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Review Article

Orthokeratology

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Abstract

Background: Orthokeratology (Ortho-K) has evolved from a temporary refractive correction technique into a well-established, evidence-based intervention for myopia management. With the increasing global prevalence of myopia, particularly among children and adolescents, orthokeratology has gained prominence because of its ability to provide daytime spectacle-free vision while slowing axial elongation through peripheral myopic defocus. Advances in reverse-geometry lens design, high oxygen-permeable materials, corneal topography, and imaging technologies have further enhanced its safety, predictability, and clinical effectiveness.

Objective: This narrative review aims to provide a comprehensive overview of the current evidence on orthokeratology, including its historical development, mechanisms of action, lens design, patient selection, clinical fitting, efficacy in myopia control, safety profile, complications, and emerging technological advances.

Methods: A structured literature search was conducted using PubMed, Scopus, Web of Science, Google Scholar, and the Cochrane Library to identify relevant English-language publications from 2000 to 2025. Original research articles, randomised controlled trials, systematic reviews, meta-analyses, consensus statements, and clinical practice guidelines addressing orthokeratology and myopia management were reviewed and synthesised narratively.

Results: Current evidence demonstrates that orthokeratology effectively provides temporary correction of low-to-moderate myopia while reducing axial elongation by approximately 30–60% compared with conventional optical correction in children. The treatment works primarily through controlled corneal epithelial redistribution and induction of relative peripheral myopic defocus, which modifies retinal signalling involved in ocular growth regulation. Modern high-Dk rigid gas-permeable lens materials, customised reverse-geometry designs, and corneal topography-guided fitting have substantially improved treatment precision and safety. Although complications such as corneal staining, lens decentration, and microbial keratitis may occur, their incidence remains low when appropriate patient selection, meticulous lens hygiene, and regular follow-up protocols are maintained. Emerging evidence also supports enhanced myopia control with combination therapy using low-dose atropine and orthokeratology.

Conclusion: Orthokeratology is a safe, reversible, and effective modality for both refractive correction and myopia control when implemented using evidence-based clinical protocols. Continued advances in lens technology, artificial intelligence-assisted fitting, ocular imaging, and combination treatment strategies are expected to further improve clinical outcomes and strengthen the role of orthokeratology in contemporary pediatric myopia management.

Introduction

Myopia has emerged as one of the most significant public health challenges worldwide, with its prevalence increasing rapidly across all age groups, particularly among children and adolescents. It is estimated that nearly half of the global population may be myopic by 2050, with approximately 10% developing high myopia. Progressive myopia substantially increases the lifetime risk of irreversible ocular complications, including retinal detachment, myopic macular degeneration, glaucoma, cataract, and choroidal neovascularisation. Consequently, interventions that not only correct refractive error but also slow myopia progression have become a major priority in contemporary eye care [1–4].

Orthokeratology (Ortho-K) is a non-surgical and reversible method of temporary refractive correction that utilises specially designed reverse-geometry rigid gas-permeable (RGP) contact

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lenses worn overnight to reshape the anterior corneal surface. The controlled redistribution of the corneal epithelium produces central corneal flattening, thereby reducing myopic refractive error and providing clear unaided daytime vision following lens removal. Unlike corneal refractive procedures such as laser-assisted in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK), orthokeratology preserves corneal tissue integrity, and its effects are completely reversible after discontinuation of lens wear [5–7].

Initially developed as a technique for temporary refractive correction, orthokeratology has evolved into one of the most extensively investigated optical interventions for myopia control. Its clinical significance extends beyond vision correction because the treatment modifies peripheral retinal image quality by inducing relative peripheral myopic defocus while maintaining central retinal focus. This alteration in retinal defocus is believed to regulate retinal signalling pathways involved in ocular growth, thereby reducing axial elongation, the principal structural determinant of progressive myopia. Randomised controlled trials and systematic reviews have consistently demonstrated that orthokeratology slows axial elongation by approximately 30–60% compared with conventional single-vision spectacles or soft contact lenses, establishing it as an evidence-based strategy for paediatric myopia management [8–14].

The development of modern orthokeratology has been driven by substantial advances in contact lens technology, corneal imaging, and fitting methodologies. Early orthokeratology relied on conventional polymethyl methacrylate (PMMA) lenses, which produced inconsistent and unpredictable refractive outcomes because of limited oxygen permeability and empirical fitting techniques. The introduction of reverse-geometry lens designs, high oxygen-transmissible fluorosilicone acrylate materials, computerised corneal topography, and customised fitting software has transformed orthokeratology into a predictable and scientifically validated clinical procedure. These technological advances have improved lens centration, treatment precision, patient comfort, and overall safety, making overnight lens wear a practical option for appropriately selected patients [5–7,15].

Successful orthokeratology requires careful patient selection, comprehensive pre-fitting assessment, accurate interpretation of corneal topography, individualised lens fitting, and regular follow-up. Optimal candidates generally include individuals with low-to-moderate myopia, healthy ocular surfaces, stable tear-film function, and regular corneal topography. In pediatric patients, treatment success also depends on appropriate parental supervision, adherence to hygiene protocols, and compliance with scheduled follow-up examinations. When these principles are followed, orthokeratology demonstrates a favourable safety profile comparable to other modalities of overnight rigid gas-permeable lens wear, with most complications being mild, reversible, and preventable through appropriate clinical management [6,15–17].

Recent advances have further expanded the scope of orthokeratology. Combination therapy with low-dose atropine has demonstrated enhanced efficacy in slowing axial elongation in rapidly progressing myopic children. In addition, artificial intelligence-assisted lens fitting, epithelial thickness mapping using anterior-segment optical coherence tomography, and customised topography-guided lens designs have improved treatment precision and individualised patient care. These innovations continue to strengthen the role of orthokeratology within modern evidence-based myopia management and personalised eye care [13,18–20].

This narrative review summarises the current evidence regarding the evolution, mechanisms of action, corneal biomechanics, lens design, patient selection, fitting methodologies, clinical applications, safety profile, complications, and future developments of orthokeratology. By integrating recent clinical evidence, technological advances, and international consensus recommendations, this review aims to provide clinicians, optometrists, ophthalmologists, and researchers with a comprehensive understanding of the role of orthokeratology in contemporary refractive correction and myopia management.

Methodology

Literature search strategy

A structured literature search was conducted to identify relevant publications on orthokeratology and myopia management. Electronic databases including PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and the Cochrane Library were searched for articles published between January 2000 and June 2025. Additional relevant publications were identified through manual screening of reference lists from selected articles and recent review papers.

The search strategy combined Medical Subject Headings (MeSH) and free-text keywords, including "orthokeratology," "Ortho-K," "corneal reshaping," "reverse-geometry lenses," "myopia control," "peripheral myopic defocus," "axial elongation," "overnight rigid gas-permeable lenses," "corneal topography," "low-dose atropine," "combination therapy," and "pediatric myopia." Boolean operators (AND/OR) were used to refine the search and improve retrieval of relevant studies.

Original research articles, randomised controlled trials, prospective and retrospective cohort studies, case-control studies, systematic reviews, meta-analyses, consensus statements, and clinical practice guidelines published in English were considered for inclusion. Preference was given to high-quality studies evaluating the efficacy, safety, mechanisms of action, lens design, fitting methodologies, patient selection, complications, and recent technological advances in orthokeratology. Publications lacking sufficient methodological detail, duplicate reports, conference abstracts without full-text availability, non-English publications, and studies with limited clinical relevance were excluded.

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The retrieved literature was critically reviewed and synthesised narratively. Evidence from landmark clinical trials, systematic reviews, meta-analyses, and international consensus recommendations was integrated to provide a comprehensive overview of current knowledge regarding orthokeratology, with particular emphasis on its role in myopia control, clinical applications, safety, and emerging developments in lens technology and personalised patient management.

History and evolution

Myopia has emerged as one of the most significant public health challenges worldwide, with projections indicating that nearly half of the global population may be myopic by 2050, and approximately 10% may develop high myopia, increasing the risk of irreversible ocular complications.[1,2] Orthokeratology (Ortho-K) is a non-surgical, reversible method of temporary refractive correction that employs specially designed reverse-geometry rigid gas-permeable contact lenses worn overnight to reshape the anterior cornea [3].

Beyond refractive correction, orthokeratology has become one of the most extensively investigated optical interventions for myopia control. Randomised clinical trials and systematic reviews have demonstrated that orthokeratology reduces axial elongation by approximately 30–60% compared with conventional optical correction, primarily through the induction of relative peripheral myopic defocus [4–8]. Recent technological advances, including high oxygen-permeable lens materials, computerised corneal topography, optical coherence tomography, and customised fitting software, have further improved treatment safety, predictability, and clinical outcomes [3,9,10].

The origins of orthokeratology date back to the 1960s, when clinicians observed that polymethyl methacrylate (PMMA) contact lenses produced temporary central corneal flattening and modest reductions in myopia [3,11]. During the 1970s and 1980s, sequential fitting of progressively flatter rigid lenses was attempted to reshape the cornea; however, outcomes were inconsistent because of limited oxygen permeability, empirical fitting methods, and the absence of corneal imaging technologies [3].

The introduction of reverse-geometry rigid gas-permeable lenses during the late 1980s and early 1990s represented a major advance, enabling controlled epithelial redistribution and more predictable refractive outcomes [3,9]. Simultaneously, computerised corneal topography transformed orthokeratology into a precision-guided clinical procedure by allowing objective assessment of corneal curvature, treatment-zone centration, and lens fitting [3,9].

Landmark clinical trials, including the Longitudinal Orthokeratology Research in Children (LORIC) study and the Retardation of Myopia in Orthokeratology (ROMIO) trial, demonstrated significant reductions in axial elongation among children undergoing orthokeratology, establishing its role as an evidence-based intervention for myopia control.[4,5] More recent systematic reviews and meta-analyses have confirmed both the efficacy and safety of orthokeratology in appropriately selected patients [7,12].

Corneal anatomy and biomechanics

The cornea contributes approximately two-thirds of the total refractive power of the eye, and successful orthokeratology depends primarily on reversible remodelling of the corneal epithelium rather than permanent structural alteration [3,13]. Optical coherence tomography studies have demonstrated that overnight orthokeratology induces central epithelial thinning and compensatory mid-peripheral epithelial thickening, while stromal thickness remains largely unchanged [3,13].

Modern reverse-geometry lenses generate pressure gradients within the post-lens tear film, facilitating controlled epithelial redistribution and central corneal flattening [3,14]. These changes modify peripheral retinal image quality, producing relative peripheral myopic defocus that is believed to reduce the stimulus for axial elongation and slow myopia progression [6,8,15].

Mechanism of action

Orthokeratology corrects myopia through controlled redistribution of the corneal epithelium while simultaneously altering retinal image quality [3]. The induced central corneal flattening temporarily reduces refractive error, whereas the resulting peripheral myopic defocus modifies retinal signalling pathways involved in ocular growth regulation [6,15].

Clinical trials have consistently demonstrated that this optical mechanism slows axial elongation in children by approximately 30–60% compared with conventional single-vision optical correction [4–8]. Recent evidence also suggests that combining orthokeratology with low-dose atropine may provide additional reductions in axial elongation compared with either treatment alone [12].

Patient selection criteria

Appropriate patient selection is fundamental to the success of orthokeratology (Ortho-K) and represents one of the most important determinants of treatment efficacy, safety, and long-term patient satisfaction. Successful outcomes depend on careful evaluation of refractive status, corneal morphology, ocular surface health, tear film stability, patient motivation, and compliance with overnight lens wear and follow-up visits. Careful selection not only optimises refractive correction and myopia control but also minimises the risk of treatment-related complications [15–20].

Orthokeratology is primarily indicated for children and adolescents with progressive myopia, particularly those between 6 and 16 years of age, in whom slowing axial elongation is the principal therapeutic objective. Early intervention has been shown to provide greater benefits because younger children generally exhibit faster myopia progression and greater responsiveness to myopia-control interventions. Adults with stable low-to-moderate myopia who seek spectacle-

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free daytime vision may also benefit from orthokeratology, provided appropriate ocular and corneal characteristics are present [3,15,16].

The most predictable refractive outcomes are achieved in patients with low-to-moderate myopia, typically up to -6.00 D, accompanied by regular corneal astigmatism of approximately 1.50 D or less. Advances in customised reverse-geometry lens designs, including toric peripheral alignment systems, have expanded the range of treatable refractive errors; however, correction of higher degrees of myopia and irregular astigmatism remains less predictable and may increase the likelihood of lens decentration, residual refractive error, glare, and higher-order aberrations [12,20].

Corneal suitability is equally important. Candidates should demonstrate regular corneal topography, normal corneal biomechanics, adequate central corneal thickness, and an absence of ectatic disorders such as keratoconus or pellucid marginal degeneration. Patients should also have a healthy ocular surface, stable tear film, and normal eyelid anatomy because these factors directly influence lens centration, tear-film dynamics, epithelial remodelling, and treatment stability. Active ocular inflammation, severe dry eye disease, chronic blepharitis, or uncontrolled allergic eye disease should be managed before orthokeratology is initiated [10,12,21].

Patient-related factors play an equally important role in treatment success. Overnight lens wear requires meticulous hygiene practices, appropriate lens handling, and strict adherence to prescribed cleaning and disinfection protocols. Children should receive adequate parental supervision to ensure correct lens insertion, removal, storage, and compliance with scheduled follow-up examinations. Patients who are unable or unwilling to comply with these requirements are poor candidates because inadequate compliance substantially increases the risk of infectious and inflammatory complications [15,16].

Equally important is appropriate patient counselling before treatment initiation. Patients should understand that orthokeratology provides temporary and reversible refractive correction requiring consistent overnight lens wear to maintain visual outcomes. Expectations regarding visual recovery, adaptation, potential visual symptoms such as halos during the initial treatment period, and the necessity of long-term follow-up should be discussed thoroughly. Comprehensive patient education has been consistently associated with improved treatment adherence, reduced discontinuation rates, and greater long-term satisfaction [12,20].

Overall, successful orthokeratology depends upon integrating refractive findings, corneal characteristics, ocular surface health, and behavioural factors into the clinical decision-making process. Careful patient selection remains the cornerstone of predictable treatment outcomes and safe long-term myopia management.

Clinical assessment and pre-fitting evaluation

Comprehensive clinical assessment is the foundation of successful orthokeratology practice and plays a pivotal role in determining treatment suitability, predicting clinical outcomes, and minimising complications. Unlike conventional contact lens fitting, orthokeratology requires precise evaluation of refractive status, corneal morphology, ocular surface health, tear-film stability, and patient-related factors because each influences lens centration, corneal reshaping, and long-term treatment success. A systematic pre-fitting examination also facilitates individualised lens design and provides baseline measurements for monitoring treatment response [10,12,15].

The assessment begins with a detailed medical and ocular history. Information regarding the age of myopia onset, rate of refractive progression, previous spectacle or contact lens wear, family history of high myopia or corneal ectasia, systemic diseases, medication use, ocular allergies, previous ocular surgery, and occupational or lifestyle requirements should be documented. In pediatric patients, documenting annual myopic progression and parental myopia is particularly important because these factors are strongly associated with future axial elongation and the expected response to myopia-control interventions [15,16].

Baseline visual function should be evaluated by measuring uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), binocular vision status, and accommodative function. Accurate objective and subjective refraction should then be performed to determine the refractive error requiring correction. Cycloplegic refraction is recommended in children and adolescents to eliminate accommodative fluctuations and accurately quantify the true refractive status. The spherical equivalent remains the principal parameter used to estimate the intended amount of corneal reshaping and to guide initial lens parameter selection [3,12].

Keratometry provides important baseline information regarding central corneal curvature and the magnitude and orientation of corneal astigmatism. However, computerised corneal topography has become indispensable in contemporary orthokeratology practice because it offers a detailed evaluation of corneal curvature, sagittal height, eccentricity, elevation profile, and anterior surface symmetry. Topographic analysis enables early detection of keratoconus, pellucid marginal degeneration, irregular astigmatism, and other corneal abnormalities that may contraindicate treatment. In addition, modern fitting software incorporates topographic data to generate individualised reverse-geometry lens designs and improve treatment predictability [12,20].

A comprehensive slit-lamp biomicroscopic examination should be performed to assess the health of the anterior segment. Particular attention should be directed toward the eyelid margins, meibomian glands, conjunctiva, corneal epithelium, limbus, and tear film. Conditions such as blepharitis, meibomian gland dysfunction, allergic conjunctivitis, corneal scars, epithelial defects, or active ocular inflammation should be identified and appropriately managed before orthokeratology is initiated. Establishing a healthy ocular surface before treatment substantially reduces the risk of discomfort, corneal staining, and infectious complications during overnight lens wear [10,21].

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Evaluation of tear-film quality is equally important because the therapeutic effect of orthokeratology depends on the hydraulic forces generated within the post-lens tear reservoir. Tear break-up time, tear meniscus height, and, when indicated, Schirmer testing should be performed to identify aqueous-deficient or evaporative dry eye disease. An unstable tear film may compromise lens centration, reduce treatment effectiveness, increase visual fluctuations, and predispose patients to epithelial staining and contact lens intolerance [12,20].

Assessment of pupil diameter under both photopic and mesopic conditions is recommended because optical zone diameter should adequately cover the entrance pupil under low illumination. Patients with relatively large mesopic pupils are more likely to experience glare, halos, and reduced contrast sensitivity if the treatment zone is insufficient. Corneal pachymetry may also be performed to establish baseline corneal thickness and exclude corneal thinning disorders. Although orthokeratology primarily induces epithelial redistribution rather than stromal remodelling, baseline pachymetric measurements provide valuable information regarding corneal safety and future monitoring [3,13].

Following completion of the clinical examination, all refractive and corneal measurements are integrated to determine the most appropriate lens diameter, base curve, reverse-curve geometry, alignment curve, and treatment-zone diameter. Many practitioners subsequently perform diagnostic trial lens fitting to evaluate lens centration, movement, fluorescein distribution, and overall fitting characteristics before ordering a customised lens. The characteristic bull's-eye fluorescein pattern, consisting of mild central touch, a well-defined reverse-curve tear reservoir, an evenly aligned landing zone, and adequate peripheral edge lift, remains the clinical hallmark of an optimal orthokeratology fit [12,20].

Patient education represents the final component of the pre-fitting evaluation. Patients and parents should receive comprehensive counselling regarding the temporary nature of treatment, overnight wearing schedule, expected adaptation period, proper lens handling and hygiene, potential adverse events, and the importance of regular follow-up examinations. Effective counselling improves compliance, reduces treatment discontinuation, and contributes significantly to successful long-term myopia management [15,21].

A meticulous pre-fitting evaluation therefore provides the basis for individualised orthokeratology treatment by ensuring accurate lens selection, predictable corneal reshaping, early recognition of contraindications, and safe long-term clinical outcomes.

Fitting methodologies of orthokeratology lenses

Successful orthokeratology depends on accurate lens fitting, as even minor deviations in lens centration or sagittal depth can influence visual outcomes, treatment-zone quality, and patient comfort. Modern orthokeratology fitting aims to achieve controlled epithelial redistribution through an optimally designed reverse-geometry lens that maintains stable centration, adequate tear exchange, and appropriate hydraulic forces beneath the lens. Contemporary fitting strategies can be broadly categorised into empirical fitting, diagnostic (trial lens) fitting, and hybrid fitting, each with distinct advantages depending on clinical experience, instrumentation, and corneal characteristics [3,12,20].

Empirical fitting has become the preferred approach in many clinical practices owing to advances in computerised corneal topography and manufacturer-specific fitting software. This method utilises patient-specific clinical data, including manifest refraction, keratometry, corneal topography, horizontal visible iris diameter, pupil diameter, corneal eccentricity, and sagittal height, to generate an individualised lens design without the need for an initial diagnostic lens. The fitting software calculates the base curve, reverse curve, alignment curve, peripheral curve, and overall lens diameter while simultaneously predicting the anticipated refractive correction and treatment-zone characteristics. The resulting customised lens generally provides excellent initial fitting accuracy and reduces chair time, making empirical fitting particularly suitable for routine clinical practice [12,20].

Despite these advantages, empirical fitting relies heavily on the quality of corneal topography and the accuracy of software algorithms. Errors in topographic acquisition or incorrect patient measurements may lead to suboptimal lens parameters, necessitating subsequent modifications. Consequently, clinicians should carefully verify topographic data before ordering customised lenses and reassess lens performance after the first overnight wear [12].

Diagnostic or trial-lens fitting remains an important technique, particularly in eyes with irregular corneal morphology, borderline topographic findings, or previous fitting failures. In this approach, an appropriately selected reverse-geometry trial lens is applied to the eye and allowed to stabilise before evaluation. Lens performance is assessed using fluorescein sodium, which reveals the interaction between the posterior lens surface and the cornea. An ideal orthokeratology fit demonstrates the characteristic bull's-eye fluorescein pattern consisting of mild central touch or alignment, a bright annular pooling zone corresponding to the reverse curve, a uniformly aligned landing zone, and adequate peripheral edge lift to permit tear exchange. This pattern reflects appropriate hydraulic forces required for predictable epithelial redistribution and corneal reshaping [3,12].

Abnormal fluorescein patterns provide valuable information for modifying lens parameters. Excessive central bearing may indicate an overly flat lens, whereas excessive central pooling suggests excessive sagittal depth or an overly steep fit. Inferior or superior decentration may result from inadequate alignment, excessive corneal toricity, or inappropriate lens diameter. Adjustments to the base curve, reverse-curve depth, alignment curve, or overall lens diameter are therefore performed iteratively until satisfactory lens centration and fluorescein distribution are achieved [20,21].

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Many contemporary orthokeratology practitioners employ a hybrid fitting strategy that combines the advantages of empirical and diagnostic approaches. Initial lens parameters are generated using computerised topography and fitting software, after which diagnostic evaluation is performed to verify centration, fluorescein pattern, lens movement, and treatment-zone location. Minor modifications can then be incorporated before ordering the final customised lens. This combined approach improves first-fit success rates, reduces the number of lens remakes, and provides greater predictability, particularly in patients with moderate astigmatism or atypical corneal geometry [12,20].

Regardless of the fitting methodology employed, several principles remain fundamental for successful orthokeratology. The lens should demonstrate stable centration over the visual axis, minimal movement during blinking, appropriate sagittal depth, adequate tear exchange, and an evenly distributed treatment zone. Poorly fitted lenses may result in decentered treatment zones, residual refractive error, induced corneal astigmatism, glare, halos, ghosting, or reduced treatment efficacy. Careful interpretation of fluorescein patterns together with serial corneal topography remains essential for confirming successful corneal reshaping and guiding subsequent lens modifications [3,12,21].

Recent technological advances have further refined orthokeratology fitting. Modern software platforms incorporate three-dimensional corneal tomography, epithelial thickness mapping, and artificial intelligence-based algorithms to improve lens parameter selection and predict treatment response. Emerging evidence suggests that these technologies enhance lens centration, reduce fitting time, improve first-lens success rates, and facilitate personalised myopia management. As digital technologies continue to evolve, individualised fitting strategies are expected to further improve the safety, predictability, and long-term effectiveness of orthokeratology [18,20].

Overall, accurate lens fitting remains the cornerstone of successful orthokeratology. Integration of comprehensive clinical assessment, advanced corneal imaging, computerised fitting algorithms, and careful post-fitting evaluation enables clinicians to achieve predictable refractive correction while maximising the effectiveness of myopia control and minimising treatment-related complications.

Safe limits of correction with orthokeratology

The effectiveness of orthokeratology is influenced by the magnitude of refractive error, corneal morphology, lens design, and patient-specific ocular characteristics. Although continuous advances in reverse-geometry lens technology have expanded the range of treatable refractive errors, orthokeratology remains most predictable in patients with low-to-moderate myopia. Careful adherence to established correction limits is essential to achieve stable visual outcomes while minimising the risk of lens decentration, optical aberrations, and corneal complications [3,12,20].

Current evidence indicates that orthokeratology provides the most reliable correction for myopia up to approximately -6.00 D. Patients with refractive errors between -1.00 D and -4.00 D generally achieve rapid visual improvement, excellent daytime unaided visual acuity, and stable treatment outcomes. Correction of myopia exceeding -6.00 D is possible using customised reverse-geometry lens designs; however, treatment becomes progressively less predictable because greater corneal reshaping is required. In such cases, residual refractive error, reduced treatment-zone quality, increased higher-order aberrations, glare, halos, and regression of visual correction may occur more frequently [3,12,20].

Astigmatism also influences treatment success. Conventional spherical orthokeratology lenses effectively manage low degrees of regular with-the-rule astigmatism, generally up to 1.50 D. Recent developments in toric peripheral alignment and quadrant-specific lens designs have expanded the treatment range to approximately 2.50 D in selected patients with regular corneal toricity. Nevertheless, increasing astigmatism reduces treatment predictability and may predispose patients to lens decentration and asymmetric treatment zones, emphasising the importance of individualised lens design and careful topographic evaluation [12,20].

Although orthokeratology is primarily indicated for myopia, specialised reverse-geometry lens designs have also been developed for the temporary correction of low hyperopia. Hyperopic orthokeratology typically steepens the central cornea rather than flattening it and is generally limited to corrections of approximately +2.00 D. Compared with myopic orthokeratology, clinical evidence supporting hyperopic treatment remains limited, and long-term refractive stability is less well established [3,21].

Several anatomical and biomechanical factors determine the maximum safe correction achievable with orthokeratology. These include baseline corneal curvature, corneal eccentricity, sagittal height, epithelial thickness, central corneal thickness, tear-film quality, pupil diameter, lens centration, and oxygen transmissibility of the lens material (Dk/t). Eyes with regular prolate corneas, adequate epithelial thickness, stable tear film, and appropriate corneal biomechanics generally demonstrate the most predictable treatment response. Conversely, irregular corneal topography, unstable tear film, or compromised ocular surface health may limit treatment effectiveness regardless of refractive error [10,12].

Attempting excessive refractive correction beyond recommended limits may compromise both visual quality and corneal health. Excessive epithelial redistribution can result in decentered treatment zones, central islands, irregular corneal flattening, increased higher-order aberrations, glare, halos, ghosting, fluctuating vision, and delayed visual stabilisation. Although stromal remodelling is minimal in properly fitted orthokeratology, excessive sagittal depth or poor lens centration may increase epithelial stress, leading to superficial punctate keratopathy, corneal staining, or lens binding [3,20,21].

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For patients with high myopia exceeding the recommended treatment range, partial correction with orthokeratology combined with spectacles or soft contact lenses during the day may provide satisfactory visual rehabilitation while maintaining the benefits of peripheral myopic defocus. Combination therapy with low-dose atropine has also demonstrated additional efficacy in slowing axial elongation and may be considered in children with rapidly progressive myopia who remain at high risk despite optical treatment alone [15,16,18].

Successful orthokeratology therefore depends not only on the magnitude of refractive correction but also on individualised assessment of ocular anatomy and careful lens design. Adhering to evidence-based correction limits, together with regular clinical monitoring and appropriate patient counselling, ensures predictable refractive outcomes while maintaining long-term corneal health and maximising the effectiveness of myopia control.

Orthokeratology lens materials and overnight wear protocol

The success of orthokeratology depends not only on appropriate lens design but also on the material properties of the lens and adherence to a standardised overnight wear protocol. Modern orthokeratology lenses are manufactured from high oxygen-permeable rigid gas-permeable (RGP) materials, primarily fluorosilicone acrylate polymers, which provide adequate oxygen transmission to the cornea during overnight wear. High oxygen transmissibility (Dk/t), rather than oxygen permeability (Dk) alone, is considered the most important parameter because it reflects the amount of oxygen reaching the cornea through the lens during closed-eye conditions. Adequate Dk/t minimises the risk of hypoxia, corneal oedema, and other physiological complications associated with extended wear [3,10,12].

Contemporary orthokeratology lenses incorporate reverse-geometry designs consisting of a flatter central base curve, a steeper reverse curve, an alignment zone, and a peripheral curve. Together, these zones establish controlled tear-film hydraulics that promote central epithelial thinning and mid-peripheral epithelial thickening while maintaining lens stability and tear exchange. Recent improvements in manufacturing precision and computer-assisted customisation have enabled individualised lens designs that improve centration, reduce higher-order aberrations, and enhance visual quality [12,20].

Although several commercial orthokeratology lens systems are available internationally, clinical success depends primarily on the fitting philosophy and lens design rather than the manufacturer. Modern lens systems differ mainly in software algorithms, reverse-geometry configuration, and customisation options. Therefore, clinicians should select a lens design based on corneal topography, sagittal height, refractive error, and clinical experience rather than brand preference alone [12,20].

Orthokeratology lenses are designed exclusively for overnight wear. Patients are typically instructed to insert the lenses approximately 15–30 minutes before bedtime to allow stabilisation before sleep. Overnight wear of approximately 6–8 hours is generally sufficient to induce adequate corneal reshaping and provide functional daytime vision after lens removal. Shorter wearing periods may produce incomplete refractive correction, whereas unnecessarily prolonged wear provides little additional benefit and may increase physiological stress on the cornea [10,21].

Upon awakening, lenses should be removed promptly after instillation of lubricating drops if necessary to reduce lens adherence. Following removal, the lenses should be cleaned using an approved rigid gas-permeable lens cleaner, rinsed with sterile saline or a recommended multipurpose solution, and stored in fresh disinfecting solution. Tap water should never be used for cleaning, rinsing, or storing orthokeratology lenses because exposure to water significantly increases the risk of microbial contamination, including *Acanthamoeba* infection [10,21].

Successful overnight orthokeratology also requires strict adherence to a structured follow-up schedule. The first examination is generally performed on the morning after the initial overnight wear to evaluate unaided visual acuity, lens centration, corneal staining, and topographic changes. Subsequent visits are commonly scheduled after one week, one month, three months, and every six months thereafter, although the frequency may be adjusted according to patient age, myopia progression, and clinical findings. At each visit, clinicians should assess visual acuity, residual refractive error, corneal topography, lens fit, tear-film stability, and ocular surface health to ensure continued treatment effectiveness and detect early complications [12,15,20].

Patient education remains a critical component of successful overnight wear. Individuals should be instructed to maintain meticulous hand hygiene before handling lenses, avoid overnight wear during episodes of ocular infection or significant redness, replace lens cases regularly, and immediately report symptoms such as pain, redness, photophobia, excessive tearing, discharge, or sudden visual deterioration. Prompt recognition and management of these symptoms substantially reduce the likelihood of sight-threatening complications associated with overnight lens wear [10,21].

Current evidence indicates that orthokeratology is a safe and effective treatment when high Dk/t lens materials are combined with appropriate patient selection, individualised lens fitting, strict hygiene practices, and regular clinical monitoring. Standardised overnight wear protocols therefore remain essential for maximising visual outcomes while preserving long-term corneal health and minimising treatment-related complications [10,12,20].

Follow-up and monitoring

Regular follow-up is an integral component of orthokeratology because successful treatment depends on continuous assessment of corneal health, treatment efficacy, lens performance, and patient compliance. Unlike conventional

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refractive correction, orthokeratology induces reversible corneal remodelling through overnight lens wear; therefore, periodic clinical evaluation is essential to ensure that corneal reshaping remains stable while minimising the risk of treatment-related complications. Consistent follow-up also enables early identification of inadequate treatment response, lens decentration, or ocular surface abnormalities before permanent damage occurs [10,12,15].

The first follow-up examination is typically scheduled on the morning after the initial overnight lens wear. During this visit, clinicians should assess unaided visual acuity, residual refractive error, lens centration, corneal staining, tear-film integrity, and corneal topography. Early topographic evaluation confirms whether the intended treatment zone has been established and whether the lens has remained appropriately centred throughout the night. The presence of a well-centred treatment zone with symmetrical mid-peripheral steepening generally indicates successful initial corneal reshaping [12,20].

Subsequent follow-up examinations are commonly performed after one week and one month of treatment, followed by reviews every three to six months depending on patient age, rate of myopia progression, and clinical stability. Pediatric patients undergoing myopia control often require more frequent monitoring because axial elongation should be evaluated regularly to determine treatment effectiveness and identify children who may benefit from additional interventions such as combination therapy with low-dose atropine [15,16].

Each follow-up visit should include a comprehensive assessment of visual function. Unaided daytime visual acuity should be measured together with objective and subjective refraction to determine residual refractive error and treatment stability. Patients should also be questioned regarding fluctuations in vision throughout the day, symptoms of glare or halos, and overall visual satisfaction. These findings help determine whether lens parameters require modification or whether treatment remains clinically effective [3,12].

Slit-lamp biomicroscopy remains one of the most important components of follow-up assessment. Careful examination should evaluate corneal epithelial integrity, conjunctival health, tear-film quality, eyelid margins, and lens-related changes such as corneal staining, epithelial defects, infiltrates, oedema, lens binding, or conjunctival hyperemia. Early recognition of these findings permits timely intervention and substantially reduces the likelihood of serious complications associated with overnight lens wear [10,21].

Corneal topography should be performed routinely because it provides objective documentation of treatment progression and lens performance. Successful orthokeratology typically demonstrates central corneal flattening surrounded by a symmetrical annular zone of mid-peripheral steepening. Progressive decentration, irregular treatment zones, central islands, or asymmetrical flattening patterns may indicate suboptimal lens fit and require modification of the base curve, alignment curve, or overall lens diameter. Serial topographic maps also facilitate long-term monitoring of treatment stability and assist clinicians in identifying subtle changes before they become clinically significant [12,20].

Lens performance should also be evaluated at every review. Appropriate centration, adequate tear exchange, minimal movement after blinking, and an acceptable fluorescein pattern indicate satisfactory lens fit. Poor centration or excessive lens movement may reduce treatment effectiveness, increase higher-order aberrations, and predispose patients to mechanical complications. Examination of the lens surface for deposits, scratches, or manufacturing defects is equally important because damaged lenses may compromise visual quality and corneal health [10,12].

Patient compliance should be reassessed during every follow-up visit. Clinicians should review overnight wearing time, cleaning and disinfection procedures, storage practices, replacement schedules, and adherence to follow-up appointments. Reinforcement of appropriate hygiene remains one of the most effective strategies for preventing microbial keratitis and other contact lens-related complications. Particular attention should be given to pediatric patients, in whom parental supervision remains essential for maintaining long-term treatment success [15,21].

Patients should be advised to seek immediate ophthalmic evaluation if they experience severe pain, redness, photophobia, excessive tearing, purulent discharge, sudden reduction in vision, or inability to remove the lens. These symptoms may indicate potentially sight-threatening complications such as infectious keratitis or significant corneal epithelial injury that require urgent management. Early diagnosis and prompt treatment remain the most important factors in preserving visual outcomes [10,21].

Overall, systematic follow-up and continuous monitoring are indispensable components of orthokeratology management. Regular clinical evaluation enables assessment of treatment effectiveness, confirmation of appropriate corneal reshaping, maintenance of ocular surface health, reinforcement of patient compliance, and early detection of complications, thereby ensuring the long-term safety and success of orthokeratology for both refractive correction and myopia control [10,12,15].

Corneal topography interpretation

Corneal topography is the cornerstone of orthokeratology practice and is indispensable for patient selection, lens fitting, assessment of treatment efficacy, and long-term monitoring. Unlike conventional keratometry, which measures only the central cornea, computerised corneal topography provides a comprehensive evaluation of corneal curvature, elevation, eccentricity, and surface regularity. These measurements enable clinicians to design individualised reverse-geometry lenses, monitor corneal reshaping, and identify complications at an early stage. Consequently, serial topographic analysis has become an essential component of evidence-based orthokeratology management [12,20].

Before treatment, corneal topography is used to determine the suitability of the cornea for orthokeratology. A regular,

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symmetrical, and prolate corneal profile generally predicts successful treatment, whereas irregular astigmatism, keratoconus, pellucid marginal degeneration, or significant corneal asymmetry are considered contraindications because they compromise lens centration and treatment predictability. Baseline topographic measurements also provide valuable information regarding corneal curvature, sagittal height, eccentricity, and corneal toricity, all of which influence lens selection and treatment planning [3,12].

Several topographic display modes are routinely used during orthokeratology practice. Axial (sagittal) maps provide an overview of global corneal curvature and are useful for initial patient assessment. Tangential maps demonstrate localised curvature changes with greater sensitivity and are particularly valuable for evaluating treatment-zone shape and centration. Difference maps compare pre-treatment and post-treatment corneal profiles, allowing objective assessment of epithelial redistribution and corneal flattening. Elevation maps and refractive power maps further assist in understanding corneal morphology and monitoring treatment progression [12,20].

Successful orthokeratology produces a characteristic topographic appearance. Central corneal flattening appears as a circular blue or green treatment zone surrounded by an annular ring of mid-peripheral steepening represented by warmer colours. This "bull's-eye" pattern reflects symmetrical epithelial redistribution and indicates appropriate lens centration. The treatment zone should be circular, centrally positioned over the visual axis, and demonstrate smooth transition zones without localised distortion. Such findings are generally associated with optimal unaided visual acuity, stable refractive correction, and effective peripheral myopic defocus [3,12].

Deviation from the ideal topographic pattern often indicates suboptimal lens fitting. Inferior displacement of the treatment zone produces the characteristic "smiley-face" pattern, whereas superior displacement creates the "frowny-face" appearance. Both patterns are associated with lens decentration and may result in ghosting, glare, monocular diplopia, or reduced visual quality. A central island, characterised by localised central steepening surrounded by flattening, usually reflects excessive sagittal depth, inadequate tear exchange, or an excessively steep lens fit. Oval or irregular treatment zones may occur in eyes with significant corneal toricity or poor lens centration and frequently require modification of the lens design [12,20,21].

Corneal topography also plays a critical role in monitoring long-term treatment stability. Serial examinations enable clinicians to assess changes in treatment-zone diameter, centration, corneal curvature, epithelial remodelling, and refractive stability. Progressive decentration, increasing corneal asymmetry, or irregular flattening patterns may indicate lens warpage, inadequate fit, or poor patient compliance. Early recognition of these changes allows timely modification of lens parameters before clinically significant visual symptoms develop [10,12].

In addition to evaluating treatment success, corneal topography facilitates early detection of complications. Irregular corneal moulding, induced astigmatism, lens decentration, epithelial warpage, and unstable treatment zones are often detectable on topographic maps before they become apparent on routine clinical examination. Integration of topographic findings with slit-lamp biomicroscopy and fluorescein assessment therefore provides a comprehensive evaluation of both corneal health and lens performance [20,21].

Recent technological advances have further enhanced the role of corneal imaging in orthokeratology. High-resolution Scheimpflug tomography, anterior-segment optical coherence tomography, and epithelial thickness mapping now permit detailed evaluation of epithelial redistribution and corneal biomechanics. These imaging modalities improve understanding of the mechanisms underlying corneal reshaping, facilitate individualised lens design, and contribute to more predictable treatment outcomes. As imaging technologies continue to evolve, their integration into routine orthokeratology practice is expected to further improve treatment precision and long-term myopia management [18,20].

Overall, corneal topography remains the most valuable diagnostic and monitoring tool in orthokeratology. Accurate interpretation of topographic changes enables appropriate patient selection, individualised lens fitting, objective assessment of treatment effectiveness, early recognition of complications, and optimisation of long-term visual outcomes.

Complications and their management

Orthokeratology is widely regarded as a safe and effective treatment for temporary refractive correction and myopia control when appropriate patient selection, meticulous lens fitting, strict hygiene, and regular follow-up are maintained. Although most adverse events are mild and reversible, complications may occur as a result of overnight lens wear, poor compliance, inadequate lens care, or inappropriate lens fitting. Early recognition and timely intervention are therefore essential to preserve corneal integrity and maintain long-term treatment success [10,12,21].

Mechanical complications are among the most frequently encountered adverse events during orthokeratology. Superficial corneal staining is commonly observed during the early stages of treatment and is generally associated with excessive lens bearing, poor tear exchange, dry eye, or minor fitting errors. Most cases resolve following temporary discontinuation of lens wear, optimisation of lens parameters, and intensive lubrication with preservative-free artificial tears. Persistent staining requires reassessment of lens centration and fluorescein patterns to identify the underlying fitting abnormality [10,21].

Lens binding is another relatively common complication resulting from excessive sagittal depth, inadequate tear exchange, or prolonged overnight wear. Patients typically present with difficulty removing the lens, discomfort upon awakening, and transient blurred vision. Management includes instillation of lubricating drops before lens removal, gentle

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removal techniques using a suction device when necessary, and modification of the alignment curve or edge lift to improve tear circulation beneath the lens [12,20].

Physiological complications primarily result from inadequate oxygen delivery to the cornea during overnight wear. Although modern orthokeratology lenses are manufactured from highly oxygen-permeable materials, corneal oedema may occasionally occur in association with reduced oxygen transmissibility (Dk/t), excessive wearing time, or poor tear exchange. Clinically, patients may experience blurred vision, corneal haze, epithelial microcysts, or stromal folds. Management involves temporary discontinuation of lens wear, reassessment of lens fit, and consideration of a higher oxygen-transmissible lens material if required [3,10].

Dry eye symptoms and tear-film instability may also develop during orthokeratology, particularly in patients with pre-existing ocular surface disease or meibomian gland dysfunction. Symptoms include ocular dryness, foreign-body sensation, fluctuating vision, and reduced wearing comfort. Treatment consists of optimising eyelid hygiene, managing meibomian gland dysfunction, prescribing preservative-free lubricants, and addressing any underlying ocular surface disorder before resuming overnight lens wear [12,21].

Lens-fitting complications may significantly compromise both visual outcomes and treatment efficacy. Decentered treatment zones are among the most common fitting-related problems and frequently produce glare, halos, monocular diplopia, ghosting, and reduced visual quality. Corneal topography typically demonstrates asymmetrical central flattening displaced from the visual axis. Management involves reassessment of sagittal depth, alignment curve design, lens diameter, and overall centration. Similarly, central islands, characterised by localised central steepening surrounded by flattening, usually result from excessive sagittal depth or inadequate tear exchange and may require flattening of the base curve or modification of reverse-curve geometry [12,20].

Visual disturbances represent another important category of complications. During the adaptation period, patients may report glare, halos, reduced contrast sensitivity, or fluctuating vision, particularly under mesopic conditions. These symptoms are usually associated with treatment-zone decentration, small optical zones relative to pupil diameter, residual refractive error, or increased higher-order aberrations. Careful adjustment of treatment-zone diameter, optimisation of lens centration, and individualised lens customisation generally improve visual quality over time [18,20].

Although uncommon, infectious keratitis remains the most serious complication associated with overnight orthokeratology. The majority of reported cases have been associated with poor hygiene practices, inappropriate lens care, exposure of lenses to tap water, prolonged lens wear, or failure to attend follow-up appointments. Patients typically present with severe ocular pain, redness, photophobia, purulent discharge, and rapid deterioration of vision. Immediate discontinuation of lens wear, urgent ophthalmic evaluation, microbiological investigation when indicated, and prompt initiation of intensive topical antimicrobial therapy are essential to prevent permanent visual loss [10,21].

Inflammatory complications such as sterile corneal infiltrates and contact lens-induced Inflammatory complications such as sterile corneal infiltrates and contact lens-induced peripheral ulcers may occasionally occur despite the absence of active infection. These conditions generally result from mechanical irritation, hypersensitivity reactions, or inflammatory responses to bacterial antigens. Management depends on the underlying cause and may include temporary discontinuation of lens wear, topical anti-inflammatory therapy, lubrication, and modification of lens fit after resolution of inflammation [12,20].

The incidence of complications can be substantially reduced through careful patient selection, individualised lens fitting, comprehensive patient education, and strict adherence to hygiene recommendations. Patients should be instructed to wash and dry their hands before handling lenses, avoid exposing lenses to tap water, replace lens cases regularly, comply with recommended disinfection protocols, and discontinue lens wear immediately if symptoms of ocular discomfort or redness develop. Reinforcement of these recommendations during every follow-up visit remains one of the most effective preventive strategies [10,15].

Overall, contemporary evidence indicates that orthokeratology has a favourable safety profile when practised according to established clinical guidelines. Most complications are mild, reversible, and readily managed through timely intervention, whereas sight-threatening events are uncommon and largely preventable through appropriate patient education, regular monitoring, meticulous hygiene, and evidence-based clinical management [10,12,15,21].

Pediatric orthokeratology

Pediatric orthokeratology has emerged as one of the most effective non-pharmacological interventions for controlling childhood myopia. With the global prevalence of myopia increasing at an unprecedented rate, particularly in East and Southeast Asia, early intervention has become a major public health priority. Progressive childhood myopia is associated with excessive axial elongation, which substantially increases the lifetime risk of vision-threatening complications, including retinal detachment, myopic macular degeneration, glaucoma, posterior staphyloma, choroidal neovascularisation, and early cataract. Consequently, contemporary myopia management focuses not only on correcting refractive error but also on slowing axial eye growth during childhood [15,16].

Orthokeratology achieves this objective by temporarily reshaping the anterior corneal surface during overnight lens wear. Central corneal flattening corrects the refractive error, while mid-peripheral corneal steepening produces relative peripheral myopic defocus. Experimental and clinical evidence suggests that peripheral myopic defocus modifies retinal signalling pathways involved in ocular growth regulation,

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thereby reducing axial elongation. Although the precise biological mechanisms continue to be investigated, alterations in retinal dopamine release, choroidal thickness, and scleral remodelling are believed to contribute to the therapeutic effect [3,12,18].

Numerous randomised clinical trials and long-term cohort studies have demonstrated that orthokeratology significantly reduces axial elongation compared with conventional single-vision spectacle correction. Landmark studies, including the Longitudinal Orthokeratology Research in Children (LORIC), Retardation of Myopia in Orthokeratology (ROMIO), and subsequent meta-analyses, have consistently reported reductions in axial elongation of approximately 30–60%, confirming orthokeratology as one of the most effective optical interventions for childhood myopia control [2,3,7,8].

Children most likely to benefit from orthokeratology are those between 6 and 16 years of age with documented progressive myopia, particularly progression exceeding approximately 0.50 D per year. Additional factors supporting treatment include a positive family history of high myopia, increasing axial length, participation in sports or outdoor activities where spectacle independence is desirable, and motivation of both the child and parents to comply with treatment recommendations. Careful patient selection remains essential because treatment success depends on appropriate corneal anatomy, healthy ocular surface, regular corneal topography, and stable tear-film function [15,16].

Comprehensive pre-treatment assessment should include cycloplegic refraction, keratometry, computerised corneal topography, slit-lamp biomicroscopy, tear-film evaluation, mesopic pupil diameter, and axial length measurement whenever possible. Baseline axial length has become an increasingly important parameter because it provides an objective indicator of myopia progression and allows clinicians to evaluate treatment efficacy throughout follow-up. Serial axial length measurements are now considered an essential component of evidence-based pediatric myopia management [15,20].

Successful treatment requires careful parental involvement throughout the entire course of therapy. Parents should supervise lens insertion and removal, ensure appropriate cleaning and disinfection procedures, monitor compliance with overnight wear, and encourage attendance at scheduled follow-up appointments. They should also be educated regarding early symptoms of potential complications, including ocular pain, redness, photophobia, excessive tearing, or sudden visual deterioration, which require immediate ophthalmic evaluation [10,21].

Clinical follow-up generally includes examinations on the morning after initial lens wear, after one week, one month, three months, and every six months thereafter. Each visit should include assessment of unaided visual acuity, residual refractive error, slit-lamp biomicroscopy, corneal topography, lens performance, ocular surface health, and axial length progression. Regular monitoring enables early detection of complications while allowing clinicians to evaluate the effectiveness of myopia control and modify treatment when necessary [12,15].

Recent evidence suggests that combining orthokeratology with low-dose atropine may provide greater reductions in axial elongation than either intervention alone. Several randomised controlled trials have demonstrated additional benefits with atropine concentrations ranging from 0.01% to 0.05%, particularly in children exhibiting rapid progression despite orthokeratology. Although long-term evidence is still emerging, combination therapy has become an increasingly important strategy in individualised myopia management [16,18].

The safety profile of pediatric orthokeratology is favourable when treatment is provided by experienced practitioners and supported by meticulous hygiene, individualised lens fitting, and regular follow-up. Most complications, including superficial corneal staining, lens binding, and transient visual disturbances, are mild and reversible. Serious complications such as microbial keratitis remain uncommon and are largely associated with poor compliance, inadequate hygiene, or delayed clinical review rather than the treatment itself [10,12,21].

Overall, pediatric orthokeratology has become an integral component of contemporary myopia management. Its ability to provide clear daytime vision while simultaneously slowing axial elongation makes it one of the most effective and evidence-based strategies for reducing the long-term burden of high myopia. Continued advances in lens technology, ocular imaging, and combination treatment strategies are expected to further improve its effectiveness and expand its role in preventive pediatric eye care.

Contraindications of orthokeratology

Although orthokeratology is considered a safe and effective treatment for temporary refractive correction and myopia control, careful identification of contraindications is essential before initiating therapy. Successful treatment depends on healthy corneal anatomy, a stable ocular surface, adequate tear-film function, and the patient's ability to comply with overnight lens wear and hygiene protocols. Failure to recognise contraindications may increase the risk of treatment failure, ocular complications, and vision-threatening infections [10,12,15].

Absolute ocular contraindications include active anterior segment infections such as bacterial, viral, or fungal keratitis, conjunctivitis, corneal ulcers, and significant blepharitis. Overnight contact lens wear in the presence of active infection may exacerbate inflammation, delay healing, and substantially increase the risk of microbial keratitis. Orthokeratology should therefore be postponed until complete resolution of the ocular disease has been achieved [10,21].

Patients with corneal ectatic disorders, including keratoconus, pellucid marginal degeneration, or advanced irregular astigmatism, are generally unsuitable candidates

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because abnormal corneal biomechanics prevent predictable corneal reshaping and increase the likelihood of lens decentration and poor visual outcomes. Similarly, significant corneal scarring, dystrophies, degenerations, or previous corneal surgery that alters corneal architecture may compromise treatment safety and effectiveness [3,12].

Severe dry eye disease represents another important contraindication. Successful orthokeratology depends on a stable tear film to maintain appropriate post-lens tear hydraulics, facilitate epithelial redistribution, and ensure adequate lens centration. Patients with aqueous-deficient or evaporative dry eye frequently experience reduced comfort, unstable vision, excessive corneal staining, and increased susceptibility to inflammatory complications. Mild dry eye may be managed before treatment initiation; however, severe ocular surface disease should generally be considered a contraindication until adequately controlled [12,20].

Chronic allergic eye disease, particularly vernal keratoconjunctivitis and severe allergic conjunctivitis, may also preclude orthokeratology because persistent ocular itching encourages eye rubbing, destabilises lens position, and increases the risk of epithelial injury. Active allergic inflammation should be effectively treated before overnight lens wear is considered [10,21].

Reduced corneal sensitivity caused by neurotrophic keratopathy, previous herpetic keratitis, or systemic neuropathies represents an additional contraindication. Because these patients may fail to recognise early symptoms of epithelial injury or infection, delayed presentation can lead to severe corneal complications and permanent visual impairment [21].

Certain systemic conditions may also influence candidacy for orthokeratology. Autoimmune diseases such as rheumatoid arthritis, systemic lupus erythematosus, and Sjögren syndrome may impair tear production and corneal healing, while uncontrolled diabetes mellitus can delay epithelial regeneration and increase susceptibility to infection. Immunocompromised individuals receiving chemotherapy, long-term corticosteroid therapy, or immunosuppressive medications should be managed cautiously because of their increased risk of infectious complications [10,15].

Patient-related factors are equally important when determining suitability for treatment. Poor personal hygiene, inability to handle lenses appropriately, unwillingness to comply with cleaning and disinfection protocols, and irregular attendance at follow-up appointments substantially increase the likelihood of adverse events. In pediatric patients, inadequate parental supervision may compromise compliance and lens care, reducing treatment effectiveness and increasing the risk of complications [15,16].

Psychological and behavioural considerations should also be evaluated before treatment initiation. Patients expecting permanent refractive correction, immediate visual perfection, or freedom from follow-up are unlikely to be satisfied with orthokeratology. Comprehensive counselling regarding the temporary and reversible nature of treatment, the necessity of consistent overnight wear, and the importance of regular clinical monitoring is therefore essential for establishing realistic expectations and promoting long-term adherence [12,20].

Some conditions should be regarded as relative rather than absolute contraindications. Mild dry eye disease, moderate regular astigmatism, large mesopic pupil diameter, controlled ocular allergy, and occupational exposure to dusty environments may not preclude treatment but require individualised lens design, careful patient education, and closer clinical monitoring. Advances in customised lens designs and modern fitting techniques have expanded the range of patients who may safely undergo orthokeratology despite these challenges [12,20].

Overall, careful identification of contraindications remains fundamental to safe orthokeratology practice. Comprehensive ocular examination, appropriate patient counselling, and individualised clinical decision-making enable practitioners to minimise complications, optimise treatment outcomes, and ensure the long-term success of orthokeratology for refractive correction and myopia control [10,12,15,21].

Evidence-based clinical outcomes and future directions

Orthokeratology has become one of the most extensively investigated optical interventions for myopia control, supported by a substantial body of evidence from randomised controlled trials, prospective cohort studies, systematic reviews, and meta-analyses. Contemporary research consistently demonstrates that orthokeratology not only provides temporary refractive correction but also significantly slows axial elongation, thereby reducing the progression of childhood myopia and the future risk of sight-threatening ocular complications [2,3,7,8].

The principal outcome measure in modern myopia research is axial length progression rather than refractive error alone. Numerous clinical trials have demonstrated that children wearing orthokeratology lenses exhibit significantly slower axial elongation than those using single-vision spectacles or conventional soft contact lenses. Landmark studies, including the Longitudinal Orthokeratology Research in Children (LORIC), Retardation of Myopia in Orthokeratology (ROMIO), and subsequent multicenter investigations, have reported reductions in axial elongation ranging from approximately 30% to 60%, with the greatest treatment benefits observed in younger children and those with rapidly progressive myopia [2-4,7].

In addition to slowing ocular growth, orthokeratology provides excellent daytime visual performance by eliminating the need for spectacles or daytime contact lenses. Most patients achieve functional unaided visual acuity after a short adaptation period, resulting in improved participation in sports, outdoor activities, and occupations where spectacle independence is advantageous. Patient-reported outcome studies have also demonstrated improvements in quality of life, self-confidence,

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and treatment satisfaction compared with conventional optical correction [10,12].

Long-term follow-up studies indicate that the effectiveness of orthokeratology is maintained with continued overnight wear. Although corneal reshaping is completely reversible after discontinuation of treatment, sustained lens wear maintains stable refractive correction while continuing to slow axial elongation. Current evidence suggests that rebound progression following discontinuation is generally less pronounced than that observed after cessation of pharmacological interventions, although continued monitoring remains essential during periods of rapid ocular growth [15,16].

The safety profile of modern orthokeratology has improved considerably with advances in reverse-geometry lens design, high oxygen-transmissible materials, computerised corneal topography, and standardised clinical protocols. Most adverse events reported in the literature are mild, self-limiting, and reversible, including superficial punctate keratopathy, transient corneal staining, lens binding, and mild visual disturbances. Serious complications, particularly microbial keratitis, are uncommon when evidence-based hygiene recommendations, individualised lens fitting, and regular follow-up are maintained [10,12,21].

Recent developments in orthokeratology have focused on improving treatment efficacy through innovations in lens design. Customised reverse-geometry lenses incorporating toric peripheral alignment curves, quadrant-specific geometries, and reduced back optic zone diameters (BOZD) have demonstrated improved lens centration and enhanced peripheral myopic defocus, potentially increasing the effectiveness of myopia control. Wavefront-guided lens designs are also being investigated to reduce higher-order aberrations and improve visual quality during treatment [18,20].

Combination therapy has emerged as one of the most promising developments in pediatric myopia management. Several randomised clinical trials have shown that combining orthokeratology with low-dose atropine produces greater reductions in axial elongation than either intervention alone. Current evidence is strongest for atropine concentrations between 0.01% and 0.05%, although the optimal dosage and treatment duration continue to be investigated. Multimodal treatment strategies are expected to become increasingly important for children at high risk of rapid myopia progression [16,18].

Artificial intelligence and digital technologies are also transforming orthokeratology practice. Machine learning algorithms are being incorporated into topography-guided fitting software to improve lens parameter selection, predict treatment response, and identify patients at increased risk of lens decentration or poor visual outcomes. Automated interpretation of corneal topography, epithelial thickness mapping, and axial length progression has the potential to improve fitting efficiency while reducing practitioner-dependent variability [18].

Advances in anterior-segment imaging have further enhanced understanding of the biological mechanisms underlying orthokeratology. High-resolution anterior-segment optical coherence tomography, Scheimpflug tomography, epithelial thickness mapping, and three-dimensional corneal imaging now permit detailed visualisation of epithelial redistribution and treatment-zone morphology. These technologies have improved both individualised lens fitting and objective monitoring of treatment response while providing new insights into corneal biomechanics and ocular growth regulation [12,20].

Future research is expected to focus on precision myopia management through personalised treatment strategies integrating ocular biometry, corneal biomechanics, genetic risk profiling, environmental risk factors, and artificial intelligence-based prediction models. Development of smart contact lenses capable of monitoring ocular physiology, drug-eluting orthokeratology lenses, and adaptive reverse-geometry designs may further enhance treatment effectiveness while improving patient safety and compliance. Continued multicenter randomised clinical trials with long-term follow-up will be essential to establish optimal treatment protocols and refine evidence-based clinical guidelines [15,16,18].

Overall, current evidence supports orthokeratology as a safe, effective, and scientifically validated intervention for both temporary refractive correction and myopia control. Ongoing advances in lens technology, ocular imaging, digital health, and combination therapy are expected to further strengthen its role within contemporary pediatric eye care and personalised myopia management.

Conclusion

Orthokeratology has evolved from an empirical corneal reshaping technique into a scientifically validated and evidence-based intervention for both temporary refractive correction and myopia control. Advances in reverse-geometry lens design, high oxygen-transmissible rigid gas-permeable materials, computerised corneal topography, anterior-segment imaging, and customised fitting algorithms have significantly improved the safety, predictability, and clinical effectiveness of this treatment modality. These developments have established orthokeratology as an integral component of contemporary myopia management, particularly in children and adolescents with progressive myopia.

The primary mechanism of orthokeratology involves controlled redistribution of the corneal epithelium, resulting in temporary central corneal flattening and the induction of relative peripheral myopic defocus. This optical modification alters retinal signalling pathways involved in ocular growth regulation, thereby reducing axial elongation and slowing the progression of myopia. Evidence from randomised controlled trials, longitudinal cohort studies, and systematic reviews consistently demonstrates that orthokeratology reduces axial elongation by approximately 30–60% compared with conventional optical correction, making it one of the most effective non-pharmacological interventions currently available for childhood myopia control [2,3,7,8].

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Successful clinical outcomes depend on careful patient selection, comprehensive pre-fitting evaluation, individualised lens design, meticulous lens hygiene, and regular follow-up. Corneal topography remains indispensable throughout treatment for patient selection, lens fitting, assessment of treatment-zone quality, and early detection of complications. Although adverse events such as corneal staining, lens binding, decentered treatment zones, and microbial keratitis may occur, most complications are preventable and manageable through adherence to evidence-based clinical protocols, appropriate patient education, and timely intervention.

Recent innovations, including toric and quadrant-specific lens designs, artificial intelligence-assisted fitting systems, advanced corneal imaging, epithelial thickness mapping, and combination therapy with low-dose atropine, are further enhancing treatment precision and expanding the role of orthokeratology in personalised myopia management. These advances are expected to improve visual outcomes while providing greater control over axial elongation in children at high risk of progressive myopia.

In conclusion, orthokeratology represents a safe, reversible, and clinically effective strategy for both refractive correction and myopia control when prescribed and monitored according to established clinical guidelines. As technological innovation and clinical evidence continue to evolve, orthokeratology is expected to remain a cornerstone of pediatric myopia management and an increasingly important component of preventive eye care worldwide.

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