

Comparison of age-related changes between corneal and ocular aberration in young and mid-age myopic patients

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Abstract

• **AIM:** To study the dynamic character of aberration between the cornea and the ocular with aging, and to evaluate the symmetry of the aberrations between right and left eye in order to supply the data for clinic to do the refractive surgery reasonably.

• **METHODS:** This is a comparative case series study. 82 normal cases (164 eyes) including 37 females (74 eyes) and 45 males (90 eyes) were recruited through the routine examinations, Topolyzer and wavefront analysis. The average age was 25.9± 5.0 years old (range 18 to 49 years old), and the mean spherical equivalent (SE) is -3.82± 2.21D (range -1.00 to -6.00D). The changes of aberrations regarding age, the relationship between anterior corneal and total aberrations were analyzed, as well as the symmetry between right and left eyes by using Zernike terms.

• **RESULTS:** The Z_3^{-1} , RMS3 of corneal aberrations, Z_3^{-1} , Z_4^0 , RMS3 and RMS4 of ocular aberrations had a positive correlation with age. The zernike terms both in corneal and whole eye were significantly correlated between right and left eyes.

• **CONCLUSION:** The corneal horizontal coma, ocular horizontal coma and ocular spherical aberrations become to increase at the age of more than 40 years old. The dynamic change of aberration with aging, balance between corneal and ocular, and the symmetric character between left eye and right eye

should be designed carefully in the treatment nomogram before the refractive surgery.

• **KEYWORDS:** cornea; ocular; aberration; age; change; character

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INTRODUCTION

The human eye's performance has not been completely characterized. Normal eye suffers from low-order wavefront aberrations such as defocus and astigmatism and high-order wavefront aberrations including coma and spherical aberration, which limit the optical quality of retinal image, especially when pupils are large^[1-4].

Previous investigations have revealed that the wavefront aberrations produced by the internal optics offsets compensate for the aberrations produced by the anterior cornea to reduce total wavefront aberrations and improve the quality of image. With aging the optical definition gradually inclines even if the vision does not change obviously so as the optical quality decreases. The balance of vision between bilateral eyes is essential to see clearly and comfortably. How do aberrations affect the balance between corneal and complete eye and between bilateral eyes to achieve normal visual functions? Unfortunately, most wavefront units are unable to differentiate aberrations from lens and from those of the cornea. The lenticular aberration will continue to change. How does the aberration will change with aging? In this study, the detail relationship of anterior corneal aberrations and the total ones with different ages and bilateral eyes were analyzed with the matching anterior and whole wavefront units to provide theoretical foundations for clinicians.

MATERIALS AND METHODS

Materials Totally 204 eyes of 102 patients were recruited from the ones willing to undertake the LASIK operation.

After the routine examinations, 164 eyes of 82 subjects including 37 women (74 eyes) and 45 men (90 eyes) without ocular disease except for refractive errors volunteered to join this study. They had best-corrected visual acuity (BCVA) of 20/20 or better and aged from 18 to 49 years old. The mean spherical equivalent refractive errors (SE) was -3.82 ± 2.21 D (range -1.00 to -6.00D). The spherical component of their manifest refraction ranged from -1.5D through -6.0 D. The cylinder component of the manifest refraction was less than -3.0 D. The research adhered to the tenets of the Declaration of Helsinki (1964).

The subjects were divided into the young group (120 eyes of 60 subjects, range 18 to 40 years old) and the middle-aged group (44 eyes of 22 subjects, range 41 to 49 years old) according their ages. According the side of eyes, the subjects were divided into the left eye group (82 eyes) and the right eye group (82 eyes).

Methods All the subjects underwent the following examinations including uncorrected visual acuity, best corrected visual acuity, intraocular pressure, objective and subjective optometry, Schirmer test, the thickness of cornea, anterior corneal aberration(Topolyzer,WaveLight, Germany), total aberration (Wavefront Analyzer, WaveLight, Germany), The total aberration measurements were performed in the eyes with at least 6mm pupil or larger dilated by tropicamide (1%).

The aberrometer used in this study is designed for wavefront measurements on the basis of the Tscherning principle, an automatic capturing mode of the Analyzer ensures that only centered measurements will be taken into account and an automatic image validation function ensures that all measurement spots are actually valid. The Analyzer's new software, A-CAT module, can automatically lead to the next logical step, and the measurement data is evaluated and standardized automatically. The Topolyzer used in this study is a Placido disk system where a camera is used to image reflections from the corneal surface. It can detect the irregularities located more peripherally, and display as Height data, Zernike Analysis. Finally, all important parameters are displayed in a summary screen. All patients were instructed to properly expose their eyes and maintain fixation on the target light during the examination. For each eye in our study, eight maps were taken using the Wavefront Analyzer and the Topolyzer. Because the variability of maps, we decided to average the data of the eight maps. The data of wavefront aberrometer were collected from the eye with dilated pupil at least more than 6mm by 0.1% Tropicamide eyedropper, and all the procedures were performed by the same operator.

Statistical Analysis Measurements were repeated at least

Table 1 Comparison of Zernik values in cornea of different age

	Young group	Middle-aged group	t	P
Z_3^{-3}	0.073±0.065	0.084±0.061	0.832	0.423
Z_3^{-1}	0.094±0.064	0.122±0.072	1.865	0.057
Z_3^1	0.114±0.067	0.164±0.089	3.041	0.005*
Z_3^3	0.105±0.062	0.090±0.075	1.039	0.297
Z_4^{-4}	0.047±0.039	0.052±0.033	0.566	0.620
Z_4^{-2}	0.037±0.032	0.044±0.039	0.779	0.426
Z_4^0	0.247±0.068	0.256±0.083	0.555	0.634
Z_4^2	0.039±0.022	0.042±0.025	0.588	0.536
Z_4^4	0.037±0.028	0.040±0.032	0.459	0.682
RMS3	0.112±0.029	0.138±0.036	3.775	0.004*
RMS4	0.122±0.031	0.125±0.034	0.417	0.720

Data are expressed as mean±SD

The star symbol indicates a significant difference at $P < 0.01$, the level corrected for multiple comparisons using the Bonferroni correction

Table 2 Comparison of Zernik values in whole eyes of different age

	Young group	Middle-aged group	t	P
Z_3^{-3}	0.153±0.155	0.147±0.132	0.186	0.758
Z_3^{-1}	0.139±0.110	0.189±0.154	1.823	0.059
Z_3^1	0.108±0.087	0.163±0.066	2.889	0.010*
Z_3^3	0.152±0.209	0.153±0.179	0.021	0.851
Z_4^{-4}	0.108±0.116	0.109±0.110	0.038	0.830
Z_4^{-2}	0.078±0.093	0.047±0.056	1.552	0.169
Z_4^0	0.076±0.067	0.267±0.099	9.479	0.000*
Z_4^2	0.078±0.077	0.077±0.086	0.044	0.760
Z_4^4	0.102±0.135	0.118±0.139	0.516	0.663
RMS3	0.198±0.145	0.270±0.186	2.032	0.043*
RMS4	0.145±0.107	0.257±0.106	4.583	0.000*

Data are expressed as mean±SD

*The star symbol indicates a significant difference at $P < 0.05$, the level corrected for multiple comparisons using the Bonferroni correction

three times for each eye in order to obtain a well-focused and properly aligned image. The averages of each component of the total and anterior corneal higher-order wavefront aberrations in the central 6mm area were calculated. Student *t* test is used to analyze the difference between two age groups and the Pearson correlation coefficients were used to analyze the relative factors in different groups with the software of Statistical Package for the Social Science (SPSS, version 10.0, SPSS Inc., Chicago, IL, USA). The statistical significance was set to the $P < 0.05$ level, the level corrected for multiple comparisons using the Bonferroni correction.

RESULTS

The Changes of Aberrations Regarding Age Table 1 and Table 2 showed the changes of anterior corneal and total aberrations in different age groups. The *t* test results suggested that the anterior corneal horizontal coma ($P < 0.01$), ocular horizontal coma and ocular spherical aberrations ($P < 0.05$) increased with aging. There were significant changes for RMS3 (only in cornea) and RMS4 (both in cornea and ocular) between different age groups ($P < 0.05$). The coefficient of anterior corneal coma aberration ($r = 0.307$; $P < 0.01$; Figure 1) and ocular coma aberration

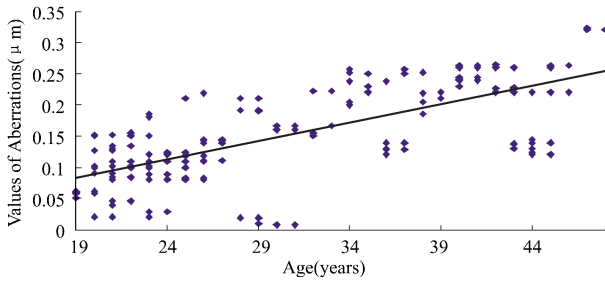


Figure 1 Correlation between age and coma-like aberration Z_3^1 of cornea. There is a statistically significant correlation between age and corneal coma-like aberration ($r = 0.307$; $P < 0.01$)

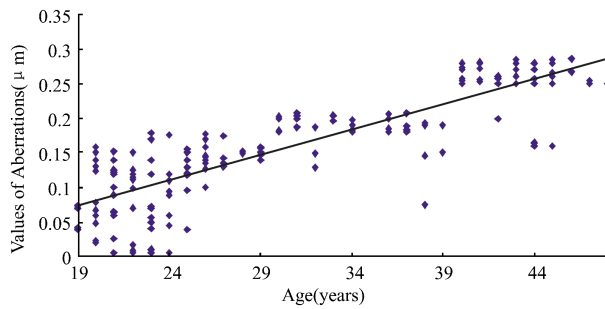


Figure 2 Correlation between age and coma-like aberration Z_3^1 of ocular. There is a statistically significant correlation between age and ocular coma aberration ($r = 0.451$; $P < 0.01$)

($r = 0.451$; $P < 0.01$; Figure 2) exhibited statistically remarkable correlated with age, and so did the ocular spherical-like aberration ($r = 0.438$; $P < 0.01$; Figure 3). In different age groups, every Zernike terms were compared between cornea and total aberration, there is no significant correlation between corneal and total aberrations both in young and middle-aged groups except for spherical aberration Z_4^0 ($P < 0.05$; Figure 4, 5). The mean absolute values of the ocular spherical aberration Z_4^0 in young subjects were significantly reduced compared to corneal coefficients ($t = 2.360$, $P < 0.05$; Figure 4). But the values of Z_4^0 in middle-aged subjects had no significantly difference in same manner ($P > 0.05$; Figure 5) which indicated that the increases of the spherical aberration of ocular was mainly because of the changing of internal optics, while the value of Z_4^0 in corneal still kept the same level as in that of young group.

The Correlation Between Bilateral Eyes The mean absolute values of anterior cornea between bilateral eyes showed no significant difference, as well as ocular aberrations ($P > 0.05$; Table 3,4). For the anterior corneal surface, the Pearson correlation coefficients between right and left eyes were 0.782 for Z_3^{-3} , 0.675 for Z_3^{-1} , 0.696 for Z_4^0 , 0.585 for Z_4^2 and -0.648 for Z_3^{-3} ($P < 0.01$, Table 5). For the ocular, there were significantly positive correlation for Z_3^{-1} ($r = 0.496$, $P < 0.05$), Z_4^0 ($r = 0.457$, $P < 0.05$), Z_4^2 ($r = 0.440$, $P < 0.05$), Z_4^2 ($r = 0.585$, $P < 0.01$) and Z_4^{-2} ($r = -0.453$, $P < 0.05$) between right and left

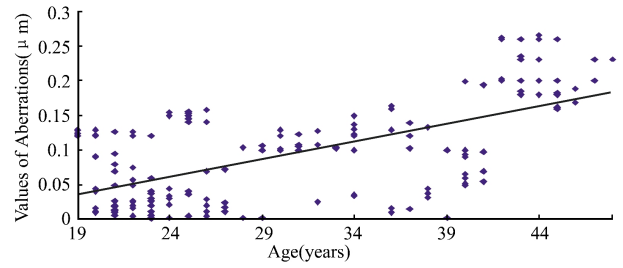


Figure 3 Correlation between age and spherical aberration Z_4^0 of ocular. There is a statistically significant correlation between age and ocular spherical aberration ($r = 0.438$; $P < 0.01$)

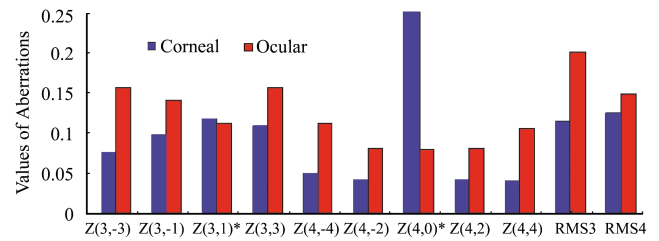


Figure 4 The high-order Zernike coefficients were compared between cornea and ocular in young group. There was no statistically significant correlation between corneal and ocular coma aberration Z_3^1 ($P > 0.05$). The mean absolute values of the ocular coefficient of spherical aberration Z_4^0 ($t = 2.360$, $P < 0.05$) of young subjects were significantly reduced compared to corneal coefficients

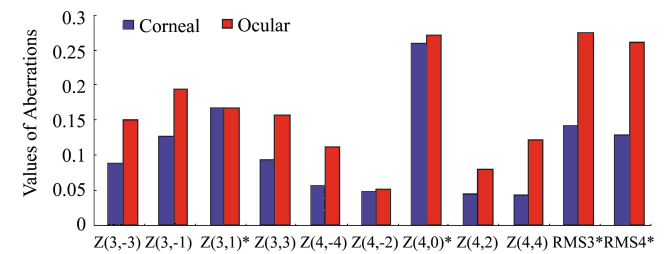


Figure 5 The high-order Zernike coefficients were compared between cornea and ocular in middle-aged group. There was still no statistically significant correlation between corneal and ocular coma aberration Z_3^1 ($P > 0.05$). The mean absolute values of the ocular coefficient of spherical aberration Z_4^0 ($P > 0.05$) of young subjects had no significantly difference compared to corneal coefficients

eyes of all the subjects and the strongest correlation was found in Z_3^1 ($r = -0.559$, $P < 0.01$; Table 5, 6). Figure 6 and 7 showed the data set symmetry of some Zernike coefficients for both anterior cornea (Z_3^{-3} , Z_3^{-1} , Z_4^4 , Z_4^2) and ocular (Z_3^{-1} , Z_3^1 , Z_4^{-4} , Z_4^{-2}) on the line $y = 0$.

DISCUSSION

To avoid interference, the effect factors as following were concerned.

Age The subjects in our study ranged in age from 18 to 49 continuously and ranged in SE from -1.00 D to -6.00 D. As

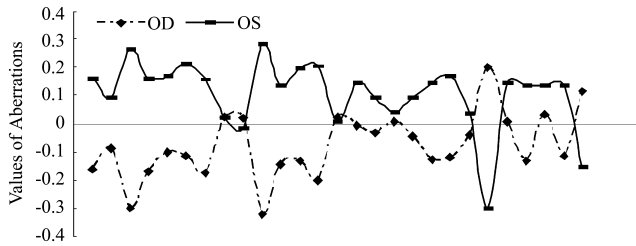


Figure 6 The individual Zernike coefficients Z3-1 of corneal aberration were plotted between bilateral eyes, showing the correlation between left and right eyes

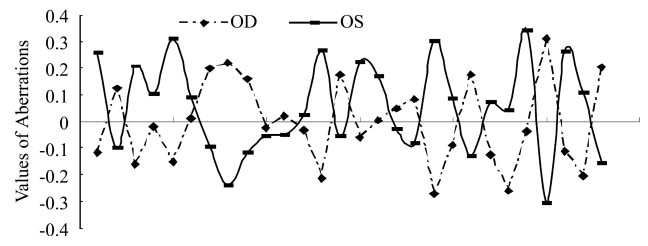


Figure 7 The individual Zernike coefficients Z31 of ocular aberration were plotted between bilateral eyes, showing the correlation between left and right eyes

Table 3 Comparison of Zernik values in the Cornea of bilateral eyes

	OS	OD	t	P
Z ₃ ⁻³	0.089±0.093	0.095±0.064	0.405	0.546
Z ₃ ⁻¹	0.096±0.067	0.080±0.062	1.335	0.173
Z ₃ ¹	0.125±0.075	0.104±0.075	1.508	0.128
Z ₃ ³	0.112±0.063	0.100±0.068	0.986	0.365
Z ₄ ⁻⁴	0.045±0.034	0.038±0.029	1.193	0.248
Z ₄ ⁻²	0.044±0.040	0.039±0.025	0.807	0.435
Z ₄ ⁰	0.257±0.068	0.251±0.058	0.511	0.517
Z ₄ ²	0.034±0.024	0.030±0.014	1.096	0.342
Z ₄ ⁴	0.048±0.020	0.043±0.027	1.133	0.276
RMS3	0.117±0.035	0.111±0.034	0.936	0.373
RMS4	0.121±0.032	0.119±0.026	0.369	0.710

Data are expressed as mean±SD

There is no statistically significant difference for anterior corneal aberration in bilateral eyes (P>0.05)

Table 4 Comparison of Zernik values in the whole eyes of bilateral eyes

	OS	OD	t	P
Z ₃ ⁻³	0.128±0.095	0.161±0.167	1.308	0.186
Z ₃ ⁻¹	0.133±0.115	0.161±0.117	1.300	0.190
Z ₃ ¹	0.109±0.089	0.086±0.069	1.555	0.124
Z ₃ ³	0.134±0.192	0.140±0.180	0.174	0.881
Z ₄ ⁻⁴	0.084±0.102	0.110±0.100	1.386	0.154
Z ₄ ⁻²	0.088±0.087	0.063±0.083	1.583	0.115
Z ₄ ⁰	0.089±0.067	0.078±0.014	1.224	0.235
Z ₄ ²	0.079±0.063	0.097±0.090	1.248	0.231
Z ₄ ⁴	0.095±0.012	0.091±0.011	1.871	0.059
RMS3	0.178±0.125	0.200±0.126	0.944	0.368
RMS4	0.146±0.093	0.139±0.098	0.395	0.580

Data are expressed as mean±SD

There is no statistically significant difference for total aberration in bilateral eyes (P>0.05)

Table 5 The correlation of corneal zernik values in bilateral eyes

	Z ₃ ⁻³	Z ₃ ⁻¹	Z ₃ ¹	Z ₃ ³	Z ₄ ⁻⁴	Z ₄ ⁻²	Z ₄ ⁰	Z ₄ ²	Z ₄ ⁴
r	0.782	0.675	-0.393	-0.181	-0.648	-0.240	0.696	0.558	0.261
P	0.000*	0.001*	0.078	0.254	0.001*	0.165	0.000*	0.009*	0.147

The star symbols indicate significant positive correlations for Z₃⁻³ (r=0.782, P<0.01), Z₃⁻¹ (r=0.675, P<0.01), Z₄⁰ (r=0.696, P<0.01), Z₄² (r=0.558, P<0.01) and negative correlation for Z₄⁻⁴ (r=-0.648, P<0.01)

Table 6 The correlation of whole eye zernik values in bilateral eyes

	Z ₃ ⁻³	Z ₃ ⁻¹	Z ₃ ¹	Z ₃ ³	Z ₄ ⁻⁴	Z ₄ ⁻²	Z ₄ ⁰	Z ₄ ²	Z ₄ ⁴
r	0.139	0.496	-0.559	-0.121	-0.068	-0.453	0.457	0.440	0.058
P	0.294	0.022*	0.008*	0.432	0.768	0.039*	0.037*	0.042*	0.88

The star symbols indicate significant positive correlations for Z₃⁻¹ (r=0.496, P<0.05), Z₄⁰ (r=0.457, P<0.05), Z₄² (r=0.440, P<0.05), Z₄² (r=0.585, P<0.01) and negative correlation for Z₃¹ (r=-0.559, P<0.01), Z₄⁻² (r=-0.453, P<0.05)

previous studies [1] have shown, higher-order wavefront aberrations for ocular increase when the subjects were more than 40 years old. Brunette *et al* [5] and associates found that the total high-order aberrations decreased gradually with age to a rock bottom before 40 years old, and then increased with aging when the subjects were more than 40, therefore subjects in our study were divided into two group (ranged in age from 18 to 40 years old and 41 to 49 years old, who also were candidates for refractive surgery).

Diopter He *et al* [6] found that high myopia and astigmatism were usually accompanied by high-order aberrations. There are statistically significant correlations between Zernike terms and diopters. In this study, the patients' spherical

component of the manifest refraction ranges from -1.00 D to -6.00 D, and cylindrical diopters are lower than -1.00D.

Pupil Size Irregular aberrations do not have a large effect on retinal image quality in normal eyes when the pupil is small (3mm). However, they play a substantial role when the pupil is large (especially larger than 6mm), reducing visual performance and the resolution of images of the living retina. That means pupillary dilation markedly increases wavefront aberrations [4]; therefore the pupils were dilated by tropicamide (1%) to larger than 6mm in this study.

Tear Film Since the tear film's instability has been proved that it could bring on the irregularity of the cornea and increasing the high-order wavefront aberrations, all the

subjects in the study group were tested by Shirmer test and BUT with normal base secretory function and stability of tear films^[5].

The balance between the anterior corneal surface and the internal structures Recently, most reports only focus on the study of whole eye aberration, and the detail aberration of corneal and internal optics (especially for lens) in the same eye could not be separately analyzed due to the limit of the aberration analyzer machine. By converting the same design aberration analyzer of corneal and whole aberration here. Our results showed that the anterior corneal horizontal coma aberration increased with aging ($r=0.307$, $P<0.01$) and total horizontal coma aberration ($r=0.451$, $P<0.05$), spherical aberration ($r=0.438$, $P<0.05$), RMS3 ($r=0.306$, $P<0.05$), RMS4 ($r=0.293$, $P<0.05$) also showed positive correlations with age. The anterior corneal and total horizontal comas were similar in the magnitude in young group, as they were in middle-aged group; whereas the absolute value of this Zernike coefficient of both cornea and ocular increased significantly. The magnitude of spherical aberration was larger in the anterior cornea than that in the complete eye in young group. Even more the total spherical aberration in middle-aged group rapidly increased to be larger than the corneal one. However, Fujikado *et al*^[7] reported that ocular coma aberration and spherical aberration were correlated with age, whereas the corneal aberrations were not significantly correlated. Wang *et al*^[8-9] reported that it was the corneal vertical coma but not the horizontal one increases rapidly with aging for the persons aged more than 50-year-old. While in our study, it were the corneal horizontal coma ($P<0.01$), ocular horizontal coma and ocular spherical aberrations ($P<0.05$) increased with aging for the persons from 18 to 49 years old. There are two reasons to explain the discrepancy in the relationship of corneal horizontal aberration and age between our study and other studies: (1) The subject recruitment is different: age less than 50 years old in our study due to receiving corneal refractive surgery, while more than 50 years in others; (2) This also indicated the characters of horizontal coma changing to vertical coma with aging, which may explain the clinical manifestation that younger with with-rule astigmatism transfer into against-rule astigmatism with aging. Therefore the changing characters of coma with different aging stage should be prospective design in clinic refractive treatment.

Our results also strongly suggested that the increase of total coma with aging was mainly because of the increase of anterior corneal coma whereas the increase of spherical aberration of the whole eye was due to the changes of internal structures, which the posterior surface of the cornea

and the crystalline lens were the major elements. The results in our study stated more detail messages than that of the previous reports on the aging relation, even though the conclusion is the same^[10-12]. Zuzana *et al*^[13] found that the lenses of keratoconus can mask the anterior corneal aberrations by regularizing the anterior corneal surface, thereby reducing higher order aberrations. However, visual performance is not the same as after correction of a normal myopic or regular astigmatic eye. This suggests that some internal structures, presumably the posterior surface of the cornea, may induce a larger amount of aberrations in eyes with keratoconus. Dubbelman *et al*^[14] reported that the asphericity of the posterior corneal surface within the central 7.0mm decreased with age. However, because the posterior corneal surface acts as a negative lens, this actually represents an age-related mild increase in 4th-order spherical aberration (SA) of the posterior corneal surface. Therefore, it is conceivable that the posterior corneal surface contributes at least a portion of the increased positive SA of the internal optics. Therefore, there is no difference in Chinese and Western person in aberration relation between unilateral and bilateral eyes with myopia and astigmatism.

The wavefront aberrations produced by the crystalline lens balance the aberrations from the anterior cornea during the earlier stage of the developing eye. But, this balance was broken in elder subjects. With aging the anterior surface of cornea gradually becomes uneven because of irregular collagenous fibril in the center of cornea, irregular interspaces between corneal fibers, reduction in corneal epithelium and endothelium counts. All of which result in deviation from visual axis when light cross the cornea. Artal *et al*^[4] and associates found that the crystalline lens tend to compensate for the corneal aberrations. With aging the irregular and rough surface of crystalline lens resulting from the changes of lens zonule and the accumulation of metabolite induced the increase of aberrations of lens even the change in sign. These changes lead to the rise of aberrations of the complete eyes with age.

Therefore the refractive surgery by corneal ablation could make a great effort to improve vision only once, but not for all the times. Mrochen *et al*^[15-16] and his associates found that wavefront-guided custom ablation decreased the aberrations of the whole eye impermanently because the rise of aberrations deriving from lens with aging led to the increase of total aberrations and subsequently influences the visual qualities. The refractive surgeon might customize the nomogram considering age. For example, if patients much younger than 40 years, the surgery goal might be to based on the correction of pre-existing high ocular SA and some dysfunctional coma. However, when the patient approaching

age 40 years, it might be advisable to shift in SA to compensate for the impending anticipated aging changes, which try to keep the balance between corneal and internal optics after the surgery with aging.

In order to optimize the visual quality, intraocular lenses have been designed with an aberration profile matching that of the cornea or the lens. As Kasper *et al*^[17] and his associates found the fourth-order RMS, Z_4^0 and total HOA RMS of the aspherical IOL were significantly lower than the spherical IOL. Clearly the ideal substitute for the natural lens is designed to compensate the aberrations of the cornea.

Kamiya *et al*^[18] reported that wavefront-guided LASIK induced significantly larger HOAs, especially spherical like HOAs, than IOL implantation. Both IOL implantation and Artisan IOL implantation are thought to induce less HOA than wavefront-guided LASIK, possibly because the shape of the cornea is unchanged. Moreover, the toric IOL implantation was better than wavefront-guided LASIK in eyes with high myopic astigmatism.

Bilateral symmetry Right and left eyes were analyzed in 68 of the 82 subjects. in the study, the anterior corneal vertical coma aberration ($r=0.675$, $P<0.01$), total vertical coma aberration ($r=0.496$, $P<0.05$) and total horizontal coma aberrations ($r=-0.559$, $P<0.01$) were significantly correlated between right and left eyes. The scatter diagrams of bilateral Zernike terms presented symmetry clearly. Therefore it is not difficult to deduce that the wavefront aberrations produced by crystalline lens are symmetric. A moderate to high degree of correlation in optical aberrations of the cornea, the whole eye and internal optics between right and left eyes has been reported^[19].

The Zernike terms are defined in polar coordinates (θ, ρ) , where θ is the radial coordinate ranging from 0 to 1 and ρ is the angular component ranging from 0 degree to 360 degrees for both right and left eyes^[20]. Mirror symmetry in the aberration structure of eyes would make wavefront for the left eye and the right eye and would cause the Zernike coefficients for both eyes to be the opposite sign for all modes with odd symmetry about the y-axis. This is likely related to that the figures of human pupils between right and left eyes appear mirror symmetric^[21]. The mirror symmetry in wavefront aberrations between bilateral eyes dues to anatomic character of human eye but not entirely.

The vertical coma was significantly correlated to shift of the pupil center in X-axis but the horizontal coma aberration was not related to offset in Y-axis and the latter probably associated with the vertical pressure produced by eyelid to eyeball^[22]. On condition that the images on the bilateral retinas are equal in size, figure, color and luminosity excellent visual balance may achieve. The equal visions

between bilateral eyes are not equal to the same images on the retina since the differences in the refractive statuses and the optical systems. Eyeball structures between right and left eyes influence the sizes, figures, colors and luminosities of images. If there are great differences in the image qualities of right and left eyes, the visual balance between bilateral eyes will be broken. Wavefront aberration is the most essential one among all the influence factors. In case great differences of aberrations lead to unbalance between bilateral visions, stereopsis may be affected. Based on this character we should pay attention to not only the compensation of cornea and internal optics but also the symmetry of bilateral eyes. The mirror symmetry of magnitude and type of HOAs seen in contralateral eye studies points toward an evolutionary adaptation of binocular vision to compensate for and reduce the impact of optical defects^[23]. This is a possible explanation for why large variations of ocular aberration in normal eyes do not lead to an equally large array of visual complaints.

Therefore, before the refractive surgery, much more attentions should be on the surgical design in the filed of optic quality (physical and psychological harmonization) besides the best visual function and the ocular dynamic change with aging also should be considered. Interventions that tend to asymmetrically change aberrations on a consistent basis could be helpful to some patients and harmful to others.

Implantation of the aspherical IOLs with aberrations of different magnitude was performed to reduce total aberrations and optimize the visual outcome. In order to design and formulate the operative nomogram reasonably during the refractive surgery, the symmetry and cooperation of aberrations between bilateral eyes should be taken into account, especially for the patients who performed the corneal refractive surgery first and then cataract surgery several years later also could see clearly, comfortably and constantly further.

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