ABSTRACT
This study examined the effects of overnight orthokeratology (OK) on higher-order wavefront aberrations (HOA), axial length elongation, and accommodation. Low to moderate myopic subjects with healthy eyes wore OK lenses nightly for 9 months. Corneal topography wavefront aberrations and accommodation were measured approximately monthly. Linear mixed-effects models were used to examine the association between the change in peripheral corneal parameters relative to the central cornea with HOA, and the association of accommodation and axial length elongation with HOA. Thirty-three participants (mean age 19.61 years) were included. Mean baseline refraction was $-2.97 \text{ D}$ (range, $-1.0$ to $-5.0 \text{ D}$). The level of spherical aberration (SA) was associated with a change in relative superior-central corneal thickness ($\beta = -0.21$, SE = 0.10, $p < 0.037$) and with the increased difference in superior-central corneal curvature ($\beta = 0.34$, SE = 0.15, $p = 0.026$). The change of coma increased with the change in relative superior corneal curvature ($\beta = 0.84$, SE = 0.18, $p < 0.001$). Axial length elongation was associated with both horizontal coma ($\beta = 0.19$, SE = 0.07, $p = 0.018$) and SA ($\beta = 0.20$, SE = 0.07, $p = 0.003$). While accommodation and axial length were correlated with HOA, axial length elongation was not correlated with accommodation in OK lens wearers.

KEYWORDS
Axial length; accommodation; higher-order aberration; myopia; orthokeratology; Orbscan II

1. Introduction
Orthokeratology (OK) can correct up to moderate myopia and slow progression by overnight wearing of rigid gas permeable (RGP) contact lenses with a “reverse geometry” design, that is, a central flat curve and a very steep reverse curve.[1–4] Wearing overnight OK lenses results in an increase in the corneal surface, central corneal flattening, thinning of the central corneal epithelium, and thickening of the mid-peripheral cornea; the lenses flatten the apical radius of the cornea and restructure it toward an oblate-like ellipse as a result of their shape.[5] Flattening of the central cornea reduces corneal power, and thus corrects the myopic refractive error, and with the removal of the lenses on awakening, satisfactory unaided vision is achieved during the daytime.[1] The effect is similar to that of laser refractive surgery, such as photorefractive keratectomy (PRK) or laser in-situ keratomileusis (LASIK).
Changes to the thickness and curvature of the cornea as a result of OK lens wear result in higher-order wavefront aberrations (HOA) of the cornea and the eye.\textsuperscript{[6–10]} The increase in HOA is believed to be primarily due to a shift in spherical aberration and an increase in coma aberrations.\textsuperscript{[6–10]} Hiraoka et al. recently reported that, during the wearing period, HOA and axial length increased significantly when compared to the baseline value, and axial length elongation was significantly correlated with HOA. The authors speculated that these results may be associated with accommodation.\textsuperscript{[11]} In addition, OK lenses worn overnight have also been shown to increase ocular and corneal astigmatism\textsuperscript{[12,13]} and decrease contrast sensitivity.\textsuperscript{[7,14]} Interestingly, in the normal internal eye, aberrations partially compensate for corneal surface aberrations and result in an overall reduction in ocular aberrations.\textsuperscript{[15]} Thus, the study of the effect of OK lenses on HOA is important for understanding the effects of treatment on vision quality.

The purpose of this study was to determine the association of OK lens wear with HOA and the effect on accommodation, HOA, and axial length elongation. The results may provide a better understanding of the effect of OK lenses on vision quality and corneal remodeling.

\section*{2. Subjects and methods}

Subjects with low to moderate myopia, healthy eyes were recruited from the Department of Ophthalmology, Tri-Service General Hospital, Taipei, Taiwan for this study. Patients with a history of keratopathy, ocular surgery, amblyopia, strabismus, xerophthalmia, or ptosis were excluded. The study was approved by the hospital Institutional Review Board and adhered to the tenets of the Declaration of Helsinki. All participants and parents for those aged <18 years provided written informed consent.

Patients, aged 9 to 62 years, who satisfied the inclusion criteria, with the myopia of 1.00 to 5.00 D (inclusive), and with-the-rule refractive astigmatism less or equal to 3.00 D were recruited at approximately the same time of the year. All subjects had unremarkable ocular and general health. All participants wore a programmed rigid reverse geometric contact lens for overnight OK. The contact lenses were designed and manufactured by Brighten Optix Corporation, Taipei, Taiwan, and were made of a fluorosilicone acrylate material. The diameter of the lenses ranged from 10.0 to 10.8 mm, and was determined by a participant’s corneal diameter. Contact lens base curve radius (BCR) was selected using an algorithm similar to that used by Nichols et al.: \( BCR = \text{apical radius} + \text{eccentricity} + 0.1 \text{ mm} \).\textsuperscript{[16]} After a baseline examination, each patient underwent a 2-h daytime trial before the first night of lens wear to confirm a successful fit. To be deemed an acceptable fit, the contact lens had to be well centered on the cornea. Subjects were instructed to wear the contact lenses every night and record the insertion and removal times. It was suggested that subjects obtain at least 7 h of closed-eye lens wear per night.

Participants wore the contact lenses to our office on the days on which examinations were performed, and removed the lenses upon request of the examining clinician. The testing protocol, including corneal topography and measurement with a wavefront aberrometer, began immediately after lens removal (i.e., within the first few minutes). All instruments were calibrated before study initiation. Corneal topography was measured with the Orbscan Slit Scan Corneal Topography/ Pachometry System Analyzer (Orbtek, Salt Lake City, UT). The Orbscan sequentially projects 20 slit images from the right eye and 20 slit image from the left eye. Each point along the anterior

| Nomenclature |
|---------------|
| **OK** | orthokeratology |
| **HOA** | higher order wavefront aberrations |
| **SA** | spherical aberration |
| **RGP** | rigid gas permeable |
| **LASIK** | laser in-situ keratomileusis |
| **PRK** | photorefractive keratectomy |
and posterior surface is triangulated using a splint fit curve. This process allows the determination of the location of both the anterior and posterior surfaces. Corneal thickness values were averaged centrally and peripherally over a circular area 2 mm in diameter by the Orbscan.

Wavefront aberrations and accommodation were measured with an iTrace wavefront analyzer (Tracey Technologies, Houston, TX). For accommodation, two distances were used: near, 35 cm; distance, 6 m (the standard distances used with the iTrace). The images were revised to pupil-centered images, and coma aberration and spherical aberration of the anterior cornea were calculated for the central 6-mm zone. For each eye, measurements were repeated at least three times, and the average of each corneal HOA in the central 6-mm area was calculated. The difference display shows accommodation, and the data from this study showed excellent agreement between iTrace measurements and standard pushup test over a range of 1–4 D of accommodation.

Axial length was evaluated by no contact optical biometry (IOL Master, Carl Zeiss Meditec, Dublin, CA). All measurements were performed by one experienced technician using the same instrument and procedures.

Examinations including visual acuity, corneal topography, wavefront aberration, and axial length were performed at baseline (visit 1), two times during the first week of wear (visits 2 and 3), and then as follows: visit 4: day 7 ± 3; visit 5: day 14 ± 3; visit 6: day 28 ± 7; visit 7: day 84 ± 14; visit 8: day 168 ± 21; visit 9: day 252 ± 28; visit 10: day x ± y; visit 11: day a ± b; visit 12: day c ± d. Axial length and accommodation were measured at baseline and at visit 9. After visit 9, all participants stopped wearing the lenses.

### 2.1. Statistical analysis

All data regarding HOA were measured for each eye at baseline, before the end of the trial (visit 9, 9 months after the start of the trial), and after the trial (visit 12, 10 months after the start of the trial). Mean corneal thickness and curvature values measured at visits 4–9 were used for analysis. Relative peripheral corneal thickness and curvature were defined as differences between each peripheral region (i.e., superior, inferior, nasal, and temporal) and the central region of the cornea. Change in relative peripheral corneal thickness and curvature was defined as the mean value of visits 4 to 9 minus the value of visit 1. Vertical coma was identified if the axis ranged 0–45°, 135–225°, or 315–360°. Horizontal coma was identified if the axis ranged 45–135° or 225–315°. Axial length elongation was defined as the difference between axial length at baseline and at visit 9. Left and right eye measurements were considered to be independent.

One-way analysis of variance (ANOVA) with repeated measurement was used to examine differences between HOA (i.e., coma and spherical aberration), spherical equivalent, and axial length measured at visits 1, 9, and 12. Bonferroni correction was used for all multiple pair-wise comparisons. Linear regression models were used to examine the association between the change in the difference of peripheral corneal parameters relative to the central cornea (i.e., thickness and curvature) and the change in HOA from baseline to visit 9. Linear regression models were also used to evaluate whether refractive error associated parameters at visit 9 (i.e., accommodation and axial length elongation) were associated with HOA at visit 9. The regression coefficients (β and corresponding standard error) of the linear regression models were calculated, to represent the direction and magnitude of the association between two variables of interest. Additional separate analyses according to vertical or horizontal coma were also performed. Association between accommodation and axial length elongation was examined by Pearson’s correlation. All statistical analyses were performed with SAS software version 9.2 (SAS Institute Inc., Cary, NC). A two-tailed p-value < 0.05 was considered to indicate statistical significance.

### 3. Results

A total of 33 participants (44.4% male) with a mean age of 19.61 years (range, 9 to 49 years) were included in the study. Complete data on each eye at each visit were collected. The mean
baseline refraction was $-2.97$ D (standard deviation = $1.35$ D), and ranged from $-1.0$ to $-5.0$ D (Table 1).

The time trend for HOA, spherical equivalent and axial length is shown in Figure 1. Results from pair-wise comparisons revealed a significant increase in coma and spherical aberration during the trial (visit 9); after the trial, the value decreased to the baseline level (Figure 1(A,B)). Similarly, the spherical equivalent was improved at visit 9 and returned to the baseline level after the trial (Figure 1(C)). There was no significant change in axial length across time, but a slightly increasing trend was found (Figure 1(D)). The mean accommodation was increased at visit 9 but declined to the baseline level at visit 12 (Figure 1(E)).

Associations between the changes in corneal parameters and HOA are summarized in Table 2. Regression models indicate that the change in relative corneal thickness was not associated with a change in a coma from baseline (the difference between visit 1 and visit 9). The associations of change in relative corneal thickness with a change in a vertical and horizontal coma were statistically non-significant ($p > 0.05$). However, the level of spherical aberration was associated with the changes in relative superior and central corneal thickness ($\beta = -0.21$, SE = 0.10, $p < 0.037$). The change in coma increased with the change in relative superior corneal curvature ($\beta = 0.84$, SE = 0.18, $p < 0.001$). In participants with vertical coma ($\beta = 0.69$, SE = 0.24, $p = 0.008$) and horizontal coma ($\beta = 1.15$, SE = 0.32, $p = 0.001$), a greater change in the relative difference in the superior corneal curvature was associated with a greater level of coma. In addition, the level of spherical aberration was associated with an increased difference in the superior and central corneal curvature ($\beta = 0.34$, SE = 0.15, $p = 0.026$).

Table 3 summarizes the associations between HOA, accommodation, and axial length elongation. A higher mean level of accommodation was associated with a higher level of coma (visit 9) ($\beta = 0.70$, SE = 0.21, $p = 0.001$). This was also true in participants with vertical ($\beta = 0.70$, SE = 0.33, $p = 0.040$) and horizontal coma ($\beta = 0.75$, SE = 0.27, $p = 0.008$). In addition, a positive correlation was found between mean accommodation and spherical aberration ($\beta = 1.08$, SE = 0.29, $p < 0.001$), and between maximum accommodation and spherical aberration ($\beta = 2.49$, SE = 0.83, $p = 0.004$). Axial length elongation was positively associated with both horizontal coma ($\beta = 0.19$, SE = 0.07, $p = 0.018$) and spherical aberration ($\beta = 0.20$, SE = 0.07, $p = 0.003$).

There was no significant correlation between axial length elongation and either mean accommodation ($r = 0.158$, $p = 0.206$) or maximum accommodation ($r = 0.180$, $p = 0.147$) (Figure 2(A,B)). Descriptive statistics of the variables used in the regression models can be found in Supplemental Table 1.

### 4. Discussion

The results of this study evaluating the effect of overnight OK on accommodation, HOA, and axial length elongation showed that during the wearing period there was no significant increase in axial length as compared to baseline, and changes in corneal curvature were significantly
correlated with HOA. While the accommodation was correlated with HOA, there was no correlation between axial length elongation and accommodation.

In our analysis, mean axial elongation increased from 25.01 (baseline) to 25.08 (visit 9) mm, and was significantly associated with horizontal coma and spherical aberration. These results are similar to those from a study by Hiraoka et al.\cite{11} in which 55 children were followed over 1 year of OK lens wear. In that study, mean axial length significantly increased from 24.20 mm at baseline to 24.43 mm at 1 year. Axial elongation was correlated with change in $C_2^\circ$, second-order aberration, coma-like aberration, spherical-like aberration, total HOA, and corneal multifocality, as well as baseline age and baseline spherical equivalent refractive error, but not $C_4^\circ$. Regression analysis indicated that the most relevant variable was the change in coma-like aberration. The authors concluded that asymmetric corneal shapes exert a larger effect on retarding axial elongation compared to concentric or radially symmetric shapes. They further suggested that OK inhibits myopia progression via a mechanism other than a reduction in peripheral hyperopic

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Figure 1. Time trend for (A) coma, (B) spherical aberration, (C) spherical equivalent, (D) axial length, and (E) accommodation. *
$p < 0.05$ for baseline (visit 1) compared to visit 9.
defocus. Differences in study design between our study and that of Hiraoka et al. may account for the contrasting results. For example, differences in subject selection resulted in a different initial visual acuity between the studies, and the period of the current study was shorter. In addition, the conclusions of Hiraoka’s study may be too simplistic, and more factors should be considered, for example, compression of the cornea, which affects HOA, is related to initial visual acuity.

Several mechanisms for the process of myopia have been proposed. The “accommodation lag theory” suggests that axial hyperopic retinal blur (due to accommodation lag during near work) accelerates eye growth.[17] The “mechanical tension theory” postulates that mechanical tension from the ciliary body and lens during accommodation restricts equatorial ocular expansion, thus

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**Table 2.** Association of corneal parameters with change in high-order aberrations from baseline during overnight orthokeratology trial.

| Parameters                                      | Overall | Vertical coma | Horizontal coma | Spherical aberration |
|-------------------------------------------------|---------|---------------|-----------------|---------------------|
| Change in relative corneal thickness (per 100 μm) |         |               |                 |                     |
| Superior-central diff.                           | −0.15 (0.13) | 0.274 | −0.18 (0.20) | 0.375 | −0.15 (0.19) | 0.427 | −0.21 (0.10) | 0.037 |
| Inferior-central diff.                           | 0.04 (0.15)  | 0.791 | −0.03 (0.23) | 0.897 | 0.09 (0.19) | 0.633 | −0.16 (0.11) | 0.149 |
| Nasal-central diff.                              | −0.15 (0.18) | 0.419 | −0.13 (0.32) | 0.699 | −0.20 (0.21) | 0.357 | −0.13 (0.13) | 0.339 |
| Temporal-central diff.                           | 0.22 (0.15)  | 0.139 | 0.32 (0.19) | 0.102 | 0.02 (0.25) | 0.945 | 0.13 (0.11) | 0.240 |
| Change in relative corneal curvature (per 10 D)  |         |               |                 |                     |
| Superior-central diff.                           | 0.84 (0.18)  | <0.001 | 0.69 (0.24) | 0.008 | 1.15 (0.32) | 0.001 | 0.34 (0.15) | 0.026 |
| Inferior-central diff.                           | 0.26 (0.25)  | 0.291 | 0.15 (0.34) | 0.651 | 0.37 (0.38) | 0.340 | 0.35 (0.18) | 0.056 |
| Nasal-central diff.                              | 0.15 (0.19)  | 0.434 | 0.19 (0.25) | 0.456 | 0.10 (0.33) | 0.764 | 0.21 (0.14) | 0.144 |
| Temporal-central diff.                           | 0.02 (0.28)  | 0.940 | 0.40 (0.40) | 0.325 | −0.53 (0.40) | 0.189 | 0.33 (0.21) | 0.113 |

SE: standard error.

*aDifference between values recorded at baseline (visit 1) and visit 9.

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**Table 3.** Association between accommodation error and high-order aberrations during overnight orthokeratology trial.

| Parameters | Mean accommodation | Maximum accommodation | Axial length elongation |
|------------|--------------------|-----------------------|------------------------|
|            | β (SE)   | p      | β (SE)   | p      | β (SE)   | p      |
| Coma       |         |        |         |        |         |        |
| Overall    | 0.74 (0.21) | 0.001 | 0.87 (0.62) | 0.166 | 0.08 (0.05) | 0.122 |
| Vertical   | 0.70 (0.33) | 0.040 | 0.66 (0.91) | 0.473 | 0.02 (0.07) | 0.761 |
| Horizontal | 0.73 (0.27) | 0.008 | 1.37 (0.91) | 0.142 | 0.19 (0.07) | 0.018 |
| Spherical  | 1.08 (0.29) | <0.001 | 2.49 (0.83) | 0.004 | 0.20 (0.07) | 0.003 |

SE: standard error.

*aValues recorded at visit 9.

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**Figure 2.** Pearson’s correlation coefficients for associations between accommodation and axial length elongation. (A) Mean accommodation vs. axial length elongation. (B) Maximum accommodation vs. axial length elongation.
Another theory suggests that axial elongation is due to accommodation-induced contraction of the ciliary muscle pulling the choroid, and thus shrinking the equatorial circumference of the sclera. Accommodation theory may explain why OK lenses cannot completely control myopia, since providing tension on the surface may not be sufficient to retard axial length elongation. However, myopia progression may result from a number of different processes that may be more or less pronounced in different situations.

OK lenses reshape the cornea to flatten the central area and create a steeper mid periphery, changes that create HOA, in particular, positive spherical aberration. The resulting reduction in axial elongation with OK lenses ranges approximately 30–60%. Zhong et al. studied 27 Chinese children aged 9–14 years over a 24-month period of OK lens wear. After OK treatment, statistically significant steepening was seen at the nasal 2 and 3 mm, temporal 3 mm, and inferior 2, 3, and 4 mm locations as compared with the apical center, and axial length increased significantly throughout the 24 months. Changes in corneal refractive power significantly affected axial elongation; 2-year axial elongation in patients with larger corneal power changes (level 2) was reduced 54–69% as compared with those with smaller corneal power changes (level 1), and maximum power changes were negatively correlated with 2-year axial growth.

Lian et al. investigated corneal thickness and wavefront aberrations over 30 days of OK lens wear in 16 adults. The study found the central cornea thinned in the horizontal and vertical meridians, thickened in the temporal, nasal, and inferior mid-peripheries, and the cornea thinned in the mid-peripheral superior region. There were significant increases in the root-mean-square (RMS) for astigmatism, spherical aberration, coma, and positive horizontal coma. The study also found significant positive correlations between the mid-peripheral-central thickness change difference and the changes in corneal and ocular RMS of the total HOA and spherical aberration (r range: 0.281–0.492). The change in corneal coma RMS was correlated only with the mid-peripheral-central thickness change difference (r = 0.270) and the change in a corneal horizontal coma was correlated only with the temporal-nasal thickness change difference (r = 0.289).

Gifford et al. also studied 18 adults 20–23 years of age over 7 days of overnight OK use. An increase in corneal and ocular RMS HOA and a positive shift in spherical aberration were noted on day 1 and increased up to day 7. By day 7, the increase in corneal spherical aberration was greater than that of the ocular spherical aberration, and the contrast sensitivity function showed an overall decrease. Hiraoko et al. assessed refraction, visual acuity, corneal topography, wavefront aberration, and contrast sensitivity before and after 3 months of overnight OK lens wear in 23 patients with a mean age of 24.2 years, and a mean spherical equivalent refraction before treatment of −2.38 ± 0.98 D. The mean magnitude of decentration (0.85 ± 0.51 mm) was significantly correlated with the amount of myopic correction, the increases in coma-like aberration and spherical-like aberration, and the reduction in contrast sensitivity function. Changes in contrast sensitivity function were also statistically significantly correlated with the amount of myopic correction, and the changes in coma-like aberration and spherical-like aberration. The magnitude of decentration was the only variable related to the contrast sensitivity function by regression analysis.

In this study, the Orbscan Slit Scan Corneal Topography System Analyzer was used to measure corneal topography, and this may be the reason the results vary from those of other reports, as the Orbscan is more sensitive to curvature than to thickness as compared to time-domain optical coherence topography (OCT). For example, studies using an optical pachometer indicated approximately 9 mm of central corneal thinning after one night of wearing OK lenses, and that the mid-peripheral and peripheral cornea were thickened after OK use. This was also reported in a study that used OCT, but a study using the Orbscan reported no changes in the mid-peripheral and peripheral cornea after wearing OK lenses. Using the Orbscan, the curvature may be more sensitive than thickness to identify a correlation with coma. Using other types
of instruments may produce different results, and when using the Obscan in a clinical setting, the curvature may be the most important factor monitored.

There are limitations to this study that should be taken into account. The number of participants was relatively small, and the duration of the study was relatively short. In addition, all participants were of Chinese ancestry, and thus the results may not be generalizable to other populations.

In conclusion, OK lens wear resulted in no significant increase in axial length as compared to baseline, but changes in the corneal curvature were significantly correlated with HOA. While the accommodation was correlated with HOA, there was no correlation between axial length elongation and accommodation.

**Disclosure statement**

The authors report no conflict of interest.

**References**

[1] Cho, P.; Cheung, S. W.; Mountford, J.; White, P. Good clinical practice in orthokeratology. *Cont. Lens Anterior Eye*. 2008, 31, 17–28.

[2] Walline, J. J.; Jones, L. A.; Sinnott, L. T. Corneal reshaping and myopia progression. *Br. J. Ophthalmol.* 2009, 93, 1181–1185.

[3] Kakita, T.; Hiraoka, T.; Oshika, T. Influence of overnight orthokeratology on axial elongation in childhood myopia. *Invest. Ophthalmol. Vis. Sci.* 2011, 52, 2170–2174.

[4] Wen, D.; Huang, J.; Chen, H.; Bao, F.; Savini, G.; Calossi, A.; Chen, H.; Li, X.; Wang, Q. Efficacy and acceptability of orthokeratology for slowing myopic progression in children: A systematic review and meta-analysis. *J. Ophthalmol.* 2015, 2015, 360806.

[5] Lu, F.; Simpson, T.; Sorbara, L.; Fonn, D. Malleability of the ocular surface in response to mechanical stress induced by orthokeratology contact lenses. *Cornea* 2008, 27, 133–141.

[6] Joslin, C. E.; Wu, S. M.; McMahon, T. T.; Shahidi, M. Higher-order wavefront aberrations in corneal refractive therapy. *Optom. Vis. Sci.* 2003, 80, 805–811.

[7] Berntsen, D. A.; Barr, J. T.; Mitchell, G. L. The effect of overnight contact lens corneal reshaping on higher-order aberrations and best-corrected visual acuity. *Optom. Vis. Sci.* 2005, 82, 490–497.

[8] El Hage, S.; Leach, N. E.; Miller, W.; Prager, T. C.; Marsack, J.; Parker, K.; Minavi, A.; Gaume, A. Empirical advanced orthokeratology through corneal topography: The university of houston clinical study. *Eye Contact Lens*. 2007, 33, 224–235.

[9] Hiraoka, T.; Okamoto, C.; Ishii, Y.; Kakita, T.; Okamoto, F.; Oshika, T. Time course of changes in ocular higher-order aberrations and contrast sensitivity after overnight orthokeratology. *Invest. Ophthalmol. Vis. Sci.* 2008, 49, 4314–4320.

[10] Hiraoka, T.; Okamoto, C.; Ishii, Y.; Takahira, T.; Kakita, T.; Oshika, T. Mesopic contrast sensitivity and ocular higher-order aberrations after overnight orthokeratology. *Am. J. Ophthalmol.* 2008, 145, 645–655.

[11] Hiraoka, T.; Kakita, T.; Okamoto, F.; Oshika, T. Influence of ocular wavefront aberrations on axial length elongation in myopic children treated with overnight orthokeratology. *Ophthalmology* 2015, 122, 93–100.

[12] Hiraoka, T.; Okamoto, F.; Kaji, Y.; Oshika, T. Optical quality of the cornea after overnight orthokeratology. *Cornea* 2006, 25, S59–S63.

[13] Hiraoka, T.; Okamoto, C.; Ishii, Y.; Okamoto, F.; Oshika, T. Recovery of corneal irregular astigmatism, ocular higher-order aberrations, and contrast sensitivity after discontinuation of overnight orthokeratology. *Br. J. Ophthalmol.* 2009, 93, 203–208.

[14] Hiraoka, T.; Okamoto, C.; Ishii, Y.; Kakita, T.; Oshika, T. Contrast sensitivity function and ocular higher-order aberrations following overnight orthokeratology. *Invest. Ophthalmol. Vis. Sci.* 2007, 48, 550–556.

[15] Artal, P.; Guirao, A.; Berrio, E.; Williams, D. R. Compensation of corneal aberrations by the internal optics in the human eye. *J. Vis.* 2001, 1, 1–8.

[16] Nichols, J. J.; Marsich, M. M.; Nguyen, M.; Barr, J. T.; Bullimore, M. A. Overnight orthokeratology. *Optom. Vis. Sci.* 2000, 77, 252–259.

[17] Charman, W. N. Near vision, lags of accommodation and myopia. *Ophthalmic Physiol. Opt.* 1999, 19, 126–133.

[18] Berntsen, D. A.; Mutti, D. O.; Zadnik, K. Study of theories about myopia progression (STAMP) design and baseline data. *Optom. Vis. Sci.* 2010, 87, 823–832.
[19] Mutti, D. O.; Sholtz, R. I.; Friedman, N. E.; Zadnik, K. Peripheral refraction and ocular shape in children. *Ophthalmol. Vis. Sci.* **2000**, *41*, 1022–1030.

[20] Cho, P.; Cheung, S. W. Retardation of myopia in orthokeratology (ROMIO) study: A 2-year randomized clinical trial. *Invest. Ophthalmol. Vis. Sci.* **2012**, *53*, 7077–7085.

[21] Hiraoka, T.; Kakita, T.; Okamoto, F.; Takahashi, H.; Oshika, T. Long-term effect of overnight orthokeratology on axial length elongation in childhood myopia: A 5-year follow-up study. *Ophthalmol. Vis. Sci.* **2012**, *53*, 3913–3919.

[22] Charm, J.; Cho, P. High myopia-partial reduction ortho-k: A 2-year randomized study. *Optom. Vis. Sci.* **2013**, *90*, 530–539.

[23] Santodomingo-Rubido, J.; Villa-Collar, C.; Gilmartin, B.; Gutiérrez-Ortega, R. Myopia control with orthokeratology contact lenses in Spain: A comparison of vision-related quality-of-life measures between orthokeratology contact lenses and single-vision spectacles. *Eye Contact Lens* **2013**, *39*, 153–157.

[24] Zhong, Y.; Chen, Z.; Xue, F.; Zhou, J.; Niu, L.; Zhou, X. Corneal power change is predictive of myopia progression in orthokeratology. *Optom. Vis. Sci.* **2014**, *91*, 404–411.

[25] Lian, Y.; Shen, M.; Huang, S.; Yuan, Y.; Wang, Y.; Zhu, D.; Jiang, J.; Mao, X.; Wang, J.; Lu, F. Corneal reshaping and wavefront aberrations during overnight orthokeratology. *Eye Contact Lens* **2014**, *40*, 161–168.

[26] Gifford, P.; Li, M.; Lu, H.; Miu, J.; Panjaya, M.; Swarbrick, H. A. Corneal versus ocular aberrations after overnight orthokeratology. *Optom. Vis. Sci.* **2013**, *90*, 439–447.

[27] Hiraoka, T.; Mihashi, T.; Okamoto, C.; Okamoto, F.; Hirohara, Y.; Oshika, T. Influence of induced decentered orthokeratology lens on ocular higher-order wavefront aberrations and contrast sensitivity function. *J. Cataract Refract. Surg.* **2009**, *35*, 1918–1926.

[28] Alharbi, A.; Swarbrick, H. A. The effects of overnight orthokeratology lens wear on corneal thickness. *Invest. Ophthalmol. Vis. Sci.* **2003**, *44*, 2518–2523.

[29] Swarbrick, H. A.; Wong, G.; O’Leary, D. J. Corneal response to orthokeratology. *Optom. Vis. Sci.* **1998**, *75*, 791–799.

[30] Wang, J.; Fonn, D.; Simpson, T. L.; Sorbara, L.; Kort, R.; Jones, L. Topographical thickness of the epithelium and total cornea after overnight wear of reverse-geometry rigid contact lenses for myopia reduction. *Invest. Ophthalmol. Vis. Sci.* **2003**, *44*, 4742–4746.