AMERICAN ACADEMY OF OPHTHALMOLOGY®

Ophthalmic Technology Assessment

Use of Orthokeratology for the Prevention of Myopic Progression in Children

A Report by the American Academy of Ophthalmology

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Purpose: To review the published evidence to evaluate the ability of orthokeratology (Ortho-K) treatment to reduce myopic progression in children and adolescents compared with the use of spectacles or daytime contact lenses for standard refractive correction.

Methods: Literature searches of the PubMed database, the Cochrane Library, and the databases of clinical trials were last conducted on August 21, 2018, with no date restrictions but limited to articles published in English. These searches yielded 162 citations, of which 13 were deemed clinically relevant for full-text review and inclusion in this assessment. The panel methodologist then assigned a level of evidence rating to the selected studies.

Results: The 13 articles selected for inclusion include 3 prospective, randomized clinical trials; 7 nonrandomized, prospective comparative studies; and 3 retrospective case series. One study provided level I evidence, 11 studies provided level II evidence, and 1 study provided level III evidence. Most studies were performed in populations of Asian ethnicity. Change in axial length was the primary outcome for 10 of 13 studies and change in refraction was the primary outcome for 3 of 13 studies. In these studies, Ortho-K typically reduced axial elongation by approximately 50% over a 2-year study period. This corresponds to average axial length change values of approximately 0.3 mm for Ortho-K patients compared with 0.6 mm for control patients, which corresponds to a typical difference in refraction of approximately 0.5 diopters (D). Younger age groups and individuals with larger than average pupil size may have a greater effect with Ortho-K. Rebound can occur after discontinuation or change to alternative refractive treatment.

Conclusions: Orthokeratology may be effective in slowing myopic progression for children and adolescents, with a potentially greater effect when initiated at an early age (6–8 years). Safety remains a concern because of the risk of potentially blinding microbial keratitis from contact lens wear. *Ophthalmology 2019;126:623-636 © 2018 by the American Academy of Ophthalmology*

The American Academy of Ophthalmology prepares Ophthalmic Technology Assessments to evaluate new and existing procedures, drugs, and diagnostic and screening tests. The goal of an Ophthalmic Technology Assessment is to systematically review the available research for clinical efficacy and safety. After review by members of the Ophthalmic Technology Assessment Committee, relevant subspecialty societies, and legal counsel, assessments are submitted to the Academy's Board of Trustees for consideration as official Academy statements. The purpose of this assessment by the Ophthalmic Technology Assessment Committee Pediatric Ophthalmology/Strabismus Panel was to compare the efficacy of orthokeratology (Ortho-K) as a treatment for reducing the progression of myopia in children and adolescents compared with standard refractive correction using spectacles or daytime contact lenses. Review of quality data for this technology was performed explicitly to understand the potential role of this treatment and to provide an unbiased assessment that is not intended to endorse or negate its use for myopic progression in children.

Background

Control of myopia progression has become of greater interest as rates of myopia and high myopia continue to increase, particularly in developed countries.[1] Myopia and high myopia prevalence have been increasing in many regions, including the United States,[2] Europe,[3] Israel,[4] Australia,[5] and many East Asian countries.[6,7] Although the majority of very young children are hyperopic,[8] myopia progression typically begins in the elementary school years,

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by 10 years of age, and progresses in the second decade of life.[9-11] The prevalence of myopia in children in population-based studies worldwide ranges from 1.2% to 42.4%, with variations due to age, race, and the definition used to classify myopia.[1] Most adults with significant refractive error are myopic,[12] and the highest rates (70%−95%) have been reported in cohorts of university students in Shanghai and Hong Kong.[13,14] Given the known ocular complications that can result in low vision or blindness with high myopia,[15-17] as well as the challenges presented by uncorrected myopic refractive error and costs of treatment,[18] myopia has been identified as one of the ocular conditions targeted by the World Health Organization's Global Initiative for the Elimination of Avoidable Blindness.[19]

The development of myopia is the result of multifactorial mechanisms. Genetic markers for myopia have been identified,[5] and genetic influence can be observed in the myopia concordance in twins,[20,21] associations with rates of parental myopia,[22-25] and variations in prevalence by ethnic association.[1,26] Environmental influences that have been implicated in myopic progression in children include increased near work and less time spent outdoors.[21,27] Adult population studies show associations of myopia with factors such as higher educational level or socioeconomic status.[28] Genome-wide association studies have identified 39 genetic loci that have a potential relationship with myopia and refractive error. Fan et al[5] evaluated genetic variants at each of these 39 genetic loci for an association with age of onset of refractive error, and they assessed the relationship between these variants and environmental factors of near work and time spent outdoors in children aged 7 to 15 years. There was evidence of genetic influence for some of the loci in both white and Asian children; a nominal relationship was seen between these genetic markers and near work but no substantive association with time spent outdoors. Studies have shown some efficacy in preventing myopic progression by targeting reduction in accommodative amplitudes. The greatest effects were shown with the use of antimuscarinic agents such as atropine or pirenzepine,[29] and a more modest effect was seen by including a near add in a spectacle correction.[30] Increased time outdoors has demonstrated a modest effect in preventing onset and progression of myopia.[31] Furthermore, there may be a differential impact of playing outdoors and participating in sports based on family history, because 1 study showed that lower hours of outdoor activity or sports increased the odds of becoming myopic more in children with 2 myopic parents than in children with 1 or zero myopic parents.[21]

Description of the Treatment

Orthokeratology is a treatment that uses specially designed, reverse geometry, gas-permeable contact lenses to temporarily reshape the corneal surface.[32] The lenses are worn overnight, and the most common application is to reduce daytime myopia by flattening the central cornea. Modern Ortho-K lenses consist of a central base curve that is fitted significantly flatter than the central corneal curvature and that has steeper peripheral curves that provide proper centration and fit to the corneal surface. This shape is called reverse geometry because typical corneal geometry is prolate, with the steepest curvature centrally and a gradual flattening toward the periphery. The treatment zone of an Ortho-K lens causes central corneal flattening by compressing the corneal epithelium; additionally, the mechanical pressure of the contact lens reduces central corneal swelling related to hypoxia. The result is thinning of the central epithelium and thickening of the mid-peripheral epithelium, along with increased peripheral edema as opposed to central stromal edema.[33,34] The extent of central corneal flattening corresponds to the amount of reduction in myopic refraction. Because the corneal changes revert to their original state when lens wear is discontinued, the lenses must be worn nightly for optimal refractive effect.

The concept of Ortho-K originated in the 1950s after clinicians noted that use of hard (polymethylmethacrylate) contact lenses resulted in transient spectacle blur, with small reductions in myopic refractive error. However, these lenses were uncomfortable, not oxygen permeable, and not suitable for corneal reshaping or overnight wear. Because rigid-gas permeable (RGP) lenses were manufactured with higher oxygen permeability, interest in Ortho-K was renewed. The first US Food and Drug Administration (FDA) approval for the reverse geometry design was obtained by Contex Incorporated (Sherman Oaks, CA) in 1998. These lenses were approved for daily wear, and overnight wear was not accepted until Paragon Vision Sciences (Mesa, AZ) received FDA approval for the Paragon corneal refractive therapy (CRT) lenses in 2002. The Paragon CRT approval was given without any age restriction, although the advisory panel suggested that approval be limited to individuals 18 years of age and older. In 2004, Euclid Systems Corporation (Herndon, VA) received FDA approval for the Boston Orthokeratology (oprifocon A) lens for overnight wear. This lens material was later acquired by Bausch & Lomb Incorporated (Bridgewater, NJ), which markets the material in different designs through different manufacturers. The lens material was also approved without age restriction; however, of note, there is a boxed warning stating that the safety and efficacy in adolescent and pediatric subjects have not been studied clinically.

The use of Ortho-K is generally accepted as a temporary treatment for the reduction of mild to moderate myopia. The Euclid-approved lenses are marketed for a reduction of up to −5.00 diopters (D) with astigmatism of up to 1.50 D, and the Paragon CRT lenses are marketed for the reduction of up to −6.00 D with astigmatism of up to 1.75 D; to use these lenses, the spherical error must be greater than the astigmatism error. Practitioners must be certified to a minimum standard for Ortho-K education and training, which can be accomplished via online training and certification courses offered by the lens manufacturers. Although no studies for FDA approval included children, the FDA grants eye care practitioners discretion to use the lenses in the pediatric population. Of note, these lenses are approved to treat myopic refractive error in nondiseased eyes but not to control myopia progression and, as such, are used off-label for this purpose in children.

The use of Ortho-K to reduce myopic progression is based on several animal studies and observational studies in humans. Primate models used to study refractive development show that peripheral refractive defocus can influence central refractive development.[35,36] Although the mechanism is unclear, the visual input to the peripheral retina appears to regulate growth of the subjacent sclera such that there is a compensatory impact on globe elongation and shape. Peripheral hyperopic defocus is associated with greater globe elongation and a more prolate globe shape, resulting in a more myopic central refraction. Orthokeratology lens wear results in a (temporary) flattening of the central cornea, which corrects the central myopic refraction but also changes the peripheral refractive status from relative hyperopic defocus to relative myopic defocus. Peripheral refractions performed in children wearing Ortho-K lenses confirm that along with a reduction in the central myopic refraction, a conversion of the relative peripheral hyperopic refraction to a relative peripheral myopic refraction is obtained, prompting interest in using Ortho-K as a tool to control myopic progression.[37]

Questions for Assessment

The purpose of this assessment is to address the following questions: (1) Does Ortho-K prevent myopic progression in children and adolescents? (2) What are the reported rates of myopic progression using Ortho-K in children and adolescents compared with standard refractive correction using spectacle or daytime contact lenses?

Description of Evidence

Literature searches were last conducted in August 2018 in PubMed, the Cochrane Library, and the databases of clinical trials with no date restrictions and limited to studies published in English. The search strategy used the following MeSH terms and text words: *ortho k, ortho k lens, ortho k lens wear, ortho k lenses, ortho k therapy, orthokeratology, corneal refractive therapy, orthokeratologic procedures, corneal refractive therapy, corneal reshaping contact lens, Orthokeratologic Procedures* [MeSH], *Orthokeratologic Procedures/methods [MeSH], Orthokeratologic Procedures/therapeutic use* [MeSH]), and *contact lenses* [MeSH].

The searches resulted in 162 potentially relevant citations. The abstracts were reviewed by the first author (D.K.V.), who marked those that potentially met the following inclusion criteria: (1) The research was original; (2) the study population consisted of children 16 years of age or younger at enrollment; (3) the study was a comparative case series or randomized trial; (4) the intervention group patients (eyes) were treated using overnight contact lenses for corneal reshaping; (5) control group patients (eyes) were treated using standard therapy (spectacles or daytime contact lenses); (6) patients were followed for at least 1 year; and (7) the primary objective was to evaluate the prevention of myopic progression by assessing refractive error or biometry measures as an outcome. Prospective, randomized trials and comparative case series were reviewed. Noncomparative case series, review articles, and commentaries were not considered in this assessment.

Fourteen articles were selected for full-text review; the majority of the other articles were eliminated because they were not comparative case series or randomized trials. The methodologist (R.T.K.) then assessed these studies according to the strength of evidence, and 1 additional article was excluded because it was a secondary analysis from a study for which the primary results article was included. On the basis of the rating sale developed by the Oxford Centre for Evidence-Based Medicine,[38] the methodologist assigned a level I rating to well-designed and well-conducted randomized clinical trials, a level II rating to well-designed case-control and cohort studies and lower-quality randomized studies, and a level III rating to comparative case series. One study met level I criteria, 11 studies met level II criteria, and 1 study met level III criteria.

Published Results

Table 1 provides a summary of the studies that met the inclusion criteria and were reviewed for this assessment.

Level I Evidence

Swarbrick et al[32] used a novel randomization technique in a within-subject crossover trial in which the eyes of each subject were randomized to use an Ortho-K lens on 1 eye at night and a daytime RGP contact lens on the fellow eye. After 6 months, the subjects were required to abstain from lens wear during a "washout" period of 2 to 3 weeks to allow the corneal parameters to return to baseline values (±0.05 mm) before measuring axial length by optical biometry or noncycloplegic autorefraction. For the second 6 months, the study continued with a new baseline and the mode of correction was switched between the eyes, after which there was a similar 2-week recovery period of no lens wear before outcome data were collected. The 32 subjects in this study were of Asian ethnicity between 8 and 16 years of age who had baseline myopia of 1 to 4 D spherical equivalent.

After the first 6-month recovery period, the RGP eyes showed a mean increase in axial length of 0.05±0.09 mm ($P = 0.001$), but no significant change was found in the Ortho-K eyes (0.01±0.08, not significant). After the second 6-month washout period, the RGP eyes had a mean increase of 0.10±0.12 mm ($P = 0.001$), with no mean increase in the Ortho-K eyes (0.00±0.11mm, not significant). The RGP eyes showed progressive axial growth throughout the study, which was statistically significant at the 6-month and 12-month visits, before and after the washout periods. Likewise, after the first 6-month washout period, there was no increase in myopia in the Ortho-K eyes, but there was a nonstatistically significant increase in myopic refraction from baseline in the RGP eyes, so that the eye using the RGP lens was on average −0.38±0.41 D more myopic than the Ortho-K eye. After the second 6-month washout period, there was again no increase in myopia in the Ortho-K eyes, but there was approximately 0.5 D more myopia in the RGP eyes, which was statistically significant ($P < 0.001$). After

Table 1. Summary of Reviewed Studies

Author(s), Year	Level of Evidence*	Treatment	Type of Study/Cohort	Timing of Visits/Final Follow-up	Primary Outcome	Results	Comments
Swarbrick et al, 2015[32]	I-1b	Ortho-K vs. contralateral eye RGP contact lenses for 6 mos Followed by 2-wk washout, then reversed treatment for 6 mos	Prospective, randomized trial contralateral-eye crossover study East Asian children Age: 8–16 yrs Baseline myopia: −1.00 to −4.00 D SE, <1.00 anisometropia 32 subjects enrolled	Visits at 3, 6, 9, 12 mos 1 yr	Axial length, optical biometry Refraction (noncycloplegic autorefraction) *Biometry and refraction after discontinuation of lenses for 2 wks*	26/32 subjects (81%) completed 6 mos of treatment 24/32 subjects (75%) completed 12 mos of treatment Axial length increase: *After first 6 mos* 0.05±0.09 mm RGP eye ($P = 0.001$) 0.01±0.08 mm Ortho-K eye (ns) *After second 6 mos* −0.00±0.11 mm Ortho-K eye (ns) 0.10±0.12 mm RGP eye ($P = 0.001$) Refraction *First 6 mos* (ns) *Second 6 mos* RGP eye increased ~0.5 D ($P < 0.05$)	Novel randomization of eyes Approximately 25% lost to follow-up Noncycloplegic refractions No details on clinical observations or safety, states will be presented elsewhere
Davis et al, 2015[42]	II- 2b	Ortho-K vs. soft contact lens	Longitudinal, multicenter, prospective, cohort study (10 US sites) Ethnicity not reported Age: 8–14 yrs Baseline myopia: criteria not specified N=172 Ortho-K N=110 soft contact lens	Visits at 1 wk, 2 wks, 1 mo, 3 mos, then every 6 mos Final at 3 yrs	Cycloplegic refraction Change in axial length (technique not standardized) *Assessed after discontinuation of Ortho-K and with stable topography, keratometry, refraction on 2 consecutive visits at least 3 days apart*	Myopic progression at 3 yrs: −0.12±0.64 D Ortho-K (ns) −1.01±0.67 D soft contact lens ($P < 0.0001$) Ortho-K slowed progression of myopia compared with soft contact lens group ($P < 0.001$) *Axial length analysis not valid because of variability in measurement methods between centers*	Exploratory nonrandomized cohort study with good reference standards, multicenter, prospective standardized follow-up Choice of treatment selected by parents High dropout rate (20% each group during first year); Ortho-K group more likely to drop out because of discomfort
Charm and Cho, 2013[40]	II-2b	Ortho-K (partial reduction of 4 D) and spectacles vs. spectacles alone	Randomized clinical trial Asian children Age: 8–11 yrs Baseline myopia: >−5.0 D sphere or −5.75 spherical equivalent 52 enrolled subjects: N=26 Ortho-K, partial (4 D) with spectacles N=26 spectacles alone	Visits every 6 mos Final at 2 yrs	Axial length by optical biometry, masked (right eye only used for analyses) Cycloplegic subjective refraction *Assessed after discontinuation of Ortho-K and with stable topography, keratometry, refraction on 2 consecutive visits at least 3 days apart*	After 1 mo, only 19/26 (73%) in each group continued in study; at 2 yrs, 16/19 in control group, and 12/19 in Ortho-K group remained Increase in axial length: 0.19±0.21 mm Ortho-K 0.51±0.32 mm control ($P = 0.005$) Refraction (median increased myopia): −0.13 D Ortho-K vs. −1.0 D control	Low-quality randomized clinical trial with wide confidence intervals and potential biases Randomization in blocks of 2 makes it easy to predict next treatment group, potential source of selection bias if block size/randomization sequence became known Potential bias in that subjects noncompliant or had problems with Ortho-K were not included in the analysis Differential in lost to follow-up/outcome completion, more in Ortho-K group dropped

Table 1. (Continued.)

Author(s), Year	Level of Evidence*	Treatment	Type of Study/Cohort	Timing of Visits/Final Follow-up	Primary Outcome	Results	Comments
Cho and Cheung, 2012[39]	II-2b	Ortho-K vs. spectacles	Randomized clinical trial Asian children Age: 6–12 yrs Baseline myopia: −0.5 D and −4 D (cylinder <1.50 D, anisometropia <1.50 D) Stratified by age, gender, and baseline refractive error 102 enrolled subjects: N=51 Ortho-K N=51 spectacles	Every 6 mos Final at 2 yrs	Axial length by masked examiner (right eye only), optical biometry *No information about lens discontinuation period before biometry*	37/51 (73%) Ortho-K and 41/51 (80%) spectacle group completed 2-yr outcome exam Increase in axial length: 0.36±0.24 mm Ortho-K 0.63±0.26 mm control ($P < 0.001$) Greater increase in axial length was correlated with younger age Data suggest difference favoring Ortho-K showing 57% slower progression in axial elongation	Low-quality randomized clinical trial with wide confidence intervals and potential biases Randomization in blocks of 2 makes it easy to predict next treatment group. Potential source of selection bias if block size/randomization sequence became known Potential bias in that subjects noncompliant or had problems with Ortho-K were not included in the analysis 27% of subjects in Ortho-K group could not complete the study because of problems with Ortho-K or inability to fit
Chen et al, 2012[43]	II-2b	Ortho-K vs. spectacles	Consecutive case series Asian children Age: 9–14 yrs Baseline myopia: −1 to −4.5 D, cylinder <1.50 D N= 27 Ortho-K (prospective data) N= 5 spectacles (retrospective)	Every 6 mos Final at 2 yrs	Axial length by optical biometry, right eyes only Pupil diameter (OPD-Scan II) *Measurements taken 2–4 hrs after lens removal*	Ortho-K with above average pupil sizes showed slower progression Axial length increase at 2 yrs: *Spectacle group* Above average pupil size 0.53±0.17 mm Less than average pupil size 0.47±0.21 mm (ns) *Ortho-K group* Above average pupil: 0.36±0.22 mm Below average pupil: 0.74±0.32 mm ($P < 0.001$)	Consecutive case series with good reference group Not randomized Minimum dropout; 7% in Ortho-K and 12% in spectacles
Hiraoka et al, 2012[62]	II-3B	Ortho-K vs. spectacles	Prospective nonconsecutive cohort study Asian children Age: 8–12 yrs Baseline myopia: −0.5 to −5.0 D; cylinder <1.50 D, anisometropia <1.50 D Participants from previous 2-yr study (Kakita et al[38]) who agreed to continue for another 5 yrs of follow-up and new participants who agreed to 5 yrs of follow-up N=29 Ortho-K N=30 spectacles	Every 3 mos Final at 5 yrs	Axial length by masked observer, optical biometry *Used axial length obtained at 3 mos as baseline to allow for stabilization of corneal thinning effects in Ortho-K group*	22/29 (76%) Ortho-K and 21/30 (70%) control group completed 5-yr visit Increase in axial length at 5 yrs: 0.99±0.47 mm Ortho-K 1.41±0.68 mm control ($P = 0.0236$) Axial length increased in both groups but increased less in the Ortho-K group by about 0.25 mm on average after 1 yr ($P = 0.0085$ for difference in axial length over time favoring Ortho-K group)	Prospective, nonrandomized, nonconsecutive cohort study Masked assessment of outcome

(*Continued*)

Table 1. (Continued.)

Author(s), Year	Level of Evidence*	Treatment	Type of Study/Cohort	Timing of Visits/Final Follow-up	Primary Outcome	Results	Comments
Kakita et al, 2011[44]	II-3B	Ortho-K vs. spectacles	Prospective, nonconsecutive cohort study Asian children Age: 8–16 yrs Baseline myopia: −0.50 to −10.0 D myopia, cylinder <1.50 D, anisometropia <1.50 D N=45 subjects Ortho-K N=60 subjects' spectacles	Every 3 mos Final at 2 yrs	Axial length by masked observer, optical biometry Noncycloplegic autorefraction *Used axial length obtained at 3 mos as baseline to allow for stabilization of corneal thinning effects in Ortho-K group*	42/45 (93%) Ortho-K and 50/60 (83%) spectacle group completed 2-yr visit Change in axial length: 0.39±0.27 mm Ortho-K 0.61±0.24 mm control ($P < 0.0001$) Axial length increased in both groups but increased less in the Ortho-K group by ~0.3 mm on average after 2 yrs ($P < 0.01$ for difference in axial length over time favoring Ortho-K group)	Prospective, nonconsecutive cohort study Not randomized Masked assessment of outcome
Lin et al, 2014[48]	II-3B	Ortho-K vs. 0.125% atropine nightly	Retrospective cohort study Asian children Age: 7–18 yrs Baseline myopia: 1.5 to 7.5 D, cylinder <1.50 D, anisometropia <2.00 D Not randomized; selected consecutive patients who met inclusion criteria including 3-yr follow-up N=105 subjects Ortho-K N=105 subjects 0.125% atropine	Every 3 mos Final at 3 yrs	Axial length by optical biometry, average of 2 eyes used for analyses Cycloplegic autorefraction *Assessment for Ortho-K group after discontinuation of lens for 3 wks*	Linear regression analysis revealed increase in axial length of: 0.28±0.08 mm/yr Ortho-K 0.34±0.09 mm/yr atropine ($P < 0.001$) Myopic progression: −0.28±0.18 D/yr Ortho-K −0.34±0.21 D/yr atropine ($P = 0.001$) Axial length increased in both groups but increased less in the Ortho-K group by ~0.1 mm axial length and 0.06 D refractive error	Retrospective consecutive cases of subjects who preferred Ortho-K vs. those who preferred atropine Potential bias by using average of 2 eyes for analysis of axial length Potential influence of age on myopic progression that was not analyzed
Santodomingo-Rubido et al, 2012[45]	II-3B	Ortho-K vs. spectacles	Prospective cohort White European children Age: 6–12 yrs Baseline myopia: −0.75 to −4.00 D, cylinder <1.00 D N=31 Ortho-K N=30 spectacles	Visits at 1, 6, 12, 18, and 24 mos Final at 2 yrs	Axial length, optical biometry, right eye only Cycloplegic autorefraction *Measurements taken within 2 hrs of lens removal*	29/31 (94%) Ortho-K and 24/30 (75%) control completed follow-up visit Increase in axial length at 2 yrs: 0.47±0.18 mm Ortho-K 0.69±0.32 mm control ($P = 0.005$)	Prospective cohort study Not randomized
Zhu et al, 2014[47]	II-3B	Ortho-K vs. spectacles	Retrospective random selection of cases Chinese children Age: 7–14 yrs Baseline myopia: −0.5 to −6.0 D, cylinder <1.50 D N=65 Ortho-K N=63 spectacles	12 and 24 mos Final at 2 yrs	Axial length, optical biometry, right eyes only *No information about lens discontinuation period before biometry*	Increase in axial length at 2 yrs: *Overall* 0.34±0.29 mm Ortho-K 0.70±0.35 mm control ($P < 0.001$) *Age <9.8 yrs (group mean)*: 0.35 mm Ortho-K 0.89 mm control ($P < 0.001$) Axial length increase was slower in the Ortho-K group by 59% in the first year and 42% in the second year (51% overall) The 2-yr axial elongation significantly associated with initial age ($P < 0.001$) and treatment ($P < 0.001$) but not with gender, initial refractive error, initial axial length, initial corneal curvature	Retrospective, random selection of cases of subjects, matched for age and degree of myopia at baseline Not randomized

Table 1. (Continued.)

Author(s), Year	Level of Evidence*	Treatment	Type of Study/Cohort	Timing of Visits/Final Follow-up	Primary Outcome	Results	Comments
Chen et al, 2013[41]	II-3B	Ortho-K vs. spectacles	Nonrandomized comparative series Asian children Age: 6–12 yrs Baseline myopia: −0.50 to −5.00 D sphere, with-the-rule astigmatism of 1.25 to 3.50 D N=43 Ortho-K N=37 spectacles	Every 6 mos Final at 2 yrs	Axial length, optical biometry, masked assessment, eye with higher astigmatism used for analyses or right eye if same *No information about lens discontinuation period before biometry*	35/43 (81%) Ortho-K and 23/37 (62%) spectacle group completed 2-yr visit Increase in axial length: 0.31±0.27 mm Ortho-K 0.64±0.31 mm control ($P < 0.001$)	Nonrandomized, prospective clinical cohort study Parents chose treatment Higher dropout rate in spectacle group (due to parent anxiety over progression)
Pauné et al, 2015[46]	II-3B	SRRG contact lenses vs. Ortho-K vs. spectacles	Prospective, nonrandomized study White children Age: 9–16 yrs Baseline myopia: −0.75 to −7.00 D sphere, <1.25 D cylinder, anisometropia <1.00 D N=30 SRRG contact lens N=29 Ortho-K N=41 spectacles	12 and 24 mos Final at 2 yrs	Cycloplegic autorefraction Axial length, contact ultrasound biometry *Refraction adjusted using keratometric changes from baseline, no lens discontinuation before biometry*	19/30 (63%) SRRG CL, 18/29 (62%) Ortho-K, and 21/41 (51%) spectacle group completed 2-yr visit. Mean myopic progression: −0.56±0.51 D SRRG contact lens −0.32±0.53 D Ortho-K −0.98±0.58 D spectacle Group comparison shows significant reduction in myopic progression for SRRG and Ortho-K group compared with spectacle group (both $P < 0.05$), no difference between Ortho-K and SRRG contact lens group Axial length increased 27% and 38% less in the SRRG and Ortho-K groups, respectively, compared with the spectacle group ($P < 0.05$)	Nonrandomized, parents chose treatment High rate of loss to follow-up Did not mask observers for measurements
Downie and Lowe, 2013[49]	III-4	Ortho-K vs. spectacles	Retrospective, case control study, selected from 2 optometry practices Australian children—Asian or white Age: <16 yrs Baseline myopia: >−0.50 D, cylinder <2.00 D, anisometropia <1.50 D N=26 Ortho-K N=30 controls	Followed every 6 mos in Ortho-K group, annually for spectacle group Final visit at 2 yrs, up to 8 yrs	Subjective noncycloplegic refraction, right eyes analyzed Change in spherical equivalent prescription at 2, 4, 6, and 8 yrs *Measurements taken in morning after prior night lens wear*	Myopic progression in control group was −0.46±0.06 D/yr in first 2 yrs, then slowed Ortho-K group had significantly less change in manifest refraction prescription at each time point ($P < 0.05$), actual changes not given	Case control study with randomly selected reference matched controls (age and baseline refraction) Only subjective, noncycloplegic refractions Actual values not consistently reported

Note: All instances of myopic progression are shown in minus sphere; there were no instances of mean myopic regression.
D = diopters; ns = not significant; Ortho-K = orthokeratology; RGP = rigid gas permeable; SRRG = soft radial refractive gradient.
*American Academy of Ophthalmology grade I, II, or III, then by Centre for Evidence-Based Medicine (March 2009) 1abc,2abc,3ab,4,5.

crossover, the RGP eye was on average −0.40±0.38 D more myopic than the Ortho-K eye, resulting in mild anisometropia. Thus, in both periods there was myopic progression in the RGP eye, but the difference was greater and only reached statistical significance in the second period, suggesting that there may be a rebound effect after discontinuation of the Ortho-K lens. It is also possible that the Ortho-K eyes had an insufficient washout period, resulting in slightly less manifest myopia in these eyes at the end of each study period, although this does not explain the difference between each study period. The authors acknowledge that further research is needed to understand what the optimal duration of therapy is to obtain stabilization and to determine if the effect in reduction of myopic progression persists long term.

Level II Evidence

The first randomized trial for Ortho-K treatment to reduce myopic progression was the Retardation of Myopia in Orthokeratology (ROMIO) study published by Cho and Cheung in 2012.[39] In this study, 102 Asian children aged 6 to 10 years with myopia of −0.5 to −4.0 D (spherical equivalent, −0.50 to −4.50) were randomly assigned to wear Ortho-K lenses or single-vision spectacles for 2 years. The main outcome was change in axial length measured by optical coherence biometry. This study reported a dropout rate in the Ortho-K group of 27%; 9 of 14 patients were excluded early because of poor lens centration or an under-response for desired correction, and 5 of 14 dropped out after 6 months because of a contraindication to continued treatment. The contraindications to continued Ortho-K wear included persistent inferior corneal staining (in 3 patients who also had chronic rhinitis or conjunctivitis), presence of blepharitis and chalazia, and poor compliance with lens care procedures (1 patient). The dropout rate in the spectacle group was 20%; 9 of 10 patients were lost to follow-up, and 1 of 10 patients had recurrent corneal inflammation. Stepwise multiple linear regression analysis showed that, among prediction factors, axial elongation was significantly correlated with treatment group and initial age at treatment. The change in axial length was significantly less in the Ortho-K group compared with the spectacle group (0.36±0.24 mm vs. 0.63±0.26 mm, $P < 0.001$). Younger children (age range, 7−8 years) showed faster axial elongation than other children (age range, 9−10 years). There were more fast progressors (axial elongation >0.36 mm/year) in the control group compared with the Ortho-K group (34% vs. 15%, $P = 0.006$), and the percentage of fast progressors in the younger age group was 65% for the control group compared with 20% in the Ortho-K group. The authors suggest that it may be more beneficial to commence Ortho-K treatment in younger children for greater impact.

Another randomized study[40] included 52 children aged 8 to 11 years who had myopia of at least −5.00 D sphere or −5.75 D spherical equivalent. They were randomized into 2 equal groups: One group used Ortho-K lenses at night for partial (4 D) correction and spectacles during the day for residual myopia correction, and the control group used single-vision spectacles for the full myopic correction. The outcome measures for the 2-year study were change in cycloplegic refraction and change in globe axial length as measured by optical biometry. Measures were obtained every 6 months, and although there was no extended period of lens discontinuation before the measures, final outcomes were assessed only after stable measures were obtained on 2 consecutive visits at least 3 days apart. After 1 month, 19 (73%) of the patients in each group of 26 continued in the study. In the Ortho-K group, reasons for dropout were unsatisfactory fit (5), discomfort (1), or no time for lens care (1). Of the 19 patients successfully fitted with Ortho-K, 12 completed the study; 2 patients were later discontinued because of corneal staining or corneal opacity, and 5 others dropped out primarily because of lack of time for proper lens management as required by study protocol. (Four of these patients elected to continue Ortho-K treatment with a practitioner outside of the study.) Of the patients randomized to the spectacle group, 10 were discontinued to pursue other myopia control methods and only 16 completed the study. At 2 years, there was a statistically significant difference in the change in axial length (0.21±0.21 mm in the Ortho-K group, 0.51±0.32 mm in the control group, $P = 0.005$). Likewise, the median increase in myopia was −0.13 D in the Ortho-K group compared with −1.00 D in the spectacle group. The authors also reported on central corneal thickness, which was significantly different between the treatment and control groups at the 6-, 18-, and 24-month visits; the control group corneas measured on average approximately 8 μm thicker than the Ortho-K corneas. Although there are limitations to this study, including small sample size, the data suggest a difference favoring Ortho-K eyes to slow progression of myopia at 2 years (95% confidence interval, −0.12 to −0.55 mm favoring Ortho-K).

A number of prospective cohort studies were performed comparing treatment methods, but the patients were not randomized. In these studies, the parents chose the treatment modality.

The Myopia Control Using Toric Orthokeratology (TO-SEE) Study enrolled 80 Asian children aged 6 to 12 years with −0.50 to −5.0 D myopia and moderate with-the-rule astigmatism (1.25−3.50 D), and compared Toric Ortho-K lenses with single-vision spectacle correction.[41] Two-year follow-up was completed by 35 of 43 patients (81%) in the Ortho-K group and 23 of 37 patients (62%) in the spectacle group. Optical biometry showed 52% less axial elongation after 2 years in the Ortho-K group (0.31±0.27 mm vs. 0.64±0.31 mm, $P < 0.001$). Axial elongation significantly correlated with initial age of the subjects ($P = 0.02$) and treatment assigned ($P = 0.04$) but not with sex, initial myopia, initial refractive cylinder, or initial corneal toricity. The authors noted that the dropout rate in the spectacle group was high and was initiated by parental concern about myopic progression, and parents subsequently decided to pursue alternative myopia treatments. In the Ortho-K group, the dropouts were initiated by the investigator. Six patients were excluded before the 3-month follow-up visit because they were unable to achieve the targeted reduction in refraction, and 2 patients were excluded later because of poor compliance with Ortho-K

treatment. No significant adverse events were noted in either group, but mild corneal staining was common in both groups (usually inferior corneal staining, up to 23% in the Ortho-K group and up to 20% in the spectacle group).

The Stabilizing Myopia by Accelerating Reshaping Technique (SMART) study was a multicenter prospective cohort study that compared changes in cycloplegic refraction and axial length in children aged 8 to 14 years who were fitted with Ortho-K lenses with children who were fitted with soft contact lenses for myopia.[42] At each of the yearly visits, the Ortho-K lenses were returned to the investigator and replaced with soft contact lenses; refraction, topography, and keratometry were assessed every 3 days until 2 consecutive visits exhibited stabilization, at which time outcome data were collected. The study enrolled 282 children at 10 sites in the United States, and 114 of 172 patients (66.4%) in the Ortho-K group and 74 of 110 patients (67.5%) in the soft contact lens group completed the 3-year study. Approximately 20% of the dropout occurred in the first year, but the timing and reasons were different between the groups. In the Ortho-K group, the mean time to discontinuation was 28 days (typically due to discomfort with lens wear), and in the contact lens group the mean time to discontinuation was 104 days (typically due to loss of interest in lens wear or loss to follow-up). At 3 years, there was a statistically higher increase in myopic progression for the soft contact lens group compared with the Ortho-K group (-1.03 ± 0.58 D vs. -0.13 ± 0.62 D, $P < 0.0001$). There was no statistically significant difference in axial length measurements. However, the method and techniques for assessment of axial length in this study were not well defined, so the variability between each center likely rendered any assessment of this outcome invalid. There were no significant adverse events or cases with loss of best-corrected visual acuity in either group.

The effect of pupil size on axial growth was reported by Chen et al,[43] who enrolled 52 Chinese children aged 9 to 14 years with myopia of -1.0 to -4.5 D to use Ortho-K lenses or single-vision spectacles for 2 years. The baseline and 24-month scotopic pupil size were measured by the pupillometer of the OPD-Scan II, and 25 of 27 patients in the Ortho-K group and 22 of 25 patients in the spectacle group completed the 2-year follow-up. Axial elongation was measured by optical biometry. The authors found that having a larger than average pupil size (based on mean of the cohort) in the Ortho-K group was correlated with less axial elongation (0.36 ± 0.22 mm vs. 0.74 ± 0.32 mm, $P < 0.001$); there was no significant effect of pupil size on axial elongation in the single-vision spectacle group. Because peripheral hyperopic defocus can contribute to myopic progression with axial elongation, the authors speculate that the peripheral myopic defocus caused by Ortho-K lenses may contribute to slowing progression of axial elongation. Because Ortho-K lenses induce myopic shift in the far periphery, pupil size may play a role because more peripheral light rays with myopic defocus will enter via a larger pupil. The authors suggest that using a cycloplegic agent in addition to the Ortho-K wear may further reduce the myopic shift.

A prospective cohort study of 105 Japanese children aged 8 to 16 years was performed by Kakita et al,[44] in which 1 group used Ortho-K lenses ($n = 45$) and the other group used spectacles ($n = 60$) to correct myopia of -0.5 to -10.0 D sphere. Optical biometry was used to assess changes in axial length at the 2-year follow-up, and 42 of 45 (93%) in the Ortho-K group and 50 of 60 (83%) in the spectacle group completed the 2-year visit. There was a statistically significant increase in axial elongation in the spectacle group compared with the Ortho-K group (0.61 ± 0.24 mm vs. 0.39 ± 0.27 mm, $P < 0.0001$). A longer-term prospective cohort study of 59 Japanese children aged 8−12 years was performed by Hiraoka et al.[45] One group used Ortho-K lenses, and the other group used spectacles to correct myopia (-0.5 to -5.0 D sphere). Masked assessment of axial elongation by optical biometry was performed annually, and 43 of 59 patients completed 5 years of follow-up. The axial elongation was 0.99 ± 0.47 mm in the Ortho-K group and 1.41 ± 0.68 mm in the spectacle group ($P = 0.02$). However, analysis by year showed that the differences in increased axial length were statistically significant in years 1 to 3 but not in years 4 and 5 of the study, and the greatest difference was seen in the first year. The authors acknowledge that the optimal duration of treatment remains unknown.

A prospective cohort study of 61 white European children aged 6 to 12 years was performed by Santodomingo-Rubido et al,[46] comparing Ortho-K with spectacle wear for myopia of -0.75 to -4.00 D; 29 of 31 (94%) in the Ortho-K group and 24 of 30 (75%) in the spectacle group completed the 2-year study.[46] After 2 years, the axial length by optical biometry increased in both the Ortho-K group and the spectacle group, but it was greater in the spectacle group (0.47 mm in the Ortho-K group and 0.69 mm in the spectacle group). The effect of time on axial length was statistically significant ($P < 0.001$), and the effect of refractive correction on axial length was not significant, but the interaction between refractive correction and time was significant at all time points ($P = 0.05$). This study also compared refractive outcomes, and the spectacle group had a mean increase in myopia of approximately 1.30 D after 2 years. However, children in the Ortho-K group were measured within 2 hours of lens removal, so the data presented reflect the effects of Ortho-K on refraction rather than on the effect on progression from baseline myopia. A second study that assessed risk factors for myopic progression in this cohort showed that, by multivariate analysis, older age and greater corneal power were associated with smaller increase in axial length in the Ortho-K group (both $P < 0.05$) and that a smaller pupil diameter was associated with smaller increase in axial length in the spectacle group ($P = 0.021$).

Another study enrolled 100 white children aged 9 to 16 years who were fitted with a soft radial refractive gradient (SRRG) contact lens, an Ortho-K lens, or spectacles to correct myopia with sphere of -0.75 to -7.00 D.[47] The premise of using the soft contact lens was to provide full central correction of the myopia but leave peripheral myopic defocus, similar to the effect of Ortho-K. After 2 years, the cycloplegic autorefraction showed a mean myopic progression of -0.56 ± 0.51 D for the soft contact lens group, -0.32 ± 0.53 D for the Ortho-K group, and -0.98 ± 0.58 D for the spectacle group. Multiple

comparisons between groups showed a significant reduction in myopic progression for each contact lens group compared with the spectacle group (SRRG vs. spectacles, 43% reduction, $P = 0.01$; Ortho-K vs. spectacles, 67% reduction, $P = 0.03$), but there was no significant difference between the SRRG and Ortho-K groups. Axial length was assessed by contact ultrasound biometry by the same optometrist; however, unmasked assessment and typical margins of error with contact ultrasound technique result in questionable validity of comparisons in axial length changes. This study had a high dropout rate in all groups (37% in the contact lens groups and 49% in the spectacle group). Nearly all of the excluded patients were lost to follow-up except for 2 cases of discomfort in the SRRG group and 1 case of infiltrative keratitis in the Ortho-K group.

Three retrospective comparative case series were included for review, 2 of which were rated as level II, 3B evidence. A retrospective chart review was performed by Zhu et al[48] of 128 Chinese children with myopia of −0.5 to −6.0 D, aged 7 to 14 years, 65 of whom were fitted with Ortho-K lenses and 63 of whom had been fitted with spectacles (randomly selected to match age and subgroups of refractive error). Axial length was assessed by optical biometry at 2 years. There was a greater increase in axial elongation in the spectacle group compared with the Ortho-K group (−0.70±0.35 mm vs. −0.34±0.29 mm, $P < 0.001$). The authors also evaluated subgroups based on degree of myopia (low: −0.5 to <−3.0 D, medium: −3.0 D to <−6.0 D, high: ≥6.0 D), which showed a significant difference between rates of axial elongation for the first and second year for those with low and medium myopia but only in the first year for those with high myopia. The authors also compared axial elongation by younger and older groups (≤9.8 vs. >9.8 years, mean age of the group). They found differences in the spectacle group (0.89 mm in the younger group vs. 0.52 mm in the older group), suggesting that the relative effect of Ortho-K treatment may be greater in younger children.

Lin et al[49] performed a retrospective, comparative case series of 210 Chinese children who underwent treatment with Ortho-K (n = 105) or atropine (0.125%) administration with spectacle correction (n = 105) to treat myopic progression and were followed for 3 years. The subjects were aged 7 to 17 years and had baseline myopia of −1.5 to −7.5 D sphere. Change in axial length using optical biometry and change in cycloplegic refraction were compared over the 3-year period. There was a negligible difference in the rates of myopic progression (−0.28±0.18 D/year in the Ortho K group and −0.3±0.21 D/year in the atropine group, $P = 0.001$) and the rates of axial elongation (−0.28±0.08 mm/year in the Ortho-K group and −0.37±0.11 mm/year in the atropine group, $P < 0.001$). The authors stated that atropine is an accepted treatment for reducing myopic progression, so smaller differences are noted between the treatment groups in this study, but both treatments show slower rates of progression compared with controls in other studies. They acknowledge that a limitation is lack of a true control group for this study, and inclusion of older patients could have diluted the effects of the treatments.

Level III Evidence

The Corneal Reshaping Influences Myopic Prescription Stability (CRIMPS) study compared Ortho-K treatment with spectacle correction of myopia in a population of 56 Australian children younger than 16 years of age.[50] Asian children made up 54% (14 of 26) of the Ortho-K group and 47% (14 of 30) of the spectacle group; all other subjects were white. This was a retrospective case-control study that evaluated changes in manifest myopic refraction over 2-year follow-up intervals for up to 8 years. Most patients were evaluated for a minimum of 2 to 4 years (23/26 in the Ortho-K group and 25/30 in the spectacle group), but a minority were available for the final study period at 6 to 8 years of age (6/26 in the Ortho-K group and 9/30 in the spectacle group). The authors found that all control eyes (n = 30) demonstrated some myopic progression during the study, but approximately 64% (18 of 26) of Ortho-K eyes experienced no progression. The last visit for these 18 eyes with no progression occurred after 2 to 4 years for 7 eyes, 4.1 to 6 years for 8 eyes, and 6 to 8 years for 3 eyes. There was a significant difference ($P < 0.05$) in the rate of myopia progression between the groups at each follow-up period. In trying to assess which factors may be associated with progression of myopia, the authors found only a correlation with greater vertical corneal asymmetry in the group that progressed. There was no association noted with ethnicity, age, or other ocular characteristics, including baseline spherical refraction or pupil size. However, the study sample size was small.

In conclusion, Ortho-K treatment is used by some practitioners as a method to try to reduce myopic progression, particularly in many Asian countries with a high prevalence of high myopia. Review of the evidence supports the idea that a modestly lower rate of myopic progression occurs when Ortho-K treatment is used for children and adolescents compared with other modes of myopic correction, such as spectacles or standard soft contact lenses, the magnitude of which is similar to the effect on myopic progression obtained with atropine. However, many of the studies have a small sample size and high dropout rate. Although statistical differences in rates of myopic progression are significant, the clinical effects were small, and standard deviations of the means reflect the large variation in individual responses. Safety remains a concern despite the lack of serious complications in the small studies reviewed, and they should be considered given that the clinical differences are small and that there are other viable, lower-cost interventions for myopia.

Efficacy

The most objective evidence to suggest that Ortho-K reduces myopic progression is the slower rate of globe axial elongation as measured by optical biometry, followed by slower rates of myopic progression as measured by cycloplegic refractions. Several studies found greater impact in the younger age groups (when defined, ≤9 years) compared with older age groups. Furthermore, the rates of myopic progression seem to be affected most in the first and

second years of treatment, with some effects still seen in the third year and beyond, although the effect is less pronounced. Although the highest rates of axial elongation occur in the early childhood years, continued axial elongation can occur in the second decade and may be variable, so that the end point for treatment of myopic progression related to axial elongation may be hard to predict.

Only 1 of the Ortho-K studies reported on myopic progression after discontinuation of Ortho-K use.[32] In this crossover study design, there was a greater rate of myopic progression when eyes were started with Ortho-K and then switched to a daytime RGP contact lens compared with the myopic progression seen when eyes were started with the RGP contact lens and then switched to the Ortho-K lens. Because the treatment period was only 6 months with each lens type, the long-term risk and duration of a rebound effect are unknown. None of the other studies evaluated regression or rebound once the Ortho-K treatment period was finished, and 1 level II study compared the effects of Ortho-K with atropine, which is another method shown to reduce myopic progression.[29] Clinically similar results were obtained, although the Ortho-K group showed slightly less axial elongation and myopic progression as measured by optical biometry and cycloplegic autorefraction. This suggests that Ortho-K treatment could be at least as effective as atropine for reducing myopic progression, but the potential risks and costs of each treatment and the clinical effect should be considered before initiating such therapies.

Safety

It is worth noting that safety was not a primary outcome of any of the studies reviewed for this assessment, and although no severe adverse events were reported, it is unclear what the true adverse event rate would be if a subject were treated outside of a research study (which probably represents a best-case scenario). The most common serious complication of Ortho-K treatment is microbial keratitis, which can cause permanent loss of vision and blindness. The safety of Ortho-K treatment for myopia in adults was evaluated as part of an Ophthalmic Technology Assessment in 2008,[51] and a meta-analysis to evaluate Ortho-K safety was performed by Liu and Xie[52] of peer-reviewed publications in English and Chinese in 2015 and by Kam et al in 2017.[53] These reviews note that a majority of the cases of microbial keratitis result in a permanent cornea scar that is often central in location and requires weeks to months of therapy; approximately 10% of cases require surgical intervention. Although there are regional variations in causative microorganisms, those commonly identified are *Acanthamoeba* and *Pseudomonas aeruginosa*. Poor visual outcomes are associated with delayed identification and treatment of these organisms, and *Pseudomonas* keratitis can result in rapid corneal melting without appropriate treatment.[54] Only 1 publication has provided an estimated rate of 7.7 cases of microbial keratitis per 10 000 patient-years for Ortho-K lenses, which is similar to other overnight contact lenses.[55] Several small case-series reports have also highlighted the risk of vision loss and blindness from microbial keratitis associated with overnight Ortho-K use.[56-59] Attributable risk factors have been lack of training of practitioners and wearers, improper fitting procedures, poor compliance with lens care regimens, or poor follow-up. Many of the early cases of *Acanthamoeba* keratitis were from countries such as China, before the Ortho-K market was regulated, when use of tap water as a multipurpose solution or for contact lens rinsing was frequent.[59]

In studies that characterize all causes of microbial keratitis in pediatric populations, contact lens wear is a major risk factor.[60-62] In these studies, most of the cases were associated with soft contact lens wear, but Lee et al[60] noted that in their referral center, there has been an increase in the overall number of cases of contact lens–related microbial keratitis that can be attributed to an increasing number of cases related to Ortho-K lens wear. In the studies reviewed for this Ophthalmic Technology Assessment that involved pediatric patients, careful initial fit of the contact lenses with regular review and potential discontinuation if undesirable corneal changes were noted were performed by experienced providers. Minor corneal staining was common, and at least 2 cases of corneal infiltrate or opacity were specifically mentioned as cause for discontinuation of Ortho-K treatment. Because of lack of sufficient data, safety cannot be extrapolated from review of these articles, because patients who were less compliant with follow-up or good lens care were excluded or dropped out. Therefore, when advising parents about treatment options to prevent myopic progression, it should be noted that Ortho-K carries a small but definite risk of infectious keratitis, corneal scarring, and irreversible vision loss. Alternatives, such as low-dose atropine, have potential side effects that are reversible, and use of spectacles alone essentially have no such risks.

Finally, cost was not a consideration in any of the articles reviewed, whether monetary or in terms of time and personal investment in the treatment. The most common treatment for myopia—spectacle wear—requires little investment in time, and there are a variety of options with regard to cost of spectacles. On the other hand, contact lens fittings typically require more office visits to ensure appropriate fit and to monitor for corneal complications, as well as added time required for proper care of the lenses at home. Ortho-K lenses are specialty lenses that require a more individualized design and fitting schedule than typical contact lenses, and a more rigorous follow-up schedule is needed to adjust the contact lens fit and monitor for complications. In the United States, contact lens–related costs are typically not covered by standard insurance plans, and costs for Ortho-K are higher than standard contact lenses or spectacles (currently, ~$1000–$2000 USD for an initial Ortho-K fitting). Alternatively, low-dose atropine may be covered by insurance plans and is significantly less costly than contact lenses. Thus, the risk and cost-to-benefit ratio should be carefully reviewed before initiating Ortho-K treatment for a child, particularly when there is a very small clinical effect.

Future Research

Additional studies are needed with respect to controlled assessment of the safety of Ortho-K in the pediatric population and on the efficacy of Ortho-K lenses to prevent myopic progression in more diverse populations, including non-Asians. Study designs should include appropriate assessment of cycloplegic refractions and optical biometry after a period of lens discontinuation as well as report data that also reflect corneal changes (pachymetry, topography, keratometry). Because the greatest effect of Ortho-K has been reported in younger age groups (6–9 years), such studies could be designed to evaluate whether any effect is limited to or more pronounced in younger ages. If such studies are to include younger children, it is clear that proper hand hygiene and compliance with contact lens wear and care procedures must be stressed before considering any contact lens fitting to avoid potentially devastating corneal infections or opacifications that can lead to permanent vision loss. Although none of the subjects in the reported studies had significant complications, case reports of complications in Ortho-K users point out the need for strict adherence to fitting and wear protocols and good follow-up.

If Ortho-K treatment is pursued, it is also unclear how long treatment should continue, both in terms of maximizing stabilization of myopia and avoiding a potential rebound effect. Generally, Ortho-K for young people is not thought of as a permanent solution but rather as a method to reduce progression during the developing years. However, for an individual patient, the end point may be unclear because of individual variation in ocular growth. Further research with longer follow-up may help answer this question.

Future studies also might evaluate whether Ortho-K treatment is equivalent to or noninferior to low-dose atropine to slow the progression of myopia or whether there may be any synergistic effect by treating with both Ortho-K and low-dose atropine.

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Abbreviations and Acronyms:
CRT = corneal refractive therapy; **D** = diopters; **FDA** = Food and Drug Administration; **Ortho-K** = orthokeratology; **RGP** = rigid-gas permeable; **SRRG** = soft radial refractive gradient.

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