Clinical and Epidemiologic Research

Long-Term Axial Length Shortening in Myopic Orthokeratology: Incident Probability, Time Course, and Influencing Factors

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Purpose. Long-term axial length (AL) shortening in myopia is uncommon but noteworthy. Current understanding on the condition is limited due to difficulties in case collection. The study reported percentage, probability, and time course of long-term AL shortening in myopic orthokeratology based on a large database.

Methods. This study reviewed 142,091 medical records from 29,825 subjects in a single-hospital orthokeratology database that were collected over 10 years. Long-term AL shortening was defined as a change in AL of −0.1 mm or less at any follow-up beyond 1 year. Incident probability was calculated based on multivariate logistic regression. Time course was estimated using mixed-effect regression model.

Results. A total of 10,093 subjects (mean initial age, 11.70 ± 2.52 years; 58.8% female) with 80,778 visits were included. The number of subjects experienced long-term AL shortening was 1,662 (16.47%; 95% confidence interval, 15.75%–17.21%). Initial age showed significant impact on the incident occurrence (OR, 1.37; 95% confidence interval, 1.34–1.40; $P < 0.001$). The estimated probability of AL shortening was approximately 2% for subjects with initial age of 6 years and 50% for those aged 18. Among the 1662 AL shortening cases, the median magnitude of the maximum AL reduction was 0.19 mm. The shortening process mostly occurred within the initial 2 years. Subject characteristics had limited associations with the shortening rate.

Conclusions. Long-term AL shortening is possible in subjects receiving myopic orthokeratology. Although age notably affect the incident probability, the time course seems to not vary significantly.

Keywords: axial length shortening, orthokeratology lenses, myopia

Myopia is an important public health issue that has sparked great concerns worldwide.[1] In recent decades, both the escalating prevalence and the tendency toward earlier onset have compounded the global burden of the condition.[2–4] A key characteristic of myopia is the pathologically rapid elongation of axial length (AL). It has been firmly established that accelerated AL growth manifests years before disease onset.[5,6] After myopia has developed, the rapider than normal AL progression continues[7] and typically stabilizes at approximately 16 years of age.[8] In some instances, axial elongation endures into early adulthood, albeit slower than that in children.[9]

The excessively elongated AL in myopia brings increased risks of irreversible blinding complications.[10,11] To retard excessive eye growth, many myopia control strategies have been developed and validated. These include low-concentration atropine,[12,13] orthokeratology,[14,15] bifocal and multifocal soft contact lenses,[16,17] and spectacles with specific optical designs.[18,19] By far, all the currently available strategies, on average, can only slow down myopic axial elongation. Nevertheless, there exist unusual but confirmed cases presenting long-term AL shortening after some myopia control interventions.

The phenomenon of reduced AL in myopia is intriguing and noteworthy, challenging the conventional notion of axial elongation as an irreversible process. A meticulous investigation of long-term AL-shortening cases might provide insight into underlying mechanisms, potentially paving the way for more effective myopia control strategies and even regression of myopia. However, limited by the rarity of the condition, some major questions remain unanswered. These include the percentage of incident occurrence, predisposing subject characteristics, and detailed time course and influencing factors of the AL change. Addressing these queries necessitates systemic analyses within a sizable cohort with considerable follow-up. and the answers might vary among subjects receiving different myopia control interventions.

Using a 10-year single-hospital database of medical records of more than 140,000 patient visits related to orthokeratology, this study aimed to ascertain the percentage of long-term AL shortening under orthokeratology treatment and the incident probability for different subject characteristics. As a secondary objective, we attempted to elucidate the time course of AL shortening and identify potential factors associated with this longitudinal change.

Methods

Subjects

This was a hospital-based cohort study using data consecutively collected over 10 years (September 2010 to October 2020) at Zhongshan Ophthalmic Center, Sun Yat-sen University. A total of 142,091 medical records from 29,825 subjects who were evaluated for orthokeratology were inclusively reviewed. Exclusions were made for subjects with best corrected visual acuity of less than 20/25 in either eye, missing data (including refraction, keratometry [K] values, visual acuity, and AL data) at the visit of first orthokeratology lens prescription, or the longest interval of AL measurements between follow-up visit and the visit of first orthokeratology lens prescription being less than 1 year. The procedures used in this study conformed to the Declaration of Helsinki. Approval from the Ethnic Committee of Zhongshan Ophthalmic Center, Sun Yat-sen University was obtained.

Lens Fitting and Measurements

Orthokeratology lenses, including Euclid (Euclid Systems Corporation, Herndon, VA, USA), Paragon CRT (Paragon Vision Sciences, Gilbert, AZ, USA), DreamLite Orthokeratology (CooperVision, Saffron Walden, UK), α ORTHO-K (ALPHA Corporation, Nagoya, Japan), LUCID ORTHO-K (LUCID Corporation, Fenghua County, Korea), and DreamVision Orthokeratology (Ovctec China Incorporation, Hefei, China), were fitted by experienced ophthalmologists and optometrists in accordance with the manufacturer's recommended procedures. Subjects were advised to wear their lenses every night for at least 7 consecutive hours unless otherwise instructed.

Before orthokeratology lens fitting, comprehensive assessments were conducted, encompassing medical history collection, visual acuity, slit-lamp and fundus examinations, autorefraction, subjective refraction, keratometric measurement, corneal topography, measurement of IOP, corneal specular microscopy, and measurement of AL. Follow-up schedules were recommended at 1 day, 1 week, 2 weeks, 1 month, 3 months, and thereafter quarterly after orthokeratology lens dispensing. At every follow-up visit, visual acuity, slit-lamp examination, refractions, and corneal topography were performed. AL was evaluated at clinician discretion during follow-up, usually every 3 or 6 months. AL was measured without cycloplegia, using a partial coherence interferometry device (IOLMaster 500; Zeiss, Jena, Germany). Five consecutive AL measurements were collected, and the average was used as a representative value.

Statistical Analyses

Longitudinal data underwent thorough cleansing. For each subject, the visit of first orthokeratology lens prescription was defined as the initial visit. Given the high correlation of AL change between the eyes (Pearson correlation coefficient = 0.89; $P < 0.0001$) and greater relevance of AL shortening in the more myopic eye, data of the initially more myopic eye (defined as the eye with greater myopic spherical equivalent at the visit of first lens prescription) were used in the current analysis. Descriptive statistics were applied. Means ± standard deviations, medians (interquartile ranges [IQRs]), and numbers and percentages were reported where appropriate.

Incident long-term AL shortening was defined as a change in AL of −0.1 mm or less at any follow-up visit beyond 1 year. This cut-off value was determined based on the reported possible AL measurement error using IOLMaster 500,[20,21] in conjunction with clinical significance of AL change. The probability of long-term AL shortening, by subject initial characteristics, were determined using multivariate logistic regression models. Given the high correlation between spherical power and AL, two models were constructed, with initial age and sex mandatorily included and additional independent variables determined via forward stepwise selection: model 1 included initial age, sex, initial spherical power, cylindrical power, and anisometropia; and model 2 included initial age, sex, initial cylindrical power, anisometropia, average K, and AL.

Mixed-effect regression models were established to decern AL change over time and factors associated with the rate of change. Time since initial visit was used as the variable time factor. Quadratic regression models, including terms of time and time square, were developed to describe the AL change over time. To investigate potential differences in AL evolution between subjects with and without AL shortening, an interaction term of time factor with AL shortening (whether AL shortened or not) was examined in models 3 and 4. Interactions of time factor with initial age (both models), sex (both models), initial spherical power (model 3), cylindrical power (both models), anisometropia (both models), average K (model 4), and AL (model 4) were included to adjust for their potential impacts. If AL evolution was proved different between subjects with and without AL shortening, the time course of AL change was further separately established for the two groups of people, and associations of initial characteristics with AL change rate were determined by examining interaction terms of initial characteristics with time factor. A statistically significant interaction would indicate that the AL change rate was associated with the initial characteristic.

Statistical analyses were performed using STATA, version 15.0 (StataCorp LLC, College Station, TX, USA) and R, version 4.1.3 (R Project for Statistical Computing, Vienna, Austria). All P values were two-sided, and no adjustments were made to the P values for the analyses undertaken. A P value of less than 0.01 was deemed statistically significant.

Results

A flowchart of study inclusion is shown in Figure 1. A total of 80,778 medical records from 10,093 subjects were identified eligible. At the initial visit, the mean age was 11.70 ± 2.52 years (range, 5.23–29.16 years), with 5930 subjects (58.75%) being female. The mean spherical equivalent was −3.87 ± 1.71 diopters (D) (range, −13.00 to −0.50 D).

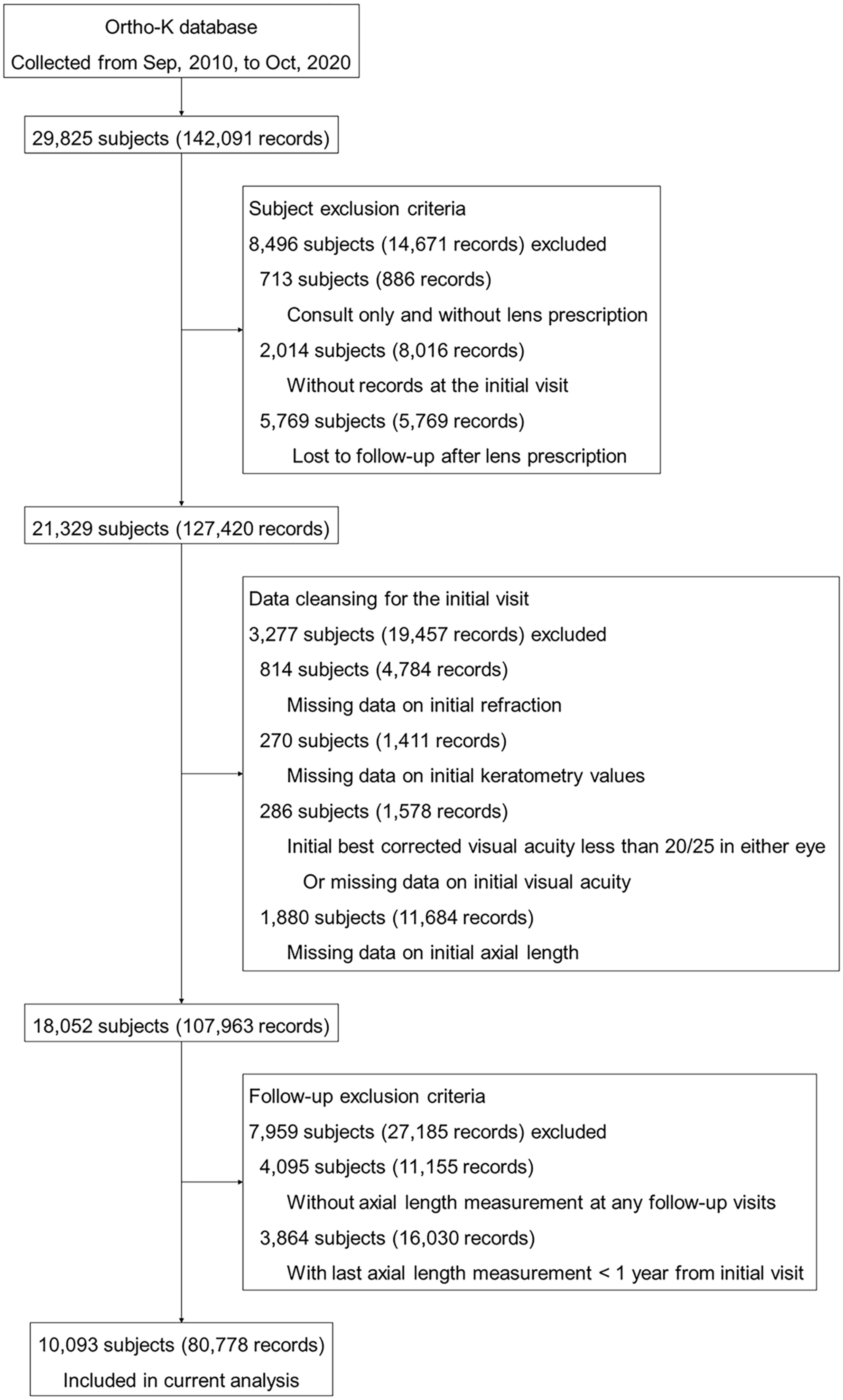

Figure 1. Flowchart of study inclusion.

TABLE 1. Initial Characteristics of Study Subjects

	Overall	Within Different Periods of Lens Wear (Year)					
		1 to <2	**2 to <3**	**3 to <4**	**4 to <5**	**5 to <6**	**6 to <10**
Number	10,093	8905	4945	2526	1235	589	247
Age, mean ± SD (years)	11.70 ± 2.52	11.63 ± 2.52	11.51 ± 2.41	11.31 ± 2.32	11.11 ± 2.25	10.87 ± 2.21	10.49 ± 1.95
Female, n (%)	5930 (58.75)	5169 (58.05)	2916 (58.97)	1508 (59.70)	750 (60.73)	380 (64.52)	159 (64.37)
Spherical power, mean ± SD (D)	−3.55 ± 1.57	−3.54 ± 1.57	−3.68 ± 1.58	−3.78 ± 1.58	−3.89 ± 1.58	−3.96 ± 1.59	−3.95 ± 1.53
Cylindrical power, median (IQR) (D)	−0.50 (−1.00 to 0)	−0.50 (−1.00 to 0)	−0.50 (−1.00 to 0)	−0.50 (−1.00 to 0)	−0.50 (−1.00 to 0)	−0.50 (−1.00 to 0)	−0.50 (−1.00 to 0)
Anisometropia, median (IQR) (D)	0.38 (0.13 to 0.75)	0.38 (0.13 to 0.75)	0.25 (0.13 to 0.75)	0.25 (0.13 to 0.75)	0.25 (0.13 to 0.63)	0.25 (0.13 to 0.63)	0.25 (0.13 to 0.50)
AL, mean ± SD (mm)	25.16 ± 0.94	25.15 ± 0.95	25.20 ± 0.95	25.22 ± 0.94	25.25 ± 0.95	25.25 ± 0.94	25.27 ± 0.89
Average K, mean ± SD (D)	43.30 ± 1.35	43.31 ± 1.35	43.32 ± 1.34	43.37 ± 1.35	43.36 ± 1.36	43.44 ± 1.30	43.33 ± 1.30

Additional initial characteristics are detailed in Table 1. Subjects were followed up for durations ranging from 1.00 to 9.54 years, with a median of 2.12 years (IQR, 1.51–3.22 years). Orthokeratology lens wear was throughout the follow-up period, unless transient cessation was advised to manage complications.

Percentage and Probability of Long-term AL Shortening

Table 2 presents the percentage of long-term AL shortening both in aggregate and within different periods of lens wear. Overall, 1662 subjects (16.47%; 95% confidence interval [CI], 15.75%–17.21%) experienced AL shortening of 0.1 mm or greater. Compared with those without AL shortening, these subjects were initially older (13.57 ± 2.50 years vs. 11.34 ± 2.35 years; $P < 0.0001$), more likely to be female (1058/1662 [63.66%] vs. 4872/8431 [57.79%]; $P < 0.001$), had more myopic spherical power (−4.32 ± 1.42 D vs. −3.40 ± 1.55 D; $P < 0.0001$), greater magnitude of anisometropia (0.50 D [IQR, 0.25–0.88 D] vs. 0.25 D [IQR, 0.13–0.75 D]; $P = 0.0001$), and longer AL (25.51 ± 0.89 mm vs. 25.09 ± 0.94 mm; $P < 0.0001$). The percentage of long-term AL shortening by subject initial characteristics is demonstrated in Supplementary Table S1.

In multivariate logistic regression models, initial age, sex, spherical power, cylindrical power, anisometropia, AL, and average K were significantly associated with incident long-term AL shortening (all $P \leq 0.002$). Subject characteristic-specified probabilities of AL shortening are presented in Figure 2. Initial age demonstrated the greatest impact on probability of the incident occurrence (odds ratio [OR], 1.37 [95% CI, 1.34–1.40]; Z value, 25.59; $P < 0.001$). The estimated probability changed from 2.41% (95% CI, 2.01%–2.88%) for girls aged 6 years to 51.47% (95% CI, 47.84%– 55.09%) for those aged 18 years and from 2.21% (95% CI, 1.84%–2.64%) for boys aged 6 years to 49.26% (95% CI, 45.17%–53.36%) for those aged 18 years. Other factors that showed considerable impacts included initial spherical power (OR, 0.76 [95% CI, 0.73–0.78]; Z value, −14.45; $P < 0.001$) and AL (OR, 1.54 [95% CI, 1.42–1.67]; Z value, 10.35; $P < 0.001$).

Change in AL Over Time

Among the 1662 subjects demonstrating long-term AL shortening, the maximum magnitude of AL decrease occurred at 1.00 to 7.16 years of lens wear (median, 1.53 year[IQR, 1.20–2.07 year]) and ranged from 0.10 to 0.73 mm (median, 0.19 mm [IQR, 0.14–0.26 mm]). The distribution of magnitude of maximum AL shortening is demonstrated in Figure 3. Although there was a statistically significant trend of greater maximum AL reduction for older initial age, more myopic spherical power, greater anisometropia, and longer AL (all P for trend ≤ 0.005), the variabilities were modest (Fig. 3).

Individual evolutions and estimated time course of AL change are demonstrated in Figures 4A and 4B. For subjects demonstrating AL shortening, the process of AL reduction mostly occurred within the initial 2 years; thereafter, the process slowed down, stabilized, and rebounded slightly (Fig. 4A). This pattern of AL change was different from that among subjects without AL shortening (β for the interaction between time factor and AL shortening, −0.17 and −0.18 in mixed-effect models 3 and 4, respectively; both $P < 0.001$),

Table 2. Percentage of Long-term AL Shortening in Subjects Who Underwent Orthokeratology, as a Whole and Within Different Periods of Lens Wear

	Total Number	Number of AL Shortening	AL Shortening Percentage (%)	95% CI (%)
Overall	10,093	1662	16.47	15.75–17.21
Within different periods of lens wear (years)				
1 to <2	8905	1408	15.81	15.06–16.59
2 to <3	4945	643	13.00	12.08–13.97
3 to <4	2526	278	11.01	9.81–12.29
4 to <5	1235	109	8.83	7.30–10.55
5 to <6	589	49	8.32	6.22–10.85
6 to <10	247	11	4.45	2.24–7.83

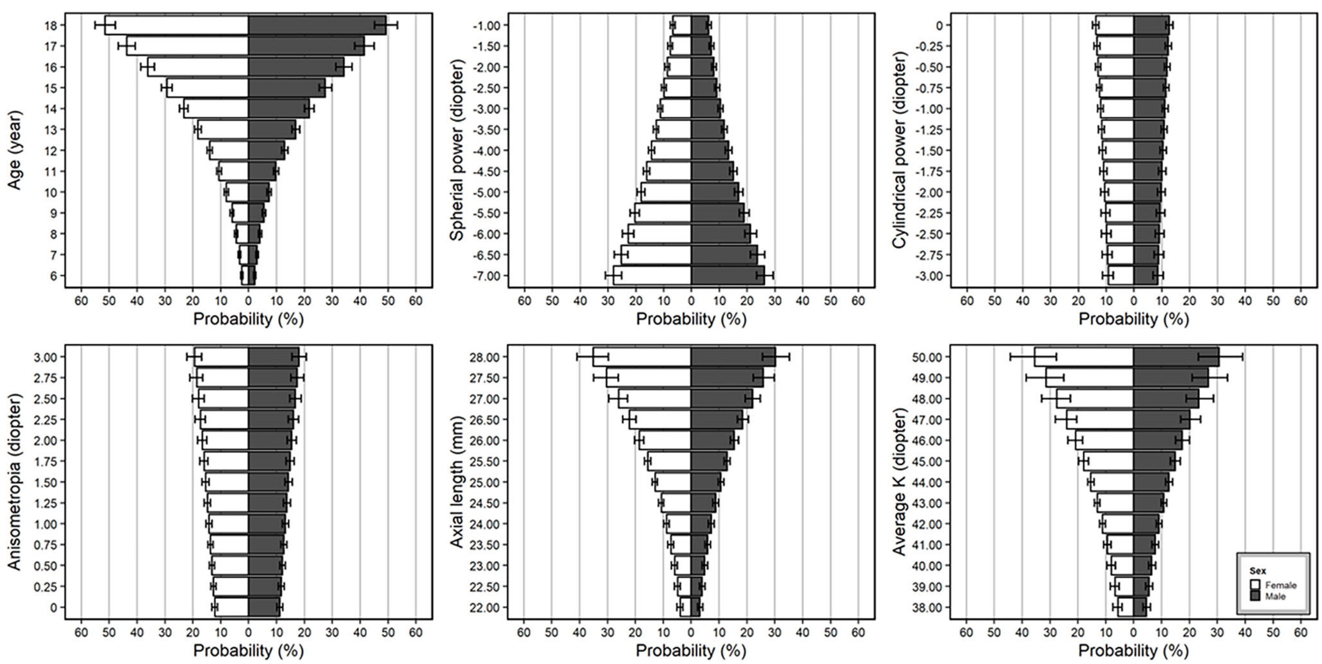

Figure 2. Initial characteristic-specified probability of long-term AL shortening in subjects who underwent orthokeratology. Estimation performed using multivariate logistic regression models.

which demonstrated approximately linear axial elongation over time (Fig. 4B).

Associations of initial characteristics with rate of AL change is shown in Table 3. Compared with subjects without AL shortening, the association between age and shortening rate was subtle (Figs. 4C and 4D, Table 3). Similarly, initial myopic spherical power, anisometropia, and AL demonstrated statistically significant, but delicate associations with the AL-shortening rate (Table 3).

Discussion

Ocular axial elongation is observed throughout the human lifespan,[7,22–24] traditionally considered irreversible. The current study, based on a considerable hospital database with adequate periods of follow-up, summarized uncommon instances of long-term AL shortening in myopic orthokeratology. The study provided subject characteristic-specified probability of the incident and gave a picture of the time course of AL reduction.

Previous reports have sporadically noted long-term negative axial growth. Qi et al.[25] observed negative axial growth (mean, −0.06 mm) in 9 of 73 children at 1 year after orthokeratology. In 34 adults receiving the same intervention, a mean AL reduction of 0.16 mm was observed after 1 year.[26] Negative axial growth has also been documented in children treated with atropine eye drops.[27,28] In the Atropine for the Treatment of Myopia (ATOM) 1 study, a mean AL decrease of 0.14 mm was observed after 1 year of treatment with 1% atropine.[27] These reports, although with limited numbers of cases, have provided evidence for the possibility of AL shortening in the long term. Despite variations in interventions, subject characteristics, and definitions of the condition, the magnitude of shortening seemed to be comparable with the current study data.

Referring to previous studies,[29–31] it seemed that AL shortening in orthokeratology could not be attributed solely to choroidal thickening and changes in the anterior segment. This study was not able to provide sufficient information on biometric changes related to the shortening. As a supplement, we identified and reviewed cases in our prospective investigations (Supplementary Table S2) and speculate that a shrunken vitreous chamber might be one major change. The underlying mechanisms behind AL shortening remain elusive. Animal experiments indicate that the shortened eye might be a compensation to imposed myopic defocus.[32]

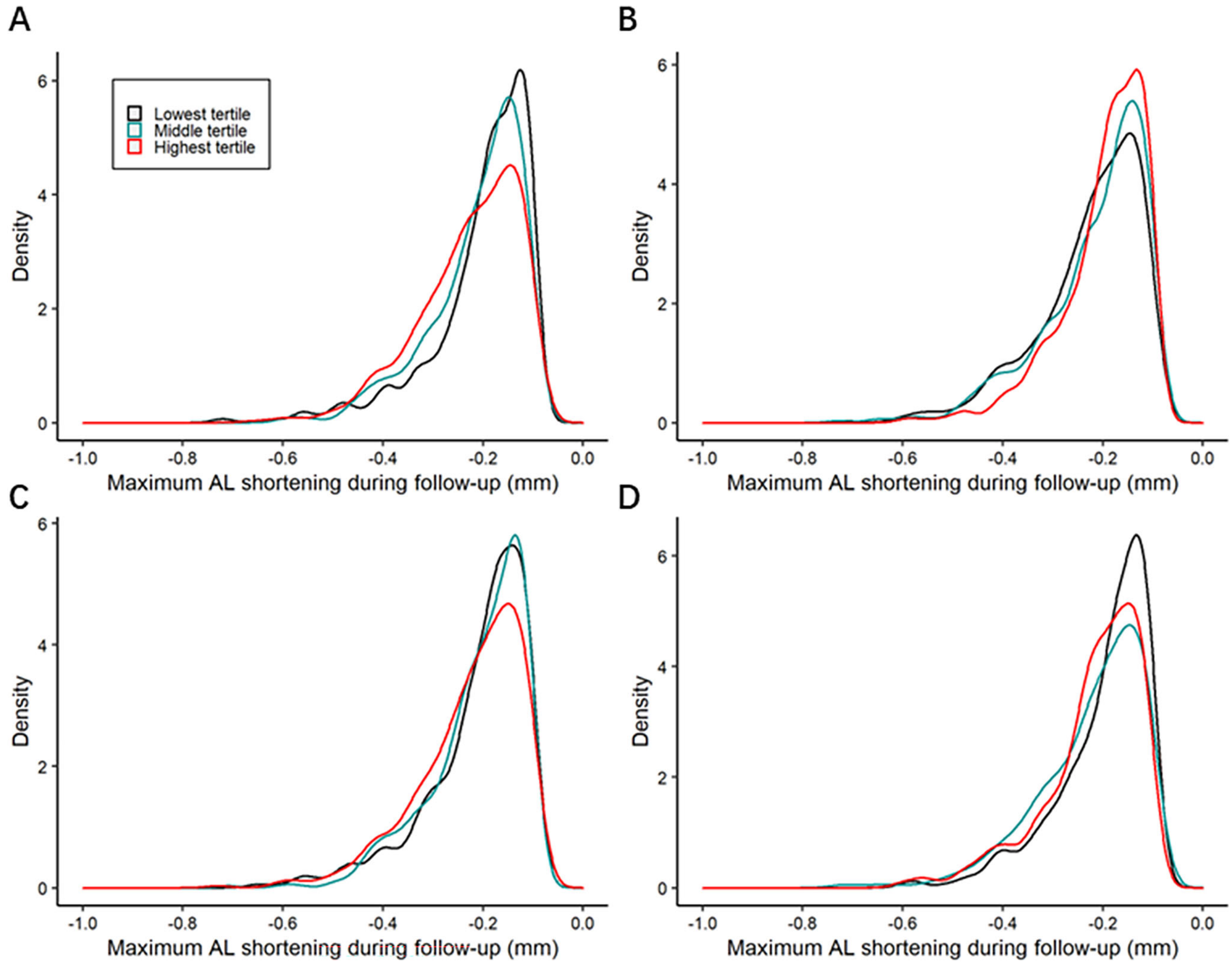

Figure 3. Distributions of magnitude of maximum AL shortening in subjects underwent orthokeratology and experienced long-term AL shortening, stratified by initial age (**A**), spherical power (**B**), anisometropia (**C**), and AL (**D**).

To the best of the authors' knowledge, this study is the first to delineate a detailed time course of long-term AL shortening in subjects underwent orthokeratology. There seemed to be a ceiling effect: the majority of shortening occurred within the first 2 years of lens wear; thereafter, the process decelerated, stabilized, and displayed a slight rebound. The phenomenon warrants further investigation to unveil its underlying causes and to develop strategies to break through.

This study found that older initial age and a higher degree of myopia were associated with a higher probability of long-term AL shortening. The finding is in consistent with a prior report suggesting that children with negative axial growth were initially older, had a higher myopic spherical equivalent, and greater corneal power compared with those who experienced AL elongation.[25] Interestingly, despite the pronounced propensity for axial shortening in some subject characteristics, the shortening process seemed to be less likely to diverge: the majority of the shortening cases exhibited a maximum AL decrease of approximately 0.2 mm and subject characteristics had limited impact on the shortening rate. However, in our database, there were rare yet noteworthy cases with a maximum AL decrease of 0.5 mm or greater. These cases might offer valuable insights into identifying key factors determining the shortening process. Further investigations exploring potential factors to amplify the process of AL shortening would be beneficial.

The main limitation of this study is its retrospective nature. However, it is not easy to obtain an adequate sample size for an uncommon condition using a prospective study design. The information provided herein might serve as a foundation for establishing a prospective cohort for further validation and deepening the findings of this study. Additionally, the unavailability of certain ocular biometric parameters hindered our understanding on the specifics of AL shortening. In compensation, we reported available data from some prospective cases and proposed a reasonable speculation.

In conclusion, this study reported that 16% myopic orthokeratology lens wearers would experience long-term ocular axial shortening. Age exerts a significant influence on the incident occurrence. The shortening process is dominantly accomplished within the initial 2 years of lens wear and does not vary significantly with subject characteristics. Further studies are warranted to elucidate detailed ocular

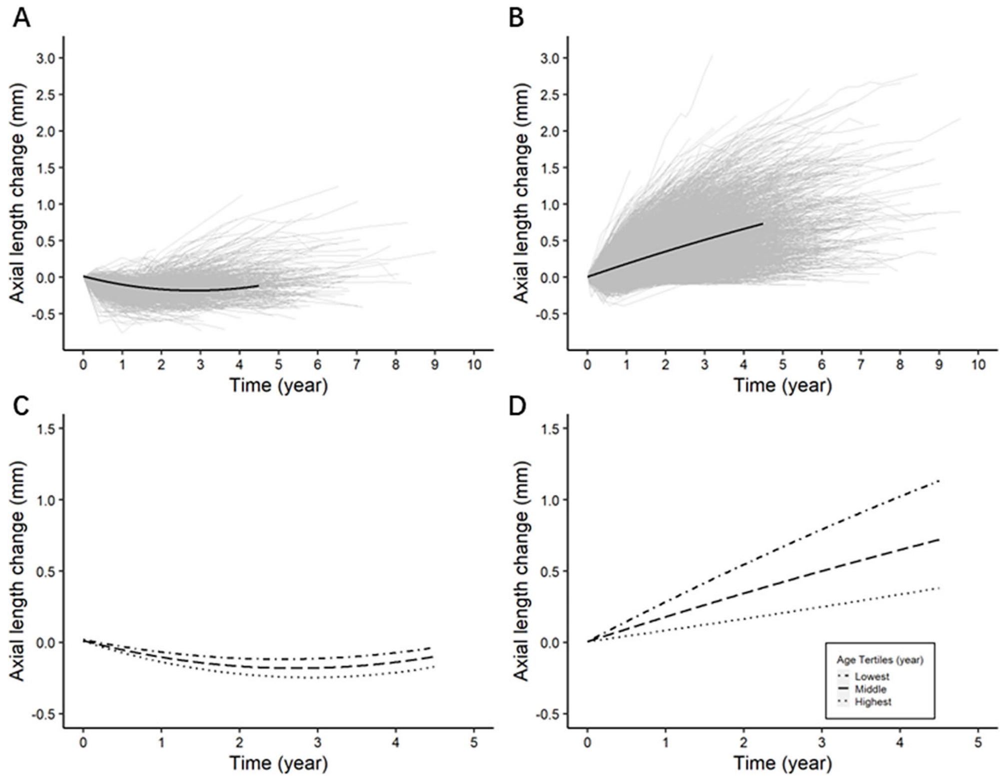

Figure 4. Time course of AL change in subjects underwent orthokeratology, with and without long-term AL shortening. Individual (gray solid lines) and estimated (black solid lines) evolutions in subjects with (**A**; estimated rate of change, −0.138 + 0.024*time mm/year) and without long-term AL shortening (**B**; estimated rate of change, 0.183–0.005*time mm/year); Estimated evolution by different initial ages in subjects with (**C**) and without long-term AL shortening (**D**). Estimated evolution lines generated using mixed-effect regression models.

Table 3. Associations of Initial Characteristics With Rate of AL Change (mm/year) in Subjects Who Underwent Orthokeratology, With and Without Long-term AL Shortening

	AL Change Rate (mm/year)			
	Mixed-Effect Model With 1 Interaction Term Included*		Mixed-Effect Model With Multiple Interaction Terms Included†	
Initial Characteristics	**β (95% CI)**	***P* Value**	**β (95% CI)**	***P***
Subjects with AL shortening (n = 1662)				
Age‡	−0.008 (−0.009 to −0.006)	<0.001	−0.007 (−0.009 to −0.006)	<0.001
Sex (male‡	0.010 (0.003 to 0.017)	0.003	0.006 (0 to 0.013)	0.049
Spherical power	0.005 (0.003 to 0.008)	<0.001	0.005 (0.003 to 0.007)	<0.001
Cylindrical power‡	0 (−0.005 to 0.005)	0.980	−0.003 (−0.008 to 0.002)	0.230
Anisometropia‡	−0.006 (−0.010 to −0.003)	0.001	−0.006 (−0.010 to −0.003)	<0.001
AL	−0.009 (−0.013 to −0.005)	<0.001	−0.011 (−0.015 to −0.006)	<0.001
Average K	0.002 (0 to 0.004)	0.117	−0.002 (−0.005 to 0.001)	0.200
Subjects without AL shortening (n = 8431)				
Age‡	−0.034 (−0.035 to −0.032)	<0.001	−0.031 (−0.032 to −0.030)	<0.001
Sex (male)‡	0.010 (0.003 to 0.017)	0.003	0.005 (0 to 0.011)	0.059
Spherical power	0.025 (0.023 to 0.027)	<0.001	0.014 (0.012 to 0.016)	<0.001
Cylindrical power‡	0.014 (0.010 to 0.019)	<0.001	−0.003 (−0.007 to 0.001)	0.185
Anisometropia‡	−0.019 (−0.024 to −0.015)	<0.001	−0.004 (−0.008 to 0)	0.028
AL	−0.040 (−0.043 to −0.037)	<0.001	−0.030 (−0.034 to −0.026)	<0.001
Average K	0.001 (−0.001 to 0.003)	0.475	−0.013 (−0.015 to −0.010)	<0.001

* Models included initial age, sex, time, time square, and one interaction term;

† Models included initial age, sex, time, time square, and multiple interaction terms (interactions of initial age, sex, spherical power, cylindrical power, and anisometropia with time factor or interactions of initial age, sex, cylindrical power, anisometropia, average K, and AL with time factor);

‡ For models with multiple interaction terms included, statistics of the model that included interaction term of initial spherical power with time factor are presented and are similar in the other model that included interaction terms of initial AL and average K with time factor.

biometric changes and potential mechanisms underlying this phenomenon.

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References

1. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *Lancet*. 2012;379:1739–1748.
2. Holden BA, Fricke TR, Wilson DA, et al. Global Prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology*. 2016;123:1036–1042.
3. Tsai DC, Fang SY, Huang N, et al. Myopia development among young schoolchildren: the Myopia Investigation Study in Taipei. *Invest Ophthalmol Vis Sci*. 2016;57:6852–6860.
4. Wang SK, Guo Y, Liao C, et al. Incidence of and factors associated with myopia and high myopia in Chinese children, based on refraction without cycloplegia. *JAMA Ophthalmol*. 2018;136:1017–1024.
5. Mutti DO, Hayes JR, Mitchell GL, et al. Refractive error, axial length, and relative peripheral refractive error before and after the onset of myopia. *Invest Ophthalmol Vis Sci*. 2007;48:2510–2519.
6. Xiang F, He M, Morgan IG. Annual changes in refractive errors and ocular components before and after the onset of myopia in Chinese children. *Ophthalmology*. 2012;119:1478–1484.
7. Jones LA, Mitchell GL, Mutti DO, Hayes JR, Moeschberger ML, Zadnik K. Comparison of ocular component growth curves among refractive error groups in children. *Invest Ophthalmol Vis Sci*. 2005;46:2317–2327.
8. Myopia stabilization and associated factors among participants in the Correction of Myopia Evaluation Trial (COMET). *Invest Ophthalmol Vis Sci*. 2013;54:7871–7884.
9. Lee SS, Lingham G, Sanfilippo PG, et al. Incidence and progression of myopia in early adulthood. *JAMA Ophthalmol*. 2022;140:162–169.
10. Gao LQ, Liu W, Liang YB, et al. Prevalence and characteristics of myopic retinopathy in a rural Chinese adult population: the Handan Eye Study. *Arch Ophthalmol*. 2011;129:1199–1204.
11. Asakuma T, Yasuda M, Ninomiya T, et al. Prevalence and risk factors for myopic retinopathy in a Japanese population: the Hisayama Study. *Ophthalmology*. 2012;119:1760–1765.
12. Chia A, Lu QS, Tan D. Five-year clinical trial on atropine for the treatment of myopia 2: myopia control with atropine 0.01% eyedrops. *Ophthalmology*. 2016;123:391–399.
13. Yam JC, Zhang XJ, Zhang Y, et al. Three-year clinical trial of Low-Concentration Atropine for Myopia Progression (LAMP) study: continued versus washout: phase 3 report. *Ophthalmology*. 2022;129:308–321.
14. Cho P, Cheung SW. Retardation of myopia in Orthokeratology (ROMIO) study: a 2-year randomized clinical trial. *Invest Ophthalmol Vis Sci*. 2012;53:7077–7085.
15. Swarbrick HA, Alharbi A, Watt K, Lum E, Kang P. Myopia control during orthokeratology lens wear in children using a novel study design. *Ophthalmology*. 2015;122:620–630.
16. Walline JJ, Walker MK, Mutti DO, et al. Effect of high add power, medium add power, or single-vision contact lenses on myopia progression in children: the BLINK randomized clinical trial. *JAMA*. 2020;324:571–580.
17. Chamberlain P, Bradley A, Arumugam B, et al. Long-term effect of dual-focus contact lenses on myopia progression in children: a 6-year multicenter clinical trial. *Optom Vis Sci*. 2022;99:204–212.
18. Lam CS, Tang WC, Lee PH, et al. Myopia control effect of defocus incorporated multiple segments (DIMS) spectacle lens in Chinese children: results of a 3-year follow-up study. *Br J Ophthalmol*. 2022;106:1110–1114.
19. Li X, Huang Y, Yin Z, et al. Myopia control efficacy of spectacle lenses with aspherical lenslets: results of a 3-year follow-up study. *Am J Ophthalmol*. 2023;253:168–168.
20. Carkeet A, Saw SM, Gazzard G, Tang W, Tan DT. Repeatability of IOLMaster biometry in children. *Optom Vis Sci*. 2004;81:829–834.
21. Chan B, Cho P, Cheung SW. Repeatability and agreement of two A-scan ultrasonic biometers and IOLMaster in non-orthokeratology subjects and post-orthokeratology children. *Clin Exp Optom*. 2006;89:160–168.
22. Zadnik K, Mutti DO, Mitchell GL, Jones LA, Burr D, Moeschberger ML. Normal eye growth in emmetropic schoolchildren. *Optom Vis Sci*. 2004;81:819–828.
23. Han X, Guo X, Lee PY, Morgan IG, He M. Six-year changes in refraction and related ocular biometric factors in an adult Chinese population. *PLoS One*. 2017;12:e0183364.
24. Mutti DO, Sinnott LT, Lynn MG, et al. Ocular component development during infancy and early childhood. *Optom Vis Sci*. 2018;95:976–985.
25. Qi Y, Liu L, Li Y, Zhang F. Factors associated with faster axial elongation after orthokeratology treatment. *BMC Ophthalmol*. 2022;22:62.
26. Gonzalez-Mesa A, Villa-Collar C, Lorente-Velazquez A, Nieto-Bona A. Anterior segment changes produced in response to long-term overnight orthokeratology. *Curr Eye Res*. 2013;38:862–870.
27. Chua WH, Balakrishnan V, Chan YH, et al. Atropine for the treatment of childhood myopia. *Ophthalmology*. 2006;113:2285–2291.
28. Li FF, Zhang Y, Zhang X, et al. Age effect on treatment responses to 0.05%, 0.025%, and 0.01% atropine: low-concentration atropine for myopia progression study. *Ophthalmology*. 2021;128:1180–1187.
29. Li Z, Hu Y, Cui D, Long W, He M, Yang X. Change in subfoveal choroidal thickness secondary to orthokeratology and its cessation: a predictor for the change in axial length. *Acta Ophthalmol*. 2019;97:e454–e459.
30. Chen Y, Shen X. Compensatory changes in the anterior segment and vascular system of the eye in myopic children after orthokeratology. *Front Pediatr*. 2021;9:663644.
31. Cheung SW, Cho P. Validity of axial length measurements for monitoring myopic progression in orthokeratology. *Invest Ophthalmol Vis Sci*. 2013;54:1613–1615.
32. Zhu X, McBrien NA, Smith ER, Troilo D, Wallman J. Eyes in various species can shorten to compensate for myopic defocus. *Invest Ophthalmol Vis Sci*. 2013;54:2634–2644.