Multi-Factor Analysis of the Influence of Orthokeratology on Controlling Myopia in Adolescents

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Abstract

Background To investigate which baseline factors are predictive for axial length growth over an average period of 1 years in a group of adolescents wearing orthokeratology (OK) contact lenses.

Methods In this retrospective study, the clinical records of 189 new OK wearers (378 eyes) between 2014 and 2018 at Xiangya Hospital of Central South University were reviewed. The primary outcome measure was axial length change from baseline to the time of 1 year. Independent variables included baseline measures of age at initiation of OK wear, refractive error (spherical equivalent), corneal thickness, corneal curvature. (1) Age group, 8 ~ 10 years old is the first group, 10 ~ 13 years old is the second group, ≥13 years old is the third group; (2) Myopia degree group, ≥-3.00D is the first group, -3.00 ~ -6.00D is the second group, <-6.00D is the third group; (3) corneal thickness group, ≤550μm is the first group,> 550μm is the second group; (4) corneal curvature group, ≤42.0D is The first group, 42.0 ~ 44.0D is the second group,> 44.0D is the third group.

Results ANOVA was used to analyze the difference between the baseline axial length of each group and the axial length for 1 year after continuous wearing of orthokeratology: (1)The mean axial difference between different age groups are 0.251mm, 0.033mm,and 0.112mm, and the difference of the three groups is not statistically significant (F=2.279，P=0.104). By pairwise comparison, only the difference between the first group and the third group is statistically significant (P=0.041); (2) The mean axial difference between different myopia degree groups are 0.173mm, 0.109mm and -0.008mm, and the difference of the three groups is statistically significant (F=8.340，P=0.000). By pairwise comparison, the difference between the first group and the second group is statistically significant (P=0.000) and the difference between the first group and the third group is statistically significant(P=0.016); (3) The mean axial difference between different corneal thickness groups and corneal curvature groups is not statistically significant.

Conclusions OKs are effective in controlling axial length elongation and myopic progression in adolescents, particularly in younger children with higher myopia.

Background

Myopia, as the highest incidence of refractive error, has an increasing incidence and a trend toward the younger. Currently, most myopia is produced by axial elongation and orthokeratology as a treatment to control the progression of myopia by controlling the axial elongation has attracted the attention of many medical institutions. Clinically, the role of orthokeratology in controlling myopia progression has been widely affirmed, but there are individual differences and related factors affecting treatment effect. Therefore, it is very necessary to understand the relevant factors. This article summarizes the effect of age, myopia degree, corneal thickness, and corneal curvature on the difference between the basic axial length and the axial length after one year of continuous wearing of orthokeratology.

Methods

Subjects A total of 189 subjects (n = 279 eyes), all of whom continuously wore orthokeratology for 1 year were enrolled. All subjects visited the Xiangya Hospital of Central South University, Changsha, China, from 2014 to 2018. Inclusion criteria comprised of patients with no amblyopia, no strabismus, no history of wearing orthokeratology and other contact lenses, no ocular inflammation, no ocular organic diseases, and good compliance.

Methods The selected subjects were grouped according to age, myopia degree, corneal thickness and corneal curvature, and the basic axial length and the axial length after 1 year of continuous wearing of orthokeratology were collected. (1) Age group, 8 ~ 10 years old is the first group, 10 ~ 13 years old is the second group, ≥ 13 years old is the third group; (2) Myopia degree group, ≥-3.00D is the first group, -3.00 ~ -6.00D is the second group, <-6.00D is the third group; (3) corneal thickness group, ≤ 550 μm is the first group,> 550 μm is the second group; (4) corneal curvature group, ≤ 42.0D is The first group, 42.0 ~ 44.0D is the second group,> 44.0D is the third group.The following pre-orthokeratology examinations are carried out in accordance with standard operations: External eye and Anterior segment (Slit-lamp microscope), Intraocular pressure (Non-contact tonometer), Fundus (Fundus photography), Breakup time of lacrimal film (BUT), Corneal morphology (Corneal curvometer and Corneal topography), Corneal endothelial cells (Non-contact corneal endothelial microscope), Axial length (IOL-MASTER), Corneal thickness (Coeneal pachymeter), Diopter (Automatic refractometer, Comprehensive refractometer).After excluding non-indications, subjects wore the appropriate OKs whose oxygen permeability coefficient was above 90, and physical properties also meet the relevant regulations of the State Food and Drug Administration. After wearing OKs, rugular examinations were performed every 1 to 3 months, including visual acuity, refractive changes, corneal curvature, corneal topography, the ocular surface and lens condition. The tear membrane, corneal endothelial cells, axial length and corneal thickness were reviewed regularly every 3 to 6 months.The baseline axial length before wearing OKs and the axial length after continuous wearing of OKs for 1 year were included in the statistical data, and the statistical analysis were performed according to the group of age, myopia degree, corneal thickness and corneal curvature.

Statistical Analysis Data analysis was performed using version 23.0 SPSS software (SPSS, Inc., Chicago, IL, USA).The comparison of the axial length difference between different groups was performed by independent sample t test (two classification) or analysis of variance (three classification), and further pairwise comparisons were performed by LSD-t test. A *P*-value of < 0.05 was considered statistically significant.

Results

The relationship between age and the mean difference of axial length

The mean difference of axial length in the three age groups are 0.173 ± 0.488 mm, 0.109 ± 0.426 mm and − 0.008 ± 0.105 mm. By pairwise comparison, the mean difference between the first group and the third group is statistically significant ($P = 0.041$).

Table 1
Comparison of mean difference of axial length between different age groups.

Related factors		N	The mean difference of axial length/mm	F	P
Age/y	8 ~ 10		0.173 ± 0.488	2.279	0.104
	10 ~ 13		0.109 ± 0.426		
	≥ 13		-0.008 ± 0.105		

Table 2
Pairwise comparison of mean difference of axial length between different age groups

Age group(I)	Age group(J)	The mean difference of axial length(I-J)/mm	P
1	2	0.064 ± 0.056	0.252
	3	0.181 ± 0.088	0.041
2	1	-0.064 ± 0.056	0.252
	3	0.117 ± 0.090	0.192
3	1	-0.181 ± 0.088	0.041
	2	-0.117 ± 0.090	0.192

The relationship between myopia degree and the mean difference of axial length

The mean difference of axial length in the three myopia degree groups are 0.251 ± 0.317 mm, 0.033 ± 0.515 mm and 0.112 ± 0.203 mm. By pairwise comparison, the difference between the first group and the second group is statistically significant ($P = 0.000$) and the difference between the first group and the third group is statistically significant($P = 0.016$).

Table 3
Comparison of mean difference of axial length between different myopia degree groups

Related factors		N	The mean difference of axial length/mm	F	P
Myopia degree/D	≥-3.00	114	0.251 ± 0.317	8.340	0.000
	-3.00~-6.00	146	0.033 ± 0.515		
	<-6.00	19	0.112 ± 0.203		

Table 4
Pairwise comparison of mean difference of axial length between different myopia degree groups

Myopia degree group(I)	Myopia degree group(J)	The mean difference of axial length(I-J)/mm	*P*
1	2	0.218 ± 0.007	0.000
	3	0.140 ± 0.027	0.016
2	1	-0.218 ± 0.007	0.000
	3	-0.080 ± 0.026	0.213
3	1	-0.140 ± 0.027	0.016
	2	0.080 ± 0.026	0.213

The relationship between corneal thickness degree and the mean difference of axial length

The mean axial difference between different corneal thickness groups are 0.148 mm and 0.113 mm, and the difference of the two groups is not statistically significant ($F = 0.664, P = 0.507$).

Table 5
Comparison of mean difference of axial length between different corneal thickness groups

Related factors		*N*	The mean difference of axial length/mm	*F*	*P*
Corneal thickness/μm	≤ 550	117	0.148 ± 0.378	0.664	0.507
	>550	162	0.113 ± 0.479		

The relationship between corneal curvature and the mean difference of axial length

The mean axial difference between different corneal curvature groups are 0.213 mm, 0.503 mm and 0.617 mm, and the difference of the three groups is not statistically significant ($F = 0.062, P = 0.940$).By pairwise comparison, the difference of the three groups is not statistically significant.

Table 6
Comparison of mean difference of axial length between different myopia degree groups

Related factors		*N*	The mean difference of axial length/mm	*F*	*P*
Corneal curvature/D	≤ 42.0	99	0.138 ± 0.214	0.062	0.940
	42.0 ~ 44.0	147	0.119 ± 0.503		
	>44.0	33	0.133 ± 0.617		

Table 7
Pairwise comparison of mean difference of axial length between different myopia degree groups

Corneal curvature group(I)	Corneal curvature group(J)	The mean difference of axial length(I-J)/mm	*P*
1	2	0.020 ± 0.007	0.732
	3	0.005 ± 0.018	0.956
2	1	-0.020 ± 0.007	0.732
	3	-0.015 ± 0.016	0.863
3	1	-0.005 ± 0.018	0.956
	2	0.015 ± 0.016	0.863

Discussion

Orthokeratology has been shown to be the most effective non-pharmacological method for controlling the progression of myopia. OKs make corneal epithelial cells to migrate and redistribute and flatten the central cornea while steeping the midperipheral cornea to reduce relative peripheral hyperopia, which may slow the elongation of the axial length[1, 2]. At present, the axial length is considered to be an effective parameter for monitoring the progression of myopia[3, 4], and the effect of the orthokeratology in controlling the axial elongation is certain[5–7], but there are many factors that affect the development of the axial length, such as age, myopia degree, corneal thickness and corneal curvature. The study has analyzed multiple factors and multiple grades and found that the axial elongation is highly correlated with the initial age and myopia degree of OK wearers.

Wong et al researched the eye growth fitting curve and found that the annual growth of the axial length decreased with age, especially after 10 years old[8]; Fledelius et al found that the average elongation of the axial length was less than 0.1 mm/year between the age of 7 to 8 and less than 0.01 mm/year between the age of 10 to 12, during their researches, axial length was about 16 mm at birth, grew to 23 mm at 3 years old, and 24 mm at adulthood[9]. The above studies have proved that the growth rate of the axial length slows down with the age. This study found that the axial elongation rate of the older children (≥ 13 years old) is slower than that of the younger children (8–10 years old). Studies at home and abroad support that the initial age of OK wearers is negatively correlated with the axial elongation[10–15] and consider that the effect of age may be due to the slower eyeball growth of older children. Cho et al proved that OKs can significantly reduce the risk of rapid progression of myopia and younger wearer can benefit more in the long term, although younger children have a higher axial growth rate[16].

The results of current researches on the relationship between initial myopia degree and axial elongation are contradictory. A small number of studies show that there is no correlation between initial myopia degree and axial elongation[17, 18]. Kakita et al obtained a negative correlation between initial myopia degree and axial elongation, however, they compared the distribution of axial elongation in different grade of myopia degree and concluded that the axial elongation wound be slower only in the higher myopia degree[19]. A large number of studies still believe that the the axial elongation is negatively correlated with the initial myopia degree[12, 20, 21]. Wang et al considered that this was related to the possible existence of the maximum threshold of myopia degree and axial length, there is a lot of room for axial elongation in lower myopia degree, and the axial length grow fast, but once it approaches the threshold, the axial elongation naturally slows down[12]. Most studies believe that this may be related to the relative peripheral hyperopia defocus which can cause axial elongation and myopia progression[22, 23], the hypothesis is that, the higher the myopia degree, the steeper the central and peripheral cornea will be, and the less harmful effects of relative peripheral hyperopia will be on the retina which can reduce the stimulation to axial length and myopia progression[24–26]. This article compares the mean value of the axial length between baseline and the follow-up time of 1 year among the low, medium, and high myopia groups and supports that the benefit in OK wearers of the moderate and high myopia is better than that of the low myopia.

This study proves that the initial corneal thickness has no correlation with the axial elongation, which is consistent with the conclusions of the current literature[12, 27]. Lee et al concluded that the initial corneal thickness was negatively correlated with the axial elongation, but they proposed that this correlation is highly dependent on the age, and believed that the younger wearers had thinner and more flexible corneal thickness which is less likely to be affected by the cornea shape changes caused by the orthokeratology lens[11].

At present, there are few studies on the relationship between initial corneal curvature and axial elongation. Some studies believe that the initial corneal curvature has nothing to do with the axial elongation[15]. Xie Jing et al believe that the initial corneal curvature is negatively correlated with the axial elongation[28], but there is no similar report in China. In this study, the initial corneal curvature is not related to the axial elongation.

In summary, the orthokeratology lens can effectively control the elongation of the axial length and is an effective method to control the progression of myopia. The initial age and myopia degree significantly affect the axial elongation. Although the older initial age and the higher myopia degree OK wearers achieve the better effect in controlling the progression of myopia, but in the long term, the earlier the treatment for myopia, the higher benefit the children will obtain.

Abbreviations

OK: Orthokeratology

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of Xiangya Hospital of Central South University. The whole procedure strictly complied with the tenets of the Declaration of Helsinki, and the written informed consent was obtained from all subjects and their guardians before joining in the project.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Author's contribution

SW and XZ designed the study, analyzed the data, and write the manuscript. SM, CX, SH, XR, XT and XX performed the examinations, collect the data, and managed the whole study. XZ instructed the whole study and revised the manuscript. The authors read and approved the final manuscript.

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References

1. Huang J, Wen D, Wang Q *et al*. Efficacy Comparison of 16 Interventions for Myopia Control in Children: A Network Meta-analysis. Ophthalmology. 2016; 123(4):697-708.
2. Smith MJ, Walline JJ. Controlling myopia progression in children and adolescents. Adolescent health, medicine and therapeutics. 2015; 6:133-140.
3. Cheung SW, Cho P. Validity of axial length measurements for monitoring myopic progression in orthokeratology. Investigative ophthalmology & visual science. 2013; 54(3):1613-1615.
4. Fledelius HC, Goldschmidt E. Oculometry findings in high myopia at adult age: considerations based on oculometric follow-up data over 28 years in a cohort-based Danish high-myopia series. Acta ophthalmologica. 2010; 88(4):472-478.

5. VanderVeen DK, Kraker RT, Pineles SL *et al*. Use of Orthokeratology for the Prevention of Myopic Progression in Children: A Report by the American Academy of Ophthalmology. Ophthalmology. 2019; 126(4):623-636.
6. Swarbrick HA, Alharbi A, Watt K *et al*. Myopia control during orthokeratology lens wear in children using a novel study design. Ophthalmology. 2015; 122(3):620-630.
7. Sheng-Fa Hu, Zhou Xia, Tan Xing Ping *et al*. Efficacy of orthokeratology lens for treatment of juvenile myopic astigmatism. China Journal of Modern Medicine. 2015.
8. Wong HB, Machin D, Tan SB *et al*. Ocular component growth curves among Singaporean children with different refractive error status. Investigative ophthalmology & visual science. 2010; 51(3):1341-1347.
9. Fledelius HC, Christensen AS, Fledelius C. Juvenile eye growth, when completed? An evaluation based on IOL-Master axial length data, cross-sectional and longitudinal. Acta ophthalmologica. 2014; 92(3):259-264.
10. Chen R, Chen Y, Lipson M *et al*. The Effect of Treatment Zone Decentration on Myopic Progression during Or-thokeratology. Current eye research. 2020; 45(5):645-651.
11. Lee EJ, Lim DH, Chung TY *et al*. Association of Axial Length Growth and Topographic Change in Orthokeratology. Eye & contact lens. 2018; 44(5):292-298.
12. Wang B, Naidu RK, Qu X. Factors related to axial length elongation and myopia progression in orthokeratology practice. PloS one. 2017; 12(4):e0175913.
13. He M, Du Y, Liu Q *et al*. Effects of orthokeratology on the progression of low to moderate myopia in Chinese children. BMC ophthalmology. 2016; 16:126.
14. Zhong Y, Chen Z, Xue F *et al*. Central and Peripheral Corneal Power Change in Myopic Orthokeratology and Its Relationship With 2-Year Axial Length Change. Investigative ophthalmology & visual science. 2015; 56(8):4514-4519.
15. Zhu MJ, Feng HY, He XG *et al*. The control effect of orthokeratology on axial length elongation in Chinese children with myopia. BMC ophthalmology. 2014; 14:141.
16. Cho P, Cheung SW. Protective Role of Orthokeratology in Reducing Risk of Rapid Axial Elongation: A Reanalysis of Data From the ROMIO and TO-SEE Studies. Investigative ophthalmology & visual science. 2017; 58(3):1411-1416.
17. Cho P, Cheung SW. Retardation of myopia in Orthokeratology (ROMIO) study: a 2-year randomized clinical trial. Investigative ophthalmology & visual science. 2012; 53(11):7077-7085.
18. Hiraoka T, Kakita T, Okamoto F *et al*. Long-term effect of overnight orthokeratology on axial length elongation in childhood myopia: a 5-year follow-up study. Investigative ophthalmology & visual science. 2012; 53(7):3913-3919.
19. Kakita T, Hiraoka T, Oshika T. Influence of overnight orthokeratology on axial elongation in childhood myopia. Investigative ophthalmology & visual science. 2011; 52(5):2170-2174.

20. Fu AC, Chen XL, Lv Y *et al*. Higher spherical equivalent refractive errors is associated with slower axial elongation wearing orthokeratology. Contact lens & anterior eye : the journal of the British Contact Lens Association. 2016; 39(1):62-66.
21. Zhong Y, Ke L, Qiong W *et al*. Orthokeratology lens for management of myopia in anisometropic children: A contralateral study. Contact lens & anterior eye : the journal of the British Contact Lens Association. 2020; 43(1):40-43.
22. Smith EL, Kee CS, Ramamirtham R *et al*. Peripheral vision can influence eye growth and refractive development in infant monkeys. Investigative ophthalmology & visual science. 2005; 46(11):3965-3972.
23. Smith EL, Huang J, Hung LF *et al*. Hemiretinal form deprivation: evidence for local control of eye growth and refractive development in infant monkeys. Investigative ophthalmology & visual science. 2009; 50(11):5057-5069.
24. Charm J, Cho P. High myopia-partial reduction ortho-k: a 2-year randomized study. Optometry and vision science : official publication of the American Academy of Optometry. 2013; 90(6):530-539.
25. Gifford KL, Gifford P, Hendicott PL *et al*. Stability of peripheral refraction changes in orthokeratology for myopia. Contact lens & anterior eye : the journal of the British Contact Lens Association. 2020; 43(1):44-53.
26. Kang P, Swarbrick H. Peripheral refraction in myopic children wearing orthokeratology and gas-permeable lenses. Optometry and vision science : official publication of the American Academy of Optometry. 2011; 88(4):476-482.
27. Wan K, Cheung SW, Wolffsohn JS *et al*. Role of corneal biomechanical properties in predicting of speed of myopic progression in children wearing orthokeratology lenses or single-vision spectacles. BMJ open ophthalmology. 2018; 3(1):e000204.
28. Xie Jing, Feng Yun Hong, Jin Shou Mei *et al*. Regression analysis on influence factors of orthokeratology controlling juvenile myopia progression. International Eye ence. 2015; 15(5):872-874.