

Original Article

# Corneal spherical aberration in Saudi population



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## Abstract

**Purpose:** To find out the mean corneal spherical aberration and its changes with age in Saudi population.

**Setting:** AlHokama Eye Specialist Center, Riyadh, Saudi Arabia.

**Methods:** Three hundred (300) eyes of 185 Saudi subjects (97 men and 88 women), whose age ranged from 15 to 85 years old, with matched refractive errors, were divided into three groups according to their age, 100 for each. All the subjects were included in measuring the spherical aberration (SA) using pentacam HR (OCULUS, Germany) at the 6-mm optical zone.

**Results:** The mean corneal spherical aberration (CSA) of the fourth order ( $Z_4^0$ ) of the whole groups was  $0.252 \pm 0.1154 \mu\text{m}$ . Patients from 15 to 35 years old have root mean square (RMS) of CSA of  $0.2068 \pm 0.07151 \mu\text{m}$ ,  $0.2370 \pm 0.08023 \mu\text{m}$  was the RMS of CSA of the patients from 35 to 50 years old, while those from 50 to 85 years old have a CSA-RMS of  $0.31511 \pm 0.1503 \mu\text{m}$  ( $P < 0.0001$ ). A positive correlation was found between the spherical aberration ( $Z_4^0$ ) and the progress of age ( $r = 0.3429$ ,  $P < 0.0001$ ). The high order aberration (HOA) presented 28.1% of the total corneal aberrations. While the fourth order corneal spherical aberration constituted 57% of the HOA and 16% of the total aberration. The pupil diameter shows a negative correlation with the increase in age ( $P = 0.0012$ ).

**Conclusion:** Our results showed a CSA ( $Z_4^0$ ) that is varied among the population, comparable to other studies, and significantly correlates to the progress of age.

**Keywords:** Spherical aberration, Saudi population, Z(4,0), Z(6,0), IOL, Cataract, Corneal aberration, Fourth order spherical aberration, High order aberration

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## Introduction

In the current era of recent corneal and phaco-refractive surgeries, thorough understanding of the human corneal topography and its inter-individual variations is becoming an ultimate need to know how corneal shape may influence postoperative outcome, and the resulting visual performance. Wavefront analysis of the ocular optical system has increased our knowledge of the aberrations in the eye.<sup>1</sup> Using Zernike polynomials, the aberrations of the ocular

system can be characterized.<sup>1</sup> The total higher-order aberrations of the phakic eye are composed of aberrations arising from the anterior and the posterior corneal surfaces, the crystalline lens and the retina.<sup>2</sup> In the aphakic eye, however, 98.2 percent of the aberrations arise from the anterior corneal surface.<sup>4</sup>

Among the large number of Zernike polynomials, Zernike coefficient for spherical aberration (SA), a symmetrical higher-order optical aberration has been found to be linked to contrast visual acuity; as this value increases, contrast

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sensitivity has been found to decrease,<sup>5,8</sup> and greater amounts of haloes and glare are induced, it has been identified as a key contributor to the deterioration of image quality, night myopia and photic complaints.<sup>9</sup> The cornea has positive SA in 90% of the cases and negative spherical aberration in the remaining 10%.<sup>3</sup> Corneal positive SA is reported to be approximately  $+0.27 \mu\text{m}$  for a diameter of 6 mm with a large standard deviation of  $0.10 \mu\text{m}$ ,<sup>9,10</sup> it is compensated mainly by the negative spherical aberration of the crystalline lens which shifts toward positive values with aging<sup>7</sup>, so no compensatory effect is expected to occur in the elderly; on the contrary, the adverse effects of an increased spherical aberration are expected to worsen with age,<sup>9–11</sup> as the best contrast sensitivity has been measured in young patients, aged 20–30 years, while it worsens thereafter.<sup>9</sup>

Time related changes in the aberration profile of the cornea plays a detrimental effect in post operative visual quality in refractive and cataract surgeries. Age changes may even affect post refractive patients as they are getting older. Earlier studies depending on calculation of aberrations from placido-based corneal videokeratographers suggest that unlike coma aberrations, SA does not vary significantly with aging.<sup>12</sup> However later studies using specialized aberrometers reported either a significant or non significant increase in 4th order ocular aberrations with age specially SA, yet they expected minor changes to occur on the cornea.<sup>13,14</sup> Others report that corneal spherical aberration becomes slightly larger with normal aging.<sup>15–17</sup>

For practical purposes, spherical aberration comes into play when pupils are greater than 4 mm; thus, it has the most impact under mesopic or scotopic conditions and in younger patients.<sup>18</sup>

Ethnic variation is thought to play an important role in interpersonal variability of SA. Corneal and ocular spherical aberrations in South East Asian Chinese eyes were significantly greater than that those in other populations.<sup>19</sup> However, Japanese patients showed a relatively smaller corneal spherical aberration than previous studies of Caucasians.<sup>20</sup> Some other studies found no clear variation between different ethnic groups.<sup>21–23</sup> A controversy is present whether SA is correlated to ocular biometric measures especially axial length based on ethnic variation.<sup>21,24</sup> Population differences in wavefront errors should be noted in patient management, and individual evaluation of spherical aberration should be done for each patient.

## Patients and methods

This cross sectional study included three hundred eyes of 185 Saudi subjects (97 men and 88 women), whose ages ranged from 15–85 years old, with comparable spherical equivalent of their refractive errors. The study was conducted according to the tenets of declarations of Helsinki in a central anterior segment referral clinic and received the approval of the institute. All the subjects signed a comprehensive written consent prior to participation in the study.

Subjects were divided into 3 groups according to their ages, 15 to <35, 35 to <50 and 50 to 85 years. Patients with history of contact lense wear, keratorefractive surgery, existing ocular or systemic pathologies were excluded. Otherwise, all patients with clear cornea, no scarring nor pigmentation were included in the study. Corneal aberrations

of the 300 eyes were obtained with Pentacam HR (OCULUS, Germany), without dilatation in dark for 6 mm optical zone. Comparisons of corneal spherical aberrations (CSA) root mean square (RMS), total and high order corneal aberrations RMS up to 6th order were made between the 3 different age groups.

## Statistical analysis

Statistical analysis of the results was done by Microsoft Excel, Graphpad prism, and Instat. *P*-value of  $<0.01$  was considered extremely significant.

## Results

Topographic and wavefront data from 300 eyes of 185 consecutive patients were obtained for analysis. Mean patient age was  $42.873 \pm 16.588$  years (range: 17–85 years).

Our results demonstrate the RMS of CSA of the fourth order ( $Z_4^0$ ) in the three age groups at 6-mm optical zone. Patients from 15–35 years old have CSA-RMS of  $+0.2068 \pm 0.07151 \mu\text{m}$ . 35–50 years old patients have RMS of CSA of  $+0.2370 \pm 0.08023 \mu\text{m}$ , while those from 50 to 85 years old have a CSA-RMS of  $+0.31511 \pm 0.1503 \mu\text{m}$ . (Fig. 1, Table 1)

In all age groups, total CSA (4th and 6th) ranged from  $-0.091$  to  $+0.733 \mu\text{m}$ , with a mean RMS of  $+0.2609 \pm 0.1103 \mu\text{m}$ .

The overall mean corneal spherical aberration ( $Z_4^0$ ) of the whole 3 groups was  $+0.252 \pm 0.1154 \mu\text{m}$  ranging from  $+0.017$  to  $+0.708 \mu\text{m}$ , and it correlates positively with the progress of age ( $r = 0.3429$ , *P* value is  $<0.0001$ ) (Fig. 2).

On the other hand, the corneal spherical aberration of the sixth order ( $Z_6^0$ ) (Table 1) decreases very slightly with age ( $r = -0.1855$ , *P* value =  $0.0012$ ) (Fig. 3).

In our study, RMS of high order aberration (HOA) presented 28% of the total corneal aberrations while the fourth order CSA constituted 57% of the high order aberrations and 16% of the total (low and high order) aberrations of the cornea (Fig. 4).

Fourth order CSA decreases slightly with increasing pupil diameter, ( $r = -0.1890$ , *P* =  $0.0010$  in all groups together) (Fig. 5), which in turn decreases with increase in age ( $r = -0.1858$ , *P* =  $0.0012$ ) (Fig. 6). The mean pupil diameter for the whole group was  $2.9 \pm 0.50$  mm under mesopic conditions. There was no correlation between SA and pupil diameter in the younger age group of 15–35 years ( $r = 0.0013$ ), and a negligible negative correlation was found in the two other groups ( $r = -0.1799$  for the middle,  $-r = 0.1035$  for the elderly age groups,  $p < 0.001$ ).

Total and high ordered aberrations were highly positively correlated with the progress of age ( $r = 0.4352$ ,  $r = 0.5596$ , respectively) with *p* value of  $<0.0001$  for both (Figs. 7 and 8).

## Discussion

Since the principle of correcting spherical aberration was advocated in 2002,<sup>25</sup> researchers were trying to find the best methods for application of this concept in optical dispensing aids to improve contrast sensitivity and vision quality especially postoperatively. It is well accepted that aberrations

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