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Assessment of central and peripheral accommodative lag by aberrometry

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Assessment of central and peripheral accommodative lag by aberrometry

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Abstract. Accommodation lag is important factor for normal vision. Higher lag of accommodation may cause various ocular symptoms particularly during near tasks. In this study, the lag of accommodation was assessed in the peripheral retina and it was compared with the central accommodative lag with aberrometer. In this cross-sectional study, fifty-three young subjects with normal visual acuity and without any active ocular disease or past ocular surgery were included. Aberrations in the central and peripheral field of view up to 30º off axis from the centre in horizontal and vertical meridian in 10º steps were measured with Hartmann-Shack aberrometer with stimulation of accommodation by -2.50D lens. Accommodative stimulus and accommodative response were calculated with defocus and hence accommodative lag was obtained. Accommodative lag in the centre and periphery was compared. Repeated measure of ANOVA showed that there were significant differences in lag of accommodation in various eccentricities ($F(8.912, 454.514) = 2.372$, $p = 0.013$). Pairwise test showed that lag in the centre was similar with lag on other peripheral field of view ($p > 0.05$). However, accommodative lag at 10º nasal field was significantly lower than the lag at 20º temporal, 20º nasal, 30º temporal and 30º nasal ($p < 0.05$). Similarly, lag at 10º superior fixation was lower than lag at 20º temporal, 20º nasal, 30º temporal and 30º nasal fixations ($p < 0.05$). We found higher lag of accommodation in horizontal off-axis fixations in comparison to that of vertical off-axis fixations ($p < 0.05$). Lag of accommodation was positive correlated with vertical coma and primary spherical aberrations but negative correlated with secondary spherical aberrations ($p < 0.05$). Thus, Hartmann-Shack aberrometer was successfully used to assess accommodative lag in the peripheral field of view up to 60º visual field. Peripheral lag of accommodation depends up on eccentricity. Lag was found higher in horizontal off-axis fixation than at vertical fixations. Coma and spherical aberration had association with lag.

1. Introduction

Accommodation is a process where crystalline lens increases converging power so that image of an object located in a closer distance focus on the retina. Generally, accommodation response differs with accommodation stimulus. When the accommodation response is less than stimulus, it is called accommodative lag. Lag is assumed normal up to 0.50D the blur originated by such small lag does not influence the quality of vision. [1] Higher lag of accommodation may cause various ocular symptoms particularly during near work.

Often in optometric clinics, accommodative response and lag are assessed by subjective methods which may be affected by subjective response. [2] So, objective methods like autorefractometer might be better. Recently, aberrometer has been used to assess accommodation function objectively. The advantage of this equipment to assess accommodative functions is that it can measure the dynamic accommodative functions. [3] Moreover, it is also possible to assess the accommodative lag in the peripheral field of view. Study of accommodative lag in the peripheral field of view might be interesting as peripheral defocus has important role on refractive error development. [4]

So, the aim of this study was to investigate the effect of eccentricity on accommodative lag. Lag of accommodation was measured in the central and peripheral field of 60º i.e., 30º off-axis in the horizontal and vertical meridian. Association of accommodative lag with Zernike coefficients like astigmatism, trefoil, coma, and spherical aberrations in the respective point of fixations was also assessed.

2. Methods

2.1. Subjects

It was a cross-sectional study conducted at the University of Minho. Young, healthy people with age 18 to 35 years from the university staff and students were included in the study. Subjects with refractive error more than +6.00D or less than -6.00D and astigmatism more than 0.75DC were excluded from the study. Subjects with best corrected visual acuity less than 6/6, past history of ocular surgery and any active disease were excluded. A complete optometric examination including slit-lamp exam was done to rule out any ocular disorders.

Ethical approval for the study was obtained from the Ethical Subcommittee of Life and Health Sciences of University of Minho. Each subjects signed a consent form after they were explained about the research process, time requirement and possible consequences. This study followed the tenets of declaration of Helsinki.

2.2. Experimental setup and procedure

Central and peripheral higher order aberrations up to 30º off-axis from the centre in horizontal and vertical meridian in 10º steps were measured with in-house Hartmann-Shack aberrometer. Detailed about the equipment has been explained elsewhere. [5] Aberrometry was done in the right eye of each subject with refractive error correction if present. Pupil size was adjusted to 4.50mm and the examination was conducted at dark room. The process was repeated with -2.50D lens on the trial frame in each subject to stimulate accommodation. The aberration values only with accommodation stimulation are used in this paper.

2.3. Data analysis

Zernike coefficients from 2nd to 6th order were obtained. Accommodation functions were calculated as follows:

Spherical equivalent (M) = $-4\sqrt{3}C_2^0/r^2$, where C_2^0 is defocus in μm and r is the pupil diameter in mm.

Accommodation stimulus (AS) = $M - \{1 + (L + d)F\}/\{L - d\,(L + d)\,F\}$

Accommodation response (AR) = $M - (M + F)/\{1 - d\,(M + F)\}$

Accommodative lag (AL) = AS - AR,

where L is distance of fixation target from eye (6m), d is vertex distance (0.02m), F is lens power to stimulate accommodation (-2.5D).

SPSS 23 (IBM Corp., Armonk, NY) was used to analyse the data. Normality test was tested, and parametric or non-parametric tests were applied depending up on the nature of data. Mean ± SD was used to describe the descriptive data. Repeated measure of ANOVA was applied to test whether the lag of accommodation was different in various central and peripheral field of fixations. Bonferroni adjustment in p values was not done as we observed chance of type II error. Correlation test was done between accommodative lag with vertical (C_2^{-2}) and horizontal astigmatism (C_2^2), vertical (C_3^{-3}) and horizontal trefoil (C_3^3) and vertical (C_3^{-1}) and horizontal coma (C_3^1), primary (C_4^0) and secondary spherical aberrations (C_6^0) in respective field of view. P values less than 0.05 were considered as statistically significant.

3. Results

Fifty-three participants were enrolled in this study with mean age 23.48±3.97 (range: 17 to 33) years and 87% were female. The mean refractive error was -0.37±1.39D.

Repeated measure of ANOVA with a Greenhouse-Geisser correction showed that there were significant differences in lag of accommodation in various eccentricities ($F(8.912, 454.514) = 2.372$, $p = 0.013$). Pairwise test showed that lag in the centre was similar with lag on other peripheral field of view ($p > 0.05$). However, accommodative lag at 10º nasal field was significantly lower than the lag at 20º temporal, 20º nasal, 30º temporal and 30º nasal ($p < 0.05$). Similarly, lag at 10º superior fixation was lower than lag at 20º temporal, 20º nasal, 30º temporal and 30º nasal fixations ($p < 0.05$). Lag at 10º inferior was also less than20º temporal field ($p = 0.029$). Lag at 20º temporal fixation was higher than lag at 20º superior, 30º superior and 30º inferior fixations ($p < 0.05$). Similarly, lag at 20º nasal fixation was higher than lag at 30º off-axis of vertical field (superior and inferior fixations) ($p < 0.05$). The other differences were: 30º temporal fixation had higher lag than at 30º inferior fixations ($p = 0.008$) and 30º nasal fixation had higher lag than at 30º superior and inferior fixations ($p < 0.05$).

We found higher lag of accommodation in horizontal off-axis fixations in comparison to that of vertical off-axis fixations ($p < 0.05$).

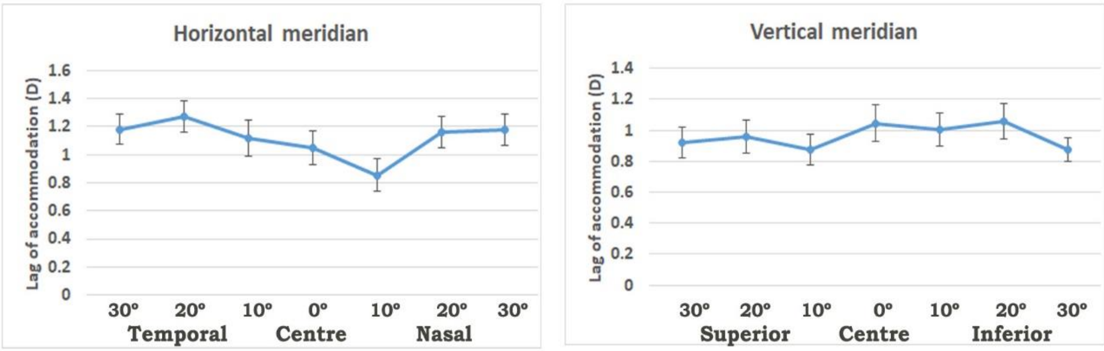

Figure 1. Lag of accommodation in the central and peripheral points of fixations. Error bars show the standard error of mean. Accommodation was stimulated with -2.50D lens.

From figure 1, we can see the trend that with the eccentricity, lag of accommodation decreases in vertical meridian but increases in horizontal meridian. Again, lag of accommodation is higher in horizontal meridian in comparison to that of vertical meridian. The average of the mean of the accommodative lag in various central and off-axis positions was 1.04D when accommodation was stimulated with -2.50D lens.

We assessed the association of accommodative lag with various Zernike coefficients in respective central and peripheral visual field. Lag of accommodation had strong positive correlation with C_2^2 and moderate to strong positive correlation with C_3^{-1}, but there was no significant correlation with other second and third order coefficients. Similarly, accommodative lag had strong positive correlation with primary spherical aberration ($r \geq 0.547$, $p \leq 0.042$) but moderate negative correlation with secondary spherical aberration ($r \leq -0.392$, $p \leq 0.040$) in respective central and peripheral points of fixation.

4. Discussion and conclusion

In this study, lag of accommodation was measured successfully both at the centre and peripheral field of view with aberrometer in a large number of young healthy subjects. When eyes were stimulated with -2.50D of lens, not any trend of change in the lag of accommodation was observed; however, the values were statistically significantly different in overall context. The minimum lag was found at 10º nasal fixation (0.85D) and the maximum was found at 20º temporal fixation (1.27D). Thus, we found higher amount of accommodative lag in comparison to other studies. [6] This might be due to the objective nature of the assessment method in this study. [2,7]

Lag of accommodation in horizontal off-axis fixation was higher than vertical off-axis fixations which supports the asymmetric accommodative function in peripheral fixations.

Moreover, in the current study, any association between accommodative lag and C_3^{-3}, C_3^{-1}, C_3^{1}, C_3^{3}, C_4^{0}, and C_6^{0} was also evaluated as these are the major contributing higher order coefficients. [8] Among the third order coefficients, C_3^{-1} was found positively correlated with accommodative lag. Primary and secondary spherical aberration also correlated with accommodative lag but in opposite direction, the former was positively correlated while the latter was negatively correlated. It supports the findings of earlier study that accommodation has opposite effect on primary and secondary spherical aberrations. [9]

One limitation of this study is that peripheral ocular aberrations were measured with round pupil. It is found that elliptical transformation is not necessary within 20º off-axis aberration measurement. [10] However, peripheral aberrations up to 30º eccentricity were assessed in the current study. So, the accommodative lag could be better expressed with elliptical transformation.

So, from this study it can be concluded that Hartmann-Shack aberrometer can be used to assess accommodative lag in the peripheral field of view up to 60º visual field. Peripheral lag of accommodation depends up on eccentricity. Lag was found higher in horizontal off-axis fixation than at vertical fixations. Lag of accommodation had association with vertical coma and spherical aberration.

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