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Change of Subfoveal Choroidal Thickness Secondary to Orthokeratology and its Cessation: A Predictor for the Change of Axial Length

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Abstract

Purpose: To investigate changes of subfoveal choroidal thickness (SFChT) during orthokeratology (Ortho-K) lens wear and after its cessation and the association of short-term change in SFChT with the long-term eye elongation in Ortho-K subjects.

Design: A prospective clinical trial.

Methods: Fifty myopic children aged between 9 and 14 years were enrolled. Twenty-nine subjects continuously wore Ortho-K lens for 12 months and discontinued for one month. Twenty-one subjects wearing single vision distance spectacles for 12 months were included as the control group. SFChT was assessed using optical coherence tomography. Ocular parameters, including axial length (AL), central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT) and apical corneal power (ACP), were also measured.

Results: After 12 months of follow-up, AL elongation was larger and SFChT change was smaller in the control group compared to the Ortho-K group (both $P < 0.001$). In the Ortho-K group, SFChT increased by 16 μm from baseline at the 1-month visit ($P < 0.001$), and the magnitude of choroidal thickening remained unchanged at the 6- and 12-month visit ($P=0.289$). One month after discontinuation of Ortho-K lens, SFChT and ocular parameters of the anterior segment, including ACP, CCT, and ACD recovered to baseline level (All $P>0.05$), and AL increased by 0.23 ± 0.18 mm.

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compared to baseline ($P=0.018$). SFChT change at 1-month was negatively associated with AL change at 13-month (Standard β , -0.581 , $P=0.001$) after adjusting for other influencing factors, including baseline age and the ocular parameters.

Conclusion: SFChT significantly increased after short-term Ortho-K lens treatment and the increase maintained throughout the period of treatment. One month after Ortho-K lens cessation, SFChT, ACP, CCT, and ACD returned to baseline. Short-term response in SFChT is associated with long-term change in AL in children undergoing Ortho-K lens and may be a predictor for the effectiveness of the treatment.

Keywords: Orthokeratology; Myopia; Choroidal thickness; SD-OCT

Introduction

Myopia is an important public health issue affecting children worldwide (Rudnicka et al. 2016), especially in East Asia, where more than 80% of students in high school are now myopic (Jung et al. 2012; Sun et al. 2012). If not treated effectively in time, it may develop into high myopia which is associated with a high risk of potentially blinding complications (Ikuno 2017), such as retinal detachment, choroidal neovascularization, glaucoma, and cataract.

Animal and human studies suggest that the choroid may play an important role in the visually guided regulation of eye growth (Chiang et al. 2000; Chakraborty et al. 2012 and 2013; Nickla & Wallman 2010; Wallman et al. 1995; Wildsoet et al. 1995; Hung et al. 2000; Troilo et al. 2000). In animal models, including chicks (Wallman et al. 1995; Wildsoet et al. 1995), macaque monkeys (Hung et al. 2000), and marmosets (Troilo et al. 2000), changes in the eye's effective refractive state can produce a rapid change in choroidal thickness (ChT), with hyperopic defocus inducing choroidal thinning and myopic defocus inducing choroidal thickening. Bidirectional changes in ChT in response to retinal defocus were also found in human eyes in a qualitatively similar manner (Chiang et al. 2000; Chakraborty et al. 2012 and 2013).

Ortho-K lens has proved to be an effective way to slow ocular growth in myopia children (Wen et al. 2015; Li et al. 2016). Nevertheless, although subjects with

Ortho-K lens treatment on average showed less axial elongation, a variation in individual response was noted (Swarbrick et al. 2015; Cho & Cheung 2012). It was found that characteristics such as baseline age (Hiraoka et al. 2012), corneal power change (Zhong et al. 2014), and scotopic pupil size (Chen et al. 2012) were significantly correlated to the efficacy of Ortho-K lens treatment (Yang et al. 2016), but the underlying mechanism is still unknown. Besides the above mentioned factors, the change of ChT may also be important in retarding axial elongation. Some studies have demonstrated a thickening of the choroid associated with Ortho-k (Chen et al. 2016; Loertscher et al. 2013), while others have reported no significant changes (Gardner et al. 2015). Our previous study (Li et al. 2017) followed up myopic children treated with Ortho-k or single vision spectacles for 6 months, and found that Ortho-K lens treatment tended to increase the subfoveal ChT (SFChT) and slow down the axial elongation compared to the single vision spectacles treatment. The change in ChT may result from the peripheral myopic defocus induced by the Ortho-K lenses. Theoretically, ChT should then recover to baseline values when Ortho-K lenses are discontinued, however there is little evidence to support this hypothesis (Hung et al. 2000; Troilo et al. 2000).

The purpose of current study was to investigate the change in SFChT and axial length (AL) during long-term Ortho-K treatment and after its cessation as well as to investigate a possible correlation between changes in SFChT induced by Ortho-K treatment and long-term eye elongation in Chinese children with myopia. The present study is a continuation of our previous study (Li et al. 2017).

Methods

Study Design

As reported in our previous study (Li et al. 2017), this prospective, observational study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the ethical committee of Zhongshan Ophthalmic Center, Sun Yat-sen University. Written consent was obtained from guardians of all children. Twenty-nine myopic children (13 boys and 16 girls; age: 12.31 ± 1.71 years) were enrolled for

Ortho-K treatment and 21 subjects with baseline parameters matched (9 boys and 12 girls; age: 11.52 ± 1.69 years) were enrolled as a control group. The inclusion criteria included: age between 8 and 15 years, mean sphere between -1.00 and -4.00 D, with-the-rule astigmatism no greater than -1.50D, and a best corrected visual acuity (BCVA) of 20/20 or better. The exclusion criteria included: ocular surface diseases, fundus diseases, or a history of use of any other modalities other than single-vision spectacles for myopia control, including rigid contact lenses, multifocal soft contact lenses, and atropine.

For the Ortho-K, participants were fitted with four-zone reverse-geometry lenses (Euclid Systems Ortho-K; Euclid System Corp., Herndon, USA), with BOSTON EQUALENS II (oprifocona) and a nominal Dk of 127×10^{-11} (cm²/s) (ml O₂/ml_mmHg) (ISO/Fatt) according to the manufacturer's fitting guidelines. After lens dispensing, the patients were advised to wear their Ortho-K lenses every night (for at least 7 consecutive hours) for 12 months and then ceased lens wear for 1 month. All the patients were instructed to return for a follow-up visit after one day, one week, and one, three, six, twelve and thirteen months. At each visit the participants underwent a slit-lamp examination to check for contact lens related complications and any adverse events. Ocular biometrics and SFChT were measured at baseline, 1-month, 6-month, 12-month and 13-month visits. Cycloplegic manifest refractions were conducted at baseline and 13-month visits.

For the control group, visual acuities with spectacle correction for all participants were 20/20 or better at baseline. All of them were instructed to wear their spectacles throughout the day time and return for assessment of visual acuity, cycloplegic manifest refraction, ocular biometric parameters, and SFChT at 1-month, 6-month and 12-month visits.

Measurements

All the following measurements were conducted twice at each visit. To avoid potential confounding effects of diurnal ocular variations on the results (Chakraborty et al. 2011), all procedures were performed at approximately the same time of the day, between 3 pm and 6 pm. To standardize the influence of the administration of the

cycloplegic agent (Li et al. 2016) on SFChT and other ocular parameters, all measurements were performed approximately 30 minutes after the last administration of the mydriatics (0.5% tropicamide plus 0.5% phenylephrine hydrochloride; three times at five minutes apart).

Ocular biometrics measurements

Ocular biometrics, including AL, central corneal thickness (CCT), anterior chamber depth (ACD), and lens thickness (LT), were measured using an optical low-coherence reflectometry device (Lenstar LS 900; Haag Streit AG, Koeniz, Switzerland). AL was defined as the distance between the anterior cornea and the retinal pigment epithelium (RPE). Five consecutive measurements were collected from each subject at each measurement session, and the values were averaged. Apical corneal power (ACP) was measured using Medmont E300.

SD-OCT scanning and analysis

SD-OCT scanning was performed twice by an experienced investigator using the Heidelberg Spectralis instrument (Spectralis HRA+OCT, Heidelberg Engineering, Heidelberg, Germany) at each visit. The instrument scans the retinal tissue using a super luminescent diode of a central wavelength of 870 nm, with an axial resolution of 3.9 μm , and a transverse resolution of 14 μm . Details of OCT measurement was described in our previous study (Li et al. 2017; Ding et al. 2011). In brief, the enhanced depth imaging (EDI) mode was used to enhance the visibility of the choroid using 100 averaged scans to improve the signal to noise ratio. All B-scans included for analysis had a quality index of no less than 25 dB (mean 28.9 ± 2.8 dB). The confocal scanning laser ophthalmoscope (SLO) was adjusted manually to obtain a clear image of the fundus prior to imaging. The linear scan pattern (vertical and horizontal line) was recorded at each visit. The single horizontal line scan was used for SFChT analysis. Repeat scans were captured with the aid of automatic registration, and the follow-up mode Spectralis was utilized to ensure the same retinal locations on each test. In order to reduce the effect of AL variability on the transverse ocular magnification of SD-OCT, only SFChT was analyzed. SFChT was manually analyzed by two independent observers experienced in analyzing OCT images using the

Heidelberg linear measurement tool. The two observers were masked to the study visit at which the measurements were collected. All OCT images were rescaled into a 1-to-1 scale (micron), which would simplify the coding of the algorithm. The thinnest part of the macula in the image was defined as the location of the fovea. Thickness of the choroid was defined as the distance from the RPE to the inner surface of the choriocleral interface (CSI) along the A-scan. The choriocleral junction was well identified in all SD-OCT images.

Data analysis

All statistical analyses were performed using SPSS Version 16.0 (SPSS 16.0, Inc., Chicago, IL). All values were represented as mean $\pm$ standard deviation unless otherwise stated. Data were firstly tested for normality using Sample K-S test. All measurements were taken twice, and the average was used for the purpose of analysis. To provide an assessment of the inter-observer agreement of the SFChT measures, the 95% limits of agreement (95% LOA) of the inter-observer difference was calculated at each visit and demonstrated using Bland-Altman plot. The interclass correlation coefficient (ICC) was calculated for SFChT measurement at each visit. Ocular parameters included AL, CCT, ACD, LT and ACP. Differences in age, sphere, cylinder, spherical equivalent refractive error, ocular parameters and SFChT of each study group were compared using an independent sample t test. Changes of SFChT and other biometric parameters from baseline to each follow-up visit were examined using a repeated measure ANOVA, with post-hoc testing on indication and correction for multiple comparisons. For the Ortho-K, stepwise multiple linear regression models were used to investigate the association of 1-month SFChT change with change in axial length at 13 months. Potential confounding factors, including baseline age, and changes in ACP, CCT, ACD and LT at the first month visit were enrolled and examined in the stepwise multiple linear regression model. The standard β indicating the relative importance of each variable in comparable standardized units (z scores) (Peat J & Barton B 2005) was used to evaluate the importance of each variable in predicting weight. $P < 0.05$ at two tails was considered statistically significant.

Results

At baseline, there were no significant differences in terms of demographic, biometric and SFChT measures between the two groups (all $P > 0.05$) (Table 1). Of the 29 subjects enrolled in the Ortho-K group, a total of 26 subjects successfully completed 12 months of lens wear, and 23 subjects completed all the study visits. Three subjects were discontinued before the 12-month visit. Two of these subjects were discontinued because of the inconvenience of travelling long distance to our hospital. One subject withdrew because of stopping lens wear. Another three subjects who missed follow-up examinations were excluded at the 13-month visit. Of the 21 subjects enrolled in the control group, a total of 17 subjects completed 12 months of follow-up. The remaining 4 discontinued the study due to the inconvenience of travel distance.

The anterior corneal power, CCT, ACD and LT did not show significant changes over time in the control group ($P > 0.05$), whereas significant changes were found for all parameters in the Ortho-K group (Table 2). After 1-month of Ortho-K lenses treatment, the corneal shape shifted toward oblate with a significant less ACP as compared to baseline ($-2.60 \pm 0.70D$, $P < 0.001$). The magnitude of change remained unchanged at 6- ($P = 0.489$) and 12-month visit ($P = 0.465$). Central corneal thickness and ACD at 1-month visit reduced significantly by $12 \pm 7\mu m$ ($P < 0.001$) and $0.02 \pm 0.04mm$ ($P = 0.010$) from baseline (CCT, $566 \pm 37\mu m$; ACD, $3.25 \pm 0.22mm$), respectively. The magnitude of change did not alter significantly at the 6- (vs. 1-month visit, CCT, $P = 0.533$; ACD, $P = 0.644$) and 12-month visit (vs. 1-month visit, CCT, $P = 0.457$; ACD, $P = 0.102$). Lens thickness significantly increased from baseline over time during Ortho-K lenses wear ($P < 0.001$).

After the Ortho-K lenses were discontinued for one month, ACP, CCT and ACD recovered toward baseline (ACP, $P = 0.206$, CCT, $P = 0.403$, ACD, $P = 0.110$). Lens thickness significantly reduced by $0.02 mm$ from the 12-month visit ($P = 0.003$), but did not recover to baseline level ($P < 0.001$).

3.1 Repeatability of SFChT analysis of inter-observer and mean change in SFChT at each visit

The 95% LOA of inter-observer difference in SFChT at each visit was $0 \pm 7\mu m$

(baseline, $0 \pm 8 \mu\text{m}$; month 1, $0 \pm 6 \mu\text{m}$; month 6, $0 \pm 7 \mu\text{m}$; month 12, $0 \pm 7 \mu\text{m}$; month 13, $-1 \pm 7 \mu\text{m}$), indicating excellent repeatability for the SFChT analysis of the two observers which was consistent across all five study visits (Fig. 1). ICC analysis also suggested excellent within-observer reliability for SFChT measures at each visit (all $\text{ICC} > 0.995$).

In the control group, SFChT did not change significantly at 1- ($P=0.130$) and 6-month visits ($P=0.442$) but reduced by $9 \mu\text{m}$ from baseline at 12-month visit ($P=0.042$, Figure 2). Subfoveal choroidal thickness increased significantly during Ortho-K lens wear compared to the control group ($P<0.001$, Figure 2). In the Ortho-K group, SFChT significantly increased by $16 \pm 11 \mu\text{m}$ from baseline at 1-month visit ($P<0.001$), and the magnitude of choroidal thickening with respect to the baseline visit remained unchanged at 6- (mean change, $21 \pm 13 \mu\text{m}$, $P=0.120$) and 12-month visits (mean change, $19 \pm 14 \mu\text{m}$, $P=0.388$). A significant increase ($\geq 8 \mu\text{m}$) in SFChT as compared to baseline was seen in 79% of the eyes (23/29) at 1-month visit, 90% (26/29) at 6-month visit and 88% (23/26) at 12-month visit. No significant difference in SFChT between 13-month visit and baseline was observed ($P=0.772$). At the end of study, SFChT in 61% (14/23) of the eyes recovered or reduced as compared to the baseline.

3.2 Influencing factors with respect to biometric measurements, age and sex on choroidal thickening

In the Ortho-K group, the mean ACP at baseline was relative flatter ($42.48 \pm 1.36\text{D}$ vs. $43.14 \pm 1.23\text{D}$; mean difference, $0.66 \pm 0.58\text{D}$, $P=0.262$), and the mean AL at baseline was relative longer ($25.36 \pm 0.50\text{mm}$ vs. $25.13 \pm 0.83\text{mm}$; mean difference, $0.23 \pm 0.36\text{mm}$, $P=0.530$) in 6 subjects without significant choroidal thickening than that in 23 subjects with significant choroidal thickening, but the differences were not significant. Other factors, including age (12.16 ± 1.47 years vs. 12.34 ± 1.80 years), sex (boys/girls, 3/3 vs. 10/13), SER ($-3.09 \pm 0.59\text{D}$ vs. $-3.18 \pm 0.92\text{D}$), CCT ($568 \pm 41 \mu\text{m}$ vs. $564 \pm 37 \mu\text{m}$), ACD ($3.23 \pm 0.32\text{mm}$ vs. $3.26 \pm 0.20\text{mm}$) and LT ($3.31 \pm 0.09\text{mm}$ vs. $3.34 \pm 0.14\text{mm}$) at baseline were similar between these subjects (All $P>0.05$).

3.3 Mean change in AL and its association with change in SFChT at 1-month visit

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During the study period, AL significantly increased over time in both groups, but the rate of axial elongation was significantly reduced in the Ortho-K group compared to the control group (Figure 3). In the Ortho-k group, the spherical equivalent refractive error (SER) also showed a significant change from baseline during 13 months of follow up (Mean change, $-0.46 \pm 0.58D$, $P = 0.001$). The adjusted R^2 of the multiple linear regression model evaluating the predictive performance of the candidate predictors, including baseline age and the changes in SFChT and biometric measurements at the first month visit, for 13-month AL change was 0.580 ($F=13.791$, $P<0.001$). Both baseline age and change in SFChT at the 1-month visit were found associated with AL change at the 13-month visit (Change in SFChT, Standard β , -0.581 , $t(23)=-3.806$, $P=0.001$; baseline age, Standard β , -0.341 , $t(23)=-2.233$, $P=0.037$) (as shown in figure 4A and B), whereas the change in ACP, CCT, ACD and LT at the first month of Ortho-K lens wear did not affect the axial elongation (All $P>0.05$).

Discussion

In the current study, we found that the increase in SFChT approached its maximum after one month of Ortho-K lens treatment in Chinese children with mild to moderate myopia and this effect was maintained throughout the 12-month period of the treatment. After lens discontinuation for one month (13-month visit), SFChT returned to baseline level. Change in SFChT after one month of Ortho-K lens wear was found correlated significantly with long-term change in AL. To our knowledge, this is the first study to investigate changes of SFChT during Ortho-k lens wear and after its cessation and the association of short-term change in SFChT with the long-term eye elongation in Ortho-k subjects.

Increasing evidence has demonstrated the association between visual stimuli and ChT change in adjusting eye growth (Nickla et al. 2017, 2017). Recently, the positive effect of Ortho-K lens on myopia control for children has been reported by several researchers (Wen et al. 2015; Li et al. 2016). It is found that the change of a relative peripheral myopic defocus after OK lens wear in most myopic eyes might act as a

possible mechanism for myopia control (Kang et al. 2011), but the underlying mechanism is still unknown. According to previous research (Wallman et al. 1995; Wildsoet et al. 1995; Hung et al. 2000; Troilo et al. 2000), ChT change induced by visual defocus is reversible. In this study, we found that Ortho-K lens induced a significant increase in SFChT which would recover to the level of baseline after Ortho-K lens wear had been discontinued for one month. Characteristic changes of the anterior segment, including ACP, CCT and LT, during Ortho-K lens treatment also returned to baseline level after Ortho-K lens wear had been discontinued for one month. Our results thus support earlier findings of choroidal thickening as a response to Ortho-K lens treatment and furthermore indicate that this response is indeed reversible once the visual stimulus has been removed.

Ortho-K lens is a well-established clinical technique with reverse- geometry rigid contact lens wearing overnight (Swarbrick et al. 2006). There is abundant evidence demonstrating that Ortho-K lens can retard progression of myopia (Wen et al. 2015; Li et al. 2016). However, as observed in current and previous studies, great individual variation in response exists (Swarbrick et al. 2015; Cho & Cheung 2012). According to previous studies, baseline age (Hiraoka et al. 2012), change in corneal power (Zhong et al. 2014), and pupil size (Chen et al. 2012) were all significantly correlate with myopic progression during Ortho-K lens treatment. As ChT appears to be involved in the eye growth response to the defocus stimuli, it is relevant to ask how ChT is affected by Ortho-K lens and how ChT changes are related to the effect of Ortho-K lens on eye elongation. In the current study, SFChT approached its maximum at the one month visit, and this effect was maintained during 12 months of Ortho-K lens treatment. For further analysis, when compared to children (23/29) with significant increase in SFChT, we found that children (6/29) without significant increase in SFChT at 1-month visit had relative flatter ACP ($43.14 \pm 1.23\text{D}$ vs. 42.48 ± 1.36 , respectively. $P=0.262$) and longer AL ($25.13 \pm 0.83\text{mm}$ vs. 25.36 ± 0.50 , respectively. $P=0.530$) at baseline, but the statistical difference was not significant. It is possible that children with steeper ACP and shorter AL are more likely to exhibit an increase in SFChT after Ortho-K lens treatment, but further research with larger

sample size is warranted to confirm this phenomenon and analyze its mechanism. Alternatively, multiple linear regression analysis demonstrates a significant correlation between short-term SFChT change and the long-term change in AL after adjusting for other factors, such as baseline age and short-term change in ACP, CCT, ACD and LT. This result supported our hypothesis that SFChT change during the first month of Ortho-K lens wear is a predictor for its long-term effect on retarding myopia development.

Accurate AL measurements are essential to monitor the myopia development in Ortho-K subjects. The AL measured by Lenstar refers to the distance between the anterior surface of the cornea and retinal pigment epithelium. Thus, Ortho-K lens induced temporary decrease in CCT and ACD and temporary increase in SFChT should cause a temporary shortening of the AL (Swarbrick et al. 2015; Read et al. 2015). In this study, long-term effect of Ortho-K lens on AL was assessed after one month of Ortho-K lens cessation, when ocular biometric parameters, including CCT, ACD and SFChT all regressed to the baseline. Thus, the changes in AL measured at the end of our study can represent the real effect of overnight OK lens on eye elongation.

It is unknown how choroidal thickening causes reduced axial elongation. Subfoveal choroidal thickness change after Ortho-K treatment was much smaller than AL change. However, our study actually demonstrated that Ortho-K treatment would significantly increase the SFChT and slow down the axial elongation compared to the control group (single vision spectacles) when the potential confounding factors influencing ChT measures were taken into account. It should be noted that the magnitude of ChT changes in humans (Chiang et al. 2000; Chakraborty et al. 2012 and 2013), tree shrews (Siegwart & Norton 1998), and macaques (Troilo et al. 2000) were considerably smaller than those observed in chicks. Although the reason for this discrepancy is unclear, it seems that less change in ChT is required for altering eye growth in human and primate than in chicks. We speculate that changes in choroidal thickness may influence oxygen supply and molecular synthesis of the retina or choroid, and thus alters the biosynthesis of scleral extracellular matrix and elongation

of the eyeball (Wallman & Winawer 2004). It is also conceivable that increased choroidal thickness provide a sign of slowed axial elongation as a result of altered synthesis of molecular signals induced by myopic defocus (McFadden et al. 2004; Jobling et al. 2009). Further studies are required to elucidate the underlying mechanisms.

A limitation in this study was that the wash-out period of one month after Ortho-K lens cessation maybe too short to determine the actual rate of axial elongation at one-year. Further studies investigating the effect of long-term Ortho-K lens treatment on ChT and AL, with a sufficient period of lens discontinuation, are warranted. Besides, in the current study, LT significantly increased over time during Ortho-K lens wear, and did not recover to baseline when the Ortho-K lens was discontinued for 1 month. The design of the current study did not allow us to further investigate this observation. Further research is warranted.

In conclusion, the current study indicates that ChT increases after short-term use of overnight Ortho-K lens and is maintained throughout the treatment period. This effect disappears after cessation of lens wear, along with recovery of other ocular biometric parameters, including ACP, CCT and ACD. Change in SFChT during short-term Ortho-K lens treatment may be a predictor for its long-term effect on retarding myopia progression.

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Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure legends

Figure 1. Bland-Altman plots illustrating the repeatability of the subfoveal choroidal thickness (SFChT) measures by two independent observers collected at each visit. 95% LOA: 95% limits of agreement. BS: baseline; M1: one-month visit; M6: six-month visit; M12: twelve-month visit; M13: thirteen-month visit.

Figure 2. Change in SFChT during 13 months of follow up between two groups. Error bars indicate standard error (SE). The red arrow mean the time point as Ortho-K lens was discontinued. * mean a significant difference between two groups ($P < 0.05$).

Figure 3. Change in AL during 13 months of follow up between two groups. Error bars indicate standard error (SE). The red arrow mean the time point as Ortho-K lens was discontinued. * mean a significant difference between two groups ($P < 0.05$).

Figure 4. Scatter plots showing long-term change in AL and short-term change in SFChT and baseline age in the Ortho-K group. A. Scatter plots of long-term change in AL and short-term change in SFChT (Standard β , -0.581, t (23) =-3.806, $P=0.001$); B. Scatter plots of long-term change in AL and baseline age (Standard β , -0.341, t (23) =-2.233, $P=0.037$).

Table 1. Demographic and biometric and subfoveal choroidal thickness measures (mean $\pm$ SD) at baseline between two groups.

Participant characteristics	Ortho-k (N=29)	Control (N=21)	P- values
Gender	16F/13M	12F/9M	0.890
Age (years)	12.31 $\pm$ 1.71	11.52 $\pm$ 1.69	0.114
Sphere (D)	-2.86 $\pm$ 0.74	-2.80 $\pm$ 1.34	0.829
Cylinder (D)	-0.59 $\pm$ 0.52	-0.37 $\pm$ 0.46	0.120
SER (D)	-3.16 $\pm$ 0.85	-2.98 $\pm$ 1.34	0.569
CCT (μ m)	566 $\pm$ 37	551 $\pm$ 29	0.146
ACD (mm)	3.25 $\pm$ 0.22	3.26 $\pm$ 0.21	0.977
LT (mm)	3.34 $\pm$ 0.13	3.38 $\pm$ 0.14	0.251

AL(mm)	25.18±0.77	24.82±0.71	0.103
SFChT(μm)	228±56	248±51	0.205

SER: spherical equivalent refractive error; CCT: central corneal thickness; LT: lens thickness; ACD: anterior chamber depth. AL: axial length; SF: sub-fovea; SFChT: subfoveal choroidal thickness. P <0.05 at two tails was considered to be statistically significant.

Table 2. Mean change from baseline in ocular variables during 13 months of follow up in the Ortho-K group.

Parameters	During Ortho-k			Cessation of Ortho-k
	1M	6M	12M	13M
	Mean ± SD			
ACP (D)	-2.60±0.70*	-2.57±0.70*	-2.64±0.77*	-0.06±0.26
CCT (μm)	-12±7*	-13±7*	-9±9*	-1±5
ACD (mm)	-0.02±0.04*	-0.02±0.04*	-0.04±0.04*	-0.01±0.04
LT (mm)	0.01±0.02*	0.04±0.02*	0.04±0.03*	0.02±0.02*
SFChT (um)	16±11*	21±13*	19±14*	1±14
AL (mm)	0.02±0.04*	0.06±0.10*	0.17±0.16*	0.23±0.17*

ACP: apical corneal power; CCT: central corneal thickness; ACD: anterior chamber depth; LT: lens thickness; SD: standard deviation; D: diopter. *P < 0.05 compared to baseline.

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