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Effect of eccentricity of overnight orthokeratology lenses on axial growth and visual quality

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角膜塑形镜的偏心对眼轴及视觉质量的影响

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摘要
目的:探讨角膜塑形(OK)镜片的偏心度对眼轴和视力质量的影响。
方法:根据OK镜片偏心程度,将患者分为三组:低偏心度组(偏心度≤0.5 mm),中偏心度组(0.5<偏心度≤1.0 mm)和高偏心度组(1<偏心度≤1.5 mm)。分析配戴OK镜后OK镜偏心程度、球面等效球镜度(SE)、未矫正视力(UCVA)、配戴OK镜前后眼轴长度(AL)、3 mm瞳孔下的总高阶像差(HOA)、彗差和球面像差(SA)。三组间各指标差异使用Kruskal-WallisH Rank分析。
结果:回顾性分析75例139眼。在低偏心组(53眼)中,平均年龄为(11.4±2.4)a,SE为(-3.24±1.48)D,AL为(24.85±1.01)mm;中偏心组(53眼),平均年龄(11.4±2.2)a,SE为(-3.22±1.29)D,AL为(25.15±0.92)mm;在高偏心组(31眼)中,平均年龄为(11.5±1.9)a,SE为(-3.54±1.43)D,AL为(24.95±0.84)mm。2a后,三组间眼轴的变化无显着性差异(P=0.089)。高偏心组HOA、SA、彗差明显高于中偏心组、低偏心组(P<0.05)。
结论:OK镜配戴过程中没有必要严格要求镜片位置的绝对居中。镜片不必要的调整可能会延迟眼轴控制。另外,眼轴控制与视觉质量之间的平衡关系应进一步探讨评估。
关键词:角膜塑形镜;镜片偏心;眼轴;高阶像差;球差;彗差

Abstract
- AIM: To explore the effect of eccentricity of overnight orthokeratology (OK) lenses on 2-year eye axial growth and visual quality.
- METHODS: Based on the degree of eccentricity of OK lenses, patients were divided into three groups: a low degree of eccentricity group (degree of eccentricity ≤0.5 mm), a group of moderate eccentricity (eccentric degree >0.5-≤1.0 mm) and a group with a high degree of eccentricity (eccentric degree >1-≤1.5 mm). The degree of eccentricity of the OK lens, spherical equivalent (SE), the uncorrected visual acuity after wearing OK lenses (UCVA), axial length before and after wearing OK lenses (AL), total higher-order aberrations (HOA), comas, and spherical aberrations (SA) for 3 mm pupils were analyzed. The difference among the three groups for all parameters was compared using the Kruskal-Wallis H Rank-Sum test.
- RESULTS: The study retrospectively analyzed 75 cases (139 eyes). In the low eccentricity group (53 eyes), the mean age was 11.4±2.4 years, SE was -3.24±1.48 D, and AL was 24.85±1.01 mm. In the moderate eccentricity group (53 eyes), the mean age was 11.4±2.2 years, SE was -3.22±1.29 D, and AL was 25.15±0.92 mm. In the high eccentricity group (31 eyes), the mean age was 11.5±1.9 years, SE was -3.54±1.43 D, and AL was 24.95±0.84mm. After two years, there was no significant difference in the changes of the axis among the three groups (P=0.089). The HOA, SA, and coma in the high eccentric group were significantly higher than in the middle eccentric group (P<0.05). The HOA, SA, and coma in the high eccentric group were also significantly higher than those in the low eccentric group (P<0.05).
- CONCLUSION: For OK lenses, it is unnecessary to strictly require the absolute centralization of the lens position. An unnecessary change of the lenses may delay the eye-axis control. However, the balance between axial control and visual quality should be assessed.
- KEYWORDS: orthokeratology lens; eccentricity of the lens; axial eye length; higher-order aberrations; spherical aberration; coma

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INTRODUCTION

The orthokeratology (OK) lens is a rigid contact lens used for remodeling the reverse geometry of the corneal shape. The OK lens can not only flatten the cornea of the central region but also steepen the peripheral cornea. The results in the generation of a myopic defocus effect of the retina, and the eye-axis growth of the myopia patient can be effectively controlled. However, a good fit of the OK lens, in particular for the optical area and the eccentric condition of the OK lens, affects the control effect of myopia. The eccentricity of the OK lens profoundly affects the visual quality, resulting in a decrease in the contrast sensitivity and an increase in the higher-order aberrations(HOA).

In the clinic, it is challenging to center the OK lens entirely. The eccentric wearing of OK lenses is, therefore, inevitable. In addition, eccentric wear will affect the visual quality, although in the clinic it is found that not every child who wears eccentrically has visual discomfort. Therefore, it should be explored how eccentric wearing of OK lenses affects the growth of the eye axis and the visual quality. We assessed the influence of different degrees of centricity of the OK lens on the eye-axis growth through a retrospective analysis to provide a basis for the clinical fitting of OK lenses.

SUBJECTS AND METHODS

Ethical Approval This study was performed following the ethical principles of the Declaration of Helsinki and was approved by the Second Affiliated Hospital of Fujian Traditional Chinese Medical University's Ethics Committee. All patients provided written informed consent after receiving a full explanation of the study.

Subjects This study included patients who were treated with OK lenses for two years at the Department of Ophthalmology of the Second People's Hospital of Fujian University of Traditional Chinese Medicine between 2015-2019. Based on the degree of eccentricity of the OK lens, patients were divided into three groups: a low degree of eccentricity group (degree of eccentricity ≤0.5 mm) including 53 eyes; a group of moderate eccentricity (eccentric degree >0.5-≤1.0 mm) including 55 eyes; and a group of 31 eyes with a high degree of eccentricity (eccentric degree >1-≤1.5 mm).

Measurements All patients underwent a complete ophthalmologic measurement. The spherical equivalent (SE) was measured by a computer optometry instrument (Japan, TOPCON, KR-800) after using cycloplegic drops. In this procedure, the subject looked at the inside pattern of the instrument, relaxed, and reduced frequent blinking. The inspector held the positioning rod to the image point to focus most clearly and pressed the measuring button to measure. Eye axial length (AL) measurements included the AL1 (the AL before wearing OK lens) and AL2 (the AL after wearing OK lens). It was measured using the IOL-Master instrument (Germany, ZEISS), and three data points were obtained for each measurement, and the average value was used for analysis. The degree of eccentricity of the OK lens was obtained using the corneal topography (the corneal front surface section) (Italy, CSO SIRIUS), the distance between the center of corneal and the center of circle shaped by the lens was measured. Total (HOA, spherical aberrations (SA), and comas for 3 mm pupils were obtained using the corneal topography (the anterior segment analysis system of the SIRIUS) (Italy, CSO SIRIUS). The uncorrected visual acuity after wearing OK lenses (UCVA) was assessed using a standard logarithmic visual acuity chart (GB11533-2011 of national standards), we recorded Decimal counting according to the formula: LogMAR = lg (1/Decimal counting) to convert values to LogMAR (Figures 1 and 2).

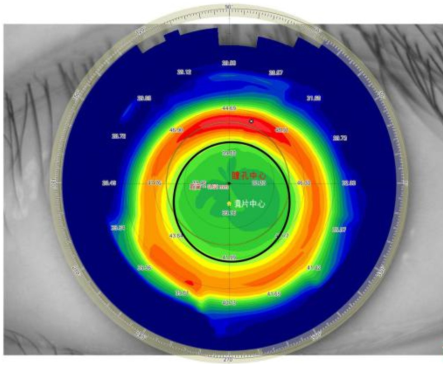

Figure 1 The degree of eccentricity of the OK lenses.

The OK Lens Parameters In this study, the OK lens used was the Euclid Systems OK Contact Lenses for overnight wear (Euclid Systems Corporation, USA). The total diameter of these lenses is 10.2-11.2 mm, the center thickness is (0.22±0.02) mm, and the oxygen permeability coefficient is 127 DK. The diameter of the optical region of the lens is 6.0-6.2 mm, the width of the inverted arc is 0.5 mm, and the suitable arc width is 1.2 mm.

Statistical Analysis Statistical analysis was performed using SPSS for Windows software (version 21, SPSS Inc., USA). The difference among the three groups for all parameters was compared using the Kruskal-Wallis H Rank-Sum test. The level of the test used was $\alpha = 0.05$, when $P < 0.05$, the difference was considered statistically significant.

RESULTS

We retrospectively analyzed 75 cases (139 eyes). In the low eccentricity group (53 eyes), the mean age was 11.4±2.4 (6-18) y, SE was -3.24±1.48 (-1.00 to -6.75) D, and AL was 24.85±1.01 (22.62-27.41) mm. In the moderate eccentricity group (53 eyes), the mean age was 11.4±2.2 (6-16) y, SE was -3.22±1.29 (-1.00 to -6.75) D, and AL was 25.15±0.92 (22.70-27.32) mm. In the high eccentricity group (31 eyes), the mean age was 11.5±1.9 (8-16) y, SE was -3.54±1.43 (-1.50 to -6.00) D, and AL was 24.95±0.84(23.00-26.18) mm. Table 1 presents the

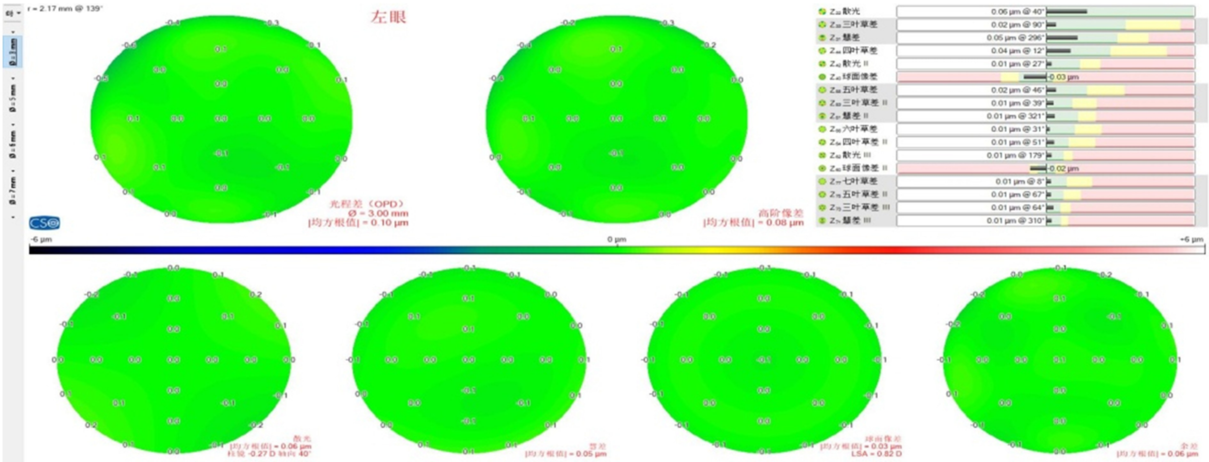

Figure 2　Total higher-order aberrations, spherical aberrations, and comas for 3 mm pupils.

Table 1　Age, SE, and AL1 before wearing OK lens in the three groups　　mean (range)

Paramenters	Low eccentricity group	Moderate eccentricity group	High eccentricity group	*P*
Eyes	53	55	31	
Age (y)	11.4 (6-18)	11.4 (6-16)	11.5 (8-16)	0.286
SE (D)	-3.24 (-1.00- -6.75)	-3.22 (-1.00- -6.75)	-3.54 (-1.50- -6.00)	0.447
AL1 (mm)	24.85 (22.62-27.41)	25.15 (22.70-27.32)	24.95 (23.00-26.18)	0.191

SE: Spherical equivalent; AL: Eye axial length.

Table 2　The UCVA, AL2, changes of AL, HOA, SA, and coma in the three groups　　mean±SD

Paramenters	Low eccentricity group	Moderate eccentricity group	High eccentricity group
UCVA (LogMAR)	0.06±0.21 (-0.18-1.40)	0.05±0.21 (-0.18-1.40)	0.03±0.12 (-0.08-0.52)
AL2 (mm)	25.26±1.02 (22.87-27.65)	25.44±0.91 (23.13-27.63)	25.20±0.79 (23.28-26.28)
changes of AL (mm)	0.40±0.33 (0.00-1.31)	0.29±0.27 (0.00-1.01)	0.25±0.21 (0.00-0.73)
HOA (μm)	0.15±0.08 (0.05-0.51)	0.17±0.09 (0.06-0.67)[b]	0.44±0.37 (0.11-1.49)[a]
SA (μm)	0.04±0.03 (0.00-0.14)	0.05±0.06(0.01-0.39)[b]	0.10±0.09 (0.01-0.32)[a]
Coma (μm)	0.08±0.07 (0.02-0.45)	0.11±0.15 (0.01-0.96)[b]	0.26±0.26 (0.02-0.96)[a]

UCVA: Uncorrected visual acuity; HOA: Total higher-order aberrations; SA: Spherical aberrations; Compared with the low eccentricity group, [a]$P<0.05$; compared with the moderate eccentricity group, [b]$P<0.05$.

age, SE, and AL before wearing OK lenses in the three groups, and there were no significant differences in these characteristics among the three groups.

The UCVA, AL2, and the change of AL before and after wearing the OK lenses, as well as the visual quality (HOA, SA, and coma) of the three groups are reported in Table 2. The mean UCVA in the low eccentricity group was LogMAR 0.06±0.21 (-0.18 to 1.40). In the moderate eccentricity group, the UCVA was LogMAR 0.05±0.21 (-0.18 to 1.40), and in the high eccentricity group this was LogMAR 0.03±0.11(-0.08 to 0.52). There were no significant differences in the UCVA among the three groups ($P=0.567$). The mean increase in AL in the low eccentricity group was 0.40±0.33 (0.00-1.31) mm, in the moderate eccentricity group this was 0.29±0.27 (0.00-1.01) mm, and in the high eccentricity group it was 0.25±0.21 (0.00-0.73) mm. There were no significant differences in the changes in AL among the three groups ($P=0.089$).

The mean HOA in the low eccentricity group was 0.15±0.08 (0.05-0.51) μm, which was 0.17±0.09 (0.06-0.67) μm in the moderate eccentricity group, and 0.44±0.37 (0.11-1.49) μm in the high eccentricity group. The mean SA in the low eccentricity group was 0.04±0.03 (0.00-0.14) μm, 0.05±0.06(0.01-0.39) μm in the moderate eccentricity group, and 10±0.09 (0.01-0.32) μm in the high eccentricity group. The mean coma in the low eccentricity group was 0.08±0.07 (0.02-0.45) μm, 0.11±0.15 (0.01-0.96) μm in the moderate eccentricity group, and 0.26±0.26 (0.02-0.96) μm in the high eccentricity group. The HOA, SA, and coma in the high eccentricity group were significantly higher than those in the moderate eccentricity group ($P<0.05$) and the low eccentricity group ($P<0.05$).

DISCUSSION

Wearing OK lenses is an effective method to control the development ofmyopia[1-3]. But the fitting of corneal plastic lenses affects the wearer's control of myopia, especially the eccentricity of corneal plastic lenses[4-5]. In this study, the grading of eccentricity was determined based on previous studies[6]. The diameter of the basal arc of the corneal plastic mirror is 6 mm, which is large enough to ensure the reverse curve area (a curve of the OK lens) does not enter the pupil area when the eccentricity range is between 1.0 and 1.5. This prevents poor visual effects for the wearer, such as double vision, glare, and poor UCVA.

A studyshowed that the annual axial growth of children around the age of 10 was 0.39 mm when wearing regular frameworks and 0.26 mm in those wearing OK lenses. There was a significant difference between two groups[7]. The increase in axial length of the group wearing OK lenses was significantly less than that in the group wearing ordinary frame glasses group after 6 and 12mo[8]. We retrospectively analyzed the eye axis changes after two years of wearing OK lenses, and found that the eye axis growth value of the low-grade eccentricity group was approximately 0.40 mm and the average annual growth value was 0.20 mm, which was close to that found in other studies. Wang *et al*[9] found that the decentering of OK lenses can significantly delay the development of myopia more effectively than centric lenses. Studies indicated that the AL growth rate is significantly associated with post-treatment relative peripheral refractive power[10]. Yang *et al*[11] also found that the probability of having a successful myopia progression control is related to the amplitude of modulation of the peripheral refractive power over the 360 degrees of the peripheral corneal zone. In this study, based on the degree of eccentricity, changes of the axial axis in three groups were compared. We found that the higher the degree of eccentricity was, the less AL increased, but there was no significant difference in the changes of AL between the three groups with varying degrees of eccentricity. This is in contrast to findings by Wang *et al*[9]. One explanation for the difference in results is that our study had three groups that may have impacted the comparison.

Other studies have suggested that overnight wearing of OK lenses can induce significant changes in opticalquality[12-14]. Sun *et al*[15] observed that the SA significantly increased in the first month (0.012 to 0.055) μm, the coma aberration significantly increased after 3mo (0.047-0.117) μm, and the HOA decreased in the first month (0.109-0.209). We found that the HOA, SA, and coma increased with a higher eccentricity of the OK lens. The HOA, SA, and coma of the high eccentricity group were significantly higher than those of the low and moderate eccentricity groups. Xia *et al*[16] measured changes in visual performances and visual quality during the first month of wearing OK lenses in children with myopia and discovered that corneal optical quality decreased steadily during the first month of lens wearing, but the visual acuity remained satisfactory. In our study, the UCVA of the three groups was not significantly different in the three groups. This indicates that UCVA, after wearing OK lenses, might not be associated with visual quality (HOA, SA, and coma).

Several studies have reported that OK lenses can increase the Root-Mean-Square of HOA, especially the SA and coma aberration[17-19]. The increase in SA is mainly attributed to the non-physiological oblate cornea after wearing the lenses, and the increase in coma aberration reflects contact lenses decentering[20]. However, few reports have assessed the relationship between eccentricity and visual qualities. We discovered that high eccentricity slightly decreases the visual qualities. Therefore, to obtain better visual quality, the lens should be centered.

In the past, many clinicians assumed that the more correct the position of the corneal plastic lens is, the better the visual acuity, visual quality, and axial length is. However, our study showed that this is not the case. Other studies have shown that in most cases, the amount of lens decentering is moderate and acceptable[21]. It will be essential to assess how to balance the AL control and the best visual quality. Our study had some limitations. First, in our study, the wearer was not tested with Ocular Surface Disease Index (OSDI) subjective visual quality scale after wearing OK lenses. It would be interesting to determine the relationship between the OSDI subjective visual quality scale and vision quality. Second, our sample size is limited. The balance between axial control and visual quality requires further research and discussion.

For wearing OK lenses, it is not necessary to strictly require the absolute centralization of the lens position. An unnecessary change of the lens may delay eye-axis control. The balance between axial control and visual quality should be assessed.

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