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ORIGINAL RESEARCH

Long-Term Efficacy of CRT, Lucid, Euclid, and IBright Orthokeratology Lenses in Controlling Myopia Progression in Children and Adolescents: A 36-Month Retrospective Cohort Study

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Purpose: This study aimed to compare the efficacy and safety of four types of orthokeratology (OK) lenses (CRT, Lucid, Euclid, and IBright) in controlling mild to moderate myopia progression among children and adolescents over 36 months.

Methods: This retrospective study analyzed clinical records of 219 children (438 eyes) who wore OK lenses for 36 months. Clinical data for the four commonly used OK lenses were collected and analyzed using one-way analysis of variance (ANOVA) and Pearson's chi-squared test.

Results: At baseline, no significant differences were observed among the four groups in terms of age, sex, spherical equivalent, corneal curvature, or corneal thickness (all $P > 0.05$). All OK lenses effectively controlled myopia progression over the observation period, with axial length changes not exceeding 1.0 mm. At the 36-month follow-up, the IBright group showed the largest flat keratometry (K1) curvature change at 3 months (-2.40 ± 0.97 D), while other groups showed no significant differences at subsequent time points. In terms of steep keratometry (K2) curvature, the Lucid group exhibited the largest change at 24 months (-3.07 ± 1.50 D), but no significant differences were observed among groups at other time points. Axial length changes showed no statistically significant differences among the four OK lenses across follow-up visits ($P > 0.05$). Subgroup analysis indicated greater axial elongation in children under 12 years old compared to those over 12 years. Among children with corneal thickness less than 530 μm, the CRT group demonstrated the largest K1 curvature change. The incidence of adverse events was comparable across groups ($P > 0.05$).

Conclusion: All four OK lenses demonstrated comparable efficacy and safety in controlling myopia progression, providing effective treatment options for children and adolescents with mild to moderate myopia. However, differences in curvature changes and age-related effects warrant further attention.

Keywords: orthokeratology, myopia control, children and adolescents, axial length, corneal curvature

Introduction

Myopia is a global public health concern that has seen a marked increase in prevalence over the past few decades, particularly among children and adolescents in East Asia.[1–5] Uncontrolled myopia progression can lead to sight-threatening complications in adulthood, including myopic maculopathy, retinal detachment, and even glaucoma.[6] Given the rising burden of myopia, early intervention strategies are essential to mitigate its progression and long-term ocular health risks.[7,8]

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Orthokeratology (OK) lenses, also known as corneal reshaping lenses, have emerged as a popular non-surgical approach for myopia management in pediatric populations. These rigid gas-permeable lenses are worn overnight to temporarily reshape the cornea, reducing refractive error and allowing for clear daytime vision without corrective eyewear. Beyond their refractive benefits, numerous studies have demonstrated the efficacy of OK lenses in slowing axial elongation, a key determinant of myopia progression.[9–11] Compared to other interventions such as low-dose atropine and multifocal soft contact lenses, OK lenses offer the dual benefit of daytime spectacle independence and effective myopia control, particularly for active children.

Different OK lens designs may lead to varying treatment effects due to differences in lens geometry. The corneal reshaping therapy (CRT) design typically features a central treatment zone and a single reverse curve, while vision shaping treatment (VST) lenses, such as Lucid, Euclid, and IBright, tend to use multizone reverse curves and more customized aspheric profiles to optimize centration and corneal reshaping. These design characteristics may influence outcomes in specific patient populations, such as younger children or those with thinner corneas, underscoring the importance of individualized lens selection in clinical practice.

Despite their widespread use, there remains a need for comparative studies examining the long-term efficacy and safety of different types of OK lenses. Various lens designs, such as CRT, and VST lenses (Lucid, Euclid, and IBright), have unique geometric and material properties that may influence treatment outcomes. However, few studies have systematically compared their performance over short periods.[12–14]

This study aimed to address this knowledge gap by conducting a 36-month continuous observational study to evaluate the efficacy and safety of four commonly used OK lenses in controlling myopia progression in children and adolescents. By providing real-world clinical data, this research seeks to inform evidence-based recommendations for OK lens selection and management strategies in pediatric myopia control.

Methods

Study Design

This was a retrospective, continuous observational study conducted over a 36-month period to evaluate the long-term effectiveness and safety of four types of orthokeratology lenses (CRT, Lucid, Euclid, and IBright) in controlling mild to moderate myopia among children and adolescents.

Participants

A total of 219 children (438 eyes) were included in this study. Participants met the following inclusion criteria: (1) age between 8 and 16 years; (2) baseline spherical equivalent refractive error (SER) between −1.00 D and −6.00 D with astigmatism less than −1.50 D; (3) regular follow-ups for 36 months; and (4) no history of ocular disease or surgery. Exclusion criteria included (1) irregular corneal astigmatism, (2) corneal thickness < 450 μm, and (3) poor compliance with lens wear.

Definitions

Mild to moderate myopia was defined as a spherical equivalent refractive error (SER) between −1.00 D and −6.00 D. Axial length growth referred to the increase in axial length (in millimeters) from baseline over the 36-month period. The SER was taken with an auto kerato refractometer (KR-1, Topcon, Japan). K1 and K2 curvature represented the flattest and steepest corneal meridians, respectively, as measured using a topographer (IOLMaster, Carl Zeiss Meditec).

Lens Fitting

Each participant underwent a comprehensive fitting process for orthokeratology lenses by certified optometrists. Lenses were selected and customized based on corneal topographic measurements, keratometry, and central corneal thickness. Proper lens fit was confirmed using fluorescein staining patterns. Participants were instructed to wear the lenses overnight for at least 8 hours. Lens wear time was tracked via a daily wear log maintained by participants, supplemented by regular follow-up assessments to verify adherence.

Examinations

Participants underwent comprehensive ophthalmic examinations at baseline and at 1 month, 3 months, 6 months, 9 months, 12 months, 18 months, 24 months, 30 months, and 36 months. Assessments included measurement of visual acuity using a Snellen chart, determination of refractive error through cycloplegic autorefraction, and evaluation of corneal topography using a computerized corneal topographer to assess K1 and K2 curvature changes. Axial length was measured with non-contact optical biometry (IOLMaster, Carl Zeiss Meditec). Safety assessments were conducted regularly to monitor for adverse events, including corneal staining, epithelial erosion, and microbial keratitis. All participating centers used the same model of the IOLMaster (Carl Zeiss Meditec) for axial length measurements, and all examiners were trained to follow a uniform set of procedures. The characteristics of four OK lens were listed in Supplementary Table 1.

Statistical Analysis

Descriptive statistics were used to summarize baseline characteristics. Continuous variables were expressed as means ± standard deviations, while categorical variables were presented as frequencies (n) and percentages (%). One-way analysis of variance (ANOVA) was used to compare changes in corneal curvature and axial length among the four lens groups. Pearson's chi-square test was used to compare categorical variables. Subgroup analyses were performed based on age, sex, SER and corneal thickness. A P-value less than 0.05 was considered statistically significant.

The study was approved by the Institutional Review Board of Tongliao Chaoju Eye Hospital and in accordance with the Declaration of Helsinki and the National Institute for Health Research guidance on ethical approval. No patient consent was obtained as the study was retrospective using de-identified data analysis and all patient confidential data was protected.

Results

Baseline Characteristics

A total of 219 participants (438 eyes) were included in the study, with 55 in the CRT group, 54 in the Euclid group, 52 in the Lucid group, and 58 in the IBright group. At baseline, there were no statistically significant differences among the groups in age (P = 0.103), sex distribution (P = 0.309), axial length (P = 0.204), SER (P = 0.425), corneal curvature (K1 and K2) (P = 0.351 and P = 0.114, respectively), or corneal thickness (P = 0.465) (Table 1).

Axial Length Changes

During the 36-month follow-up, all groups demonstrated an increase in axial length of no more than 1.0 D (Figure 1). The mean changes in axial length at 36 months were 0.57 ± 0.35 mm for the CRT group, 0.57 ± 0.36 mm for the Euclid group, 0.55 ± 0.44 mm for the Lucid group, and 0.60 ± 0.42 mm for the IBright group (Table 2). There were no statistically significant differences among the groups (P = 0.670).

Table 1 Baseline Demographics Data of All Subjects

Characteristics	CRT (N=55)	Euclid (N=54)	Lucid (N=52)	IBright (N=58)	P-value
Age (year)	10.56 ± 2.04	10.41 ± 2.12	11.10 ± 2.02	10.12 ± 2.16	0.103
Sex, No (%)					0.309
Female	29 (52.7)	31 (57.4)	31 (59.6)	25 (43.1)	
Male	26 (47.3)	23 (42.6)	21 (40.4)	33 (56.9)	
Axial length (mm)	24.71 ± 0.68	24.40 ± 0.93	24.50 ± 0.83	24.50 ± 0.67	0.204
Spherical equivalent error (D)	−2.91 ± 1.32	−2.52 ± 1.21	−2.79 ± 1.28	−2.74 ± 1.22	0.425
K1 (D)	42.70 ± 1.17	43.10 ± 1.70	43.13 ± 1.30	42.99 ± 1.28	0.351
K2 (D)	43.81 ± 1.24	44.29 ± 1.93	44.50 ± 1.46	44.33 ± 1.36	0.114
Corneal thickness (mm)	543.31 ± 36.91	537.36 ± 33.35	533.02 ± 34.29	538.86 ± 33.55	0.465

Abbreviations: K1, flat keratometry; K2, steep keratometry; D, diopter.

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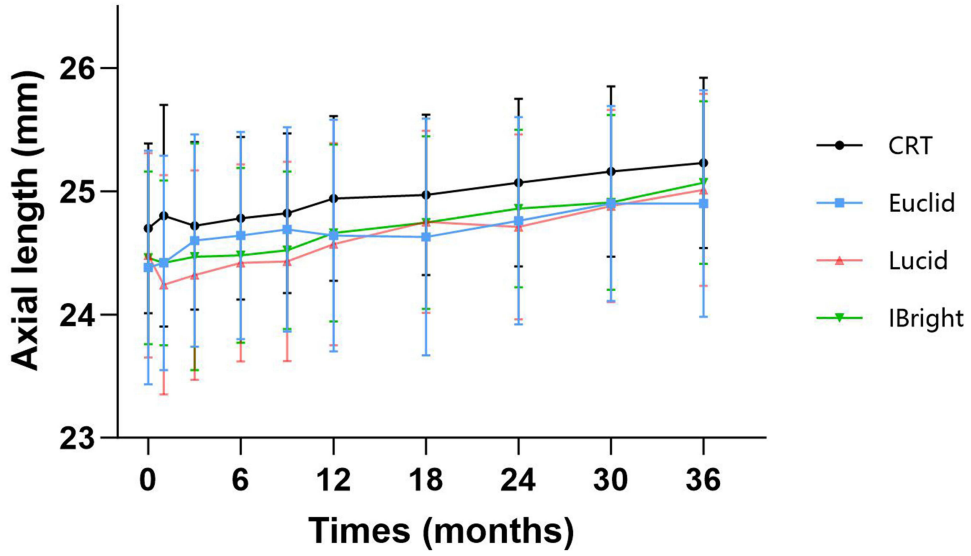

Figure 1 Trend of axial length changes between four types of orthokeratology (OK) lenses (CRT, Lucid, Euclid, and IBright).

Corneal Curvature (K1 and K2) Changes

The changes of K1 were shown in Figure 2. At 36 months, the mean changes in K1 curvature were −2.51 ± 1.41 D for the CRT group, −2.04 ± 1.25 D for the Euclid group, −2.58 ± 1.25 D for the Lucid group, and −2.37 ± 1.09 D for the IBright group (Table 2). There were no significant differences among the groups (P = 0.245). For K2 curvature (Figure 3), the changes at 36 months were −2.98 ± 1.55 D, −2.73 ± 1.36 D, −3.14 ± 1.62 D, and −2.95 ± 1.56 D, respectively, with no statistically significant differences (P = 0.349). At the 36-month follow-up, the IBright group exhibited the greatest change in K1 curvature at 3 months (−2.40 ± 0.97 D), whereas no significant differences were found across the other groups at later time points. Regarding K2 curvature, the Lucid group showed the largest change at 24 months (−3.07 ± 1.50 D), but no significant differences were observed among the groups at other time intervals.

Subgroup Analysis

Subgroup analysis revealed that axial elongation was more pronounced in children under 12 years old compared to those aged 12 and above across all groups (Supplementary Table 2, all P < 0.05). Among children with corneal thickness <530 μm, the CRT group showed the largest K1 curvature change (−3.20 ± 1.35 D) compared to the other groups

Table 2 Baseline and 36-month Measurements of Myopia Among Different Groups

Outcome	CRT (N=55)	Euclid (N=54)	Lucid (N=52)	IBright (N=58)	P-value
Axial length (mm)					
Pre-treatment	24.66 ± 0.71	24.31 ± 0.94	24.45 ± 0.85	24.49 ± 0.68	0.649
Post-treatment	25.23 ± 0.69	24.88 ± 0.91	25.00 ± 0.78	25.09 ± 0.67	0.347
Change	0.57 ± 0.35	0.57 ± 0.36	0.55 ± 0.44	0.60 ± 0.42	0.670
K1 (D)					
Pre-treatment	42.73 ± 1.20	43.31 ± 1.68	43.18 ± 1.31	42.95 ± 1.21	0.202
Post-treatment	40.22 ± 1.79	41.27 ± 2.20	40.61 ± 1.30	40.59 ± 1.09	0.254
Change	−2.51 ± 1.41	−2.04 ± 1.25	−2.58 ± 1.25	−2.37 ± 1.09	0.245
K2 (D)					
Pre-treatment	43.87 ± 1.24	44.48 ± 1.90	44.51 ± 1.46	44.22 ± 1.39	0.061
Post-treatment	40.89 ± 1.63	41.75 ± 2.45	41.38 ± 2.02	41.26 ± 1.62	0.335
Change	−2.98 ± 1.55	−2.73 ± 1.36	−3.14 ± 1.62	−2.95 ± 1.56	0.349

Abbreviations: K1, flat keratometry; K2, steep keratometry; D, diopter.

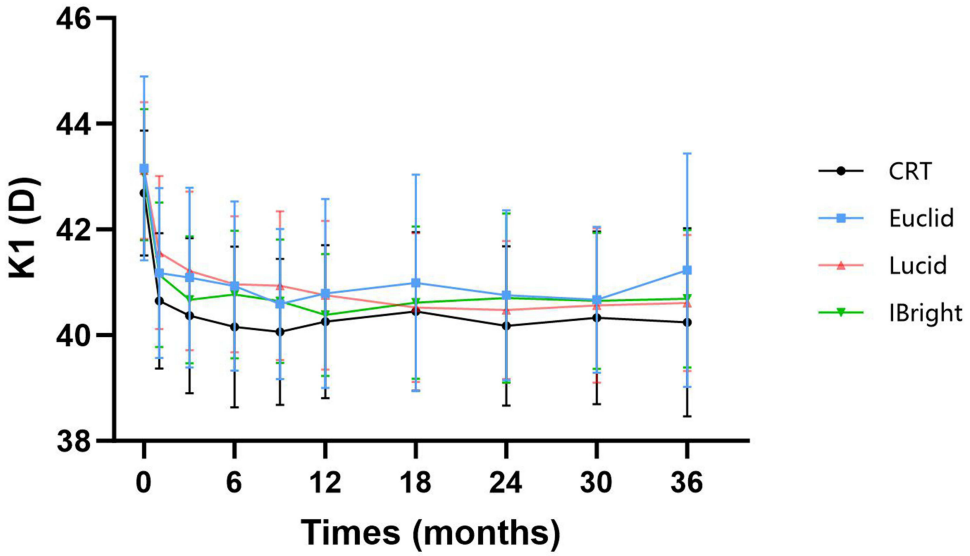

Figure 2 Trend of flat keratometry (K1) changes between four types of orthokeratology (OK) lenses (CRT, Lucid, Euclid, and IBright).
Abbreviation: D, diopter.

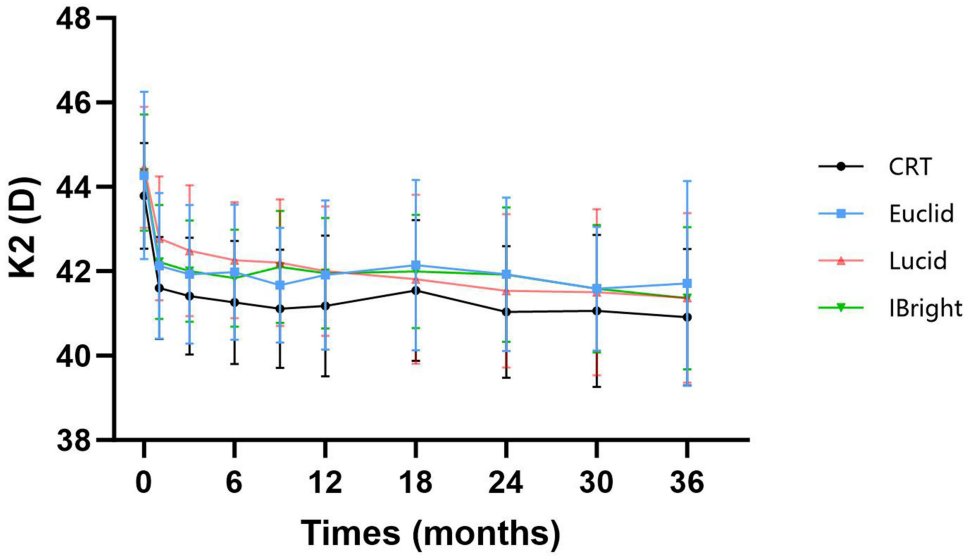

Figure 3 Trend of steep keratometry (K2) changes between four types of orthokeratology (OK) lenses (CRT, Lucid, Euclid, and IBright).
Abbreviation: D, diopter.

(Supplementary Table 3, P = 0.048). The changes of K2 among subgroup were shown in Supplementary Table 4. No significant differences were found in axial length or curvature changes between participants with SRE < −3.0 D and those with SRE ≥ −3.0 D. Similar findings were also found by sex.

Safety Outcomes

Throughout the 36-month follow-up, a total of 41 adverse events were recorded across all lens groups. These included 28 cases of mild corneal staining (CRT: 7, Euclid: 8, Lucid: 6, IBright: 7), 9 cases of epithelial erosion (CRT: 2, Euclid: 3, Lucid: 2, IBright: 2), and 4 cases of microbial keratitis (CRT: 1, Euclid: 1, Lucid: 1, IBright: 1). All cases of corneal staining and epithelial erosion were mild and resolved with temporary discontinuation of lens wear and the use of topical lubricants or antibiotics as needed. For microbial keratitis, the affected subjects were treated with topical broad-spectrum

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antibiotics, and full recovery was achieved in all cases without long-term sequelae. No significant differences in the incidence of adverse events, including corneal staining, epithelial erosion, and microbial keratitis, were observed among the four groups throughout the follow-up period (all $P > 0.05$).

Discussion

This study evaluated the long-term efficacy and safety of four commonly used orthokeratology (OK) lenses, CRT, Lucid, Euclid, and IBright, in controlling myopia progression in children and adolescents over 36 months. The primary finding of this study is that all four types of OK lenses demonstrated comparable efficacy in controlling axial elongation and corneal curvature changes, providing effective management options for mild to moderate myopia in pediatric populations. Despite slight variations in curvature changes, the axial length changes across the groups were similar, with no significant differences observed in any of the lens types. Furthermore, the safety profile of all four lenses was comparable, with no significant differences in adverse event rates across groups.

Previous studies have explored the efficacy of orthokeratology lenses in controlling myopia progression, but limited comparative research has evaluated the long-term effects of different OK lenses.[12–14] Our findings align with previous studies that suggest OK lenses can effectively slow axial elongation and myopia progression over extended periods. Previously, a study by ROMIO/MCOS/TO-SEE Groups demonstrated the axial length change from baseline was 0.41 ± 0.25 mm for the orthokeratology group and 0.65 ± 0.30 mm for the control group, resulting in a treatment effect of 0.24 mm (95% confidence interval: 0.15 to 0.34 mm) after 2 years of lens wear.[9] Similarly, another study by Nakamura et al found that myopia progression in school-aged children was inhibited regardless of the OK lens design. The suppression of myopia was assessed using both axial length changes and SER measurements. Over the 2-year period, the myopia control effect of OK lenses was observed to be 0.85 D.[15] The results of the current study expand upon these findings by providing a longer observation period (36 months) and comparing multiple OK lens types. The observed differences in corneal reshaping between the four orthokeratology lenses (CRT, Lucid, Euclid, and IBright) may be attributed to specific design features. The optical zone diameter (OZD) slightly varies, with CRT having a smaller OZD (6.0), which could cause more central flattening, while the others (6.2) may offer more gradual reshaping. The material Dk values, ranging from 100 (CRT) to 127 (Euclid), affect oxygen permeability, with higher Dk values like those in Euclid and IBright potentially promoting better corneal health and more stable reshaping. Lucid's higher DK/t value (75) also suggests better oxygen transmission, important for thinner corneas. The curvature design, particularly the IBright lens, which showed the largest K1 change at 3 months, may influence short-term reshaping, though these differences did not persist long-term. These design factors should be considered when selecting lenses, especially for younger patients or those with thinner corneas.

While axial length changes were similar across the four groups, there were minor differences in corneal curvature, particularly with the IBright group showing the largest change in K1 curvature at 3 months. This is consistent with findings from earlier studies, which suggest that different lens designs may influence corneal reshaping to varying extents.[16] However, the lack of significant differences in curvature changes between the groups at later points (12, 24, and 36 months) suggests that all four lenses provide similar long-term reshaping effects on the cornea.

The efficacy of orthokeratology lenses in controlling myopia progression is thought to be primarily related to their ability to reshape the cornea and reduce the axial elongation of the eye. The lenses apply gentle pressure on the cornea overnight, resulting in a temporary flattening of the central corneal area, which alters the refractive error and slows the growth of the eye.[17] The findings of this study support the notion that all four OK lenses achieve this effect, although slight variations in corneal reshaping may be attributed to differences in lens design and materials. The mechanisms underlying the differences in K1 curvature changes, particularly in children with thinner corneas, suggest that the lens fit and material properties play a role in the extent of corneal reshaping.[18] This could be further explored in future studies that investigate the interaction between corneal characteristics and lens design.

The findings of this study have important clinical implications for the management of myopia in children and adolescents. Given the similar efficacy and safety profiles of the four OK lenses, clinicians can choose a lens based on individual patient characteristics, such as corneal thickness, lens fit, and patient preference. The greater axial elongation observed in children under 12 years old emphasizes the importance of early intervention to prevent excessive myopia

progression in younger patients. Clinicians should consider the age and corneal characteristics of their patients when selecting an appropriate OK lens for myopia control. Furthermore, while the incidence of device-related serious adverse events was low and similar across all groups, which is also consistent with previous studies[19] clinicians should still monitor for potential complications such as corneal staining or microbial keratitis.[20] The safety profile observed in this study supports the use of OK lenses as a safe and effective option for myopia management in children and adolescents.

This study has several strengths, including its long follow-up period, and real-world clinical setting. The continuous 36-month observation provides valuable insights into the long-term effectiveness and safety of OK lenses in managing myopia progression. Additionally, the inclusion of multiple lens types allows for a direct comparison of their performance in a clinical population.

However, there are several limitations to consider. First, this was a retrospective study, and data were extracted from clinical records, which may have introduced biases or inconsistencies in data collection. Additionally, the study did not include a control group of children wearing traditional single-vision spectacles, which could have provided a clearer comparison of the efficacy of OK lenses versus conventional treatments. Furthermore, the study did not assess the potential impact of environmental factors, such as screen time and outdoor activity, on myopia progression, which could influence the results. Although the same model of the IOLMaster was utilized across all participating centers and standardized protocols were rigorously followed for axial length measurements, minor inter-measurement variability cannot be entirely excluded. The definition of myopia used in this study (spherical equivalent refractive error between –1.00 D and –6.00 D) differs slightly from that employed by the International Myopia Institute (IMI). However, this definition is considered clinically appropriate given the age range and refractive characteristics of the study population. Furthermore, the generalisability of these findings to non–East Asian populations is limited, and additional research involving ethnically and geographically diverse cohorts is warranted to validate and extend these results. Finally, while the study provided valuable insights into the effects of OK lenses, further randomized controlled trials with larger sample sizes and more controlled conditions are needed to confirm these findings.

Conclusion

In summary, this 36-month retrospective study demonstrates that CRT, Lucid, Euclid, and IBright orthokeratology lenses exhibit comparable efficacy in controlling myopia progression among children and adolescents, with no significant differences in axial elongation or refractive outcomes across lens types. Importantly, the safety profile of all four lenses was favorable, with low incidences of adverse events such as corneal staining, epithelial erosion, and microbial keratitis, and no severe complications reported. These findings support the clinical utility of orthokeratology as a safe and effective myopia management strategy across a range of lens designs.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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