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Effect of accommodation on coma at central and peripheral retina

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Abstract. Coma is one of the most common ocular higher order aberrations and highly affects the quality of image. It is assumed that corneal aberrations are balanced by internal (lenticular) aberrations so that retinal image quality may not have great impact. However, during accommodation, the shape, position, and curvature of the crystalline lens changes which might disrupt this balance between internal and corneal aberration. This study aimed to investigate the effect of accommodation on primary coma (C_3^{-1} and C_3^1) and secondary coma (C_5^{-1} and C_5^1) in relaxed and accommodated eyes. Zernike coefficients were measured in 53 subjects with Hartmann-Shack aberrometer both at the central and peripheral retina up to 30º off-axis in horizontal and vertical meridians. The process was repeated with 2.50 D accommodation stimulus and comas were compared with and without accommodation. Root-mean-square of total coma was also assessed. With accommodation, vertical comas changed to more negative value and horizontal comas changed to more positive values in most of the off-axis positions. In contrast, the secondary vertical comas became less negative and secondary horizontal comas became more negative with accommodation in most of the off-axis fixations. Thus, the results showed that accommodation affects coma which depends up on position of the fixation.

1. Introduction

Higher order aberration has important role on optical quality of an image; but conventional methods of refractive error correction are unable to correct it. There are many types of higher order aberrations, however, spherical aberration and coma are the most common.[1] Both primary and secondary coma (C_3^{-1}, C_3^1, C_5^{-1} and C_5^1) have important role in the vision as they degrade the retinal image quality. Peripheral vision is important for everybody, but it is vital in people with central vision loss. So, coma may have effect on the peripheral retinal image quality. With the use of aberrometer, it is possible to analyse higher order aberrations in the central as well as peripheral field of view.

Ocular accommodation is the process where the optical system of eye focusses the image on retina when the object is located at a closer distance. With accommodation, change in curvature and thickness of crystalline lens take place which might affect ocular higher order aberrations. [2] The effect of accommodation on higher order aberrations has been widely studied, however, mostly focused on central fixation. It was found that spherical aberration becomes more negative with accommodation in the central fixation.[3] Although, coma are the most common higher order aberrations, no previous research investigated the association of accommodation and coma neither in the central nor in the peripheral retina. So, this research was designed to investigate the effect of accommodation on coma on both central and peripheral field of view. Primary and secondary comas were assessed with and without accommodation.

2. Methods

2.1. Subjects
Young healthy subjects with best corrected visual acuity 6/6 or better were included in the study. Subjects with ocular pathology, any past history of ocular surgery or any active disease were excluded from the study. Optometric examination was conducted to select the subjects.

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

2.2. Experimental setup and procedure
Higher order aberrations were measured with in-house Hartmann-Shack aberrometer (Thor labs WF150-7AR) with 1280 x 1024 resolution and 39 x 31 lenslet working at 15Hz frequency. A super luminescent diode of 12µW generates the optical beam of 830 nm. The Hartmann-Shack sensor has been widely used in assessing optical quality of eye with high reliability and reproducibility. [4] With some modifications, we were able to measure the ocular aberrations on the peripheral field of view of up to 60º, 30º off-axis in both horizontal and vertical meridians. [5]

Aberrometry was done in right eye of each subject with refractive error correction if present. The fixation target (a black cross on white background) was presented on a monitor and can be moved in vertical or horizontal direction up to 30º off-axis in 10º steps. The position of the infrared light source was fixed which was overlapped during the measurement of central fixation. The fixation target was then moved away from the centre in 10º steps in temporal, nasal, superior and inferior positions. The process was repeated with accommodation stimulation by -2.50D lens which was kept on a trial frame worn by the subject. Accommodation stimulus of -2.50D was used in this study because it is equivalent to the vergence of 40cm distance which is common near working distance. Measurements were taken in a dark room to insure the minimum pupillary diameter which was 4.50 mm used in this study.

2.3. Data analysis
Data of all the Zernike coefficients were obtained both without accommodation and with accommodation, however, only the data of vertical coma (C_3^{-1}), horizontal coma (C_3^1), secondary vertical coma (C_5^{-1}) and secondary horizontal coma (C_5^1) were used for the analysis in this particular study. Baseline data were reduced from the values obtained from aberrometer to get the exact aberrations of the subjects. Root mean square (RMS) of coma was also calculated as follow:

$$\text{RMS} = \sqrt{(C_3^{-1})^2 + (C_3^1)^2 + (C_5^{-1})^2 + (C_5^1)^2} \quad 1$$

SPSS 23 (IBM Corp., Armonk, NY) was used to analyse the data. Normality was tested, and parametric or non-parametric tests were applied depending up on the nature of data. P values less than 0.05 were considered as statistically significant.

3. Results
Total number of 53 subjects participated in the study and 85% (45) were females. The mean age of the participants was 24.9 ± 5.8 years. Figure 1 presents the primary comas (C_3^{-1} and C_3^1) in the horizontal and vertical meridian respectively. It can be observed that vertical comas changed to more negative values after accommodation in all the central and peripheral points of fixations except at 20º nasal fixation. In the contrary, horizontal coma becomes more positive after accommodation in all the central and off-axis fixations except at 10º nasal fixation.

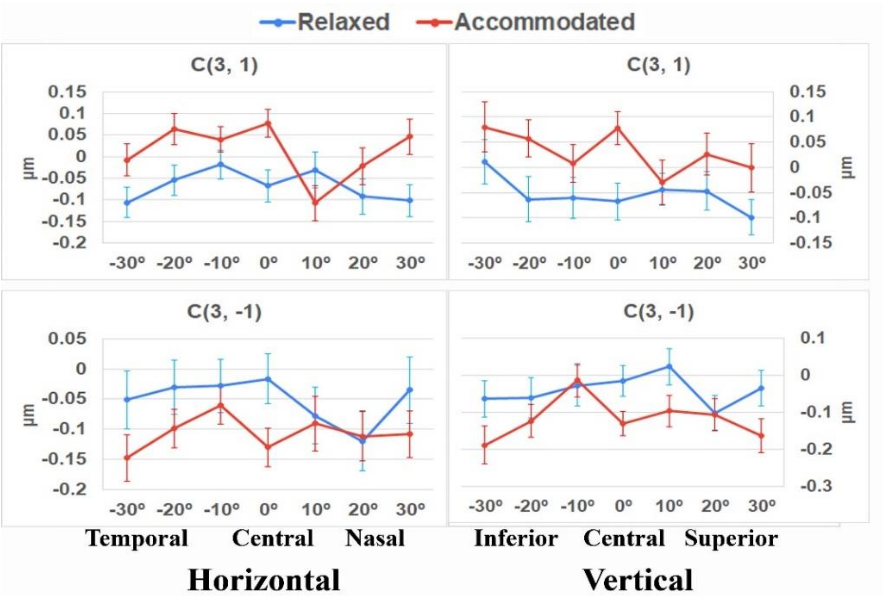

Figure 1. Plot of primary comas (C_3^{-1} and C_3^{1}) in various points of fixation with and without accommodation in vertical and in horizontal meridian. The error bars represent the standard error of mean.

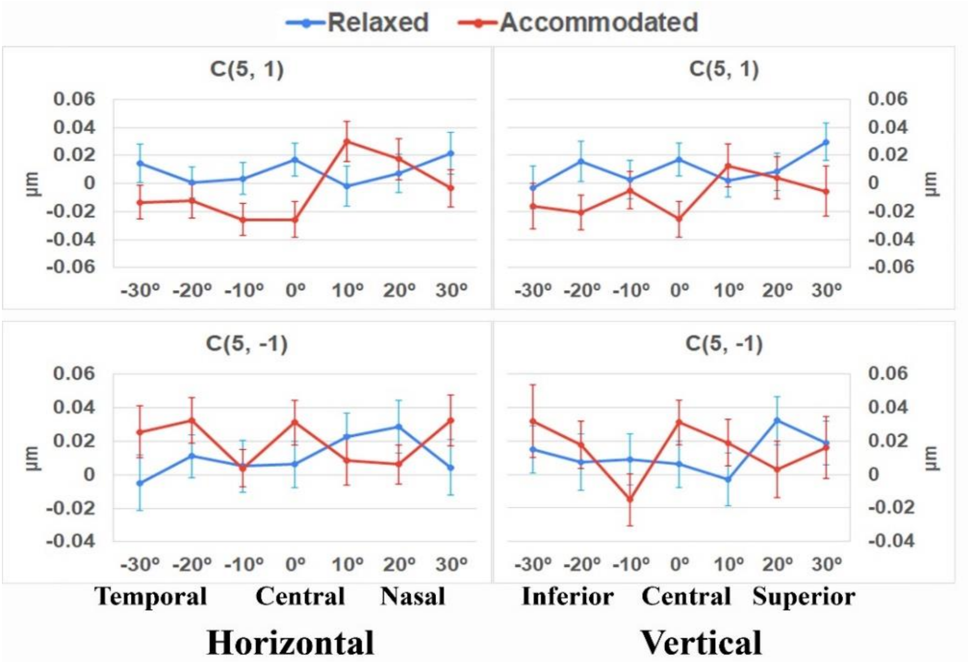

Figure 2. Plot of secondary comas (C_5^{-1} and C_5^{1}) in various points of fixation with and without accommodation in vertical and horizontal meridians. The error bars represent the standard error of mean.

As presented in figure 2, secondary coma (C_5^{-1} and C_5^{1}) behaved differently with accommodation. In majority of the fixations, secondary vertical coma became less negative and secondary horizontal coma became more negative with accommodation, however, it did not follow this trend in some fixations for example, secondary vertical coma changed to more negative at 10º and 20º nasal fixations. Secondary horizontal coma changed to less negative values at 10º and 20º nasal field of view.

No statistically significant effect of accommodation was found on the total RMS of coma ($p > 0.05$).

4. Discussion and conclusion

In this study, third and fifth order comas were measured with Hartmann-Shack aberrometer at relaxed and accommodated state of eyes at central and peripheral field of view. From results obtained, it can be observed that primary vertical coma changed to negative direction and primary horizontal coma changed to positive direction with accommodation. Earlier studies conducted in central vision also found change in direction of the coma with accommodation. [6] This may be due to the change in shape of crystalline lens, which becomes more hyperbolic with accommodation.[7] As seen in the figure 1, the variation was asymmetrical in different off-axis fixations. Vertical coma was similar with and without accommodation at 10º and 20º nasal fixation and 10º inferior and 20º superior fixations. Horizontal coma was more negative with accommodation at 10º nasal fixation while it was similar with and without accommodation at 10º superior fixation.

Secondary vertical coma increased with accommodation and the secondary horizontal coma decreased with accommodation in all the central and off-axis fixations except 10º nasal, 20º nasal and 20º superior fixations. As the opposite effect of accommodation on primary and secondary spherical aberrations, we found opposite effect of accommodation on primary and secondary coma.[8]

In a past study conducted in central and peripheral field of view, no effect of accommodation was found on either vertical or horizontal coma, however, the number of subjects was quite low in that study, 15 in that study vs 53 in the current study.[5]

One limitation of this study is the measurement of coma with a round pupil i.e., without elliptical transformation. It is not necessary to do elliptical transformation to measure peripheral aberrations up to 20º off-axis; however, in the current study, comas were assessed up to 30º off-axis eccentricity. [9]

So, it can be concluded that accommodation affects coma at central as well as at peripheral field of view and it varies between vertical and horizontal and primary and secondary. Future study with large amount of accommodation stimulus is recommended to ascertain the findings of this study.

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References

[1] Fan R et al 2012 Comparison of wavefront aberrations under cycloplegic, scotopic and photopic conditions using WaveScan *Arq. Bras. Oftalmol.* **75** 116-21

[2] Kasthurirangan S et al 2011 MRI study of the changes in crystalline lens shape with accommodation and aging in humans *J. Vis*. **11** 3

[3] Plainis S et al 2005 The effect of ocular aberrations on steady-state errors of accommodative response *J. Vis*. **5** 466-477

[4] Atchison DA et al 2007 Measuring ocular aberrations in the peripheral visual field using Hartmann – Shack aberrometry *J. Opt. Soc. Am*. **24** 2963-2973

[5] Sapkota K, Gomes J and Franco S 2022 Effect of Accommodation on Peripheral Higher Order Aberrations *Photonics* **9**:64

[6] Cheng H et al 2004 A population study on changes in wave aberrations with accommodation *J. Vis*. **16** 4

[7] Dubbelman M et al 2005 Change in shape of the aging human crystalline lens with accommodation *Vision Research* **45** 117-132

[8] Zhou X et al 2015 Wavefront aberration changes caused by a gradient of increasing accommodation stimuli *Eye* **29** 115-121

[9] Hartwig A et al 2011 Peripheral aberration measurements: elliptical pupil transformation and variations in horizontal coma across the visual field *Clin. Exp. Optom.* **94** 443-451