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Original Article

Clinical advantages of multifocal soft contact lenses in myopia control for adolescents

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Abstract: Objective: To compare the clinical effectiveness of multifocal soft contact lenses (MFSCLs) and orthokeratology (OK) lenses in managing myopia in adolescents. Methods: This retrospective study enrolled 106 myopic adolescents, divided into two groups: OK (n=50) and MFSCLs (n=56). Refractive error (RE), intraocular pressure (IOP), axial length (AL), and choroidal thickness were measured at baseline (T0), 6-month follow-up (T1), and 12-month follow-up (T2). Additionally, accommodative amplitude, accommodative sensitivity, negative/positive relative accommodation (NRA/PRA), interleukin-6 (IL-6), epidermal growth factor (EGF), psychological status, and quality of life were compared between T0 and T2. Safety during treatment was also assessed. Results: Both interventions resulted in a significant increase in RE at T1 and T2 ($P<0.05$), with no significant differences between groups ($P>0.05$). IOP, AL, and choroidal thickness remained stable (all $P>0.05$). At T2, the MFSCLs group showed significant improvements in accommodative amplitude, accommodative sensitivity, and NRA (all $P<0.05$), along with a reduction in PRA ($P<0.05$), although no significant inter-group differences were observed ($P>0.05$). Furthermore, the MFSCLs group exhibited significantly lower IL-6 levels, higher EGF, and fewer adverse reactions (all $P<0.05$). Psychological status and quality of life improvements were significantly greater in the MFSCLs group ($P<0.05$). Conclusion: MFSCLs and OK lenses demonstrate comparable myopia control effects. However, MFSCLs offer additional benefits in reducing inflammation, enhancing safety, and improving mental health and quality of life.

Keywords: Multifocal soft contact lenses, orthokeratology lenses, adolescent myopia, myopia management

Introduction

Myopia, a prevalent ocular disorder typically developing during childhood and adolescence, is one of the leading causes of visual impairment and blindness worldwide [1]. Epidemiological studies indicate a striking prevalence, with nearly one-third of adolescents (30.0%) affected by myopia, and approximately 10.0% of these cases progressing to high myopia [2]. The clinical significance of adolescent myopia extends beyond refractive error (RE) as it increases the lifetime risk of vision-threatening complications, including open-angle glaucoma, retinal detachment, posterior subcapsular cataracts, and myopic macular degeneration. The risk of these adverse events rises proportionally with the severity of myopia [3]. Additionally, myopia has broader effects, influencing adolescents' psychological and social development, as well as their daily lives. For many affected adolescents, this condition leads to academic challenges, impaired social interactions, and diminished overall well-being [4]. Several factors contributing to myopia progression have been identified, including limited outdoor time, intensive near-focused work, insufficient sleep, and familial myopia [5]. Therefore, implementing evidence-based interventions to slow myopia progression, reduce myopia-related complications, and prevent blindness is critical.

Among available treatments, orthokeratology (OK) has emerged as a widely used method for myopia control. This therapy involves the overnight wear of reverse-geometry rigid contact lenses that temporarily flatten the central cornea and optimize peripheral defocus, leading to a reversible decrease in myopia and enhanced unaided daytime vision [6-8]. As a non-invasive approach, OK offers effective myopia control, freedom from daytime visual aids, and indepen-

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dence from spectacles [9]. However, adverse events occur four times more frequently in OK lens users (both pediatric and adult) compared to conventional contact lens wearers, raising concerns regarding safety [10]. Multifocal soft contact lenses (MFSCLs) represent another key innovation for myopia control. MFSCLs utilize concentric optical zones alternating between distance correction and +2.50 D myopic defocus rings, providing RE correction while slowing axial length (AL) growth [11, 12]. According to Han et al. [13], MFSCLs outperform traditional corrections in limiting myopia progression among Chinese children, with superior outcomes in vision-related quality of life, cosmetic satisfaction, peer approval, and physical activity tolerance.

Although both OK lenses and MFSCLs are increasingly employed, there is limited evidence from controlled studies comparing their effectiveness, safety, and quality of life outcomes in adolescent myopia management. This study aims to evaluate MFSCLs against OK lenses in terms of effectiveness, safety, and quality of life, with the goal of determining clinical superiority. We hypothesize that MFSCLs will offer superior safety and patient-reported outcomes compared to OK, while providing comparable myopia control.

Materials and methods

Study population and selection criteria

We retrospectively studied myopic adolescents treated at Suzhou Lixiang Eye Hospital (January 2022-December 2023), ensuring participant inclusion based on predefined, rigorous criteria. Eligible participants met the following conditions: (1) confirmed bilateral myopia diagnosis; (2) age range: 8-15 years; (3) anisometropia ≤1.25 diopters (D); (4) astigmatism ≤1.00 D; (5) best-corrected visual acuity (VA) ≥1.0 with spectacles or contact lenses; (6) eligibility for MFSCL and OK lens therapy; (7) no prior or concurrent myopia treatments; (8) adherence to 8-10 hours of nocturnal lens wear, ≤3-day discontinuations, and regular follow-ups for 1 year; (9) absence of manifest strabismus; (10) no familial ocular disorders (e.g., glaucoma, retinal detachment); (11) completeness of medical records.

Participants were excluded if they presented with any of the following: (1) concurrent amblyopia diagnosis; (2) history of ocular surgery or active ocular surface allergies; (3) active ocular inflammation or chronic ophthalmic conditions; (4) significant systemic comorbidities (e.g., glaucoma, cardiovascular disorders, major psychiatric conditions); (5) ocular or systemic conditions potentially affecting visual function or refractive development; (6) corneal topography-confirmed irregular astigmatism; (7) fundus examination showing tessellated fundus changes ≥ Grade C2; (8) history of non-compliance with medical advice or irregular use of corrective eyewear; (9) daily outdoor activity exceeding 2 hours. After comprehensive screening, 106 participants were stratified into an OK group (n=50) receiving OK intervention or an MFSCL group (n=56) receiving MFSCL intervention. The study was approved by the Ethics Committee of Suzhou Lixiang Eye Hospital.

Diagnostic criteria for myopia [14]

Myopia is diagnosed when patients present with blurred distance vision while maintaining good near vision and demonstrate habitual squinting when viewing distant objects. The condition and its severity are confirmed through both objective and subjective refraction measurements. Myopia is classified as follows: mild myopia (spherical equivalent between -0.50 and -3.00 D), moderate myopia (-3.25 to -6.00 D), and high myopia (spherical equivalent > -6.00 D).

Intervention methods

All participants underwent a comprehensive baseline ophthalmic examination, including: visual acuity assessment using standard eye charts (Jiaxing Baichen International Trade Co., Ltd., SC-1700P), anterior segment evaluation with a panoramic analyzer (Shanghai Huanxi Medical Equipment Co., Ltd., SS-1000), corneal surface aberrometry measurements using an aberrometer (Qisheng (Shanghai) Medical Equipment Co., Ltd., CT-6), complete refractive assessment with a phoropter (Shanghai Jumu Medical Equipment Co., Ltd., DR-900), optical biometry for ocular parameter measurement (Shanghai Huanxi Medical Equipment Co., Ltd., IOL Master 500), and detailed slit-lamp micro-

scope examination (Shanghai Jumu Medical Equipment Co., Ltd., c1185). These diagnostic procedures ensured accurate determination of each participant's refractive status and appropriate lens selection. The OK group received treatment using corneal reshaping lenses (Autek China Inc., DreamVision IV-AP), while the MFSCL group was fitted with innovative MFSCLs (CooperVision Products Trading (Shanghai) Co., Ltd., MiSight), which feature peripheral defocus technology.

In both groups, a standardized lens fitting protocol was followed, and visual performance and comfort were assessed. Clinicians adjusted prescriptions as needed. Participants and their guardians received thorough guidance on correct lens handling, wearing times, and safety precautions. Regular follow-ups were conducted at 1 week, 1 month, 2 months, and 3 months after the initial fitting, and quarterly thereafter. To maximize therapeutic benefits, ≥8 hours of overnight wear was emphasized for OK lens users. Adherence to this regimen and lens efficacy were assessed during each follow-up appointment.

Data acquisition and outcome assessment

(1) RE: RE was measured using an autorefractor at T0, T1, and T2, corresponding to the pretreatment baseline, 6-month, and 12-month follow-ups, respectively.

(2) Intraocular Pressure (IOP): IOP was measured at all time points. Prior to assessment, participants rested for 5 minutes, followed by non-contact tonometry (Ailaibao (Jinan) Medical Technology Co., Ltd., ST-1000).

(3) AL: AL was determined using optical biometry (IOL Master) at T0, T1, and T2.

(4) Choroidal Thickness: High-definition spectral-domain optical coherence tomography (Foshan Guangwei Technology Co., Ltd., LVM-500) was used to obtain choroidal cross-sections. Image analysis software facilitated precise choroidal thickness measurements.

(5) Assessment of Accommodative Function: Key accommodative parameters, including amplitude of accommodation, accommodative sensitivity, negative relative accommodation (NRA), and positive relative accommodation (PRA), were assessed at T0 and T2. The amplitude of accommodation was measured using the push-up method, and accommodative sensitivity was evaluated with ±2.00 D flipper lenses.

NRA Measurement: Patients viewed an optotype one line above their best-corrected visual acuity at 40 cm. Positive lenses were added binocularly in +0.25 D increments until the first sustained report of blur. The NRA value was recorded as the total positive lens power added.

PRA Measurement: Following the same procedure, negative lenses were added in -0.25 D steps.

(6) Tear Fluid Biochemical Analysis: Tear fluid samples were collected at T0 and T2 between 9:00-11:00 AM after patients had abstained from contact lens wear for at least 48 hours. Biomarkers, including interleukin-6 (IL-6) and epidermal growth factor (EGF), were analyzed using enzyme-linked immunosorbent assay (ELISA; Shanghai Genetimes Technology, Inc., EH004, EH016). Basal tears were collected via non-stimulated Schirmer strip sampling (3-minute collection), followed by centrifugation.

(7) Adverse Effects: Ocular adverse events, including foreign body sensation, pupillary dilation, light sensitivity, and visual disturbances, were systematically documented and analyzed.

(8) Psychological Status [15]: Mental health status was objectively assessed using the self-reported Anxiety Self-Rating Scale (SAS) for anxiety symptoms and the Self-Rating Depression Scale (SDS) for depressive symptoms. Both scales use a 100-point metric, where higher scores indicate greater symptom severity.

(9) Quality of Life [16]: The Short-Form 36-item Health Survey (SF-36) was administered to assess multiple quality-of-life domains. Scores were based on a 100-point scale, with higher scores reflecting better life quality.

The primary endpoints in this study were RE, IOP, AL, choroidal thickness, NRA, PRA, and adverse events. IL-6, EGF, SAS, SDS, and SF-36 scores were assessed as secondary endpoints.

Table 1. Comparison of baseline characteristics

Data	OK group (n=50)	MFSCLs group (n=56)	χ^2/t	P
Gender			0.463	0.496
Male	22 (44.00)	21 (37.50)		
Female	28 (56.00)	35 (62.50)		
Age (years)	10.46±1.55	10.16±1.52	1.005	0.317
Body mass index (kg/m^2)	22.44±2.36	23.04±2.63	1.230	0.221
Astigmatism (D)	0.58±0.25	0.51±0.28	1.351	0.180
Outdoor activity duration (h/d)	2.42±1.26	2.77±1.54	1.271	0.207

MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

Statistical methods

Data processing was conducted using IBM SPSS Statistics (version 22.0). Descriptive statistics for categorical variables were presented as frequency distributions (%), while continuous variables were expressed as mean ± standard error of the mean (SEM). Comparative analyses were performed using χ^2 tests for categorical variables, independent t-tests for between-group comparisons of continuous variables, and paired t-tests for comparisons between two time points. For data involving multiple groups or time points, one-way ANOVA followed by Bonferroni tests was used. Statistical significance was defined as P<0.05.

Results

Comparison of baseline characteristics

Baseline characteristics were well-balanced between the groups. Statistical analysis confirmed no significant differences in gender distribution, age, BMI, astigmatism, or daily outdoor activity duration. Complete baseline data are presented in **Table 1**.

Comparison of RE outcomes

Longitudinal analysis of RE showed comparable spherical equivalent (D) between the groups at all time points (P>0.05). However, both groups exhibited significant increases in RE at T1 and T2 compared to baseline (P<0.01) (**Figure 1**).

Comparison of IOP measurements

No significant differences in IOP were observed within groups across time points or between groups at any assessment (all P>0.05) (**Figure 2**).

Comparison of AL changes

AL measurements remained stable throughout the study, with no significant within-group or between-group differences (all P>0.05) (**Figure 3**).

Comparison of choroidal thickness analysis

Choroidal thickness measurements showed no significant variations across time points or between treatment groups (all P>0.05) (**Figure 4**).

Comparison of accommodative function parameters

At T0, no significant differences between the groups were observed in accommodation amplitude, accommodative sensitivity, NRA, or PRA (P>0.05). At T2, both groups showed significant improvements in accommodation amplitude, accommodative sensitivity, and NRA, while PRA significantly decreased (P<0.05). However, inter-group comparisons at T2 revealed no statistically significant differences in any of these parameters (P>0.05) (**Figure 5**).

Comparison of tear film biomarkers

Baseline (T0) IL-6 and EGF levels did not differ significantly between the two groups (P>0.05). At T2, IL-6 levels significantly increased in both groups; however, the MFSCLs group showed significantly lower IL-6 concentrations compared to the controls (P<0.05). EGF levels in the MFSCLs group remained stable (P>0.05) but were significantly higher than those in the OK group (P<0.05) (**Figure 6**).

Comparison of adverse events

Reported adverse events included foreign body sensation, mydriasis, photophobia, and blurred vision. The MFSCLs group had a lower overall incidence of adverse events compared to the control group (P<0.05) (**Table 2**).

Comparison of psychological status assessment

Evaluation using the SAS and SDS scales revealed comparable baseline scores between the groups (both P>0.05). However, significant

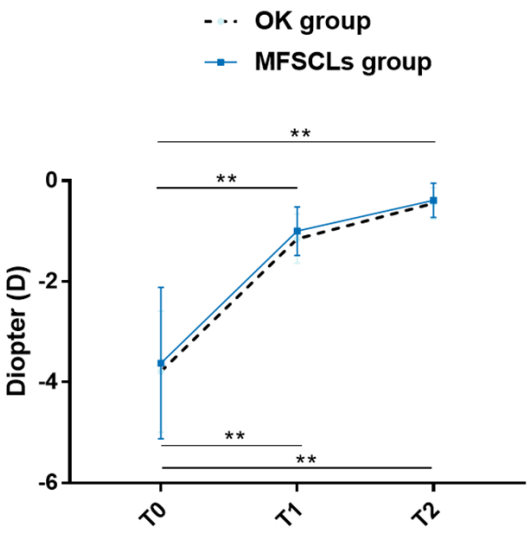

Figure 1. Comparison of Refractive error. Note: Significant differences (**P<0.01) were observed in within-group comparisons over time (marked by the line). MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

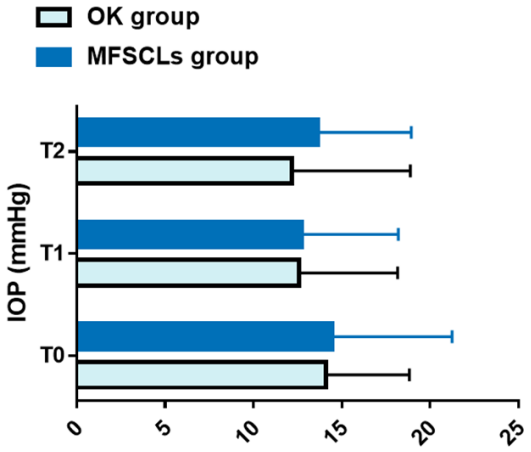

Figure 2. Comparison of intraocular pressure. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

reductions in scores were observed in both groups at T2 compared to T0 (both P<0.05), with the MFSCLs group demonstrating superior psychological outcomes (both P<0.05) (**Table 3**).

Comparison of quality of life outcomes

Quality of life assessment using the SF-36 demonstrated equivalent baseline scores (P>0.05). Both groups showed significant increases in SF-36 scores at T2 (P<0.05), with

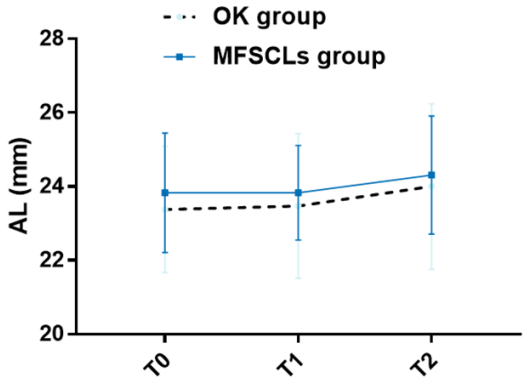

Figure 3. Comparison of axial length. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

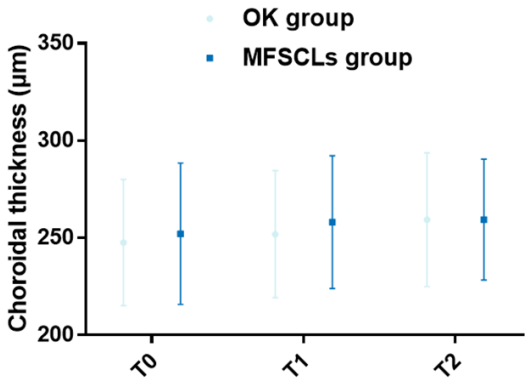

Figure 4. Comparison of choroidal thickness. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

the MFSCLs group reporting superior scores (P<0.001) (**Table 4**).

Discussion

Myopia, a prevalent refractive disorder characterized by impaired distance vision when ocular accommodation is relaxed [17], typically develops during adolescence or earlier, with its overall prevalence increasing as educational duration extends [18]. The underlying pathophysiology involves multiple mechanisms, including equatorial and posterior scleral thinning, Bruch's membrane defects at the optic disc periphery, and choroidal neovascularization [19]. This comparative study aimed to investigate whether MFSCLs offer superior clinical advantages over OK lenses in controlling myopia progression among adolescents, with the goal of providing better options for myopia management in this population.

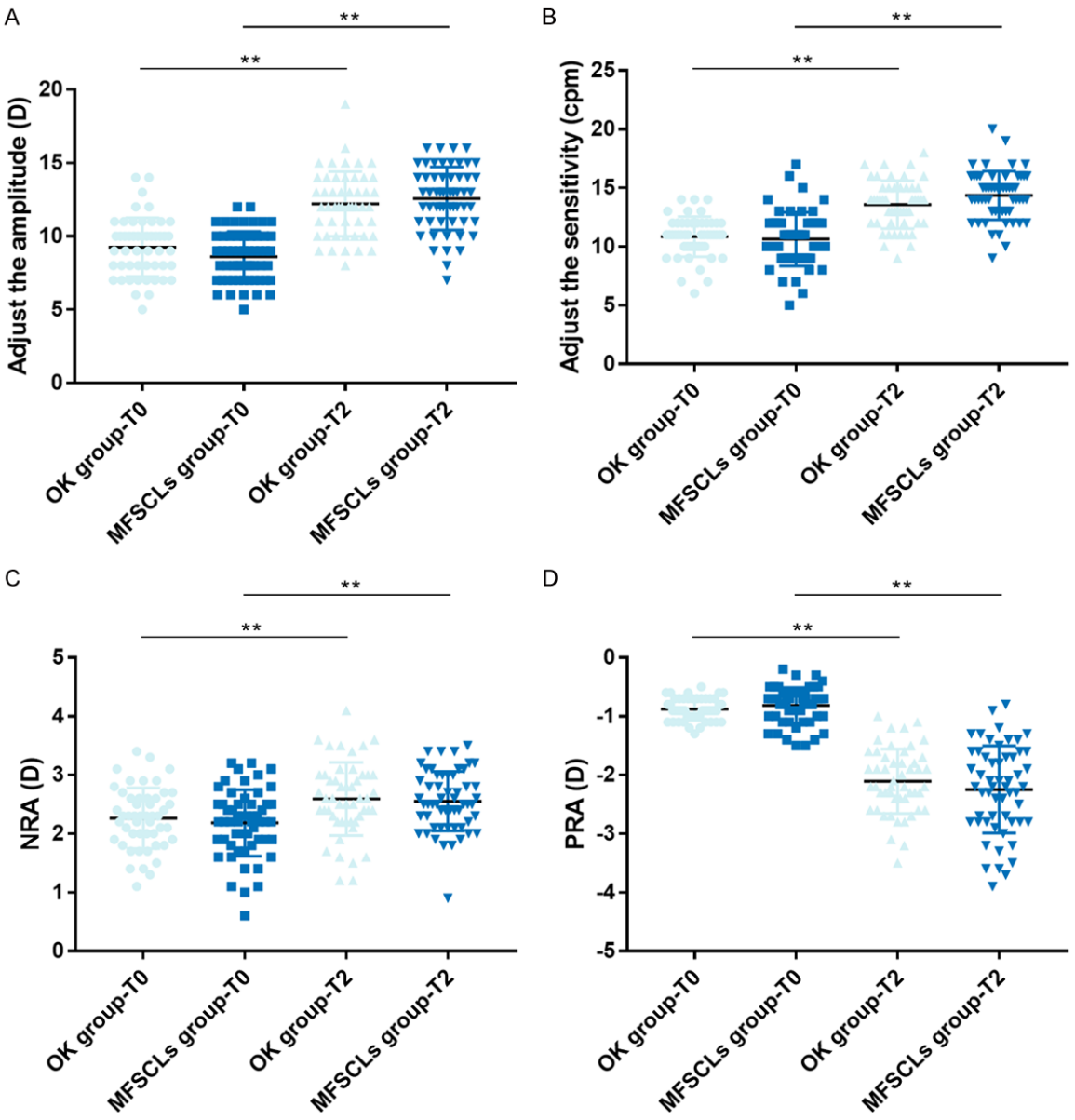

Figure 5. Comparison of ocular accommodation parameters. A. Changes in accommodation amplitude. B. Changes in accommodative sensitivity. C. Changes in negative relative accommodation (NRA). D. Changes in positive relative accommodation (PRA). Notes: **P<0.01. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

It is well-established that adolescent myopia progresses naturally as increasing negative RE, which serves as a direct measure of disease severity. Concurrent physiological changes may include elevated IOP, which potentially exacerbates AL elongation, with AL growth strongly correlating with myopic progression. Additionally, progressive choroidal thinning has been identified as another characteristic change in adolescent myopes, exhibiting an inverse relationship with AL elongation [20-23].

Thus, this study analyzed the effects of both interventions on RE, IOP, AL, and choroidal thickness in adolescent myopes. Our findings demonstrated that MFSCLs and OK lenses provided comparable improvements in RE among adolescent myopes. Moreover, MFSCLs had no significant effects on IOP, AL, or choroidal thickness, showing efficacy equivalent to OK lenses. These results support MFSCLs as a comparably effective alternative to OK lenses in adolescent myopia management, with additional ben-

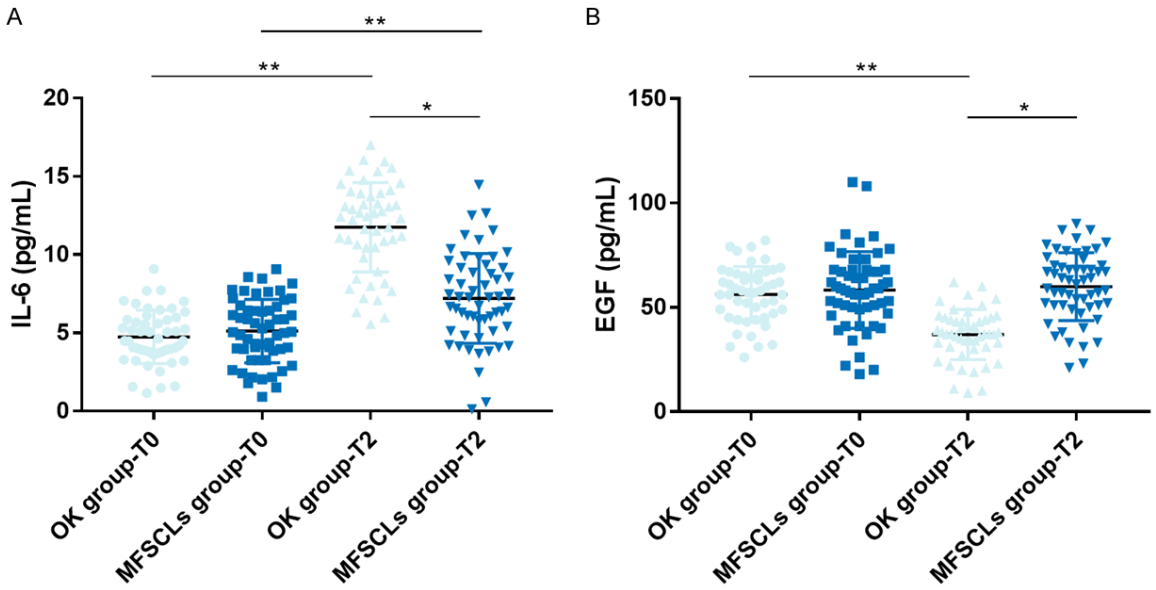

Figure 6. Comparison of Tear film biomarker profiles. A. Interleukin-6 (IL-6) levels in tear fluid. B. Epidermal growth factor (EGF) levels in tear fluid. Notes: *P<0.05, **P<0.01. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

Table 2. Comparison of adverse events

Adverse events	OK group (n=50)	MFSCLs group (n=56)	χ^2	P
Foreign body sensation	4 (8.00)	2 (3.57)		
Mydriasis	2 (4.00)	0 (0.00)		
Photophobia	1 (2.00)	1 (1.79)		
Blurred vision	2 (4.00)	0 (0.00)		
Total	9 (18.00)	3 (5.36)	4.206	0.040

MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

Table 3. Comparison of psychological status

Psychological status	OK group (n=50)	MFSCLs group (n=56)	t	P
SAS (points)				
T0	50.56±9.66	53.11±12.50	1.165	0.247
T2	30.82±7.68*	23.11±5.70**	5.909	<0.001
SDS (points)				
T0	49.92±8.53	51.64±9.68	0.965	0.337
T2	29.72±7.49*	22.96±6.52**	4.968	<0.001

Note: SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale. *P<0.05, **P<0.01 compared to T0. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

efits regarding daytime wear and reversible effects. Few studies have directly compared these two interventions, as most available literature has focused on multifocal lenses versus conventional spectacles. For instance, Chamberlain et al. [24] demonstrated the superior efficacy of MFSCLs (MiSight) over single-vision correction (Proclear) in controlling spherical equivalent refraction and AL progression. Ruiz-Pomeda et al. [25] found that MFSCLs more effectively reduce AL elongation and inhibit myopia progression compared to single-vision spectacles. Similarly, Prieto-Garrido et al. [26] reported no significant impact on choroidal thickness in myopic children using MFSCLs versus single-vision spectacles. This study evaluates the comparative effectiveness of MFSCLs versus OK lenses in adolescent myopia treatment, with results indicating similar therapeutic outcomes across multiple parameters (e.g., RE, IOP, AL, and choroidal thickness).

Our findings indicate that both correction modalities are equally effective, despite their distinct mechanistic pathways, ultimately achieving comparable improvements in VA regulation. MFSCLs, however, excel in maintaining ocular surface homeostasis by inducing low-grade, physiologically tolerable inflammation without compromising ocular surface repair capacity-a

Table 4. Comparison of quality of life

SF-36 (points)	OK group (n=50)	MFSCLs group (n=56)	t	P
T0	73.52±11.90	70.48±13.77	1.209	0.229
T2	80.22±7.16*	87.32±7.33**	5.033	<0.001

Note: SF-36, Short-Form 36-item Health Survey. *P<0.05, **P<0.01 compared to T0. MFSCLs: multifocal soft contact lenses, OK: orthokeratology.

significant advantage over other correction strategies. In terms of safety, MFSCLs were associated with fewer adverse events, suggesting their superior safety profile. A narrative evidence review confirmed that MFSCLs effectively slow myopia progression in young patients, supported by U.S. Food and Drug Administration-backed safety data [27]. Our further analysis indicated that, in addition to myopia control effects comparable to OK lenses, MFSCLs provided enhanced mental and overall well-being, evidenced by greater reductions in anxiety and depression, as well as superior quality-of-life improvements in MFSCL wearers compared to OK users. These advantages may stem from MFSCLs' favorable safety profile. While refractive errors, AL, and choroidal thickness show no significant differences between the two methods, MFSCLs cause fewer adverse events, positively impacting emotional well-being, routine tasks, and life quality [28]. In contrast, OK lenses must be worn overnight (minimum 8 hours) and require stringent care routines (e.g., proper hygiene and storage). Daytime VA changes from lens fit or environmental triggers may also exacerbate discomfort and emotional distress [29]. MFSCLs, on the other hand, are designed for single-day use, offering distinct convenience benefits. As one-time-use products, they do not require upkeep such as cleaning and storage, significantly reducing time investment and infection risks associated with lens care. Their simplified usage protocol-requiring no special wearing conditions-enhances overall convenience for patients. Importantly, this user-friendly design contributes to improved treatment compliance and may help alleviate patient anxiety and negative emotions [30].

Based on the evidence presented, while MFSCLs and OK lenses show comparable effects on ocular accommodative function, MFSCLs offer superior advantages across multiple dimensions. Specifically, MFSCLs demonstrate greater efficacy in controlling tear inflammatory responses, provide higher clinical safety, improve psychological well-being (particularly in alleviating anxiety and depression), and offer more comprehensive enhancements in overall quality of life.

This study has several limitations, primarily in the following three areas: First, the duration of follow-up observations was limited. A more extended tracking period (3-5 years) would provide a more robust evaluation of the long-term efficacy and safety of these two myopia control interventions. Second, the analysis of tear film biomarkers was limited to IL-6 and EGF levels. Including additional inflammation-related markers (e.g., tumor necrosis factor-α) or tear film stability parameters (such as tear breakup time) would offer a more comprehensive assessment of how these interventions affect tear film homeostasis. Finally, the study did not conduct a detailed statistical comparison across specific quality-of-life dimensions. Future research with a more comprehensive evaluation in this area could clarify the distinct effects of the two interventions on patients' daily functioning across different aspects of life.

In conclusion, MFSCLs represent a clinically advantageous alternative to OK lenses for adolescent myopia management. While both modalities achieve comparable optical and biometric outcomes (RE, IOP, AL, choroidal thickness, accommodative amplitude, accommodative sensitivity, NRA, and PRA), MFSCLs excel in inflammation control, ocular surface repair capacity, safety, tolerability, and patient-centered benefits-including emotional well-being and quality of life. These findings support the broader adoption of MFSCLs as a first-line intervention for myopia control in adolescents, offering new insights into adolescent myopia management and providing a clinically superior intervention strategy.

Disclosure of conflict of interest

None.

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