251-1254.
20. Buckhurst PJ, Wolffsohn JS, Shah S, Naroo SA, Davies N, Berrow EJ. A new optical coherence reflectometry device for ocular biometry in cataract patients. Br J Ophthalmol. Published online 19 Apr 2009; doi:10.1136/bjo.2008.156554. Accessed September 29, 2009.
21. Cruysberg LPJ, Doors M, Verbakel F, Berendschot TTJM, De Brabander J, Nuijts RMMA. Evaluation of the Lenstar LS900 non-contact biometer. Br J Ophthalmol. Published online Aug 18 2009; doi:10.1136/bjo.2009.161729. Accessed September 29, 2009.
22. Holzer MP, Mamusa M, Auffarth GU. Accuracy of a new partial coherence interferometry analyser for biometric measurements. Br J Ophthalmol 2009;93:807-810.

23. Rohrer K, Frueh BE, Wälti R, Clemetson IA, Tappeiner C, Goldblum D. Comparison and evaluation of ocular biometry using a new noncontact optical low-coherence reflectometer. Ophthalmology. Published online Sep 8 2009; doi:10.1016/j.ophtha.209.04.019. Accessed September 29, 2009.

24. Atchison DA, Smith G. Possible errors in determining axial length changes during accommodation with the IOLMaster. Optom Vis Sci 2004;81:282-285.

25. McBrien NA, Gentle A. Role of the sclera in the development and pathological complications of myopia. Prog Retin Eye Res 2003;22:307-338.

26. Read SA, Buehren T, Collins MJ. Influence of accommodation on the anterior and posterior cornea. J Cataract Refract Surg 2007;33:1877-1885.

## FIGURES & TABLES:

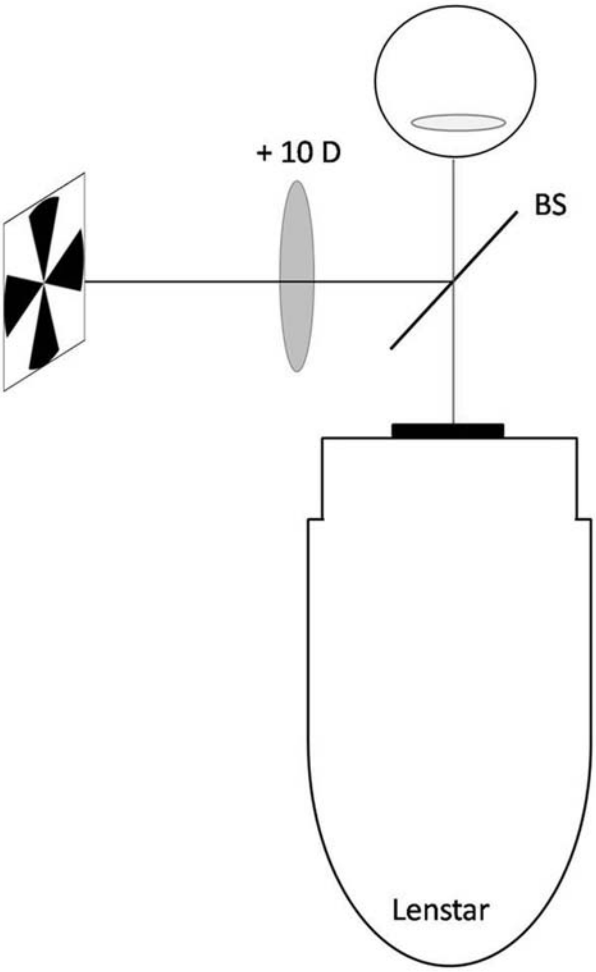

**Figure 1:** Illustration of experimental setup utilising a maltese cross target viewed through a beam splitter (BS) and a +10 D Badal lens, to allow ocular biometry to be carried out with the Lenstar instrument with different accommodation stimuli. Maltese cross target can be moved toward or away from the +10D lens to alter the stimulus to accommodation required to view the target.

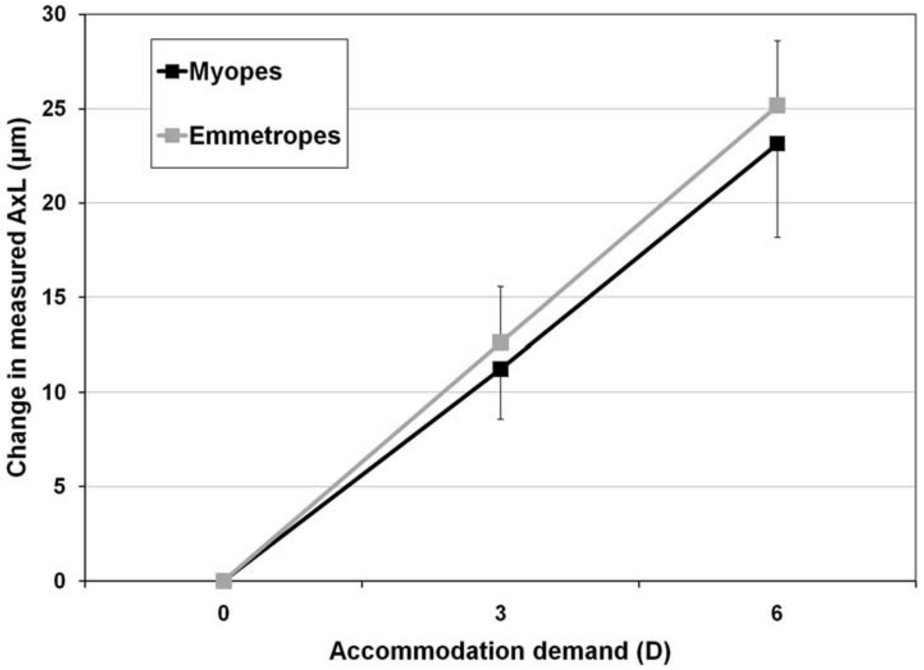

**Figure 2:** Mean change in measured axial length with accommodation for emmetropes (n=19) and myopes (n=21). Error bars represent the standard error of the mean. Repeated measures ANOVA revealed the change in axial length with accommodation was statistically significant ($p<0.001$), but there was no significant difference between the emmetropic and myopic subjects in terms of the magnitude of change in eye length with accommodation ($p>0.05$).

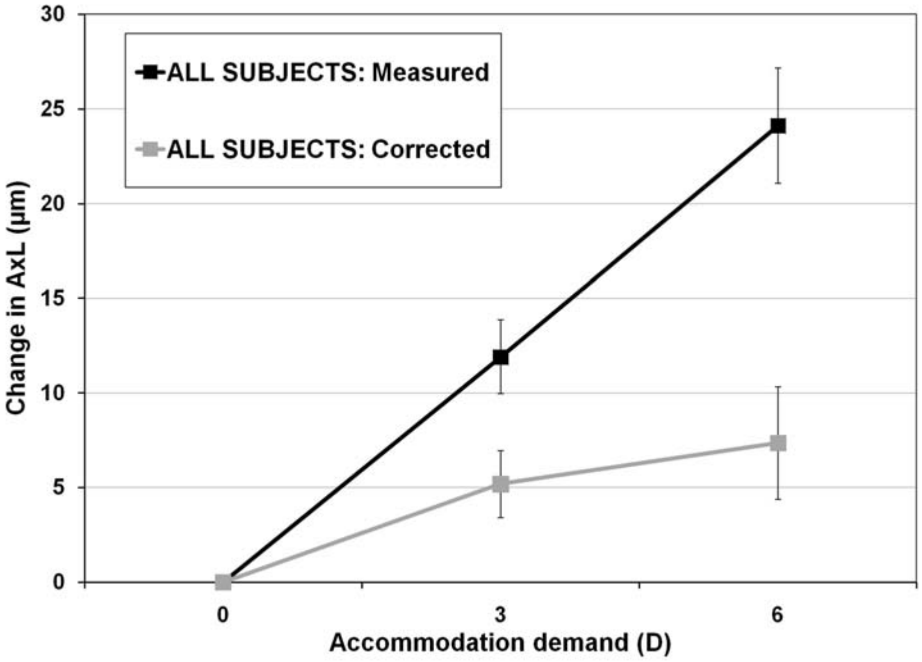

**Figure 3:** Mean change in measured and corrected axial length with accommodation for all subjects (n= 40). Corrected measures represent the change in axial length with accommodation, accounting for potential measurement error due to changes in lens thickness. Repeated measures ANOVA revealed a significant effect of accommodation for both 'measured' and 'corrected' axial length measures ($p<0.05$). Error bars represent the standard error of the mean.

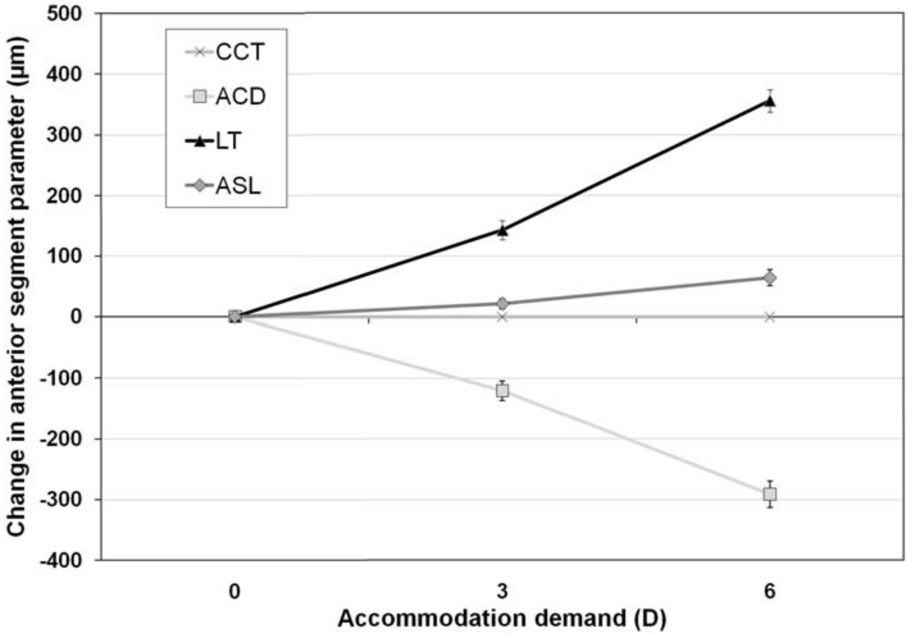

**Figure 4:** Mean change in anterior segment biometric parameters with accommodation for all subjects tested (n=40). Repeated measures ANOVA revealed all parameters except central corneal thickness (CCT) exhibited significant change with accommodation ($p<0.05$). Error bars represent standard error of the mean. CCT= central corneal thickness (the distance from the anterior to the posterior corneal surfaces), ACD= anterior chamber depth (the distance from the posterior corneal surface to the anterior lens surface), LT= lens thickness (the distance from the anterior lens surface to the posterior lens surface), ASL= anterior segment length (the distance from the anterior corneal surface to the posterior lens surface).

**Table 1:** Mean ocular biometric parameters for the 3 different accommodation demands for the emmetropic (n=19) and myopic (n=21) populations. P-values from repeated measures ANOVA for within subjects effect of accommodation level and between subjects effect of refractive error group are also shown for each parameter.

| Biometric Parameter* | Refractive error group | Mean ± SD Biometric parameter (mm) | | | P-value | | |
|---|---|---|---|---|---|---|---|
| | | 0 D | 3 D | 6 D | Accommodation | Accommodation* Refraction | Refraction |
| CCT | Myopes | 0.533 ± 0.025 | 0.532 ± 0.025 | 0.533 ± 0.025 | 0.65 | 0.01 | 0.40 |
| | Emmetropes | 0.539 ± 0.029 | 0.540 ± 0.029 | 0.540 ± 0.029 | | | |
| ACD | Myopes | 3.32 ± 0.31 | 3.18 ± 0.30 | 3.03 ± 0.28 | <0.001 | 0.40 | 0.07 |
| | Emmetropes | 3.13 ± 0.34 | 3.03 ± 0.32 | 2.83 ± 0.33 | | | |
| LT | Myopes | 3.52 ± 0.21 | 3.68 ± 0.19 | 3.87 ± 0.19 | <0.001 | 0.41 | 0.40 |
| | Emmetropes | 3.57 ± 0.20 | 3.70 ± 0.24 | 3.94 ± 0.18 | | | |
| ASL | Myopes | 7.37 ± 0.28 | 7.38 ± 0.29 | 7.43 ± 0.27 | <0.001 | 0.84 | 0.18 |
| | Emmetropes | 7.24 ± 0.28 | 7.27 ± 0.27 | 7.31 ± 0.29 | | | |
| VCD | Myopes | 17.02 ± 0.63 | 17.02 ± 0.63 | 16.99 ± 0.64 | 0.007 | 0.87 | 0.01 |
| | Emmetropes | 16.46 ± 0.77 | 16.44 ± 0.77 | 16.41 ± 0.74 | | | |
| AxL “Measured” | Myopes | 24.39 ± 0.62 | 24.40 ± 0.61 | 24.41 ± 0.61 | <0.001 | 0.88 | 0.003 |
| | Emmetropes | 23.70 ± 0.75 | 23.71 ± 0.75 | 23.72 ± 0.75 | | | |
| AxL | Myopes | 24.39 ± 0.62 | 24.39 ± 0.62 | 24.40 ± 0.61 | 0.007 | 0.71 | 0.003 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Emmetropes | 23.70 ± 0.75 | 23.70 ± 0.75 | 23.71 ± 0.75 | | | |

*CCT= Central corneal thickness (the distance from the anterior to the posterior corneal surfaces), ACD= anterior chamber depth (the distance from the posterior corneal surface to the anterior lens surface), LT=lens thickness (the distance from the anterior lens surface to the posterior lens surface), ASL= anterior segment length (the distance from the anterior corneal surface to the posterior lens surface), VCD= vitreous chamber depth (the distance from the posterior lens surface to the retinal pigment epithelium) and AxL= axial length (the distance from the anterior corneal surface to the retinal pigment epithelium).