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Original Article

Effectiveness of orthokeratology plus vision therapy for controlling myopia progression in children

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Abstract: Objective: Addressing myopia in children, this study analyzed the effectiveness of orthokeratology (Ortho-K) plus vision therapy (VT) for controlling myopia progression. Methods: The study population was composed of 155 myopia-affected children (August 2022-August 2025), who were assigned to the ortho-K group (n=75) wearing Ortho-K lenses and the Ortho-K+VT group (n=80) that was additionally given VT intervention. Inter-group comparative assessments were then conducted from the perspectives of clinical effectiveness, visual acuity (VA) measures (best-corrected VA, uncorrected VA), refractive structural parameters (axial length, spherical equivalent), corneal parameters (central corneal thickness, mean keratometry), accommodation parameters (accommodation amplitude, accommodative facility, accommodative response), accommodation-convergence synergy parameters (positive/negative relative accommodation, accommodative convergence/accommodation ratio), complications (corneal epithelial punctate staining, conjunctival congestion, dry eye symptoms, papillary conjunctivitis), and vision-related quality of life (25-Item National Eye Institute Visual Function Questionnaire). Results: The total effective rate was significantly higher in the Ortho-K+VT group than in the Ortho-K group. After the intervention, all VA measures, refractive structure parameters, corneal parameters, accommodation parameters, accommodation-convergence synergy parameters, and vision-related quality of life were significantly better in patients receiving Ortho-K+VT. The total complication rate was significantly lower in the Ortho-K+VT group than in the Ortho-K group. Conclusion: Ortho-K combined with VT was effective in controlling myopia progression in children.

Keywords: Orthokeratology lenses, vision therapy, myopia in children, effectiveness, quality of life

Introduction

Myopia, an ametropia type featuring excessively prolonged axial length (AL), carries a risk of complications (e.g., myopic macular degeneration and high myopia-induced optic neuropathy), which can trigger diminution of vision and even blindness [1, 2].

The global prevalence of myopia among children is remarkable. The disease, affecting nearly 33.3% of children and adolescents, is projected to affect 740 million people by 2050 [3]. Heredity, excessive use of electronic products, poor study habits, lack of outdoor activities, and malnutrition, are all recognized contributors to myopia in children [4].

Childhood myopia management is primarily based on optical, pharmacologic, and behavioral interventions. Pharmacological therapy is represented by atropine. Yet, this may cause side effects such as cycloplegia (inhibition of accommodation) and mydriasis (leading to blurred vision and photophobia) while carrying a risk of myopia rebound [5, 6]. Behavioral intervention involves mainly increasing outdoor time. Although effective, it has a limited influence on disease progression after myopia onset [7].

Optical intervention involves the use of a variety of glasses and contact lens designs, that can prevent myopia from progressing. It is non-invasive and easy to operate, with orthokeratology lenses (Ortho-K) being the most extensively used. Ortho-K is a type of rigid, breathable contact lens worn during sleep, that can temporarily reshape the corneal morphology and produce myopic defocus in the periph-

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eral retina [8]. Tang et al. [9] analyzed 7 randomized controlled trials and found that Ortho-K can effectively control AL growth in children's myopia, thus delaying myopia progression; however, the myopia control effect weakens with time.

Vision therapy (VT) is a behavioral intervention delivered in the visual function training room of the Children's Hospital of Hebei Province, including +/-2.00 diopter (D) flipper training, near-far Hart chart training, and lens reading/sorting training. It is safe and effective for controlling the progression of childhood myopia [10]. In a randomized controlled trial, VT slowed down myopia progression in children and was well tolerated [11].

This study aimed to evaluate the efficacy of this combined approach, with the goal of establishing a more effective prevention and control strategy for childhood myopia.

Patients and methods

General information

This retrospective study enrolled 155 children with myopia who visited Children's Hospital of Hebei Province between August 2022 and August 2025. Of these, 75 children receiving Ortho-K therapy constituted the Ortho-K group, and the remaining 80 formed the Ortho-K+VT group, who received VT in addition to Ortho-K lenses. Clinical comparability was supported by balanced baseline data distributions between the study cohorts ($P>0.05$). This study was approved by the Ethics Committee of Children's Hospital of Hebei Province.

A *post-hoc* power analysis was conducted using G*Power 3.1, with a two-tailed α set to 0.05. Based on the observed efficacy rates (77.33% vs. 92.50%) and sample sizes (75 cases and 80 cases), a chi-square test was employed. The unadjusted power was 0.75, which decreased to 0.68 after Yates' continuity correction.

Myopia diagnostic criteria [12]: A cycloplegic refraction revealed a spherical equivalent (SE) of ≤-0.50 D in either eye. Myopia was classified as low, moderate, or high based on thresholds of -3.00 D and -6.00 D.

Patient enrollment criteria

The enrollment into the Ortho-K group required: a myopia diagnosis [13]; an age range of 8-16; a SE of -0.75 D - -5.75 D with an astigmatism power of <1.50 D; a corneal curvature of 39.00-48.00 D; no active ocular diseases or contraindications for contact lens wear, with good glasses-wearing compliance; no allergic history of Ortho-K lenses or Ortho-K lens care solution; no use of other myopia control methods prior to enrollment; and complete clinical data. The Ortho-K+VT group, in addition to meeting the above criteria, had the following inclusion criteria: binocular accommodative facility (AF) measured with ±2.00 D flippers was below the age-normal values, or the accommodation amplitude (AMP) was more than 2 D below the value predicted by the minimum AMP formula (15 - 0.25 × age).

Study exclusion was based on: a history of eye surgery or trauma; the presence of organic diseases like strabismus, amblyopia, and glaucoma; concurrent active inflammation of the anterior segment, moderate dry eye syndrome, meibomian gland dysfunction, or lagophthalmos; abnormal corneal endothelial cell count or morphology, too great or too small a corneal curvature (keratometry, K), or insufficient corneal thickness; coexisting dyslexia or cognitive deficits; or impaired vision due to other causes.

Treatment methods

All children underwent routine anterior and posterior segment examinations before lens fitting to confirm that the ocular surface and fundus were in normal physiologic condition.

The Ortho-K group received DreamVision Ortho-K contact lenses (Autek China Inc., IV-DF). According to eye parameters (refraction, astigmatism prescription, intraocular pressure, corneal diameter, etc.), the lenses were customized and fitted. After a 30-minute trial fitting, the optical center alignment and lens mobility were observed under a slit-lamp microscope until a satisfactory fit was achieved. During the one-year lens-wearing period, regular follow-up examinations were conducted on the children to inspect the anterior segment of their eyes and the fitting of the lenses under a slit lamp microscope. In the case of corneal epithelial staining or keratitis, Ortho-K lens wear was discontinued and appropriate treatment was administered.

VT was additionally provided to children in the Ortho-K+VT group: The children underwent standardized training in the hospital's visual function room, which was delivered by the same experienced optometrist using VT instruments from Tianjin OPT Science-technology Development Co., Ltd. ① +/-2.00 D flipper training: Monocular training was conducted. The child was asked to gaze at the reading card at a distance of 40 cm. First, they were instructed to look at the reading card through the positive lens. Once they could clearly see the target, they were then instructed to quickly switch to the negative lens until it became clear. This process was repeated. This training was conducted once a day for 5 minutes each time. ② Near-far Hart chart eye exercise: The large chart was fixed 3 meters away from the child. The optometrist held the small chart and placed it 40 cm in front of the child and asked the child to focus on the first row of the small chart. Then, the small chart was gradually moved closer until the letters appeared blurred to the child. Next, the small chart was moved away by 2.5 cm, and the child was instructed to alternately read the second row of the large and small charts from this new distance. This exercise was performed once daily. ③ Lens reading and sorting training: +2.50 D to -6.00 D lenses were placed 40 cm away from the child, who was asked to read the chart from small to large letters, and to read lenses from plus to minus diopter powers, until the child could clearly read 20 letters per minute. Then came lens sorting. Eight of the lenses were selected with the order disrupted, and the child was asked to quickly and correctly sort these lenses from plus to minus D powers within one minute. This training was performed once daily.

This was a retrospective, non-randomized comparative study. Treatment allocation was based on individual conditions, patient preferences, and clinical recommendations.

Outcome measures

① Clinical effectiveness. Assessment criteria: marked effectiveness was indicated by visual acuity (VA) improvement by ≥2 lines (≥0.2 decline in the logarithm of the minimum angle of resolution) with stabilized or decreased SE; VA improvement by one line (≥0.1 decrease in the logarithm of the minimum angle of resolution) with slowed SE progression was effectiveness; no VA improvement or continuous SE progression was ineffectiveness. The total effective rate was the marked effectiveness and effectiveness rates combined.

② VA measures. Best-corrected VA (BCVA) and uncorrected VA (UCVA) were measured using a standard logarithmic VA chart and recorded in decimal notation before treatment and 6 months after it.

③ Refractive structural parameters. Pre- and post-treatment (at 6 months) AL measurements were conducted. SE levels of patients before and after treatment were recorded.

④ Corneal parameters. The central corneal thickness (CCT) and mean corneal curvature (mean K) were measured before and after treatment.

⑤ Accommodation parameters. The children were examined for AMP, AF, and accommodative response (AR) before treatment and at 6 months after treatment. Among them, AMP was measured by the push-up method. The distance at which the visual target became blurry was recorded and converted into D. AF was measured at 40 cm using a ±2.00 D flipper, and the number of cycles completed within 1 minute was recorded as cycles per minute. AR was measured at a working distance of 40 cm by the monocular estimated method, and the additional lens power required to neutralize the motion was taken as the accommodative lag (D).

⑥ Accommodation-convergence synergy parameters. Positive relative accommodation (PRA) and negative relative accommodation (NRA) were measured by adding plus and minus spheres binocularly. Accommodative convergence/accommodation ratio (AC/A) measurement method: Near phoria was measured on the basis of adding +1.00 D and -1.00 D, respectively. The change in phoria before and after adding the lens was calculated, which was then divided by the change in accommodative stimulus (1 D) to get the gradient AC/A.

⑦ Complications. We recorded the post-treatment occurrence of corneal epithelial punc-

Table 1. Between-group comparison of general information

Data	Ortho-K group (n=75)	Ortho-K+VT group (n=80)	χ^2/Z	P
Sex			1.706	0.192
Male	31 (41.33)	25 (31.25)		
Female	44 (58.67)	55 (68.75)		
Age (years)	12.00 (9.00, 13.00)	12.00 (10.00, 14.00)	-0.999	0.318
Disease course (years)	2.00 (2.00, 3.00)	2.00 (2.00, 3.00)	-1.242	0.214
Myopia degree			0.445	0.801
Mild	20 (26.67)	19 (23.75)		
Moderate	42 (56.00)	44 (55.00)		
Severe	13 (17.33)	17 (21.25)		
Family medical history			0.205	0.651
No	49 (65.33)	55 (68.75)		
Yes	26 (34.67)	25 (31.25)		

Note: Ortho-K, orthokeratology; VT, vision therapy.

tate staining, conjunctival congestion, dry eye symptoms, and papillary conjunctivitis complications in the two groups for comparative analysis.

⑧ Vision-related quality of life (VR-QOL). The assessment was made with the 25-Item National Eye Institute Visual Function Questionnaire (NEI-VFQ-25) [14]. According to the characteristics of childhood myopia, this study focused on four dimensions: near vision, distance vision, mental health, and social functioning. The scores of all items were summed and converted to a 0-100 scale, with 100 representing the best quality of life. The NEI-VFQ-25 composite score was calculated as the average score of the 11 vision-related subdimensions (excluding the General Health domain). The questionnaire was completed by the children with the assistance of parents or researchers.

Statistical methods

SPSS 22.0 was used for data processing and analysis. The counted data were statistically described as case numbers/percentages (n/%), with between-group differences examined using the chi-square test. Normality was evaluated using the Shapiro-Wilk method. When they followed a Gaussian distribution, the data were presented in the form of mean ± standard deviation, with independent sample t-test and paired t-test used to examine inter-group differences and within-group differences (pre- vs. post-treatment), respectively. For non-normally distributed data, the statistical presentation used the median (Q1, Q3), and the between-group differences were assessed by the Mann-Whitney U test. A *P*-value <0.05 was considered significant.

Results

General data comparison

The Ortho-K+VT and Ortho-K groups showed no significant differences in sex, age, disease course, myopia degree, or family history (P>0.05; **Table 1**).

Comparative clinical efficacy evaluation

We determined there were 23 markedly effective and 35 effective cases in the Ortho-K group, while the corresponding case numbers in the Ortho-K+VT group were 37 and 37. Through calculation, the Ortho-K+VT group was found to have a higher total effective rate than the Ortho-K group (P=0.008; **Table 2**).

Comparative assessment of VA measures

The two groups were not statistically different in baseline BCVA and UCVA (P>0.05). The post-treatment BCVA did not alter significantly from baseline across groups (P>0.05); however, the inter-group comparison revealed lower post-treatment BCVA in the Ortho-K + VT group compared with the Ortho-K group (P<0.05). Regarding UCVA, the within-group comparison showed a significant post-treatment decrease from baseline in both groups (P<0.05), and the between-group comparison further indicated a lower level in the Ortho-K + VT group than in the Ortho-K group after treatment (P<0.05; **Table 3**).

Table 2. Clinical efficacy comparison

Indicator	Ortho-K group (n=75)	Ortho-K+VT group (n=80)	χ^2	P
Marked effectiveness	23 (30.67)	37 (46.25)		
Effectiveness	35 (46.67)	37 (46.25)		
Ineffectiveness	17 (22.67)	6 (7.50)		
Overall effectiveness	58 (77.33)	74 (92.50)	7.046	0.008

Note: Ortho-K, orthokeratology; VT, vision therapy.

Table 3. Comparative assessment of visual acuity measures

Indicator	Ortho-K group (n=75)	Ortho-K+VT group (n=80)	t	P
BCVA (logMAR)				
Before	-0.00±0.07	-0.00±0.06	0.000	>0.999
After	-0.01±0.06	-0.03±0.05	2.560	0.025
UCVA (logMAR)				
Before	0.40±0.18	0.38±0.18	0.691	0.490
After	0.06±0.08	0.03±0.07	2.489	0.014

Note: BCVA, best-corrected visual acuity; UCVA, uncorrected visual acuity; Ortho-K, orthokeratology; VT, vision therapy; logMAR, logarithm of the minimum angle of resolution.

Table 4. Comparative assessment of refractive structural parameters

Indicator	Ortho-K group (n=75)	Ortho-K+VT group (n=80)	t	P
AL (mm)				
Before	24.79±0.79	24.67±0.79	0.945	0.346
After	24.91±0.71	24.78±0.80	1.067	0.288
SE (D)				
Before	-2.83±1.32	-2.75±1.15	0.403	0.688
After	-0.54±0.35	-0.41±0.24	2.711	0.008

Note: AL, axial length; SE, spherical equivalent; D, diopter; Ortho-K, orthokeratology; VT, vision therapy.

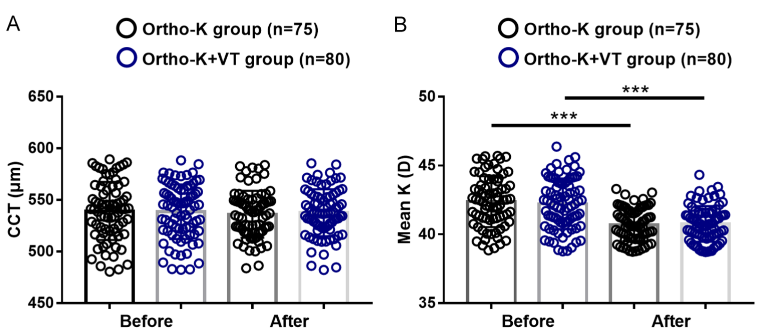

Figure 1. Comparative evaluation of corneal parameters. A. Pre- and post-treatment CCT across groups. B. Mean K pre- and post-treatment. Note: Ortho-K, orthokeratology; VT, vision therapy; CCT, central corneal thickness; Mean K, mean keratometry; ***P<0.001.

Comparison of refractive structural parameters

Baseline AL and SE did not differ significantly between groups (P>0.05). AL did not change significantly from baseline in either group after treatment (P>0.05), and no significant between-group difference was observed in post-treatment AL (P>0.05). In contrast, SE increased significantly from baseline in both groups after treatment (P<0.05), with a significantly greater increase in the Ortho-K+VT group (P<0.05; **Table 4**).

Comparison of corneal parameters

The groups did not differ significantly in pre- and post-treatment CCT or mean K (P>0.05). In the within-group (pre- vs. post-treatment) comparison, statistical significance was absent in post-treatment CCT for both groups (P>0.05), while the mean K decreased significantly after treatment (P<0.001; **Figure 1**).

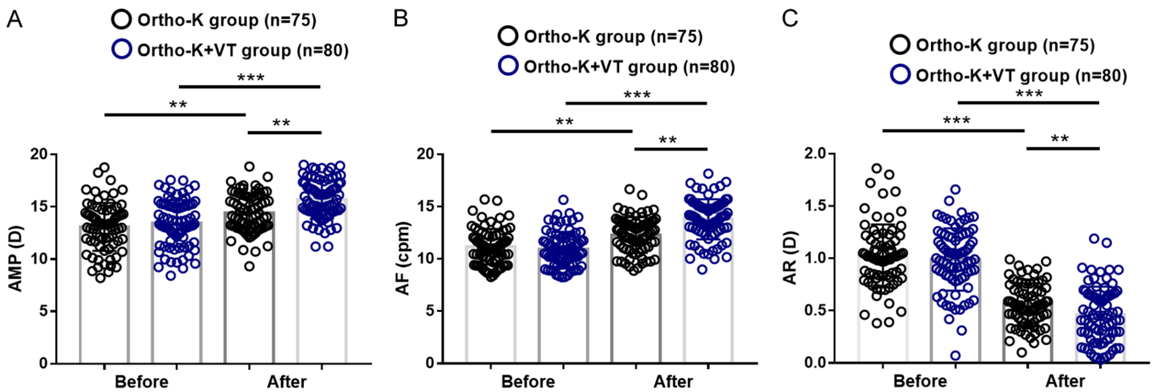

Figure 2. Comparative evaluation of accommodation parameters. A. Pre- and post-treatment AMP across groups. B. Pre- and post-treatment AF. C. AR pre- and post-treatment. Note: Ortho-K, orthokeratology; VT, vision therapy; AMP, accommodation amplitude; AF, accommodative facility; AR, accommodative response; **P<0.01; ***P<0.001.

Table 5. Comparison of accommodation-convergence synergy values

Indicator	Ortho-K group (n=75)	Ortho-K+VT group (n=80)	t	P
PRA (D)				
Before	-2.40±0.67	-2.57±0.81	1.419	0.158
After	-3.10±0.70	-3.55±0.71	3.970	<0.001
NRA (D)				
Before	2.19±0.44	2.26±0.52	0.902	0.369
After	2.42±0.48	2.59±0.40	2.401	0.018
AC/A (Δ/D)				
Before	4.96±1.23	5.18±1.54	0.979	0.329
After	4.30±1.09	3.83±1.10	2.670	0.008

Note: PRA/NRA, positive/negative relative accommodation; AC/A, accommodative convergence/accommodation ratio; Ortho-K, orthokeratology; VT, vision therapy; D, diopter.

Accommodation function comparison

AMP, AF, and AR were comparable between groups prior to treatment (P>0.05). Both groups exhibited an increase in AMP and AF and a reduction in AR post-treatment (P<0.01), with the Ortho-K+VT group showing significantly greater improvements in all three parameters (P<0.01; **Figure 2**).

Comparison of accommodation-convergence synergy parameters

The data showed inter-group compatibility in baseline PRA, NRA, and AC/A (P>0.05). Both treatments induced a decline in PRA and AC/A as well as an elevation in NRA (P<0.05), with Ortho-K+VT therapy leading to lower PRA and AC/A and higher NRA than Ortho-K intervention alone (P<0.05; **Table 5**).

Complication rate comparison

Statistics on complications indicated corneal epithelial punctate staining in 16 cases, conjunctival congestion in 3, dry eye symptoms in 5, and papillary conjunctivitis in 2 in the Ortho-K group, while the corresponding case numbers in the Ortho-K+VT group were 8, 1, 2, and 1, respectively. Ortho-K+VT intervention had a lower overall incidence of complications than Ortho-K therapy alone (P=0.004; **Table 6**).

Comparative VR-QOL analysis

No significant between-group differences were observed for the scores of near vision, distance vision, mental health, and social functioning, or the NEI-VFQ-25 composite score before treatment (P>0.05). Both cohorts exhibited an increase in all the above scores post-treatment

Table 6. Complication rate comparison

Indicator	Ortho-K group (n=75)	Ortho-K+VT group (n=80)	χ^2	P
Corneal epithelial punctate staining	16 (21.33)	8 (10.00)		
Conjunctival congestion	3 (4.00)	1 (1.25)		
Dry eye symptoms	5 (6.67)	2 (2.50)		
Papillary conjunctivitis	2 (2.67)	1 (1.25)		
Total	26 (34.67)	12 (15.00)	8.090	0.004

Note: Ortho-K, orthokeratology; VT, vision therapy.

(P<0.05), particularly in the Ortho-K+VT group (P<0.05; **Figure 3**).

Discussion

Myopia is a public health challenge. It mainly affects children and adolescents, with an earlier onset age linked to a greater predisposition to high myopia development [15]. If intervened timely and effectively, childhood myopia can be effectively slowed down, with an effective control rate of at least 50.0% [16]. This study evaluated the effect of Ortho-K+VT relative to simple Ortho-K therapy in preventing myopia progression in children. First, we found that the total effective rate of the combined intervention was statistically higher compared to Ortho-K alone, improving the overall effectiveness rate from 77.3% to 92.5%. Second, the combined intervention exhibited high efficacy for improving myopia indices in children with myopia, thus effectively enhancing their VA. Ortho-K works mainly by reshaping the corneal shape by mechanical compression, thus improving VA [17]. The ±2.00 D flipper training, near-far Hart chart training, and lens reading and sorting training provided by VT can enhance AF (improving distance-near switching speed), amplify AMP (enhancing maximum accommodation), and optimize PRA and NRA (enhancing accommodative reserve and relaxation), respectively, while also reducing accommodation lags. This synergistically enhances accommodation function, controls myopia progression, and improves VA with Ortho-K [18]. As reported by Jin et al. [19], VT used in 100 adult myopia patients aged 17 to 40 effectively improved spherical consistency among InnovEyes Sitemap (a comprehensive optometry diagnostic system used for personalized preoperative planning of refractive surgery), autorefraction, and subjective refraction, with no significant effect on cylindrical agreement. They further noted that VT was especially suitable for myopia patients with more serious myopia undercorrection, thicker lenses, and longer AL [19], which complements our findings.

Both treatments appeared to limit AL elongation, although the changes were not statistically significant within groups, with Ortho-K+VT achieving better optical correction effects. Ortho-K can cause the peripheral retina to be in a myopic defocus state, which induces the light to converge and form an image in front of the peripheral retina, thus delaying AL growth and enabling the control of myopia progression [20]. The mechanism of VT, we speculate, may be attributed to its improvement of tear film stability, but the specific mechanism needs further verification. According to corneal parameter assessments, the two treatment schemes could effectively inhibit the abnormal corneal thickness and flatten the central corneal curvature. Accommodation parameters were also tested, supporting the ability of the combined intervention to significantly improve the accommodation function of children with myopia. In the study of Lv et al. [21], 110 children (age range: 6-12) with myopia showed significantly improved binocular VA and enhanced AF following VT for 3 months, similar to our observations. The improvement of VT on accommodation function may be related to its contribution to improving the efficiency of brain networks and enhancing the functional connection between static brain networks and dynamic neurovascular coupling [22].

In terms of accommodation-convergence synergy parameters, we observed superior effects of the combined intervention on improving accommodative reserve and relaxation function, as well as enhancing the accommodation-convergence synergy in children with myopia. Specifically, the flipper training provided by VT

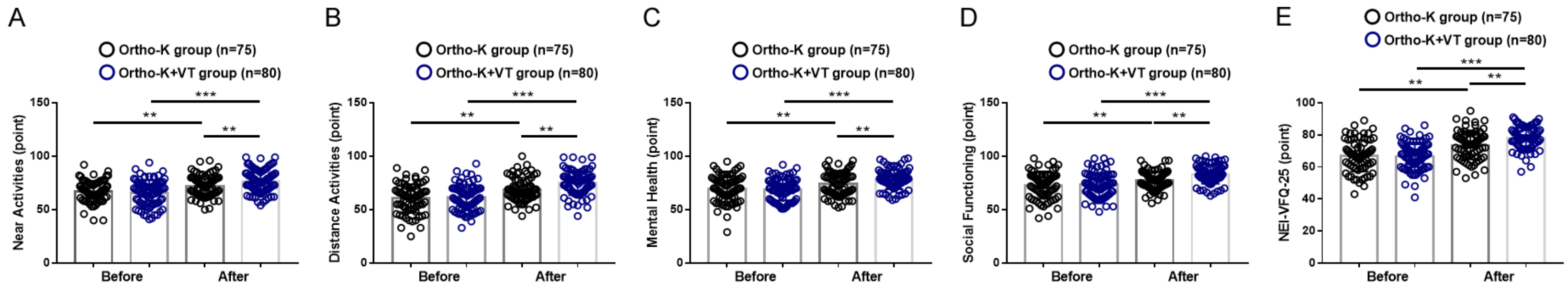

Figure 3. Comparison of vision-related quality of life. A. Pre- and post-treatment near vision scores across groups. B. Pre- and post-treatment distance vision scores for the two groups. C. Mental health scores pre- and post-treatment. D. Pre- and post-treatment social functioning scores. E. Pre- and post-treatment NEI-VFQ-25 composite scores. Note: Ortho-K, orthokeratology; VT, vision therapy; NEI-VFQ-25, 25-Item National Eye Institute Visual Function Questionnaire; **P<0.01; ***P<0.001.

strengthens the bidirectional switching flexibility of the accommodative system through the rapid alternation of ±2.00 D lenses, which indirectly optimizes the accommodation-convergence synergy. The near-far Hart chart training can directly exercise the natural coordination and rapid switching of accommodation-convergence by alternately gazing at far (3 m) and near (40 cm). Through the gradual transition from plus to minus lenses, lens reading and sorting training can expand the threshold range of accommodative reserve and relaxation, which aids in improving accommodative reserve and relaxation capacity. Concerning safety, the combined intervention was associated with a significantly lower overall complication rate in children with myopia. This may be attributed to the active blinking and ocular surface relaxation of children with myopia during VT intervention, which may help to improve tear film distribution and stability [23]. As far as the VR-QOL is concerned, children receiving the combined intervention showed superior VR-QOL enhancement in near vision, far vision, mental health, and social functioning dimensions. This is because the overall visual function improvement brought by VT enables children with myopia to have a greater sense of control when performing visual tasks. In addition, the enhanced accommodation function helps relieve visual fatigue, possibly enhancing the subjective comfort level of patients in their studies and daily lives.

To summarize, Ortho-K+VT intervention for childhood myopia can effectively curb myopia progression and improve curative outcome. Also, it leads to enhancements in accommodation function, accommodative reserve and relaxation, and accommodation-convergence synergy, a lowered risk of total complications, and a boosted VR-QOL.

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Disclosure of conflict of interest

None.

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