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Refractive Errors Preferred Practice Pattern®

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REFRACTIVE MANAGEMENT/INTERVENTION PREFERRED PRACTICE PATTERN® DEVELOPMENT PROCESS AND PARTICIPANTS

The **Refractive Management/Intervention Preferred Practice Pattern Panel** members wrote the Refractive Errors Preferred Practice Pattern (PPP) guidelines. The PPP Panel members discussed and reviewed successive drafts of the document, meeting in person once and conducting other review by e-mail discussion, to develop a consensus over the final version of the document.

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We thank our partners, the Cochrane Eyes and Vision US Satellite (CEV@US), for identifying reliable systematic reviews that we cite and discuss in support of the PPP recommendations.

The **Preferred Practice Patterns Committee** members reviewed and discussed the document during a meeting in June 2022. The document was edited in response to the discussion and comments.

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The Refractive Errors PPP was then sent for review to additional internal and external groups and individuals in July 2022. All those returning comments were required to provide disclosure of relevant relationships with industry to have their comments considered (indicated with an asterisk below). Members of the Refractive Management/Intervention Preferred Practice Pattern Panel reviewed and discussed these comments and determined revisions to the document.

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FINANCIAL DISCLOSURES

In compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies (available at https://cmss.org/code-for-interactions-with-companies/), relevant relationships with industry are listed. The Academy has Relationship with Industry Procedures to comply with the Code (available at www.aao.org/about-preferred-practice-patterns). A majority (83%) of the members of the Refractive Management/Intervention Preferred Practice Pattern Panel 2021–2022 had no financial relationship to disclose.

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The disclosures of relevant relationships to industry of other reviewers of the document from January to October 2022 are available online at www.aao.org/ppp.

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OBJECTIVES OF PREFERRED PRACTICE PATTERN® GUIDELINES

As a service to its members and the public, the American Academy of Ophthalmology has developed a series of Preferred Practice Pattern guidelines that **identify characteristics and components of quality eye care.** Appendix 1 describes the core criteria of quality eye care.

The Preferred Practice Pattern guidelines are based on the best available scientific data as interpreted by panels of knowledgeable health professionals. In some instances, such as when results of carefully conducted clinical trials are available, the data are particularly persuasive and provide clear guidance. In other instances, the panels have to rely on their collective judgment and evaluation of available evidence.

These documents provide guidance for the pattern of practice, not for the care of a particular individual. While they should generally meet the needs of most patients, they cannot possibly best meet the needs of all patients. Adherence to these PPPs will not ensure a successful outcome in every situation. These practice patterns should not be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed at obtaining the best results. It may be necessary to approach different patients' needs in different ways. The physician must make the ultimate judgment about the propriety of the care of a particular patient in light of all of the circumstances presented by that patient. The American Academy of Ophthalmology is available to assist members in resolving ethical dilemmas that arise in the course of ophthalmic practice.

Preferred Practice Pattern guidelines are not medical standards to be adhered to in all individual situations. The Academy specifically disclaims any and all liability for injury or other damages of any kind, from negligence or otherwise, for any and all claims that may arise out of the use of any recommendations or other information contained herein.

References to certain drugs, instruments, and other products are made for illustrative purposes only and are not intended to constitute an endorsement of such. Such material may include information on applications that are not considered community standard, that reflect indications not included in approved U.S. Food and Drug Administration (FDA) labeling, or that are approved for use only in restricted research settings. The FDA has stated that it is the responsibility of the physician to determine the FDA status of each drug or device he or she wishes to use, and to use them with appropriate patient consent in compliance with applicable law.

Innovation in medicine is essential to ensure the future health of the American public, and the Academy encourages the development of new diagnostic and therapeutic methods that will improve eye care. It is essential to recognize that true medical excellence is achieved only when the patients' needs are the foremost consideration.

All Preferred Practice Pattern guidelines are reviewed by their parent panel annually or earlier if developments warrant and updated accordingly. To ensure that all PPPs are current, each is valid for 5 years from the approved by date unless superseded by a revision. Preferred Practice Pattern guidelines are funded by the Academy without commercial support. Authors and reviewers of PPPs are volunteers and do not receive any financial compensation for their contributions to the documents. The PPPs are externally reviewed by experts and stakeholders, including consumer representatives, before publication. The PPPs are developed in compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies. The Academy has Relationship with Industry Procedures (available at www.aao.org/about-preferred-practice-patterns) to comply with the Code.

Appendix 2 contains the International Statistical Classification of Diseases and Related Health Problems (ICD) codes for the disease entities that this PPP covers. The intended users of the Refractive Errors PPP are ophthalmologists.

METHODS AND KEY TO RATINGS

Preferred Practice Pattern® guidelines should be clinically relevant and specific enough to provide useful information to practitioners. Where evidence exists to support a recommendation for care, the recommendation should be given an explicit rating that shows the strength of evidence. To accomplish these aims, methods from the Scottish Intercollegiate Guideline Network[1] (SIGN) and the Grading of Recommendations Assessment, Development and Evaluation[2] (GRADE) group are used. GRADE is a systematic approach to grading the strength of the total body of evidence that is available to support recommendations on a specific clinical management issue. Organizations that have adopted GRADE include SIGN, the World Health Organization, the Agency for Healthcare Research and Quality, and the American College of Physicians.[3]

- All studies used to form a recommendation for care are graded for strength of evidence individually, and that grade is listed with the study citation.
- To rate individual studies, a scale based on SIGN[1] is used. The definitions and levels of evidence to rate individual studies are as follows:

I++	High-quality meta-analyses, systematic reviews of randomized controlled trials (RCTs), or RCTs with a very low risk of bias
I+	Well-conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias
I-	Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias
II++	High-quality systematic reviews of case-control or cohort studies High-quality case-control or cohort studies with a very low risk of confounding or bias and a high probability that the relationship is causal
II+	Well-conducted case-control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
II-	Case-control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
III	Nonanalytic studies (e.g., case reports, case series)

- Recommendations for care are formed based on the body of the evidence. The body of evidence quality ratings are defined by GRADE[2] as follows:

Good quality	Further research is very unlikely to change our confidence in the estimate of effect
Moderate quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Insufficient quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate Any estimate of effect is very uncertain

- Key recommendations for care are defined by GRADE[2] as follows:

Strong recommendation	Used when the desirable effects of an intervention clearly outweigh the undesirable effects or clearly do not
Discretionary recommendation	Used when the trade-offs are less certain—either because of low-quality evidence or because evidence suggests that desirable and undesirable effects are closely balanced

- The Highlighted Findings and Recommendations for Care section lists points determined by the PPP Panel to be of particular importance to vision and quality of life outcomes.
- All recommendations for care in this PPP were rated using the system described above. Ratings are embedded throughout the PPP main text in italics.
- Literature searches to update the PPP were undertaken in March 2021 and May 2022 in the PubMed database. Complete details of the literature searches are available in Appendix 7.

HIGHLIGHTED FINDINGS AND RECOMMENDATIONS FOR CARE

The prevalence of myopia is increasing in the United States and other industrialized societies. Increased time spent outdoors appears to be protective against myopia in children. Increased levels of near work are less of a risk factor than previously believed.

Increased outdoor time and low-concentration atropine have been shown to reduce the likelihood of myopia onset.

Antimuscarinic eyedrops, multifocal spectacles and contact lenses, and overnight orthokeratology have been shown to be varibly effective in some populations for myopia control, that is, to reduce the progression of myopia in school age children.

Studies from around the world have confirmed that that the incidence of microbial keratitis has not been reduced with the introduction of new lens types and that overnight wear of any contact lens is associated with a higher risk of infection than daily wear.

Although there are lenses approved by the FDA for extended wear, alternatives should be presented to patients for whom this mode of contact lens wear is being considered because overnight wear, regardless of contact lens type, increases risk of microbial keratitis.

Daily disposable contact lenses (rather than planned replacement lenses) are the safest lenses with the lowest rate of complications associated with soft contact lens wear.

No-rub cleaning, topping off (reuse) of solutions, contaminated lens cases, exposure to tap water, wearing contact lenses in hot tubs and showers and while swimming, and changes in water supply are associated with *Acanthamoeba* and fungal keratitis related to contact lens wear in the recent decades.

Hydrogen peroxide systems are superior to multipurpose solutions for reducing the likelihood of infections or inflammatory complications; they are the preferred mode of nightly disinfection for patients who cannot wear daily disposable lenses, especially if they have had complications of contact lens wear in the past.

Presbyopia can be managed by using eyeglasses; contact lenses; topical agents; intraocular lenses with multifocal, accommodating, or extended depth of focus features; and monovision strategies with contact lenses or intraocular lenses.

Adverse events related to FDA-approved drugs and devices should be reported to MedWatch (www.fda.gov/medwatch).

INTRODUCTION

DISEASE DEFINITION

Refractive error (ametropia) is present when parallel rays of light entering the nonaccommodating eye do not focus on the retina. The visual effect is a blurred image. Myopia is a common optical aberration in which parallel light rays from a distant image are focused on a point anterior to the retina. Hyperopia is also a common aberration and one in which distant light rays converge incompletely before striking the retina. Astigmatism and other forms of optical aberrations occur when incident light rays do not converge at a single focal point. Total refractive astigmatism can be divided into corneal (or keratometric) astigmatism, lenticular astigmatism, and retinal astigmatism. Most astigmatism is corneal in origin. Lenticular astigmatism is a result of uneven lens curvature, lens tilt, and differing refractive indices within the lens.[4]

In regular corneal astigmatism, the refractive power varies successively from one meridian to the next, and each meridian has a uniform curvature. The meridians of greatest and least power, or the principal meridians, are located 90 degrees apart.[5]

In irregular corneal astigmatism, the magnitude and the axis of astigmatism vary in different points of the cornea, which can be clinically significant in conditions such as keratoconus and other corneal ectasias, corneal epithelial basement membrane and stromal dystrophies, corneal scarring, and postsurgical corneas.[5] Coma, spherical aberration, and trefoil are examples of types of optical aberration termed higher order aberrations (HOAs). Higher order aberrations cannot be fully corrected by spherocylindrical corrective lenses. Methods for describing HOAs include Zernike and Fourier reconstruction algorithms. Zernike coefficients that most affect visual quality are coma, spherical aberration, and trefoil.

In this document, low to moderate refractive errors are defined as spherical equivalents of less than 6.00 diopters (D) of myopia, less than 3.00 D of hyperopia, and less than 3.00 D of regular astigmatism. High refractive errors are defined as 6.00 D or more of myopia, 3.00 D or more of hyperopia, and 3.00 D or more of regular astigmatism.

Natural presbyopia is a condition that develops with aging and results in insufficient accommodation for near work in a patient whose distance refractive error is fully corrected. Although not truly a refractive error, presbyopia will be considered in this document because its correction has similarities to the correction of refractive errors. The correction of presbyopia is also discussed in the Cataract in the Adult Eye PPP.[6]

PATIENT POPULATION

Individuals who have refractive errors.

CLINICAL OBJECTIVES

- Determine the patient's visual needs
- Identify and quantify any refractive errors
- Discuss with the patient the nature of the refractive error, appropriate alternatives for correction, and the risks and benefits of each approach
- Consider low-dose atropine and increased outdoor time for myopia prevention in young children at risk
- Consider antimuscarinic agents, multifocal spectacles or contact lenses, and orthokeratology for myopia control in school age children
- Inform patients, especially those with high refractive errors, about the potentially increased incidence of associated pathologic conditions
- Correct symptomatic refractive errors with eyeglasses, contact lenses, or surgery, as desired by the patient and as deemed appropriate by the physician
- Address contact lens safety in those at risk or with history of complications of contact lens wear, including elimination of extended wear (overnight wear), recommending conversion from planned

replacement to daily disposable lenses, and/or recommending switch from multipurpose solution to peroxide disinifection systems.

- Provide the patient with follow-up care and management of any side effects or complications resulting from the correction provided
- Consider the emerging field of topical agents for presbyopia

BACKGROUND

PREVALENCE AND RISK FACTORS

Over half of Americans older than 40 have ametropia of sufficient magnitude to require refractive correction.[7] Currently, an estimated 93 million Americans aged 12 years and older use some form of eyewear to correct refractive errors at distance.[8] About 41 million people in the United States used contact lenses in 2014.[9] It has been estimated that over 8.5 million people in the United States have undergone keratorefractive surgery since 1995[10] and over 13 million laser in situ keratomileusis (LASIK) procedures have been performed in the United States.[11]

Myopia

The prevalence of myopia (0.75 D or more) is estimated to be 9% in children in the United States aged 5 to 17 years.[12] In children aged 6 to 72 months, the prevalence of myopia in non-Hispanic white children was 1.2% and for Asian children it was 4.0%.[13] For African American children it was 6.6% and for Hispanic children it was 3.7%.[14] A meta-analysis of population-based studies found a 25% prevalence of myopia (1.00 D or more) in persons over age 40 in the United States;[15] a study based on a sample representative of the U.S. population found a prevalence of 31% in those aged 40 and older and of 36% in those aged 20 and older.[7] A number of population-based studies have shown that the prevalence of myopia is lower in older persons than in younger persons. The prevalence is about 35% to 40% among persons in their 20s to 40s and decreases to about 15% to 20% among those in their 60s, 70s, and 80s.[7, 16-18] Individuals who develop nuclear sclerosis, however, tend to undergo a myopic shift over time.[19-21] In the United States, myopia was found to be significantly more prevalent among non-Hispanic white adults than among adults of non-Hispanic black or Mexican American race/ethnicity, in contrast to some studies in children.[7]

Both hereditary and environmental factors appear to play a role in the development of myopia. Birth weight/gestational age at birth have been suggested as potentially associated with refractive error; a recent meta-analysis found a modest effect of lower birth weight on risk of myopic refractive error.[22] Studies suggest a higher concordance of myopia between monozygotic than dizygotic twins[23] and between children and parents.[24-27] Studies have identified links between several gene regions, particularly chromosome 18p, and myopia,[28-33] although other studies have either found no association[34] or more complex relationships.[35, 36] Other genetic variations associated with high myopia have been found in Asian populations.[37-43] More years of formal education have been strongly associated with a higher prevalence of myopia.[36, 44-52] Some studies have reported that a higher level of near work is associated with a higher prevalence and progression of myopia,[52-57] but other studies have not, especially with respect to middle-distance activities such as those that involve video display terminals.[47, 58-61] However, a recent study from the U.K. Biobank provided further evidence that higher levels of formal education increase the risk of myopia,[62] as has a study of the U.S. population.[63] The use of night lights for children under age 2 years has been reported as a strong risk factor for myopia;[64] however, other studies that were able to adjust for parental refractive status did not find such an association.[55, 65] Many studies in various countries have reported that myopia is associated with less time spent outdoors.[60, 65-78] Studies in Israel and England have found an association between higher prevalence of myopia and birth during the summer months.[78] In a longitudinal study of myopic children, investigators found that myopia progressed more slowly during summer than during other months.[79] A study reporting on myopic children from control groups (fitted with traditional single-vision eyeglasses) of clinical trials with 1-year follow-up

found that progression of myopia was less in summer months that in other seasons, both in terms of spherical equivalent and axial length.[80] In two meta-analyses, investigators found that increasing time spent outdoors significantly decreased risk of myopic progression.[81-83] Recent evidence suggests that violet light plays a role in prevention of myopia progression.[84, 85] In 2021, the International myopia institute summarized that associations between more nearwork and more myopia are generally weak and inconsistent, but have been supported by meta-analysis. Associations between time outdoors and less myopia are stronger and more consistently observed, including by meta-analysis.[86]

Studies of ethnic Chinese in Taiwan documented an increase in the prevalence and severity of myopia over two generations.[53, 67, 87-90] Similar increases in prevalence have been noted in Australian middle-aged adults,[91] among Indian schoolchildren,[92] and in a study of Japanese adults.[93] Genetics alone are unlikely to account for such a rapid change. One study has speculated that genetic factors do not preclude such a change.[94] A study of myopia in Japan found increasing prevalence in recent decades, suggesting environmental factors, but little change in prevalence of extreme myopia, suggesting high genetic predisposition.[95] More recent studies have demonstrated that both genetic and environmental factors are involved.[96] A study of successive cohorts of enlistees in the Israeli army showed a marked increase in prevalence of myopia over a 13-year period.[97] A study in Finland showed that the prevalence of myopia doubled among teenagers and young adults over the course of the 20th century.[98] A study comparing U.S. population-based estimates in 1971 to 1972 and 1999 to 2004 also found a marked increase in the prevalence of myopia, although the reasons for this increase could not be identified.[99] Several additional studies have reported that the prevalence of myopia is increasing.[49, 100, 101] In East Asia, the prevalence of myopia is rapidly increasing (now 80%–90%) in school-aged children.[102, 103] The global prevalence of myopia and high myopia are projected to increase to nearly 5000/million and 1000/million respectively by 2050.[104]

Hyperopia

A meta-analysis of population-based studies found the prevalence of hyperopia was 10% in the United States and increased with increasing age.[15] Another study, based on a sample representative of the U.S. population, found that the prevalence of hyperopia in those aged 40 and older was 5%, with little variation by race/ethnicity.[7] Population-based studies of Caucasians aged 40 and older report that the prevalence of hyperopia increases from about 20% among those in their 40s to about 60% among those in their 70s and 80s.[16, 17, 105] A similar pattern of higher prevalence of hyperopia in older ages was observed in a U.S. population-based study.[7] A similar prevalence and changes with age were seen among African Americans in Baltimore.[17] In contrast to myopia, hyperopia was associated with fewer years of formal education in the same populations.[16, 17]

Astigmatism

Kleinstein et al[12] found that 28% of their U.S.-based study population aged 5 to 17 years had astigmatism of 1.00 D or more. In a multiethnic pediatric eye disease study, the prevalence of astigmatism in African American and Hispanic children aged 6 to 72 months was 12.7% and 16.8%, respectively.[106] Astigmatism of 1.00 D or more is common among older adults (31% in persons aged 40 and older), and the prevalence is higher in older age groups.[7] In adult Americans, the prevalence of astigmatism has been reported to be 20% higher among men than women but was not associated with number of years of formal education and did not vary substantially by race/ethnicity.[7, 17] There have been conflicting data about the association of astigmatism with prematurity or low birth weight and with retinopathy of prematurity.[107-110]

Further discussion of the epidemiology of refractive errors is presented in Appendix 3.

NATURAL HISTORY

The distribution of refractive errors changes with age. Newborns average 3.00 D of hyperopia.[111] This may increase slightly in the first few months, but then it declines toward an average of 1.00 D of hyperopia by 1 year of age.[111] Fewer than 5% of infants have more than 3.00 D of hyperopia at age 1

year.[111, 112] This shift toward emmetropia is a complex process that involves changes in the power of the refractive components of the eye, including thinning of the crystalline lens.[113] Visual stimulation appears to play a role in this process.[114, 115]

Myopia typically appears between 6 and 12 years of age, and the mean rate of progression is approximately 0.50 D per year, based on studies of mostly Caucasian children.[116-118] A study reported that progression of myopia varied by ethnicity and by age of the child.[119] For ethnic Chinese children, the rate of progression has been found to be higher.[120-125]

Astigmatism in children is commonly oriented with the steep axis vertical (with the rule). In older adults, astigmatism oriented with the steep axis horizontally is more common (against the rule)[126, 127] and remains relatively stable in older adults,[128] although one study found that the axis of astigmatism tended to shift against the rule over a 5-year period.[129]

Individuals with high refractive errors are more likely to develop pathologic ocular changes over time.[130-134] Highly myopic patients have an increased incidence of progressive retinal and choroidal thinning, peripheral retinal degeneration, retinal detachment,[135] cataract,[136] glaucoma,[137-140] and myopic choroidal neovascularization.[141, 142] An increased risk of glaucoma and visual field defects with myopia has also been found,[143-149] although a more recent study found no evidence of genetic overlap between myopia and glaucoma.[150] An increased risk of developing primary angle-closure glaucoma among individuals with hyperopia has been reported.[151] Hyperopia is associated with progressive retinopathy in patients with Type I diabetes.[152] Individuals with higher levels of myopia are more likely to have decreased foveal function as assessed by multifocal full-field electroretinogram.[153] Although refractive error has little effect on development of age-related macular degeneration,[154] patients with "physiological myopia" in 0 to -6.00 D range are also at higher risk of ocular pathologies.[155]

RATIONALE FOR TREATMENT

The major reasons for treating refractive errors are to improve a patient's visual acuity, visual function, and visual comfort. It may be desirable to correct a very small error in one patient, whereas another patient may function well with no ill effects when the same very small refractive error is not corrected. Patients with moderate to high refractive errors generally require correction to achieve satisfactory vision. Other reasons for treatment include enhancing binocular vision (e.g., for driver safety), controlling strabismus (e.g., accommodative esotropia), and, on a societal level, preventing economic productivity loss associated with uncorrected refractive error.[156-159] In patients beyond visual maturity (see Amblyopia PPP[160]), uncorrected refractive errors do not result in amblyopia. There is evidence that uncorrected peripheral hyperopic defocus may lead to worsening of axial myopia in children who might otherwise have other uncorrected refractive errors alone.[161-163] Globally, 10 million individuals are estimated to have visual impairment from myopic macular degeneration, and 3.3 million of them are blind.[27] These numbers are estimated to grow to 55.7 million people with visual impairment and 18.5 million individuals with blindness by 2050 unless new strategies to control myopia are implemented.[27] The importance of reducing the global burden of myopia by delaying the onset of myopia and reducing myopic progression in children warrants attention from clinicians, public health officials, agencies, and industry.[164]

CARE PROCESS

PATIENT OUTCOME CRITERIA

Outcome criteria vary depending on the individual's needs, lifestyle, and overall medical condition. The goal is to provide vision that meets the patient's functional needs with minimal side effects. The relevant questions are to evaluate the safety and effectiveness of different nonsurgical and surgical approaches to treat refractive error in the adult patient population in terms of visual acuity, complications, and refraction. Studies selected for inclusion met the following criteria: they were published between 2017 and 2022 in the English, and they were human and clinical studies. Studies

that had fewer than 10 patients, that did not include interventions of interest, that did not adjust for bias, and in which the outcomes were not well defined were excluded.

DIAGNOSIS

The evaluation of refractive errors in children differs in technique, instrumentation, and diagnostic capacity for each child, depending on their age, developmental status, level of cooperation, and ability to interact with the examiner. (See Pediatric Eye Evaluations PPP.[165])

The evaluation of refractive errors in adults requires an assessment of the refractive status of the eye, the patient's current mode of correction, symptoms, and visual needs. Refraction is often performed in conjunction with a comprehensive medical eye evaluation.[166]

History

The history should incorporate the elements of the comprehensive adult medical eye evaluation to consider the patient's visual needs and any ocular pathology. (See Appendix 4.)

Examination

Measuring Visual Acuity

Distance visual acuity is usually measured in a dimly lit room, typically at 20 feet or 6 meters, as the patient looks at a chart with lines of high-contrast characters. Distance acuity should be measured separately for each eye with current correction. Near acuity is usually measured while the patient looks at a well-lit reading card of high-contrast characters held at a specified near working distance, typically 14 inches or 36 centimeters.

Refraction

Each eye should be evaluated independently. The refraction may be performed objectively by retinoscopy, an autorefractor, or a wavefront analyzer, or it may be done subjectively. In cooperative patients, subjective refinement of refraction using a phoropter or trial lens set is preferred. Determination of vertex distance (using a vertex meter) and precise astigmatic axis is especially important in patients with high refractive errors.

The reproducibility of subjective refraction has been found to be within 0.50 D for spherical equivalent, spherical power, and cylindrical power.[167, 168]

Distance refraction should be performed with accommodation relaxed. This may be accomplished by using manifest (noncycloplegic) refraction with fogging or other techniques to minimize accommodation with care to not provide excess minus power correction to the patient. In some cases, especially in children and many adolescents,[165] a cycloplegic refraction can be useful.

Near vision should be measured in each eye before cycloplegia for patients with high hyperopia, presbyopia, or complaints about near vision. If the patient is presbyopic, the near-vision add is determined at the reading or working distance preferred by the patient.

Cycloplegic refraction is especially indicated for patients in whom accommodation cannot be relaxed and for patients whose symptoms are not consistent with the manifest (noncycloplegic) refractive error. It is advised for patients when the accuracy of the refraction is in question for any reason. In adults, tropicamide and cyclopentolate are commonly used for cycloplegic refraction; tropicamide provides a more rapid onset of action and a shorter duration of effect, whereas cyclopentolate provides greater cycloplegia that may allow a more accurate refraction but a longer duration of effect.[169] A significant difference between manifest and cycloplegic refraction is observed frequently in children; in adults, a substantial difference between manifest and cycloplegic refraction may require a postcycloplegic refraction on a subsequent day when the cycloplegic refraction is used to guide the final manifest prescription. The postcycloplegic refraction is performed after full accommodation has returned.

Although most normal eyes should have a corrected acuity of 20/25 or better, it may not be possible to achieve this level of acuity in patients with high refractive errors, even with optimal

refraction. For a subset of patients, this might be due to the minification produced by high myopic correction at the spectacle plane. In other cases, refractive amblyopia may be the cause. However, a pathologic basis for reduced best-corrected visual acuity should be sought. A suddenly acquired refractive change may signal a systemic or local disease, or a drug effect. Excellent visual acuity does not preclude serious eye disease; therefore, all adult patients should have comprehensive medical eye evaluations at the recommended intervals.[165, 166]

Contact lens wearers should have a contact lens examination every 1 to 2 years to monitor for adverse effects of contact lens wear and for an update on healthy practices for contact lens wear and care.

The recommended frequency for an adult comprehensive medical eye examination for asymptomatic patients who do not have risk factors for eye disease is as follows: every 5–10 years for patients under 40 years old; every 2–4 years for patients 40 to 54 years old; every 1–3 years for patients 55 to 64 years old; and every 1–2 years for patients 65 years or older, as specified in the Comprehensive Adult Medical Eye Evaluation PPP.[166]

MANAGEMENT

The need to correct refractive errors depends on the patient's symptoms and visual needs. Patients with low or monocular refractive errors may not require correction; small changes in refractive corrections in asymptomatic patients are generally not recommended. Correction options include eyeglasses, contact lenses, and surgery. Surgical options are discussed in the Refractive Surgery PPP.[170] These include refractive surgery to the cornea, such as LASIK and photorefractive keratectomy, and lens surgery, such as clear lens extraction, phakic intraocular lenses, and cataract surgery. Various occupational and recreational requirements as well as personal preferences affect the specific choices for any individual patient.

Presbyopia can be managed with eyeglasses or contact lenses (soft, rigid gas-permeable, or aspheric bifocal or multifocal). These can be used bilaterally or for monovision and modified monovision. Modified monovision is a treatment in which a bifocal or multifocal contact lens is used in one eye and a distance contact lens is used in the fellow eye. Surgical management of presbyopia includes keratorefractive surgery for monovision, intracorneal lens implants, or intraocular lens implantation (including monofocal lenses for monovision, multifocal lenses, or accommodative lenses).

Eyeglasses

Provision of appropriate spectacles is one of the simplest, most cost-effective strategies to improve vision; therefore, eyeglasses should be considered before contact lenses or refractive surgery.[171] Additionally, patients whose primary mode of optical correction is contact lenses should have a pair of eyeglasses to decrease the risk of contact lens overwear and the use of contact lenses when the eye is red or inflamed. A patient's eyeglasses and refraction are typically evaluated whenever visual symptoms develop. Optimal eyeglass correction for higher refractive errors requires precision in fitting, especially with respect to the position of the optical center of each lens relative to the pupil. High-index lenses, which reduce the lens thickness and weight, are useful in correcting high refractive errors and providing increased comfort and better cosmetic appearance. The principles for correcting specific refractive errors with eyeglasses are outlined in Appendix 5.

When hyperopia is accompanied by esotropia, eyeglasses may be required to control the strabismus or to improve fusion.[172] If minus lenses improve fusion in intermittent exotropia, eyeglass correction may be indicated even if the patient is not myopic.

A nonrefractive, yet important, indication for eyeglasses is to protect the eyes from accidental injury. Safety glasses or eye protectors are strongly recommended for individuals involved in certain sports (e.g., racquetball, squash) and hazardous activities in which there is risk of flying particles (e.g., using hammers, saws, weed trimmers) or risk of UV toxicity (welders).[173] Shatterproof eyeglasses are also recommended for all individuals with good vision in only one eye. When ocular protection is the foremost consideration, polycarbonate plastic is the material

of choice because it is much more impact resistant than regular plastic or hardened glass.[174] Depending on the activity, frames with side protection may be important.

Contact Lenses

A contact lens can correct a wide range of refractive errors by acting as the initial refractive surface of the eye. In 2013, there were an estimated 140 million contact lens wearers globally.[175] Approximately 41 million individuals in the United States 18 years or older successfully used contact lenses for visual correction in 2014, and 93% of this population demographic wore soft contact lenses.[9] Soft hydrogel contact lenses, silicone hydrogel contact lenses with greater oxygen transmissibility, or rigid gas-permeable contact lenses are used most commonly. Use of rigid gas-permeable lenses represents 10.8% of all lens fits globally, with stabilization of this declining number due to wider use of scleral and orthokeratology lenses. There is considerable variance across the 40 countries surveyed, with the highest fit rate of 37% reported in Malaysia. Ten percent of the overall reported use of rigid gas-permeable lenses is for orthokeratology.[176] Market research in the United States projects growth of scleral, hybrid, and orthokeratology prescriptions and sales, suggesting an increasing role of specialty lenses in clinical practice.[177] Polymethylmethacrylate (PMMA) contact lenses are now rarely used because the material is not permeable to oxygen. Although contact lenses are of great visual benefit, their use does carry some risk of ocular complications.

Indications

Reduced reliance on eyeglasses to correct refractive error is the most common indication for contact lens use. Many patients who use contact lenses note better field of vision, greater comfort, and/or improved quality of vision. Some patients have special occupational needs that cannot be met by eyeglasses, and others prefer their appearance without eyeglasses. Some patients achieve adequate visual function only with contact lenses. This may include patients with high refractive errors, anisometropia, or an irregular corneal surface or shape. Finally, contact lenses may be prescribed for therapeutic purposes after surgery or trauma or in the setting of ocular surface disease.

Relative Contraindications

The use of contact lenses to correct refractive errors may not be advisable when there are significant eyelid, tear film, or ocular surface abnormalities related to any of the following:

- Keratoconjunctivitis sicca
- Blepharoconjunctivitis
- Acne rosacea
- Conjunctival cicatrization
- Corneal exposure
- Neurotrophic keratitis
- Other corneal abnormalities

Other relative contraindications include the following:

- Use of topical corticosteroids
- Inflammation of the anterior segment
- Presence of a filtering bleb
- Poor personal hygiene (e.g., dirty hands and fingernails)
- Certain environmental or work settings (e.g., dust, volatile chemicals)
- History of corneal complications related to contact lenses
- Limited dexterity
- Inability to understand the risks and responsibilities involved

The risks of complications associated with contact lenses should be weighed against the protective benefit of eyeglasses for monocular or functionally monocular patients.

Complications

Centers for Disease Control and Prevention (CDC) data for 2014 reported that approximately one-third of all contact lens wearers reported previous red or painful eye conditions that required a doctor visit; at least one contact lens hygiene risk behavior was reported by almost 99% of contact lens wearers.[9] The most serious risk of contact lens wear is the development of microbial keratitis, which can lead to visual loss even if properly treated.[178] Other complications with all types of contact lens wear include hypersensitivity reactions such as giant papillary conjunctivitis, problems of the ocular surface such as superficial keratitis, recurrent erosions, Salzmann nodules, subepithelial fibrosis, subepithelial opacification, and limbal stem cell deficiency, as well as corneal neovascularization, sterile infiltrates, and corneal warpage.[179-186] Transient subclinical stromal edema frequently occurs, and corneal thinning of the epithelium and stroma during contact lens wear has also been reported.[184, 187-189] Endothelial changes can occur, including polymegethism, pleomorphism, and, rarely, reduction of endothelial cell density.[190-192] The clinical significance of transient edema, thinning, and endothelial changes is uncertain.

Microbial keratitis as a complication of contact lens wear is most frequently caused by bacteria, but it can also be caused by more unusual organisms that are difficult to diagnose and treat, such as *Acanthamoeba* and fungi.[193-199]

When soft contact lenses were introduced for extended wear in the early 1980s, *Pseudomonas aeruginosa* became a frequently identified pathogen in cases of keratitis in individuals using extended-wear soft contact lenses.[193, 195] Investigations into the pathogenesis of *Pseudomonas* keratitis showed that *P. aeruginosa* adhered readily to contact lens deposits.[200] This was of concern because contact lenses develop more deposits as duration of use increases. Other investigations demonstrated that the relative risk of microbial keratitis was 10 to 15 times greater in patients using soft contact lenses on an extended-wear basis compared with patients using soft lenses for daily wear[201] and that extended-wear soft contact lens users had an annualized incidence five times that of daily-wear patients (21 vs. 4 per 10,000 persons).[202]

Disposable soft contact lenses for extended wear were introduced in the late 1980s in an attempt to improve the safety of extended wear by allowing more frequent contact lens replacement. Disposable soft contact lenses for extended wear were eventually found to have the same incidence of microbial keratitis as conventional reusable soft lenses for overnight wear.[203, 204] It was the pattern of contact lens wear (overnight vs. daily) rather than the type of contact lens (disposable vs. nondisposable) that appeared to be the overriding risk factor for microbial keratitis.[203-209] Despite the increased risk of microbial keratitis associated with overnight wear, there are contact lenses approved by the FDA for extended (including overnight) wear. Generally, *Pseudomonas* remains the most commonly isolated organism in microbial keratitis associated with contact lens use.[210] A study of pediatric microbial keratitis in Taiwan found that contact lens wear was a significant risk factor and that the number of isolated coagulase negative staphylococcus cases had increased over time. The presence of a gram negative isolate was correlated with a poorer visual outcome compared with other infectious isolates.[211]

Although disposable contact lenses were initially developed for extended wear use, they were introduced for daily disposable use in 1995. These lenses are intended to be worn for one day and then discarded before bedtime. These represent a popular alternative to nondisposable daily wear lenses and result in fewer lens-related user complaints when compared with conventional daily-wear soft contact lenses.[212] Their use currently represents the safest method of soft contact lens wear with regard to adverse events such as infiltrates and infections.[213, 214] There are no good studies comparing different contemporary modes of wear or materials with respect to impact on the corneal endothelium.

Even though investigators have shown that contact lenses of lower oxygen transmission are more likely to be associated with corneal epithelial binding of *P. aeruginosa* than are higher oxygen transmissible lenses,[215-218] the introduction of soft silicone hydrogel contact lenses with extremely high gas transmission has not resulted in a reduction in the rate of microbial keratitis with extended wear[219-221] or with daily wear.[222] Studies from around the world have confirmed that that the incidence of microbial keratitis has not been reduced with the introduction of new

lens types and that overnight wear of any contact lens is associated with a higher risk than daily wear.[213, 221, 223, 224]

These newer materials meet central and peripheral oxygen transmissibility thresholds to avoid corneal swelling during open-eye soft contact lens wear[225] but have not resulted in lower infection rates as detailed above. However, they are useful options in cases where there is neovascularization suggestive of hypoxia, when thicker lenses for the correction of high refractive error are required, or when contact lenses are used therapeutically.[226] Clinicians should be aware that a cosmetic iris incorporated into any contact lens is likely to reduce oxygen transmission through that lens; such a lens may not be an appropriate choice for an eye already at higher risk of complications from hypoxia. Cosmetic lens wear to change the appearance of the eye rather than to correct refractive error accounts for a substantial fraction (29.6%) of contact lens–related infection in a 2021 report from Asia. Wide internet availability, questionable quality control, and uneven regulation of the sale of these lenses present significant challenges.[227]

Overnight wear of silicone hydrogel contact lenses is associated with sterile inflammatory peripheral corneal infiltrative events (CIEs), as are smoking and lens or eyelid microbes (bioburden).[228-231] Tear stagnation may play a role in alterations of corneal epithelium associated with overnight contact lens wear.[232] Neither of the more recently introduced contact lens modalities, daily disposable or silicone hydrogel material, reduced the overall risk of acute nonulcerative events presenting to an emergency room.[233] Bioburden and specific lens care products or modalities may play a role in the development of CIEs, yet there appears to be no advantage to the use of antibiotics to reduce the incidence of CIEs during extended wear of silicone hydrogel lenses.[234-238] The exact relationship between CIEs and microbial keratitis remains unclear.

Overnight wear of a soft lens may be used on a therapeutic basis for ocular surface problems; there also are highly gas-permeable silicone hydrogel lenses that are FDA approved for extended wear on that basis. Overnight use of any contact lens is associated with a higher risk of infectious keratitis, and daily wear of a rigid gas-permeable lens is associated with the lowest rate of microbial keratitis of any lens type and wearing schedule.[221, 222] Overnight wear, regardless of contact lens type (including the newest highly gas-permeable silicone hydrogel lenses), increases the likelihood of corneal infection.[202-204, 219-222, 239] Although there are lenses approved by the FDA for extended wear, this and other risks, benefits, and alternatives should be presented to patients for whom this mode of contact lens wear is being considered.[202-204, 219, 220, 222, 239, 240]

There have been outbreaks and reports of increases in *Acanthamoeba* and fungal keratitis in association with contact lens wear in the past several decades.[241-259] This trend predates the association with the use of certain multipurpose solutions with reduced antimicrobial efficacy that are no longer on the market,[260-263] and it is associated with all lens types.[264] The trend has continued even with the removal of ineffective antimicrobial solutions in the case of *Acanthamoeba*.[265] Environmental risk factors and hygiene practices, such as no-rub cleaning, topping off (reuse) of solutions, contaminated lens cases, exposure to tap water, wearing lenses while swimming or in hot tubs, and changes in water supply are emerging as risk factors.[222, 223, 266-269] A study of *Fusaria* isolates from the U.S. outbreaks of 2005 and 2006 found a high degree of phylogenetic diversity consistent with multiple sources of contamination.[270]

MedWatch (www.fda.gov/medwatch) is the Safety Information and Adverse Reporting Program for drugs and other medical products regulated by the FDA. Adverse events related to contact lens wear should be reported to MedWatch.

Selection and Fitting

Before fitting a patient for contact lenses, an ocular history that includes past contact lens experience should be obtained, and a comprehensive medical eye evaluation should be performed.[165, 166] During this examination, particular attention should be directed at evaluating the patient's hygiene and ability to adhere to proper contact lens care as well as to ocular parameters such as eyelid function, eyelid margins, meibomian glands, tear film, conjunctival surface, and the corneal surface. General principles for selecting and fitting contact lenses are described in Appendix 6.

Patient Education and Contact Lens Care

The FDA and CDC have made recommendations for contact lens wearers regarding proper lens care practices. These are incorporated into the following recommendations:[271-273]

- Wash hands with soap and water, and dry (lint-free method) before handling contact lenses every time.
- Do not sleep in your contact lenses unless approved by your eye doctor.
- Never store your contact lenses in water.
- Keep tap water away from your contact lenses. Remove contact lenses before showering, swimming, or using a hot tub.
- For contact lenses other than daily disposables:
    - Rub and rinse contact lenses in disinfecting solution each time you remove them.
    - Rub and rinse the case with contact lens solution, dry it with a clean tissue, and store it upside down with the caps off after each use.
    - Do not top off solution. Use only fresh contact lens disinfecting solution in your case—never mix old and new solutions.
    - Wear and replace contact lenses according to the schedule prescribed by your doctor.
    - Follow the specific contact lens cleaning and storage guidelines from your doctor and the solution manufacturer.
    - Keep the contact lens case clean and replace it every 3 months.
- Remove the contact lenses and consult your doctor immediately if you experience symptoms such as redness, pain, tearing, increased light sensitivity, blurry vision, discharge, or swelling.
- See your eye doctor as often as they recommend for contact lens examination and for an update on wear and care practices.

These recommendations apply to contact lenses prescribed for refractive error as well as those used to alter the appearance of the eye.[274, 275] All contact lenses, including decorative and costume contact lenses, are medical devices requiring a physician's prescription and supervision. Doctors, patients, and consumers should be aware that there is a federal statute prohibiting contact lens sellers from providing contact lenses to customers without a valid prescription.[276] Stores or websites selling contact lenses without requiring a prescription are engaging in illegal business activity that is subject to federal law enforcement. Unregulated contact lens products may be counterfeit.

When contact lenses are initially prescribed and dispensed (whether for refractive or cosmetic purposes), patients should be trained and supervised in contact lens insertion and removal. Contact lens cleaning and disinfection should be carefully explained, because improper care may be associated with complications of contact lens wear.[204, 222, 245, 277] Hydrogen peroxide systems may be superior to preserved disinfecting solutions in reducing pathogen binding and cysticidal disinfection, but they require more complex care regimens.[223, 278-280] Patients should be instructed to use only sterile products that are commercially prepared specifically for contact lens care and to replace these at the intervals recommended by the manufacturers.[281] Specifically, patients should be instructed not to rinse contact lenses or lens cases with water (e.g., tap water, bottled water)[222] and to eliminate any water exposure as part of their wear and care regimen.[282] Patients should also be instructed to clean and replace contact lens cases at least every 3 months, because they can be a source of lens contamination.[222, 255, 283] Patients should be instructed to replace the solution in contact lens cases each time the lenses are disinfected.[284] Contact lens wearers should also use only fresh contact lens disinfecting solution in their case, and never mix old and new solutions (e.g., "topping off" solution).[9]

Patients should be made aware that using contact lenses can be associated with the development of ocular problems, including corneal infections that may threaten vision, and that overnight wear of contact lenses is associated with a fivefold relative risk of these corneal infections compared with daily wear.[202, 220, 221, 239, 285, 286] Even occasional overnight wear has risks[287] and is discouraged. The increased risk of corneal infections with overnight contact lens wear should

be discussed with patients who are considering this modality of vision correction. If patients choose overnight wear, they should be instructed to use only lenses specifically approved for extended wear.

Swimming with contact lenses has been associated with the development of *Acanthamoeba* keratitis,[285] and showering with lenses seems to be part of a pattern of risk.[245] Patients should be instructed to minimize water contact when wearing contact lenses and informed of the risks of wearing contact lenses while swimming, sitting in a hot tub, showering, bathing, and washing hair.

Patients should be advised to have regularly scheduled examinations to monitor the fit of the contact lens; to monitor ocular health, including pannus, scarring, inflammation and ectasia; and to reinforce proper lens care and hygiene.[288]

For additional information about contact lens selection, fitting, and care, see Appendix 6.

Follow-up Examination and Contact Lens Replacement

The initial contact lens fitting process should include follow-up examinations to assess visual acuity, comfort, contact lens fit, and the effect of the contact lens on the health of the ocular surface. First-time daily-wear or extended-wear contact lens users should be checked soon after the contact lenses are initially dispensed. Experienced contact lens wearers should generally be examined every 1 to 2 years to monitor for adverse effects of contact lens wear and for an update on healthy practices in contact lens wear and care. Patients should be questioned about problems such as irritation, redness, itching, discharge, decreased vision, or eyeglass blur upon contact lens removal. The patient's wear schedule and contact lens care regimen should be reviewed, and any deviations from recommended practice should be addressed. Of note, patient noncompliance with recommended hygienic practices in contact lens wear is often considered a significant risk factor for microbial keratitis and adverse contact-lens-related events. One study found that 86% of patients believed that they were compliant with hygienic practices; however, an interview about their lens care practices revealed that only 34% of those who reported themselves as compliant exhibited good lens care practices.[289] Patient-reported compliance does not indicate appropriate patient behavior, as a large proportion of patients remain noncompliant despite being aware of risk.[289, 290] Visual acuity with the contact lenses should be checked and the cause of any changes should be determined. The contact lenses themselves should be examined to make certain that they fit and wet well and are free of deposits or defects.

The external eye and cornea should also be evaluated in the follow-up examination. Findings of conjunctival injection, corneal edema, staining, infiltrates, changes at the superior limbus, or tarsal papillary conjunctivitis all indicate possible problems with contact lens wear. The practitioner should examine patients for signs of corneal hypoxia, evidence of infiltrative events, corneal neovascularization, and corneal warpage. If findings of corneal hypoxia are recognized, the contact lens fit, material, or wearing time should be adjusted to allow for better oxygenation of the cornea. Keratometry or corneal topography/tomography as well as refraction without the contact lenses should be compared with initial readings for patients suspected of having corneal warpage.

As far as replacement, the length of time a particular pair of rigid gas-permeable contact lenses can be used will vary among individual patients. Rigid gas-permeable contact lenses are generally useful for 18 to 24 months, although the surface quality of these lenses may deteriorate more rapidly for some individuals. Other individuals can use the same lenses for several years with little deterioration in optical or surface qualities. Replacement schedules are determined by the eye care practitioner based on clinical evaluation.

Traditional daily-wear soft contact lenses typically require replacement at least annually. Traditional extended-wear soft contact lenses often require replacement more frequently than once a year. Disposable lenses, which includes frequent/planned replacement and daily disposable hydrogel and silicone hydrogel lenses, for daily wear (less than 24 hours while awake) or extended wear (greater than 24 hours, including while asleep) should be replaced per manufacturers' guidelines, which vary from 1 day to several months. These guidelines are included in the lens package insert that can be found in the box of lenses and online. The

frequency of contact lens replacement should also be adjusted based on patient symptoms and findings at eye examinations. If a contact lens shows excessive deterioration or deposits, it should be replaced regardless of the length of wear. Typically, contact lens prescriptions are written with a 1-year expiration, although there are some situations where the expiration is shortened.

Rigid gas-permeable corneal lenses continue to have the lowest rate of adverse events of any lens type,[220, 221, 288] but initial patient discomfort and resources required for fitting and supplying these lenses compared with soft lenses have resulted in a continued decline in their use.[291] Of soft lens options, daily disposable lenses worn on a daily-wear basis remains the safest regimen.[220, 292] Extended (overnight) wear, regardless of lens type (including the newest highly gas-permeable silicone hydrogel lenses), increases the likelihood of infection,[220, 221] and discussion of this increased risk should be undertaken with patients who continue with this modality of vision correction. Patients should be instructed that contact lens hygiene, including case lens replacement, is important for any lens that is to be reworn. Finally, hydrogen peroxide disinfection has the lowest rate of adverse events compared with any other disinfection system regardless of lens type.

Orthokeratology

Rigid gas-permeable contact lenses can be prescribed as a nonsurgical and reversible method of refractive error reduction for the treatment of mild to moderate myopia with less than 1.50 D of corneal astigmatism. The technique of corneal reshaping is known as orthokeratology.

Orthokeratology, as originally described, utilized the application of sequentially flatter PMMA hard contact lenses to flatten the cornea and thereby reduce the myopic refractive error. When patients stop wearing contact lenses after undergoing orthokeratology, their corneas tend to revert to their original shape.[293, 294] Earlier attempts to predict which patients would respond to orthokeratology based on ocular biomechanical or biometric parameters were not successful,[295] and the effects of orthokeratology were unpredictable and poorly controlled.[293] In the 1990s, there was a resurgence using highly gas-permeable rigid contact lenses for temporary corneal reshaping. In this technique, patients with myopia are fitted with reverse-geometry rigid gas-permeable contact lenses that are used only during sleep. The center of the contact lens is deliberately fitted flatter than the central corneal curvature to transiently induce central corneal flattening by a thinning or molding of the epithelium, which will reverse myopia during the day when the lens is not worn. The contact lens must be used every one to two nights in order to maintain the effect. Approval by the FDA has been granted for the use of this technique, often referred to as overnight orthokeratology, for temporary reduction of up to 6.00 D of myopia (in eyes with up to 1.75 D of astigmatism). Average uncorrected visual acuity (UCVA) ranges from 20/19 to 20/24, with a refractive error ranging from +0.27 to –0.41 D after 1 to 6 months of wearing reverse-geometry contact lenses.[296-301]

The complications of overnight orthokeratology overlap those of rigid contact lens wear. As with any overnight contact lens modality, orthokeratology is associated with an increased risk of microbial keratitis,[299, 302-304] which is a risk similar to that of any overnight wear.[305] Microbial keratitis in association with overnight orthokeratology was first reported in 2001.[306, 307] Most of these cases originated in Asia, particularly in China and Taiwan, and were reported during a relatively short period when regulation of orthokeratology was limited.[308] A high incidence of cases of *Acanthamoeba* keratitis reported with this modality demonstrates the importance of eliminating the use of tap water in care regimens for overnight orthokeratology.[308, 309] A report of *Acanthamoeba* keratitis in minors from a single center in the United States collected over a decade as solutions came on and off the market and as lens care standards have evolved found increased risk among orthokeratology users.[264] Recent meta-analysis suggests that risk of microbial keratitis with orthokeratology is similar to that of other types of overnight wear of contact lenses[310] even though reports of safety in small cohorts have been reported globally.[311, 312] Orthokeratology patients may note a decreased quality of vision, especially under low-illumination conditions, as a result of induction of irregular astigmatism and an increase in HOAs that sometimes occurs with orthokeratology.

In addition to a transient reduction in refractive error, orthokeratology has been shown to slow myopic progression in children and adolescents (myopia control).[311, 313, 314] *(II++, moderate, discretionary)*

Myopia Control

A global increase in the prevalence of myopia is the subject of increased attention.[164] Treatments that aim to minimize progression of refractive errors, particularly myopia, have been reported. Low-concentration atropine and increased outdoor time have been shown to reduce the likelihood of myopia onset. [315-317] There is evidence that interventions should be considered for patients thought to be at risk for myopia progression.[318-325] *(I++, good, strong)* Effective interventions for slowing the progression of myopia include topical antimuscarinic agents, which are most effective, as well as multifocal contact lenses and spectacles, and orthokeratology.[165, 169, 319, 322, 326, 327] *(II+, moderate, discretionary)*

Most myopic refractive errors develop and progress during childhood and adolescence.[118] Slowing progression of myopia has a considerable public health impact, and thus the field of myopia control has emerged. A Cochrane review assessed the effects of several types of interventions (eye drops; undercorrection of nearsightedness; multifocal eyeglasses; and contact lenses, including multifocal contact lenses and orthokeratology) on the progression of nearsightedness in myopic children. It compared these interventions with each other and to eyeglasses, placebo, or no treatment. The largest positive effects for slowing myopia progression were exhibited by antimuscarinic medications. Antimuscarinic eyedrops have undesirable side effects at commercially available concentrations and are not available commercially in the United States at low concentrations except through compounding pharmacies. Multifocal spectacles and contact lenses and orthokeratology are also effective in slowing progression, but to a lesser degree.[317] Reduction of peripheral hyperopic defocus may be the mechanism by which these interventions are effective. Despite the belief that excessive near work (e.g., reading, screen time) is a causative factor in the myopia epidemic, recent evidence suggests that it is time outdoors that is the controlling factor.[81, 328] Recently, there have been a number of studies investigating this factor. A meta-analysis indicated that outdoor time as an intervention was correlated with a reduced myopia shift over a 3-year follow-up period.[329] In a study of 693 first grade schoolchildren in 16 schools, children with longer outdoor time while at school (more than 200 minutes) showed significantly less myopic shift.[330] In a cohort of high school students, more than 1 hour of outdoor activity was protective from cumulative spherical-equivalent refractive decrease.[331] Other studies have similarly found outdoor time to be a factor in reducing myopia progression.[332, 333]

A multifocal soft lens was found to slow myopia progression in Hong Kong Chinese schoolchildren.[327] The BLINK randomized clinical trial in the United States found that treatment with high add power multifocal contact lenses significantly reduced the rate of myopia over 3 years.[334] In 2019, the FDA approved the first multifocal soft contact lens to slow the progression of myopia in children ages 8 to 12 years at initiation of treatment .[335]

Spectacle Correction of Myopia with Myopia Control Features

Optical correction in the form of bifocal eyeglasses, multifocal eyeglasses, or removal of distance eyeglasses when performing close work has been recommended in an attempt to reduce accommodation, since accommodation has been implicated in the progression of myopia. Studies examining distance eyeglasses alone have failed to demonstrate any overall effects on the progression of human myopia.[336] Furthermore, undercorrection of human myopia is myopigenic.[337]

A study of 75 esophoric children, approximately half of whom used +1.50 D add bifocals, did show a slight reduction in the progression of myopia compared with controls. Among the children completing the 30 months of follow-up, mean myopia progression was statistically significantly lower for bifocals than for single-vision eyeglasses (1.00 to 1.24 D).[338] Progressive addition lenses have been shown to have similar effect.[339] Another study of 469 children ages 6 to 11 years reported that progressive addition lenses compared with single-vision lenses slowed the

progression of myopia by a small, statistically significant amount only during the first year.[340] A meta-analysis of nine clinical trials comparing the effects of multifocal and single-vision lenses in school aged children found that multifocal lenses with powers ranging from +1.50 to +2.00 D were associated with a significant decrease in myopia progression compared with single-vision lenses.[341] One randomized trial found that bifocal eyeglasses slowed myopia progression over 3 years in children who previously had an annual progression rate of at least 0.50 D.[342] Meta-analysis suggests that early treatment effects may not be maintained.[343] There are novel spectacle lens designs for myopia control that are in the early stages of study and regulatory oversight.[344]

Atropine (Antimuscarinic Agents)

Administration of atropine eyedrops has long been proposed as a treatment to prevent progression of myopia. Atropine inhibits accommodation, which may exert forces on the eye that result in axial elongation. In animal studies, atropine also appears to inhibit growth factors acting to elongate the eye independent of accommodation.[345-347]

There are clinical trials from around the world demonstrating the effect of low-dose atropine in slowing the progression of myopia.

The results of randomized, controlled clinical trials conducted in Taiwan and Singapore (three of which were masked) provide reasonable evidence that administration of atropine eyedrops retards the progression of myopia in school children.[123, 124, 348, 349] In one study, a range of atropine concentrations was utilized: 0.1%, 0.25%, and 0.5%. All reduced progression of myopia compared with the control group. Furthermore, atropine 0.01% has been found to have efficacy in controlling myopia progression compared with atropine 0.1% and 0.5% with minimal side effects.[320, 321] A more significant myopic rebound was noted after 0.5% atropine treatment cessation compared with 0.01%.[324]

Another published study (LAMP), a randomized, double-masked clinical trial from the Chinese University of Hong Kong, looked at the efficacy and safety of 0.05%, 0.025%, and 0.01% from atropine eye drops over 2 years. The efficacy of topical 0.05% atropine was double that of 0.01% atropine, and it remained the optimal concentration among the studied atropine concentrations in slowing myopia progression.[350] There is a continued benefit in year 3 compared with stopping treatment.[351]

It has also been shown that atropine eyedrops are effective in populations in the United States, where children generally have less rapid rates of progression of myopia than in Taiwan and Singapore.[321, 352-354] Different concentrations of atropine have been studied. Atropine 0.01% eye drops are more effective in slowing myopia progression with fewer visual side effects compared with atropine 0.1% or 0.5% eyedrops over a 5-year period.[321] A recent meta-analysis of atropine concentrations for myopia control has shown that the ranking probability of efficacy was not proportional to the dose.[355] Once the use of atropine is discontinued, the beneficial effects remain.[354] Potential risks of long-term atropine use are uncertain and include the risk of light toxicity to ocular structures, the potential for local allergic and systemic reactions, and reduced accommodative amplitudes following discontinuation of atropine. However, it has been reported that daily atropine usage over 2 years for the treatment of myopia has no significant effect on retinal function, as demonstrated by multifocal electroretinograms in children.[356] Other potential disadvantages include the inconvenience of using daily eyedrops and the possible need for bifocal or multifocal eyeglasses for near work (depending on the concentration of atropine administered), photosensitivity and glare, and rebound upon cessation of use. Use of lower concentrations of atropine reduce or eliminate these potential disadvanges.[325]

Cyclopentolate 1% administered nightly was evaluated in one study in school children in Taiwan and was found to slow the rate of progression of myopia compared with controls, but not as much as atropine did.[348] One study of tropicamide 1% found no significant difference in the progression of myopia compared with controls.[357]

Pirenzepine hydrochloride has been evaluated in two multicenter, double-masked, placebo-controlled parallel studies to slow the progression of myopia in school aged children.[358, 359] Both studies found 2% pirenzepine ophthalmic gel effective and relatively safe in slowing myopia progression over a 1-year treatment period. Further investigation of this selective muscarinic antagonist was abandoned by industry.

A network meta-analysis based on 30 randomized controlled trials involving 5422 eyes compared the efficacy of 16 interventions for myopia control in children. It concluded that muscarinic antagonists, such as atropine and pirenzepine, were the most effective in reducing myopia progression, followed by specially designed contact lenses.[318] *(I++, good, strong)* In a Cochrane analysis of the effect of several interventions on myopia progression, antimuscarinic agents were shown to have the largest positive impact on slowing myopia.[317]

In another meta-analysis looking at 10 randomized controlled trials, myopia progression slowed down the most with atropine treatment compared with controls.[360] A smaller meta-analysis showed that myopia from axial elongation was lower in the group that received a combination of atropine and orthokeratology compared with orthokeratology alone.[361]

Contact Lenses for Myopia Control

It has long been postulated that rigid contact lens wear could slow the progression of myopia in children.[362, 363] Previous published studies were limited by methodological difficulties.[364-369] A 2-year randomized clinical trial evaluating the effect of rigid contact lenses on myopia progression in school children was conducted in Singapore,[370] and another study was conducted concurrently in the United States.[371] Together they indicated that rigid gas-permeable contact lenses should not be prescribed primarily for myopia control.[371]

A randomized clinical trial in the United States evaluated soft contact lens wear compared with spectacle correction on the course of myopia.[372] No statistically significant difference in the rate of myopia progression could be demonstrated between the contact lens group and the group using single-vision eyeglasses. Soft contact lenses with a positive spherical aberration were compared with the spherical design and were found to slow axial growth in children after 1 to 2 years of treatment. However, spherical equivalent cycloplegic autorefraction was not significantly affected in concordance.[323]

Bifocal or multifocal contact soft lenses have been studied as a method of slowing progression of myopia, with the presumed mechanism being a reduction of peripheral hyperopic defocus. As of this writing, there is one multifocal daily disposable soft contact lens, MiSight (CooperVision, San Ramon, CA) that is approved by the FDA for myopia control. This mode of wear was not associated with complications during monitoring over 6 years in children ages 8 to 12 years.[373]

There is emerging evidence from Hong Kong, Australia, and Spain that there is a role for orthokeratology in the control of myopia,[322, 374-376] with reduction of peripheral hyperopic defocus as the likely mechanism.[377] Whether these results will apply to broader populations remains to be proven. The risk of microbial keratitis with this approach must be considered.[313]

The safest way to incorporate contact lens into clinical practice for reduction of axial elongation in young children remains to be determined.

Other Approaches

Pressure-Lowering Eyedrops

Lowering IOP has been suggested as a pharmacologic intervention that might reduce progression of myopia, presumably by reducing internal pressure on the ocular wall. One prospective clinical trial comparing the administration of 0.25% timolol maleate with the use of single-vision eyeglasses failed to show any retardation of progression of myopia.[378, 379] Therefore, this treatment is not recommended.

Visual Training

Visual training purported to reduce myopia includes exercises such as near-far focusing change activities.[380-382] There are no scientifically acceptable studies that document that these treatments are clinically effective, and, therefore, this therapy is not recommended.[380, 383, 384]

Acupuncture, and Nutrition

In a Cochrane review, acupuncture was studied for slowing the progression of myopia in children, but no conclusions could be drawn.[385] Information about the effects of nutritional changes on the progression of myopia is largely anecdotal and no scientifically valid studies are available.

Medical Management of Presbyopia

The management of presbyopia can be divided to nonsurgical and surgical approaches.

Nonsurgical management of presbyopia includes eyeglasses (reading glasses, bifocal, trifocal, or progressive lenses) and contact lenses (soft or rigid gas-permeable with aspheric bifocal or multifocal optics). Monovision strategies can also be used. A modified monovision involves using a bifocal or multifocal contact lens in one eye and a distance contact lens in the fellow eye.

Recently, there have been a number of clinical trials studying the effect of topical therapies to manage presbyopia, and the results have been promising. In 2021, 1.25% pilocarpine ophthalmic solution (Vuity, Allergan) was approved by the FDA for daily use to treat presbyopia. Retinal detachement and retinal tear have been reported with miotics, including 1.25% topical pilocarpine.[386] Individuals with pre-existing retinal disease are at increased risk. Dilated fundus examination is advised in all patients prior to initiation of therapy to look for holes, tears, or breaks in the retina. Numerous trials of other agents are ongoing globally.

Refractive surgery for presbyopia is covered in the Refractive Surgery PPP.[170] The use of intraocular lenses for presbyopia is covered in the Cataract PPP.[6]

PROVIDER AND SETTING

Patients with refractive errors should be examined and evaluated for treatment by an ophthalmologist or an optometrist.

SOCIOECONOMIC CONSIDERATIONS

Global Burden of Uncorrected Refractive Error

The Global Burden of Disease study estimates that 123 million people have vision worse than 20/60 due to uncorrected refractive error, with the burden of disease greatest in developing countries.[387] Globally, uncorrected refractive error is the leading cause of moderate to severe visual impairment (52% of cases)[387] and the third-leading cause of blindness after cataract and glaucoma.[388] A 2016 report estimates that within the United States, up to 8.2 million people have a vision impairment due to uncorrected refractive error.[389] The global burden of refractive error increases when presbyopia is taken into account. An estimated 1.8 billion people are estimated to have presbyopia, over half of whom do not have adequate presbyopic correction.[390]

Quality of Life

Numerous patient-reported outcomes instruments have been developed to estimate quality of life specifically in the context of refractive error.[391] Studies have demonstrated that refractive error reduces vision-related quality of life. In a British study, persons with myopia of 10.00 D or more had significantly worse vision-related quality of life compared with persons with less severe myopia.[392] An Australian study found that individuals with myopia of 0.50 D or more reported worse vision-related quality of life measures compared with emmetropes.[393] In a European study, more than half of pseudophakic patients who wore eyeglasses after cataract surgery would be willing to pay more than €0.50 per day to be free from wearing eyeglasses.[394]

Eye-related quality of life and functional vision were reduced in children wearing glasses for refractive error and not other eye conditions and in their parents, compared to controls.[395] Overall, systematic review of long-term contact lens wear reveals that contact lens use improves quality of life in children and adults.[396]

Cost-Effectiveness

A 2013 report estimated that the cost of eye disorders and vision loss in the United States was approximately $139 billion per year. Refractive error was the most expensive eye condition in this report, accounting for $16 billion per year.[397] Worldwide, the burden of uncorrected refractive error has substantial economic repercussions. The global productivity loss of $244 billion has been estimated for uncorrected myopia alone—a far greater cost than the estimated $20 billion that would be required to correct the world's refractive error.[158, 398]

APPENDIX 1. QUALITY OF OPHTHALMIC CARE CORE CRITERIA

Providing quality care
is the physician's foremost ethical obligation, and is
the basis of public trust in physicians.
AMA Board of Trustees, 1986

Quality ophthalmic care is provided in a manner and with the skill that is consistent with the best interests of the patient. The discussion that follows characterizes the core elements of such care.

The ophthalmologist is first and foremost a physician. As such, the ophthalmologist demonstrates compassion and concern for the individual, and utilizes the science and art of medicine to help alleviate patient fear and suffering. The ophthalmologist strives to develop and maintain clinical skills at the highest feasible level, consistent with the needs of patients, through training and continuing education. The ophthalmologist evaluates those skills and medical knowledge in relation to the needs of the patient and responds accordingly. The ophthalmologist also ensures that needy patients receive necessary care directly or through referral to appropriate persons and facilities that will provide such care, and he or she supports activities that promote health and prevent disease and disability.

The ophthalmologist recognizes that disease places patients in a disadvantaged, dependent state. The ophthalmologist respects the dignity and integrity of his or her patients and does not exploit their vulnerability.

Quality ophthalmic care has the following optimal attributes, among others.

- The essence of quality care is a meaningful partnership relationship between patient and physician. The ophthalmologist strives to communicate effectively with his or her patients, listening carefully to their needs and concerns. In turn, the ophthalmologist educates his or her patients about the nature and prognosis of their condition and about proper and appropriate therapeutic modalities. This is to ensure their meaningful participation (appropriate to their unique physical, intellectual, and emotional state) in decisions affecting their management and care, to improve their motivation and compliance with the agreed plan of treatment, and to help alleviate their fears and concerns.
- The ophthalmologist uses his or her best judgment in choosing and timing appropriate diagnostic and therapeutic modalities as well as the frequency of evaluation and follow-up, with due regard to the urgency and nature of the patient's condition and unique needs and desires.
- The ophthalmologist carries out only those procedures for which he or she is adequately trained, experienced, and competent, or, when necessary, is assisted by someone who is, depending on the urgency of the problem and availability and accessibility of alternative providers.
- Patients are assured access to, and continuity of, needed and appropriate ophthalmic care, which can be described as follows.
  - The ophthalmologist treats patients with due regard to timeliness, appropriateness, and his or her own ability to provide such care.
  - The operating ophthalmologist makes adequate provision for appropriate pre- and postoperative patient care.
  - When the ophthalmologist is unavailable for his or her patient, he or she provides appropriate alternative ophthalmic care, with adequate mechanisms for informing patients of the existence of such care and procedures for obtaining it.
  - The ophthalmologist refers patients to other ophthalmologists and eye care providers based on the timeliness and appropriateness of such referral, the patient's needs, the competence and qualifications of the person to whom the referral is made, and access and availability.
  - The ophthalmologist seeks appropriate consultation with due regard to the nature of the ocular or other medical or surgical problem. Consultants are suggested for their skill, competence, and accessibility. They receive as complete and accurate an accounting of the problem as necessary to provide efficient and effective advice or intervention, and in turn they respond in an adequate and timely manner.
  - The ophthalmologist maintains complete and accurate medical records.
  - On appropriate request, the ophthalmologist provides a full and accurate rendering of the patient's records in his or her possession.

  - The ophthalmologist reviews the results of consultations and laboratory tests in a timely and effective manner and takes appropriate actions.
  - The ophthalmologist and those who assist in providing care identify themselves and their profession.
  - For patients whose conditions fail to respond to treatment and for whom further treatment is unavailable, the ophthalmologist provides proper professional support, counseling, rehabilitative and social services, and referral as appropriate and accessible.
- Prior to therapeutic or invasive diagnostic procedures, the ophthalmologist becomes appropriately conversant with the patient's condition by collecting pertinent historical information and performing relevant preoperative examinations. Additionally, he or she enables the patient to reach a fully informed decision by providing an accurate and truthful explanation of the diagnosis; the nature, purpose, risks, benefits, and probability of success of the proposed treatment and of alternative treatment; and the risks and benefits of no treatment.
- The ophthalmologist adopts new technology (e.g., drugs, devices, surgical techniques) in judicious fashion, appropriate to the cost and potential benefit relative to existing alternatives and to its demonstrated safety and efficacy.
- The ophthalmologist enhances the quality of care he or she provides by periodically reviewing and assessing his or her personal performance in relation to established standards, and by revising or altering his or her practices and techniques appropriately.
- The ophthalmologist improves ophthalmic care by communicating to colleagues, through appropriate professional channels, knowledge gained through clinical research and practice. This includes alerting colleagues of instances of unusual or unexpected rates of complications and problems related to new drugs, devices, or procedures.
- The ophthalmologist provides care in suitably staffed and equipped facilities adequate to deal with potential ocular and systemic complications requiring immediate attention.
- The ophthalmologist also provides ophthalmic care in a manner that is cost-effective without unacceptably compromising accepted standards of quality.

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APPENDIX 2. INTERNATIONAL STATISTICAL CLASSIFICATION OF DISEASES AND RELATED HEALTH PROBLEMS (ICD) CODES

Refractive errors, which includes entities with the following ICD-10 classifications:

	ICD-10 CM
Aniseikonia	H52.32
Anisometropia	H52.31
Hyperopia	H52.0–
Myopia (axial) (congenital)	H52.1–
Astigmatism, regular	H52.22–
Astigmatism, irregular	H52.21–
Astigmatism, postkeratoplasty	T86.848–
Astigmatism, postoperative, surgically induced	T88.8
Presbyopia	H52.4
Specified NEC	H52.6

CM = Clinical Modification used in the United States; NEC = Not elsewhere classified; (–) = 0, unspecified eye; 1, right eye; 2, left eye; 3, bilateral

Additional Information:

- Certain categories have applicable 7th characters. The applicable 7th character is required for all codes within the category, or as the notes in the Tabular List instruct. The 7th character must always be the 7th character in the data field. If a code that requires a 7th character is not 6 characters, a placeholder X must be used to fill in the empty characters.
- For bilateral sites, the final character of the codes indicates laterality. An unspecified side code is also provided should the side not be identified in the medical record. If no bilateral code is provided and the condition is bilateral, assign separate codes for both the left and right side.
- When the diagnosis code specifies laterality, regardless of which digit it is found in (i.e., 4th digit, 5th digit, or 6th digit):
    - Right is always 1
    - Left is always 2
    - Bilateral is always 3

APPENDIX 3. GLOBAL EPIDEMIOLOGY OF REFRACTIVE ERRORS

Over half of Americans over the age of 40 have ametropia of sufficient magnitude to require refractive correction.[7] It has been estimated that 93 million Americans aged 12 years and older use some form of eyewear to correct refractive errors in distance.[8] About 41 million people in the United States used contact lenses in 2005.[399] It has been estimated that over 8.5 million people in the United States have undergone refractive surgery since 1995[10] and it is estimated that over 13 million LASIK procedures have been performed in the United States.[11]

The prevalence of myopia in the U.S. population was estimated in the early 1970s to be 25% in persons aged 12 to 54 years.[400] A meta-analysis of population-based studies found a prevalence of 25% in persons over age 40.[15] A study based on a sample representative of the U.S. population found a prevalence of 31% in those 40 and older and of 36% in those 20 and older.[7] A number of population-based studies have shown that the prevalence of myopia is lower in older persons than in younger ones, ranging from about 35% to 40% among persons in their 20s to 40s to about 15% to 20% among persons in their 60s, 70s, and 80s.[16-18] Individuals who develop nuclear sclerosis, however, tend to undergo a myopic shift over time.[19-21]

MYOPIA

Studies of ethnic Chinese in Taiwan documented an increase in the prevalence and severity of myopia over two generations.[53, 67, 87-90] Similar increases in prevalence have been noted in Australian middle-aged adults,[91] among Indian schoolchildren,[92] and in a study of Japanese adults.[93] Genetics alone are unlikely to account for such a rapid change. One study has speculated that genetic factors do not preclude such a change.[94] A study of successive cohorts of enlistees in the Israeli army showed a marked increase in prevalence of myopia over a 13-year period.[97] A study in Finland showed that the prevalence of myopia doubled among teenagers and young adults over the course of the 20th century.[98] A study comparing U.S. population-based estimates in 1971 to 1972 and 1999 to 2004 also found a marked increase in the prevalence of myopia, although the reasons for this increase could not be identified.[99] Several additional studies have reported that the prevalence of myopia is increasing.[49, 53, 67, 91-93, 100, 101] In one report from East Asia, the prevalence of myopia was found to be rapidly increasing (now 80%–90%) in school aged children.[103]

In the United States, myopia was found to be significantly more prevalent among non-Hispanic white persons than among persons of non-Hispanic black or Mexican American race/ethnicity.[7] Two population-based studies in the United States have reported that the prevalence of myopia in Latino persons aged 40 and older was 17% to 18%.[15, 401] A similar pattern was reported in Australia[105, 402] and in populations of African descent in Baltimore and Barbados.[17, 403] The prevalence of myopia in Chinese Americans aged 50 years and older has been estimated at 35.1% (at least 0.50 D of myopia), and high myopia (at least 5 D of myopia) was found in 7.4%.[404] There have been a number of population-based studies in different East Asian countries that indicate that the prevalence of myopia varies considerably. In elderly Taiwanese persons, the prevalence was 19% (65 years and older);[405] in Indonesia, the prevalence was 26%;[406] in Beijing, the prevalence was 23% (40 years and older).[407] In Chinese people aged 30 years and older, the prevalence was 26.7%,[408] and the prevalence was 9.5% in persons living in southern China aged 50 years and older.[409] A study of Japanese persons aged 40 years and older found a prevalence of myopia (0.50 D or more) of 41.8%;[410] more recent studies have found prevalence estimates increasing from 38% to 46% from 2005 to 2017, with a concurrent increase in the prevalence of myopic maculopathy,[93] and a prevalence of 50% in a different Japanese population, with much higher prevalence in those aged 34 to 59 than in older indivduals.[95] Other studies of young adult East Asian populations indicate that the prevalence of myopia is much higher than in their U.S. counterparts, ranging from 56% in 15- to 19-year-old Singaporean students[411] to 85% in 19- to 23-year-old medical students in Singapore,[412] to 30.7% in persons of Malay ethnicity aged 40 to 80 years.[413] A more recent study in Korea found myopia prevalence in ages 19 to 49 to be very high, nearly 71%.[52] Studies in South Asian countries found prevalences of 13% for persons aged 30 or older living in rural India,[414] 37% for persons living in Andhra Pradesh state (India),[415] and 36% for persons aged 30 and older in Pakistan.[416] A survey in Nigeria found that the prevalence of myopia in persons aged 40 years or older was 16.2%.[417] Finally, a study of the prevalence of myopia in

Australian adults aged 49 to 70 years found it ranging from 29% (in the 2010s) to 16% (in the early 1990s).[91]

The prevalence of myopia in American children aged 12 to 17 was estimated to be approximately 25% in the early 1970s.[400] In one study, myopia (0.75 D or more) was found in 9% of children aged 5 to 17 years.[12] In children aged 6 to 72 months, the prevalence of myopia in non-Hispanic white children was 1.2% and for Asian children it was 3.98%.[13] For African American children it was 6.6% and for Hispanic children it was 3.7%.[14] Data from the Orinda, California, Longitudinal Study found that the prevalence of 0.50 D or more of myopia was about 3% among 5- to 7-year-olds, 8% among 8- to 10-year-olds, and 14% among 11- to 12-year-olds.[113] In a U.S. study based on Kaiser Permanente data in California, prevalence of myopia was greater in Asian/Pacific Islander participants than in white or Black participants.[418] Data suggest that ethnic Chinese children have much higher rates of myopia at all ages. A national survey in Taiwan found the prevalence was 12% among 6-year-old children and 84% among those 16 to 18 years old.[87] More recent studies in Taiwan (2017) found that the prevalence of myopia increased to 25% in 7-year-olds and to 77% in 12-year-olds[53] and the prevalence of myopia in 5- and 6-year-olds dropped from 15% in 2014 to 8% in 2016. This decrease was attributed to a policy intervention promoting outdoor activities.[67] In a series of studies using similar methodology and definitions for myopia (0.50 D or more of myopia) in children aged 7 to 15 years, prevalences of myopia varied widely by country and ethnicity: 4% in India,[419] 10% to 34% in Malaysia,[420] 5% to 17% in southern China,[421] 7% in New Delhi,[422] and 9% to 40% in Malaysia and Singapore.[423] A study of individuals aged 6 to 21 years in Inner Mongolia found a prevalence of myopia of 77% without cycloplegia and 54% after cycloplegia, highlighting an important methodological consideration in population prevalence estimates of refractive error, particularly myopia.[424] A recent meta-analysis of prevalence of myopia (-0.50 D or more) in schoolchildren in India found that the prevalence was 7.5% over the past 44 decades for ages 5 to 15.[92] Similar rates have been found in Singapore (12% among 6- to 7-year-olds to 79% among 18-year-old males), and in Japan (44% among 12-year-olds to 66% among 17-year-olds).[44, 88, 425, 426] A study in the Netherlands found a prevalence of myopia of 2.4% in 6-year-olds;[68] a study of Israeli military candidates (ages 17 to 18) found a high prevalence of myopia that varied by intensity of religious educational programs (range, 30% to 50% to 82%).[51] The Ireland Eye Study[427] found that myopia prevalence in 6- to 7-year-olds was 3.3%, and in 12- to 13-year-olds it was nearly 20%. A study of disadvantaged Australian schoolchildren aged 6 to 15 found that prevalence of myopia was between 3.5% and 4.4% over a 4-year period, lower than prevalence estimates among schoolchildren from areas with higher socioeconomic status.[428] In young Australian men enlisting in the military, prevalence of myopia increased from 14% to 24% over a 35-year period.[429] A survey in Bhutanese schoolchildren found a prevalence of myopia of 6.6% in those aged 10 to 15 years.[430] In a meta-analysis of available data from Middle Eastern countries, the prevalence of myopia in those 15 years and younger was 4%; for individuals over 15 years old, the prevalence was 30%.[431]

A meta-analysis of prevalence studies from the WHO-defined world regions found the prevalence of myopia in children was 11.7%, ranging from 4.9% in South-East Asia to 18.2% in the Western Pacific region. In adults, the prevalence of myopia was 26.5%, ranging from 16.2% in the Americas to 32.9% in South-East Asia. This study also found that the prevalence of myopia increased from 1993 (10.4%) to 2016 (34.2%), although this difference did not reach statistical signficiance.[432]

HYPEROPIA

Less is known about the epidemiology of hyperopia and astigmatism than about myopia. Population-based studies of Caucasians aged 40 and older report that the prevalence of hyperopia increases from about 20% among those in their 40s to about 60% among those in their 70s and 80s.[16, 17, 105] A meta-analysis of population-based studies found the prevalence of hyperopia was 10% in the United States and increased with increasing age.[15] Another study, based on a sample representative of the U.S. population, found that the prevalence of hyperopia in those aged 40 and older was 5%, with little variation by race/ethnicity.[7] A similar pattern of higher prevalence of hyperopia in older ages was observed in a U.S. population-based study.[7] In a population of rural Chinese persons aged 50 and older, the prevalence of hyperopia was 8.9%,[409] and in another rural Chinese population aged 30 and older, the prevalence was 15.9%.[408] A similar prevalence and association with age were seen among African Americans in Baltimore.[17] In Australian children aged 6 years and 12 years, the prevalence of hyperopia was 13.2% and 5.0%, respectively.[433] In a multiethnic pediatric eye disease study, the

prevalence of hyperopia was found to be significantly higher in African American and Hispanic children aged 6 to 72 months than in non-Hispanic white children.[434] Data from a 5-year follow-up of residents of Beaver Dam, Wisconsin, documented a hyperopic shift in individuals under age 70 but a myopic shift in individuals who were developing nuclear sclerosis even if under age 70.[19] A study in Salisbury, Maryland, also found that nuclear sclerosis was associated with myopia,[435] consistent with a report from a Latino population.[21] In contrast to myopia, hyperopia was associated with fewer years of formal education in the same populations.[16, 17] African American men in Baltimore, Maryland, had half the prevalence of hyperopia that women had[17] and female Mexican American participants in the Proyecto Ver study were more likely than their male counterparts to have hyperopia,[15] but this gender difference was not observed among individuals of European descent.[15-17] A study of persons aged 30 or older in rural India found a prevalence of hyperopia (0.50 D or more) of 18% [414] and a study of persons of similar age in Pakistan found a prevalence of 27%.[416] A study of persons of Malay ethnicity in Singapore, aged 40 to 80, found a prevalence of hyperopia of 27%.[413] In Japanese persons aged 40 and older, the prevalence of hyperopia was 28%.[410] The prevalence of hyperopia in Asian children in the United States aged 6 to 72 months was 13.5%; in non-Hispanic white children it was 25.6%.[13] In Chinese kindergartners, the prevalence of hyperopia greater than 2.00 D was 14.3%.[436] In adult populations, the prevalence of hyperopia greater than 0.50 D ranged from 31.5% in Singapore[437] to 31.8% in Germany,[438] and 41.8% in Korea.[439] In a meta-analysis of available data from Middle Eastern countries, the prevalence of hyperopia in those 15 years and younger was 8%; for individuals over 15 years, the prevalence was 21%.[431] For hyperopia of 1.00 D or less, prevalence was reported as 25.2% in Europeans aged 25 to 90 years[440] and 22.1% in Latinos 40 years and older in the United States.[441] More recently, the Ireland Eye Study[427] found that hyperopia (2.00 D or more) prevalence in 6- to 7-year-olds was 25% and in 12- to 13-year-olds it was nearly 9%. A survey in Bhutanese schoolchildren found a prevalence of hyperopia (2.00 D or more) of 2.2% in those aged 10 to 15 years.[430] In young Australian men enlisting in the military, the prevalence of hyperopia (0.50 D or more) was less than 5% over a 35-year period.[429]

A meta-analysis of population studies combining information from world-wide regions found the prevalence of hyperopia in children to be 4.6%, ranging from 2.2% in South-East Asia to 14.3% in the Americas. In adults, the prevalence of hyperopia was 30.9%, ranging from 23.1% in Europe to 38.6% in Africa and 37.2% in the Americas.[432]

ASTIGMATISM

Population-based data document the prevalence of astigmatism in children or young adults. In a multiethnic pediatric eye disease study, the prevalence of astigmatism in African American and Hispanic children aged 6 to 72 months was 12.7% and 16.8%, respectively.[106] Kleinstein et al[12] found that 28% of their U.S.-based study population aged 5 to 17 years had at least 1.00 D of astigmatism. A study of Australian 6-year-olds found a prevalence of astigmatism of nearly 5%.[442] A series of studies carried out in children aged 7 to 15 from different countries but using similar methodology found a wide range of prevalences of astigmatism, varying from approximately 3% in Andhra Pradesh, India,[419] to 7% in New Delhi,[422] to 6% in Chinese children.[125] The prevalence of high astigmatism in Native American children was reported as 23% to 29% in those aged 2 to 7 years.[443] In Taiwanese preschoolers, the prevalence of astigmatism was 13.3%.[444] One or more diopters of astigmatism is common among older adults (31% in persons aged 40 years and older) and the prevalence is higher in older-age groups.[7, 17] This increase with age was also seen among African Americans, although the prevalence was about 30% lower than among Caucasians at every age.[17] In adult Americans, the prevalence of astigmatism has been reported to be 20% higher among men than women but was not associated with number of years of formal education.[7, 17] Astigmatism was found in 7.6% of Chinese subjects aged 50 and older[409] and in 24.5% of subjects aged 30 and older.[408] A study of persons of Malay ethnicity aged 40 to 80 living in Singapore reported a prevalence of astigmatism of 33%.[413] In Japanese persons aged 40 and older the prevalence of astigmatism was 54%.[410] A study of persons aged 30 and older in Pakistan found a prevalence of astigmatism of 37%.[416] In a meta-analysis of available data from Middle Eastern countries, the prevalence of astigmatism in those age 15 years and younger was 15%; for individuals over 15 years, the prevalence was 24%.[431] A survey in Bhutanese schoolchildren found prevalence of astigmatism (0.75 D or more) of 9.8% in those aged 10 to 15 years.[430] More recently, the Ireland Eye Study[427] found that astigmatism (1.00 D or more) prevalence in 6- to 7-year-olds was 19% and in 12- to 13-year-olds it was 16%. There have been conflicting data about the association of astigmatism with prematurity or low birth weight or with retinopathy of prematurity.[107-110]

These studies cannot be directly compared because the definitions of myopia, hyperopia, and astigmatism vary greatly from study to study, as do the populations under study.

In the abovementioned meta-analysis of WHO regions, the prevalence of astigmatism in children was estimated to be 14.9%, ranging from 9.8% in South-East Asia to 27.2% in the Americas. In adults, the prevalence of astigmatism was 40.4%, ranging from 11.4% in Africa to 45.6% in the Americas, 51% in Mexico, and 44.8% in South-East Asia.[432, 445]

APPENDIX 4. ELEMENTS OF THE COMPREHENSIVE ADULT MEDICAL EYE EVALUATION PPP EXCERPT[166]

A comprehensive medical eye evaluation includes a history, examination, diagnosis, and initiation of management.[166] The examination includes a careful and thorough detection and diagnosis of ophthalmic disorders, implementation of appropriate therapy for refractive error and for both ocular and systemic disease. The items listed are basic areas of evaluation or investigation and are not meant to exclude additional elements when appropriate. For example, because history-taking is an interactive process, the patient's responses may guide the clinician to pursue additional questions and evaluation.

HISTORY

In general, a thorough history may include the following items:

- Demographic data (e.g., name, date of birth, gender, and ethnicity or race)
- Patient's other pertinent health care providers
- Chief complaint and history of present illness
- Present status of visual function (e.g., patient's self-assessment of visual status, visual needs, any recent or current visual symptoms, and use of eyeglasses or contact lenses)
- Ocular symptoms (e.g., eyelid swelling, diplopia, redness, photophobia)
- Ocular history (e.g., prior eye diseases, injuries, surgery, including cosmetic eyelid and refractive surgery, or other treatments and medications)
- Systemic history: medical conditions and previous surgery
- Medications: ophthalmic and systemic medications currently used, including nutritional supplements and other over-the-counter products
- Allergies or adverse reactions to medications
- Family history: pertinent familial ocular (e.g., glaucoma, age-related macular degeneration) and systemic disease
- Social history (e.g., occupation; tobacco, alcohol, illicit drug use; family and living situation as appropriate)
- Sexual history
- Directed review of systems

OCULAR EXAMINATION

The comprehensive eye examination consists of an evaluation of the physiologic function and the anatomical status of the eye, visual system, and its related structures. This usually includes the following elements:

- Visual acuity with current correction (the power of the present correction recorded) at distance and, when appropriate, at near
- Refraction when indicated
- Visual fields by confrontation
- External examination (e.g., eyelid position and character, lashes, lacrimal apparatus and tear function; globe position; and pertinent facial features)
- Pupillary function (e.g., size and response to light, relative afferent pupillary defect)
- Ocular alignment and motility (e.g., cover/uncover test, alternate cover test, ductions and versions)
- Slit-lamp biomicroscopic examination: eyelid margins and lashes; tear film; conjunctiva; sclera; cornea; anterior chamber; and assessment of central and peripheral anterior chamber depth, iris, lens, and anterior vitreous
- Intraocular pressure measurement, preferably with a contact applanation method (typically a Goldmann tonometer). Contact tonometry may be deferred in the setting of suspected ocular infection or corneal trauma.
- Fundus examination: mid and posterior vitreous, retina (including posterior pole and periphery), vasculature, and optic nerve
- Assessment of relevant aspects of patient's mental and physical status

Examination of anterior segment structures routinely involves gross and biomicroscopic evaluation prior to and after dilation. Evaluation of structures situated posterior to the iris is best performed through a dilated pupil. Optimal examination of optic nerve, macula, and the peripheral retina requires the use of the indirect ophthalmoscope or slit-lamp fundus biomicroscopy with appropriate accessory diagnostic lenses.

Based on the patient's history and findings, additional tests or evaluations might be indicated to evaluate further a particular structure or function. These are not routinely part of the comprehensive medical eye clinical evaluation. Specialized clinical evaluation may include the following:

- Monocular near-vision testing
- Potential acuity testing
- Glare testing
- Contrast sensitivity testing
- Color-vision testing
- Testing of stereoacuity and fusion
- Testing of accommodation and convergence amplitudes
- Central visual field testing (Amsler grid)
- Expanded evaluation of ocular motility and alignment in multiple fields of gaze at distance and near
- Exophthalmometry (e.g., Hertel)
- Tear breakup time
- Ocular surface vital dye staining
- Corneal sensation
- Gonioscopy
- Functional evaluation of the nasolacrimal system
- Indirect ophthalmoscopy with scleral indentation
- Contact lens stereoscopic biomicroscopy (e.g., Goldmann three-mirror lens)

Additional diagnostic testing may include the following:

- Keratometry (e.g., to assess surface quality and power)
- Corneal topography/tomography, including analysis
- Measurement of corneal thickness (optical and ultrasonic pachymetry)
- Corneal endothelial cell analysis
- Meibomography
- Tear osmolarity
- External, slit-lamp, or fundus photography
- Anterior and posterior segment optical coherence tomography
- Confocoal microscopy
- Wavefront analysis
- Visual fields by automated and/or manual perimetry
- Biometry
- Stereophotography or computer-based image analysis of the optic disc and retinal nerve fiber layer or macula
- Ophthalmic ultrasonography (A-scan, B-scan, ultrasound biomicroscopy)
- Fluorescein, indocyanine green, and optical coherence tomography angiography
- Electrophysiological testing
- Microbiology and cytology of ocular or periocular specimens
- In-office point-of-care testing (e.g., immunochromatography)
- Radiologic imaging
- Laboratory tests for systemic disease

APPENDIX 5. Eyeglasses

Guidelines for correcting specific refractive errors with eyeglasses are outlined below.

MYOPIA

Individuals with low myopia may not need eyeglass correction except for distance activities such as driving or school work. Overcorrecting myopic patients will cause excessive accommodation, which may create symptoms. Some patients may become symptomatic from an increased degree of myopia that occurs at low levels of illumination (night myopia), and they may require increased minus correction for clearer vision at night.

Because of the progressive nature of myopia in childhood and adolescence, screening examinations that include visual acuity are recommended every 1 to 2 years (see Pediatric Eye Evaluations PPP[165]).

HYPEROPIA

Slight undercorrection may be desirable in young and middle-aged individuals with hyperopia because there is some physiologic accommodative tone. As the patient ages, full correction may be necessary to provide optimal distance vision and to minimize difficulties with near vision.

ASTIGMATISM

Full correction may not be needed for individuals with regular astigmatism. Adults with astigmatism may not accept full cylindrical correction in their first pair of eyeglasses or in subsequent eyeglasses if their astigmatism has been only partially corrected. In general, substantial changes in axis or power are not well tolerated.

PRESBYOPIA

Patients with presbyopia have several options for eyeglass correction: bifocals; trifocals; progressive addition lenses; or separate eyeglasses for distance, intermediate, and reading. Individuals with myopia must exert more accommodative effort when using contact lenses, or after refractive surgery, than when using eyeglasses. Individuals with hyperopia must exert more accommodative effort when using eyeglasses than contact lenses.

Bifocals

Bifocals come as flat-top, round-top, and executive styles. Flat top is the most popular but can induce a base-up prism effect, whereas round top can create a base-down prism effect. The height of the segment is more critical than its width. The top of the segment is generally set about 3 to 5 mm below the optical center of the distance lens and is usually positioned to align with the level of the lower limbus, but it may need to be higher or lower for certain occupations or depending on individual preference. Individuals who use computers may find a modified bifocal helpful; the upper segment is selected for the computer monitor distance and the lower segment is selected for reading.

Trifocals

Trifocals should be considered for patients with specific intermediate-vision needs, and they may also be very helpful for individuals who use computers. Identifying the specific working distances allows the trifocal powers to be prescribed most accurately.

Progressive Addition Lenses

Progressive addition lenses can be useful to increase the range of vision, and they are cosmetically well accepted. A good candidate for this type of lens is an individual with early presbyopia who has not worn bifocals before and who does not require an especially wide field of vision at near. The disadvantages of progressive lenses are peripheral distortion inherent in

the lens design, the smaller size of the reading zone compared with bifocals, higher cost, and the difficulty in properly fitting the lenses. The positioning of the optical centers and progressive add corridors are critical if the visual advantages of these lenses are to be appreciated. Problems with reading zone size and peripheral distortion increase with stronger addition lenses.

ANISOMETROPIA

The majority of adults can tolerate up to 3.00 D of difference in eyeglass refractive correction between the two eyes.[446] Occasionally, individuals may tolerate more than 3.00 D of difference. Reduction of symptomatic aniseikonia may be accomplished either by undercorrecting at the expense of acuity or modifying the lens base curve or lens thickness to alter relative image size.[447]

Vertical prism-induced diplopia can be a problem in presbyopic patients who wear bifocals. Small amounts of induced prism can be corrected by either slabbing-off or slabbing-on the bifocal segment.[447] Dissimilar segment types can also be used. A separate pair of reading eyeglasses, although less convenient, will avoid the problem of vertical anisophoria.

DIFFICULTIES AND COMPLICATIONS OF EYEGLASS WEAR

A variety of factors related to lenses and frames may cause difficulties in wearing eyeglasses. These include the following:

- Incorrect prescription
- Base curve and location of the cylinder on the front or back surface
- Bifocal power and segment position (height and size)
- Tint
- Anisometropia (if large)
- Prisms or prism effects
- Pantoscopic tilt
- Centration of lenses with respect to the pupil
- Vertex distance
- Size of frame and fit
- Contact sensitivity to frame material
- Change in lens material

In addition, the lenses in the eyeglasses can cause spherical and chromatic aberrations as well as lens distortions, including magnification (hyperopic lenses) and minification (myopic lenses). Eyeglasses are protective, however, which is especially important for monocular patients.

APPENDIX 6. CONTACT LENSES

CONTACT LENS FITTING

Careful attention should be directed towards optimizing contact lens fit, including size, centration, and movement in order to minimize contact lens interference with normal ocular function.

Keratometry or corneal topography/tomography is usually performed to assist in the fitting process. The refractive error can also be compared with keratometry or corneal topography/tomography readings to assess the relative contributions of the cornea and the natural lens to astigmatism and to help determine what type of contact lens will provide the best vision and fit. These readings also provide baseline information for future comparison.

Once a contact lens that provides good vision has been selected, the contact lens should be evaluated to ensure good movement on the eye.

CONTACT LENS SELECTION

The type of contact lens selected (soft hydrogel, rigid gas-permeable, silicone hydrogel, or hybrid) and the method of wear (daily or overnight) depend on the needs of an informed patient. Additionally, contact lenses can be replaced at various intervals ranging from every day for daily disposable soft lenses to every 1 to 2 years for certain rigid gas-permeable lenses.

Type of Contact Lens

Spherical refractive errors can be corrected with soft hydrogel, rigid gas-permeable, or silicone hydrogel contact lenses.[448] Low to moderate astigmatism can be corrected with soft toric contact lenses or with rigid gas-permeable contact lenses. Rigid gas-permeable, soft hydrogel, and silicone hydrogel contact lenses with varying abilities to transmit oxygen are available for patients with different corneal metabolic demands, and some are approved for extended wear. A recent study showed that neither hydrogel nor silicone hydrogel showed superiority in comfort. Adverse event rates were low with each material type, suggesting that choice of material is a patient and practitioner preference; however, for patients ar risk of hypoxia related complications, SiHy material should be considered.[226]

Daily disposable lenses as a type of lens and mode of wear have emerged as the type of soft lens, regardless of material, that is least likely to be associated with infectious or inflammatory complications. Daily disposable wear of contact lenses causes less damage to the ocular surface and less increase in proinflammatory cytokine levels compared with the use of reusable lenses.[449, 450] Finally, reusable daily wear lenses require adherence to disinfection protocols and use of solutions, and noncompliance increases the likelihood of complications.[451]

High astigmatic errors can be corrected effectively with rigid gas-permeable and hybrid contact lenses. In cases of greater amounts of corneal astigmatism, it may be preferable to use a bitoric or back-surface toric contact lens–design in order to minimize corneal bearing and improve centration. Custom-designed soft toric contact lenses provide another means to correct high astigmatic refractive errors. These contact lenses offer good centration when properly fitted, a flexible wear schedule, and improved comfort in some patients. The piggyback modality, in which a rigid gas-permeable lens is worn on top of a soft lens, may have utility in some of these circumstances. Aspheric and reverse geometry designs may also be useful for high astigmatism or postoperative refractive error. Regardless of the design chosen, adequate contact lens movement is essential for comfortable wear and maintenance of corneal integrity.

Rigid gas-permeable scleral lenses (diameter more than 17 mm) are an option for the correction of high and/or irregular astigmatism, particularly if combined with anisometropia. These lenses do not contact the cornea and are not designed to rely on movement for physiologic tolerance.

Contact lenses used to correct high refractive errors place increased physiologic demands on the cornea and anterior segment. The thickness and weight of some of these contact lenses may adversely affect delivery of oxygen to the cornea, leading to hypoxia, pannus, neovascularization, and opacification.

Soft hydrogel and rigid gas-permeable bifocal or multifocal contact lenses can be used to address presbyopia. Another option for the management of presbyopia with contact lenses is monovision. Generally, the dominant eye is corrected for distance and the nondominant eye for near. Patients wearing monofocal contact lenses may benefit from eyeglasses worn over the contact lenses while driving, especially at night, or for critical visual needs to correct the near eye for distance and thereby improve depth perception. Modified monovision is the use of a bifocal or multifocal contact lens in one eye and a distance contact lens in the fellow eye.

Polymethylmethacrylate hard contact lenses are now rarely fitted to correct refractive errors because they have a very limited ability to transmit oxygen to the corneal surface.

Method/Modality of Wear

Disposable soft contact lenses, rigid gas-permeable contact lenses, and silicone hydrogel contact lenses are available for either daily or extended wear. Daily wearis defined as less than 24 hours of continuous wear. Extended wear is defined as under closed eyelids, but to the lay person it means overnight wear.

Several FDA-mandated clinical studies carried out into the late 1990s have confirmed that overnight wear of contact lenses is the most important risk factor for microbial keratitis. Fifty to seventy-five percent of the risk of microbial keratitis can be attributed to overnight wear. Generally speaking, the longer the duration of continuous wear, the greater the chance of developing microbial keratitis. The risk for those who used daily wear contact lenses and sometimes wore them overnight was estimated to be approximately 12 times the risk of those who used daily wear lenses and did not wear them overnight. Extended-wear users who wear their contact lens overnight have a 10- to 15-fold risk over conventional daily wear lens users who do not sleep in their contact lens.[203] Reports from the United Kingdom,[220] Australia[221] and France in 2020[452] confirmed substantial increased risk of microbial keratitis with overnight wear regardless of lens type.

The increased risk of corneal infections with overnight contact lens wear should be discussed with patients who are considering this modality of vision correction. If patients choose overnight wear, they should be instructed to use only lenses specifically approved for extended wear.

CONTACT LENS CARE

Proper contact lens care involves a combination of cleaning, disinfecting, rinsing, and wetting solutions.[284] Surfactant cleaning solutions act like detergents to solubilize debris that is not chemically bonded to the contact lens. Rubbing the contact lens enhances the cleaning performance of the solution, likely by removing loosely bound deposits.[253, 258, 453] Enzymatic cleaners remove deposits that are chemically bonded to the surface. Disinfecting solutions reduce the number of microorganisms carried on the contact lens. Wetting solutions make a water-repellant lens surface hydrophilic. Many manufacturers combine these agents into multipurpose solutions.

Patients should also be instructed to clean and replace contact lens cases every 3 months because they can be a source of lens contamination,[222, 255, 283, 454] and damaged or cracked cases should be discarded. Patients should be instructed to eliminate all water exposure in their wear-and-care regimens to reduce risk of *Acanthamoeba* keratitis.[282]

The American Academy of Ophthalmology (www.aao.org/store) and the Contact Lens Association of Ophthalmologists ((www.clao.org/publications) have patient information brochures for contact lens care. Also, the FDA and CDC have issued recommendations.[284, 454]

Daily Wear Soft Contact Lenses

Daily disposable soft contact lenses should not be worn longer than manufacturers' recommendations, nor should they be reused. Standard daily wear soft contact lenses (non-daily disposable) should be cleaned with a contact lens cleaner or multipurpose solution daily at time of removal from the eye to remove biofilm and deposits from the lens surface. Rubbing the contact lenses during cleaning and rinsing with contact lens solution is necessary for removal of deposits.[246, 253, 453] Contact lenses should be disinfected using either a chemical or peroxide

system. Contact lens cases should be rinsed with disinfecting solution and air dried. The frequency of adverse events varies with silicone hydrogel contact lens and lens-solution combinations; nonpreserved (hydrogen peroxide) systems have the lowest incidence of corneal infiltrates.[455] Hydrogen peroxide systems may be superior to preserved disinfecting solutions in reducing pathogen binding and cysticidal disinfection, but they require more complex care regimens.[278] Hydroben peroxide systems may have advantages over multipurpose solution for symptomatic contact lens wearers.[456]

Periodic enzymatic cleaning may be useful for some patients. Manufacturers' recommendations for contact lens care and replacement should be followed. As mentioned above, daily disposable lens wear has the advantages of less risk of complication as a result of poor compliance with disinfection, storage, and replacement recommendations.[451]

Extended-Wear Soft Hydrogel Contact Lenses and Silicone Hydrogel Contact Lenses

The FDA recommends that overnight-wear soft hydrogel contact lenses be removed at least once a week for overnight cleaning and disinfection.[224, 457] Disposable contact lenses for extended wear should also be discarded on a regular basis consistent with manufacturers' recommendations or the specific instructions of eye care professionals. Silicone hydrogel contact lenses are now FDA approved for up to 30 days of continuous wear. Extended-wear soft hydrogel and silicone hydrogel contact lenses worn on a daily basis are cared for in the same way as daily wear soft lenses.

Rigid Gas-Permeable Contact Lenses

After rigid gas-permeable contact lenses are removed, they should be surface cleaned and rinsed. As with soft contact lenses, nonsterile water such as tap or bottled water should not be used. The lenses should be stored overnight in a disinfecting solution. Tap water should be eliminated from the care regimen, as its use is associated with the prevalence of *Acanthamoeba* keratitis, particularly in cases associated with overnight orthokeratology, as is topping off of solutions.[266, 308] Cases for lenses should be rinsed with disinfection solution and air dried after insertion of the lenses. Rigid gas-permeable contact lenses may also require periodic enzymatic cleaning. Rigid gas-permeable contact lenses that are approved for overnight wear should be cared for according to the above guidelines for daily wear rigid gas-permeable contact lenses.[458]

Specialized Uses of Contact Lenses

Contact lenses are also used for therapeutic purposes in corneal and ocular surface diseases.

Decorative Contact Lenses

Physicians should advise patients and consumers that there are risks of using unprescribed costume contact lenses. The risks include adverse events, such as corneal abrasions and corneal ulcers and infections, including blinding infections. Contact lenses, including colored contact lenses, theatrical designs, Halloween-inspired designs, and other holiday designs, require a prescription and supervision by an eye care professional. They should never be shared, just like regular contact lenses.[459]

APPENDIX 7. LITERATURE SEARCHES FOR THIS PPP

Literature searches of the PubMed database were conducted on July 2021. The search strategies were as follows. Specific limited update searches were conducted after May 2022. The searches had added filters for randomized controlled trials and systematic reviews and date limiters to capture literature published since 2017. The panel analyzed 5360 studies of which 79 were included in the PPP.

Refractive Errors - Epidemiology & Risk Factors:

(("refractive errors/epidemiology"[MAJR:noexp]) OR ("refractive errors/ethnology"[MAJR:noexp]) OR (hyperopia/epidemiology[MAJR:noexp]) OR (hyperopia/ethnology[MAJR:noexp]) OR (myopia/epidemiology[MAJR:noexp]) OR (myopia/ethnology[MAJR:noexp]) OR (astigmatism/epidemiology[MAJR:noexp]) OR (astigmatism/ethnology[MAJR:noexp]) OR (presbyopia/epidemiology[MAJR:noexp]) OR (presbyopia/ethnology[MAJR:noexp]))

((Refractive Errors[MAJR:noexp]) OR (Hyperopia[MAJR:noexp]) OR (Myopia[MAJR:noexp]) OR (Astigmatism[MAJR:noexp]) OR (Presbyopia[MAJR:noexp])) AND (Prevalence[MeSH Terms)

((Refractive Errors[MAJR:noexp]) OR (Hyperopia[MAJR:noexp]) OR (Myopia[MAJR:noexp]) OR (Astigmatism[MAJR:noexp]) OR (Presbyopia[MAJR:noexp])) AND (Risk Factors[MeSH Terms])

(("myopia/epidemiology"[MeSH Terms]) OR (("myopia"[MeSH Terms]) AND ("risk factors"[MeSH Terms]))) AND ((reading[tiab]) OR (near work[tiab]) OR (nearwork[tiab]) OR (cylinder power[tiab]) OR (optical power[tiab]) OR (accommodation[tiab]))

(refractive error*[tiab] OR hyperopia[tiab] OR myopia[tiab] OR astigmatism[tiab] OR presbyopia[tiab]) AND (epidemiolog*[tiab] OR ethnolog*[tiab] OR prevalen*[tiab] OR risk factor*[tiab])

(myopia[tiab]) AND (reading[tiab] OR nearwork[tiab] OR near work[tiab])

Diagnosis – Reproducibility of Results:

("refractive errors/diagnosis"[MAJR]) AND ("reproducibility of results"[MeSH Terms]) OR (refractive error*[tiab] OR hyperopia[tiab] OR myopia[tiab] OR astigmatism[tiab] OR presbyopia[tiab]) AND (diagnos*[tiab] OR reproducib*[tiab]) OR (refractive error*[tiab] OR hyperopia[tiab] OR myopia[tiab] OR astigmatism[tiab] OR presbyopia[tiab]) AND (accur*[tiab] OR detect*[tiab])

Refractive Errors – Prevention & Control:

((hyperopia[MAJR:noexp]) OR (myopia[MAJR:noexp]) OR (astigmatism[MAJR:noexp]) OR (presbyopia[MAJR:noexp])) AND (disease progression[MeSH Terms])

(("refractive errors/prevention and control"[MAJR:noexp]) OR ("hyperopia/prevention and control"[MAJR:noexp]) OR ("myopia/prevention and control"[MAJR:noexp]) OR ("astigmatism/prevention and control"[MAJR:noexp]) OR ("presbyopia/prevention and control"[MAJR:noexp]))

("myopia"[MeSH Terms]) AND (("atropine"[MeSH Terms]) OR ("cyclopentolate"[MeSH Terms]) OR ("tropicamide"[MeSH Terms]) OR ("pirenzepine"[MeSH Terms]))

(refractive error*[tiab] OR hyperopia[tiab] OR myopia[tiab] OR astigmatism[tiab] OR presbyopia[tiab]) AND (progress*[tiab] OR prevent*[tiab] OR atropine[tiab] OR cyclopentolate[tiab] OR tropicamide[tiab] OR pirenzepine[tiab])

Aniseikonia: "aniseikonia"[MeSH Terms] OR aniseikonia[tiab]

Contact Lenses: ("contact lenses"[MAJR]) AND ("keratitis"[MeSH Terms]) OR "contact lenses/adverse effects"[MAJR] OR (contact lens*[tiab]) AND (keratitis[tiab] OR ulcer*[tiab]) OR (contact lens*[tiab]) AND (dry eye*[tiab] OR meibomian[tiab] OR cornea*[tiab] OR inflamm*[tiab] OR ptosis[tiab] OR adverse[tiab])

Orthokeratology: (orthokeratology[tw])

Keratorefractive Surgery:

(("keratomileusis, laser in situ"[MeSH Terms]) OR ("photorefractive keratectomy"[MeSH Terms]) OR ("keratectomy, subepithelial, laser assisted"[MeSH Terms]) OR (epi-LASIK[tw]) OR (epi-laser in situ keratomileusis[tw]) OR (epipolis-laser in situ keratomileusis[tw]) OR (epi-LASEK[tw]) OR (epi-Laser-Assisted Sub-Epithelial Keratectomy[tw]) OR (epi-Laser-Assisted Subepithelial Keratectomy[tw]) OR (epi-

Laser Epithelial Keratomileusis[tw])) AND ((Quality of Life[MeSH Terms]) OR (Patient Satisfaction[MeSH Terms]))

(("pregnancy"[MeSH Terms]) OR ("lactation"[MeSH Terms])) AND (("keratectomy, subepithelial, laser assisted"[MeSH Terms]) OR ("photorefractive keratectomy"[MeSH Terms]) OR ("keratomileusis, laser in situ"[MeSH Terms]) OR (Lasers, Excimer[MeSH Terms]))

((Norplant[tw]) OR (levonorgestrel[tw])) AND (("keratectomy, subepithelial, laser assisted"[MeSH Terms]) OR ("photorefractive keratectomy"[MeSH Terms]) OR ("keratomileusis, laser in situ"[MeSH Terms]) OR (Lasers, Excimer[MeSH Terms]))

("wound healing"[MeSH Terms]) AND (("colchicine"[MeSH Terms]) OR ("levonorgestrel"[MeSH Terms]) OR ("sumatriptan"[MeSH Terms]) OR (norplant[tw])) AND ((Retina[MeSH Terms]) OR (Cornea[MeSH Terms]))

(("keratectomy, subepithelial, laser assisted"[MeSH Terms]) OR ("photorefractive keratectomy"[MeSH Terms]) OR ("keratomileusis, laser in situ"[MeSH Terms]) OR (Lasers, Excimer[MeSH Terms])) AND (("colchicine"[MeSH Terms]) OR ("levonorgestrel"[MeSH Terms]) OR ("sumatriptan"[MeSH Terms]) OR (norplant[tw]))

(lasik[tiab] OR prk[tiab] OR lasek[tiab] OR epi-lasik[tiab] OR epi-lasek[tiab] OR laser in situ keratomileusis[tiab] OR photorefractive keratectomy[tiab] OR subepithelial laser-assisted keratectomy[tiab] OR surface ablation*[tiab]) AND (quality of life[tw] OR patient satisfaction[tw] OR pregnan*[tw] OR lactat*[tw] OR norplant[tw] OR levonorgestrel[tw] OR sumatriptan[tw] OR colchicine[tw])

Wavefront Aberrometry: (wavefront[tw]) AND (aberromet*[tw])

PRK: ("photorefractive keratectomy/adverse effects"[MeSH Terms]) OR (photorefractive keratectomy[MeSH Terms]) AND (Treatment Outcome[MeSH Terms]) OR (photorefractive keratectomy[MeSH Terms]) AND (Time Factors[MeSH Terms]) OR (photorefractive keratectomy[MeSH Terms]) OR (photorefractive keratectomy[tiab] OR PRK[tiab])

LASEK: (keratectomy, subepithelial, laser assisted[MeSH Terms]) OR (LASEK[tiab]) OR (laser-assisted subepithelial keratectomy[tiab]) OR (lasek[tiab] OR laser assisted subepithelial keratectomy[tiab]) AND

Epi-LASIK: (epi-LASIK[tw]) OR (epi-laser in situ keratomileusis[tw]) OR (epipolis-laser in situ keratomileusis[tw])

Epi-LASEK: (epi-LASEK[tw]) OR (epi-Laser-Assisted Sub-Epithelial Keratectomy[tw]) OR (epi-Laser-Assisted Subepithelial Keratectomy[tw]) OR (epi-Laser Epithelial Keratomileusis[tw])

LASIK:

(keratomileusis, laser in situ/adverse effects[MAJR])

(keratomileusis, laser in situ[MAJR]) AND (Treatment Outcome[MeSH Terms])

(keratomileusis, laser in situ[MAJR]) AND (Time Factors[MeSH Terms])

(keratomileusis, laser in situ[MAJR])

(lasik[tiab] OR laser in situ keratomileusis[tiab]) AND (outcome*[tiab] OR adverse[tiab] OR long-term[tiab] OR effect*[tiab] OR complication*[tiab] OR safety[tiab] OR trial[tiab] OR random*[tiab] OR review[tiab] OR comparative[tiab]) NOT (rabbit*[tiab] OR mouse[tiab] OR mice[tiab] OR animal*[tw])

Intrastromal Corneal Ring Segments: (intrastromal corneal ring*[tw]) OR (intacs[tw]) OR ((intracorneal[tw]) AND ((implant*[tw]) OR (ring*[tw]) OR inlay*[tw])) OR ((ICRS[tw]) AND (cornea*[tw]))

Radial Keratotomy: Keratotomy, Radial[MAJR] OR (radial keratotomy[tiab])

Thermal Keratoplasty: (thermal keratoplasty[tw]) OR (conductive keratoplasty[tw])

Incisional Astigmatic (Transverse or Arcuate) Keratotomy: (keratotomy[tiab]) AND ((astigmatic[tiab]) OR (arcuate[tiab]) OR (transverse[tw]))

Automated Lamellar Keratoplasty: (Automated Lamellar Keratoplasty[tw])

Epikeratoplasty: (Epikeratoplasty[tw]) OR (Epikeratophakia[tw])

Intracorneal Alloplastic Inlays: (intracorneal inlay*[tiab]) OR (intracorneal lens*[tiab]) OR (intracorneal implant*[tiab])

Intraocular Refractive Surgery: "phakic intraocular lenses"[MeSH Terms] OR (phakic intraocular lens*[tiab]) OR (refractive lens exchange[tw]) OR (clear lens extraction[tw])

Refractive Surgery for Presbyopia:

"presbyopia/surgery"[MeSH Terms] OR ((photoablation[tw]) OR (ablation[tw])) AND (presbyop*[tw]) OR (anterior ciliary sclerotomy[tw]) OR ((Sclerostomy[MeSH Terms]) AND (Ciliary Body[MeSH Terms])) OR (scleral expansion[tw]) OR (presbyop*[tiab]) AND (surg*[tiab]) OR (sclerostomy[tiab]) AND (ciliary[tiab]) OR scleral expan*[tiab])

Surface Ablation: (Surface ablation*[tiab])

Socioeconomic: "refractive errors"[MeSH Terms] AND "refractive surgical procedures"[MeSH Terms] AND "economics"[MeSH Terms] OR "refractive errors"[MeSH Terms] AND "refractive surgical procedures"[MeSH Terms] AND "quality of life"[MeSH Terms]

RELATED ACADEMY MATERIALS

Basic and Clinical Science Course

- Clinical Optics (Section 3, 2022-2023)
- Refractive Surgery (Section 13, 2022-2023)

Focal Points

- Intracameral Medications for Cataract Surgery (2018)
- Management of Postoperative Refractive Surprises After Cataract Surgery (2019)
- Management of Cataract Surgery and Uveitis (2020)
- Micro-Invasive Glaucoma Surgery and Cataract Surgery Synergy (2018)

Ophthalmic Technology Assessment - Published in *Ophthalmology*, which is distributed free to Academy members; links to abstracts and full text available at www.aao.org/ota.

- Femtosecond Laser-Assisted Cataract Surgery (2022)
- Intraocular Lens Power Calculations in Eyes with Previous Excimer Laser Surgery for Myopia (2021)

Patient Education Downloadable Handout

- Contact Lenses (2022)
- Laser Eye Surgery (2022)
- LASIK (2022)
- Laser Surgery of the Eye (2022)
- Photorefractive Keratectomy (PRK) (2022)
- Refractive Errors (2022)

- Refractive Surgery (subscription) (2022)
- Wavefront-Guided LASIK (2022)

Patient Education Video

- Microkeratome LASIK
- Femto LASIK
- PRK

Preferred Practice Pattern® Guidelines - Free download available at www.aao.org/ppp.

- Cataract in the Adult Eye (2021)
- Comprehensive Adult Medical Eye Evaluation (2020)

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REFERENCES

1. Scottish Intercollegiate Guidelines Network. Annex B: Key to evidence statements and grades of recommendations. In: SIGN 50: A guideline developer's handbook. 2008 edition, revised 2011. Edinburgh, Scotland: Scottish Intercollegiate Guidelines Network. https://www.sign.ac.uk/our-guidelines/sign-50-a-guideline-developers-handbook/. Accessed August 25, 2022.
2. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: An emerging consensus on rating quality of evidence and strength of recommendations. *BMJ.* 2008;336:924-926.
3. Grade Working Group. Organizations that have endorsed or that are using GRADE. www.gradeworkinggroup.org/. Accessed August 25, 2022.
4. Abrams D. Duke-Elder's practice of refraction, 10th ed. London: Churchill Livingstone, 1993; Chap 6:65.
5. American Academy of Ophthalmology Basic and Clinical Science Course Subcommittee. Basic and clinical science course. Section 3: Clinical optics, 2022-2023. San Francisco, CA: American Academy of Ophthalmology; 2022.
6. Miller KM, Oetting TA, Tweeten JP, et al. Cataract in the Adult Eye Preferred Practice Pattern. *Ophthalmology.* 2021.
7. Vitale S, Ellwein L, Cotch MF, et al. Prevalence of refractive error in the United States, 1999-2004. *Arch Ophthalmol.* 2008;126:1111-1119.
8. Vitale S, Cotch MF, Sperduto R, Ellwein L. Costs of refractive correction of distance vision impairment in the United States, 1999-2002. *Ophthalmology.* 2006;113:2163-2170.
9. Cope JR, Collier SA, Rao MM, et al. Contact lens wearer demographics and risk behaviors for contact lens-related eye infections--United States, 2014. *MMWR Morb Mortal Wkly Rep.* 2015;64:865-870.
10. 2010 Global Refractive Market Report. Market Scope 2010.
11. Corcoran KJ. Macroeconomic landscape of refractive surgery in the United States. *Curr Opin Ophthalmol.* 2015;26:249-254.
12. Kleinstein RN, Jones LA, Hullett S, et al. Refractive error and ethnicity in children. *Arch Ophthalmol.* 2003;121:1141-1147.
13. Wen G, Tarczy-Hornoch K, McKean-Cowdin R, et al. Multi-ethnic Pediatric Eye Disease Study Group. Prevalence of myopia, hyperopia, and astigmatism in non-Hispanic white and Asian children: Multi-Ethnic Pediatric Eye Disease Study. *Ophthalmology.* 2013;120:2109-2116.
14. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of myopia and hyperopia in 6- to 72-month-old African American and Hispanic children: The Multi-Ethnic Pediatric Eye Disease Study. *Ophthalmology.* 2010;117:140-147.
15. Kempen JH, Mitchell P, Lee KE, et al. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol.* 2004;122:495-505.

16. Wang Q, Klein BE, Klein R, Moss SE. Refractive status in the Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci.* 1994;35:4344-4347.
17. Katz J, Tielsch JM, Sommer A. Prevalence and risk factors for refractive errors in an adult inner city population. *Invest Ophthalmol Vis Sci.* 1997;38:334-340.
18. Framingham Offspring Eye Study Group. Familial aggregation and prevalence of myopia in the Framingham Offspring Eye Study. *Arch Ophthalmol.* 1996;114:326-32
19. Lee KE, Klein BE, Klein R. Changes in refractive error over a 5-year interval in the Beaver Dam Eye Study. *Invest Ophthalmol Vis Sci.* 1999;40:1645-1649.
20. Mutti DO, Zadnik K. Age-related decreases in the prevalence of myopia: Longitudinal change or cohort effect? *Invest Ophthalmol Vis Sci.* 2000;41:2103-2107.
21. Shufelt C, Fraser-Bell S, Ying-Lai M, et al. Refractive error, ocular biometry, and lens opalescence in an adult population: The Los Angeles Latino Eye Study. *Invest Ophthalmol Vis Sci.* 2005;46:4450-4460.
22. Plotnikov D, Williams C, Guggenheim JA. Association between birth weight and refractive error in adulthood: A mendelian randomisation study. *Br J Ophthalmol.* 2020;104:214-219.
23. Chen CJ, Cohen BH, Diamond EL. Genetic and environmental effects on the development of myopia in Chinese twin children. *Ophthalmic Paediatr Genet.* 1985;6:353-359.
24. Jiang X, Tarczy-Hornoch K, Cotter SA, et al. Association of parental myopia with higher risk of myopia among multiethnic children before school age. *JAMA Ophthalmol.* 2020;138:501-509.
25. Saw SM, Nieto FJ, Katz J, et al. Familial clustering and myopia progression in Singapore school children. *Ophthalmic Epidemiol.* 2001;8:227-236.
26. Zadnik K, Satariano WA, Mutti DO, et al. The effect of parental history of myopia on children's eye size. *JAMA.* 1994;271:1323-1327.
27. Dirani M, Chamberlain M, Shekar SN, et al. Heritability of refractive error and ocular biometrics: The Genes in Myopia (GEM) twin study. *Invest Ophthalmol Vis Sci.* 2006;47:4756-4761.
28. Farbrother JE, Kirov G, Owen MJ, et al. Linkage analysis of the genetic loci for high myopia on 18p, 12q, and 17q in 51 U.K. Families. *Invest Ophthalmol Vis Sci.* 2004;45:2879-2885.
29. Hammond CJ, Andrew T, Mak YT, Spector TD. A susceptibility locus for myopia in the normal population is linked to the PAX6 gene region on chromosome 11: A genomewide scan of dizygotic twins. *Am J Hum Genet.* 2004;75:294-304.
30. Lam DS, Tam PO, Fan DS, et al. Familial high myopia linkage to chromosome 18p. *Ophthalmologica.* 2003;217:115-118.
31. Stambolian D, Ibay G, Reider L, et al. Genomewide linkage scan for myopia susceptibility loci among Ashkenazi Jewish families shows evidence of linkage on chromosome 22q12. *Am J Hum Genet.* 2004;75:448-459.
32. Wojciechowski R, Congdon N, Bowie H, et al. Heritability of refractive error and familial aggregation of myopia in an elderly American population. *Invest Ophthalmol Vis Sci.* 2005;46:1588-1592.
33. Zhang Q, Guo X, Xiao X, et al. Novel locus for X linked recessive high myopia maps to Xq23-q25 but outside MYP1. *J Med Genet.* 2006;43:e20.
34. Ibay G, Doan B, Reider L, et al. Candidate high myopia loci on chromosomes 18p and 12q do not play a major role in susceptibility to common myopia. *BMC Med Genet.* 2004;5:20.
35. Wojciechowski R. Nature and nurture: The complex genetics of myopia and refractive error. *Clin Genet.* 2011;79:301-320.
36. Verhoeven VJ, Buitendijk GH; Consortium for Refractive Error and Myopia (CREAM). Education influences the role of genetics in myopia. *Eur J Epidemiol.* 2013;28:973-980.
37. Klein AP, Duggal P, Lee KE, et al. Support for polygenic influences on ocular refractive error. *Invest Ophthalmol Vis Sci.* 2005;46:442-446.
38. Mak W, Kwan MW, Cheng TS, et al. Myopia as a latent phenotype of a pleiotropic gene positively selected for facilitating neurocognitive development, and the effects of environmental factors in its expression. *Med Hypotheses.* 2006;66:1209-1215.
39. Dirani M, Shekar SN, Baird PN. The role of educational attainment in refraction: The Genes in Myopia (GEM) twin study. *Invest Ophthalmol Vis Sci.* 2008;49:534-538.
40. Hayashi H, Yamashiro K, Nakanishi H, et al. Association of 15q14 and 15q25 with high myopia in Japanese. *Invest Ophthalmol Vis Sci.* 2011;52:4853-4858.
41. Li Z, Qu J, Xu X, et al. A genome-wide association study reveals association between common variants in an intergenic region of 4q25 and high-grade myopia in the Chinese Han population. *Hum Mol Genet.* 2011;20:2861-2868.
42. Shi Y, Qu J, Zhang D, et al. Genetic variants at 13q12.12 are associated with high myopia in the Han Chinese population. *Am J Hum Genet.* 2011;88:805-813.

43. Shi Y, Gong B, Chen L, et al. A genome-wide meta-analysis identifies two novel loci associated with high myopia in the Han Chinese population. *Hum Mol Genet.* 2013;22:2325-2333.
44. Wu HM, Seet B, Yap EP, et al. Does education explain ethnic differences in myopia prevalence? A population-based study of young adult males in Singapore. *Optom Vis Sci.* 2001;78:234-239.
45. Tan GJ, Ng YP, Lim YC, et al. Cross-sectional study of near-work and myopia in kindergarten children in Singapore. *Ann Acad Med Singapore.* 2000;29:740-744.
46. Tan NW, Saw SM, Lam DS, et al. Temporal variations in myopia progression in Singaporean children within an academic year. *Optom Vis Sci.* 2000;77:465-472.
47. Kinge B, Midelfart A, Jacobsen G, Rystad J. The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. *Acta Ophthalmol Scand.* 2000;78:26-29.
48. Gwiazda J, Deng L, Dias L, Marsh-Tootle W. Association of education and occupation with myopia in COMET parents. *Optom Vis Sci.* 2011;88:1045-1053.
49. Williams KM, Bertelsen G, Cumberland P, et al. European Eye Epidemiology (E(3)) Consortium. Increasing prevalence of myopia in Europe and the impact of education. *Ophthalmology.* 2015;122:1489-1497.
50. Mirshahi A, Ponto KA, Hoehn R, et al. Myopia and level of education: Results from the Gutenberg Health Study. *Ophthalmology.* 2014;121:2047-2052.
51. Bez D, Megreli J, Bez M, et al. Association between type of educational system and prevalence and severity of myopia among male adolescents in Israel. *JAMA Ophthalmol.* 2019;137:887-893.
52. Han SB, Jang J, Yang HK, et al. Prevalence and risk factors of myopia in adult Korean population: Korea National Health and Nutrition Examination survey 2013-2014 (KNHANES VI). *PLoS One.* 2019;14:e0211204.
53. Tsai TH, Liu YL, Ma IH, et al. Evolution of the prevalence of myopia among Taiwanese schoolchildren: A review of survey data from 1983 through 2017. *Ophthalmology.* 2021;128:290-301.
54. Mutti DO, Mitchell GL, Moeschberger ML, et al. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci.* 2002;43:3633-3640.
55. Saw SM, Zhang MZ, Hong RZ, et al. Near-work activity, night-lights, and myopia in the Singapore-China study. *Arch Ophthalmol.* 2002;120:620-627.
56. Saw SM, Chua WH, Hong CY, et al. Nearwork in early-onset myopia. *Invest Ophthalmol Vis Sci.* 2002;43:332-339.
57. Rahi JS, Cumberland PM, Peckham CS. Myopia over the lifecourse: Prevalence and early life influences in the 1958 British birth cohort. *Ophthalmology.* 2011;118:797-804.
58. Rechichi C, Scullica L. Trends regarding myopia in video terminal operators. *Acta Ophthalmol Scand.* 1996;74:493-496.
59. Saw SM, Nieto FJ, Katz J, et al. Factors related to the progression of myopia in Singaporean children. *Optom Vis Sci.* 2000;77:549-554.
60. Ip JM, Saw SM, Rose KA, et al. Role of near work in myopia: Findings in a sample of Australian school children. *Invest Ophthalmol Vis Sci.* 2008;49:2903-2910.
61. Saw SM, Shankar A, Tan SB, et al. A cohort study of incident myopia in Singaporean children. *Invest Ophthalmol Vis Sci.* 2006;47:1839-1844.
62. Mountjoy E, Davies NM, Plotnikov D, et al. Education and myopia: Assessing the direction of causality by mendelian randomisation. *BMJ.* 2018;361:k2022.
63. Nickels S, Hopf S, Pfeiffer N, Schuster AK. Myopia is associated with education: Results from NHANES 1999-2008. *PLoS One.* 2019;14:e0211196.
64. Quinn GE, Shin CH, Maguire MG, Stone RA. Myopia and ambient lighting at night. *Nature.* 1999;399:113-114.
65. Zadnik K, Jones LA, Irvin BC, et al. Collaborative longitudinal evaluation of ethnicity and refractive error (CLEERE) study group. Myopia and ambient night-time lighting. *Nature.* 2000;404:143-144.
66. McMahon G, Zayats T, Chen YP, et al. Season of birth, daylight hours at birth, and high myopia. *Ophthalmology.* 2009;116:468-473.
67. Yang YC, Hsu NW, Wang CY, et al. Prevalence trend of myopia after promoting eye care in preschoolers: A serial survey in Taiwan before and during the coronavirus disease 2019 pandemic. *Ophthalmology.* 2021.
68. Tideman JWL, Polling JR, Hofman A, et al. Environmental factors explain socioeconomic prevalence differences in myopia in 6-year-old children. *Br J Ophthalmol.* 2018;102:243-247.
69. Dirani M, Tong L, Gazzard G, et al. Outdoor activity and myopia in Singapore teenage children. *Br J Ophthalmol.* 2009;93:997-1000.
70. Jones LA, Sinnott LT, Mutti DO, et al. Parental history of myopia, sports and outdoor activities, and future myopia. *Invest Ophthalmol Vis Sci.* 2007;48:3524-3532.

71. Rose KA, Morgan IG, Ip J, et al. Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology.* 2008;115:1279-1285.
72. He M, Xiang F, Zeng Y, et al. Effect of time spent outdoors at school on the development of myopia among children in China: A randomized clinical trial. *JAMA.* 2015;314:1142-1148.
73. Jin JX, Hua WJ, Jiang X, et al. Effect of outdoor activity on myopia onset and progression in school-aged children in Northeast China: The Sujiatun Eye Care Study. *BMC Ophthalmol.* 2015;15:73.
74. McKnight CM, Sherwin JC, Yazar S, et al. Myopia in young adults is inversely related to an objective marker of ocular sun exposure: The Western Australian Raine Cohort Study. *Am J Ophthalmol.* 2014;158:1079-1085.
75. French AN, Morgan IG, Mitchell P, Rose KA. Risk factors for incident myopia in Australian schoolchildren: The Sydney Adolescent Vascular and Eye Study. *Ophthalmology.* 2013;120:2100-2108.
76. Wu PC, Tsai CL, Wu HL, et al. Outdoor activity during class recess reduces myopia onset and progression in school children. *Ophthalmology.* 2013;120:1080-1085.
77. Li M, Lanca C, Tan CS, et al. Association of time outdoors and patterns of light exposure with myopia in children. *Br J Ophthalmol.* 2021.
78. Mandel Y, Grotto I, El-Yaniv R, et al. Season of birth, natural light, and myopia. *Ophthalmology.* 2008;115:686-692.
79. Gwiazda J, Deng L, Manny R, Norton TT. COMET study group. Seasonal variations in the progression of myopia in children enrolled in the correction of myopia evaluation trial. *Invest Ophthalmol Vis Sci.* 2014;55:752-758.
80. Donovan L, Sankaridurg P, Ho A, et al. Myopia progression in chinese children is slower in summer than in winter. *Optom Vis Sci.* 2012;89:1196-1202.
81. Williams KM, Bentham GC, Young IS, et al. Association between myopia, ultraviolet B radiation exposure, serum vitamin D concentrations, and genetic polymorphisms in vitamin D metabolic pathways in a multicountry European study. *JAMA Ophthalmol.* 2017;135:47-53.
82. Sherwin JC, Reacher MH, Keogh RH, et al. The association between time spent outdoors and myopia in children and adolescents: A systematic review and meta-analysis. *Ophthalmology.* 2012;119:2141-2151.
83. Saw SM, Matsumura S, Hoang QV. Prevention and management of myopia and myopic pathology. *Invest Ophthalmol Vis Sci.* 2019;60:488-499.
84. Torii H, Kurihara T, Seko Y, et al. Violet light exposure can be a preventive strategy against myopia progression. *EBioMedicine.* 2017;15:210-219.
85. Jiang X, Pardue MT, Mori K, et al. Violet light suppresses lens-induced myopia via neuropsin (OPN5) in mice. *Proc Natl Acad Sci U S A.* 2021;118.
86. Morgan IG, Wu PC, Ostrin LA, et al. IMI risk factors for myopia. *Invest Ophthalmol Vis Sci.* 2021;62:3.
87. Lin LL, Shih YF, Tsai CB, et al. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. *Optom Vis Sci.* 1999;76:275-281.
88. Lin LL, Chen CJ, Hung PT, Ko LS. Nation-wide survey of myopia among schoolchildren in Taiwan, 1986. *Acta Ophthalmol Suppl.* 1988;185:29-33.
89. Wu MM, Edwards MH. The effect of having myopic parents: An analysis of myopia in three generations. *Optom Vis Sci.* 1999;76:387-392.
90. Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. *Ann Acad Med Singapore.* 2004;33:27-33.
91. Mackey DA, Lingham G, Lee SS, et al. Change in the prevalence of myopia in Australian middle-aged adults across 20 years. *Clin Exp Ophthalmol.* 2021.
92. Agarwal D, Saxena R, Gupta V, et al. Prevalence of myopia in Indian school children: Meta-analysis of last four decades. *PLoS One.* 2020;15:e0240750.
93. Ueda E, Yasuda M, Fujiwara K, et al. Trends in the prevalence of myopia and myopic maculopathy in a Japanese population: The Hisayama Study. *Invest Ophthalmol Vis Sci.* 2019;60:2781-2786.
94. Rose KA, Morgan IG, Smith W, Mitchell P. High heritability of myopia does not preclude rapid changes in prevalence. *Clin Experiment Ophthalmol.* 2002;30:168-172.
95. Nakao SY, Miyake M, Hosoda Y, et al. Myopia prevalence and ocular biometry features in a general Japanese population: The Nagahama Study. *Ophthalmology.* 2021;128:522-531.
96. Enthoven CA, Tideman JWL, Polling JR, et al. Interaction between lifestyle and genetic susceptibility in myopia: The Generation R study. *Eur J Epidemiol.* 2019;34:777-784.
97. Dayan YB, Levin A, Morad Y, et al. The changing prevalence of myopia in young adults: A 13-year series of population-based prevalence surveys. *Invest Ophthalmol Vis Sci.* 2005;46:2760-2765.
98. Parssinen O. The increased prevalence of myopia in Finland. *Acta Ophthalmol.* 2012;90:497-502.
99. Vitale S, Sperduto RD, Ferris FL, 3rd. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. *Arch Ophthalmol.* 2009;127:1632-1639.

100. Pan CW, Zheng YF, Wong TY, et al. Variation in prevalence of myopia between generations of migrant Indians living in Singapore. *Am J Ophthalmol.* 2012;154:376-381.
101. Lam CS, Lam CH, Cheng SC, Chan LY. Prevalence of myopia among Hong Kong Chinese schoolchildren: Changes over two decades. *Ophthalmic Physiol Opt.* 2012;32:17-24.
102. Chen M, Wu A, Zhang L, et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua City, Eastern China: A 15-year population-based survey. *BMC Ophthalmol.* 2018;18:159.
103. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *Lancet.* 2012;379:1739-1748.
104. Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology.* 2016;123:1036-1042.
105. Attebo K, Ivers RQ, Mitchell P. Refractive errors in an older population: The Blue Mountains Eye Study. *Ophthalmology.* 1999;106:1066-1072.
106. Writing Committee for the MEPEDS study group. Prevalence of astigmatism in 6- to 72-month-old African American and Hispanic children: The Multi-Ethnic Pediatric Eye Disease Study. *Ophthalmology.* 2011;118:284-293.
107. Holmstrom M, el Azazi M, Kugelberg U. Ophthalmological long-term follow up of preterm infants: A population based, prospective study of the refraction and its development. *Br J Ophthalmol.* 1998;82:1265-1271.
108. Larsson EK, Rydberg AC, Holmstrom GE. A population-based study of the refractive outcome in 10-year-old preterm and full-term children. *Arch Ophthalmol.* 2003;121:1430-1436.
109. Saw SM, Chew SJ. Myopia in children born premature or with low birth weight. *Acta Ophthalmol Scand.* 1997;75:548-550.
110. Ton Y, Wysenbeek YS, Spierer A. Refractive error in premature infants. *J AAPOS.* 2004;8:534-538.
111. Saunders KJ. Early refractive development in humans. *Surv Ophthalmol.* 1995;40:207-216.
112. Holmstrom GE, Larsson EK. Development of spherical equivalent refraction in prematurely born children during the first 10 years of life: A population-based study. *Arch Ophthalmol.* 2005;123:1404-1411.
113. Zadnik K, Mutti DO, Friedman NE, Adams AJ. Initial cross-sectional results from the Orinda longitudinal study of myopia. *Optom Vis Sci.* 1993;70:750-758.
114. Robb RM. Refractive errors associated with hemangiomas of the eyelids and orbit in infancy. *Am J Ophthalmol.* 1977;83:52-58.
115. Rabin J, Van Sluyters RC, Malach R. Emmetropization: A vision-dependent phenomenon. *Invest Ophthalmol Vis Sci.* 1981;20:561-564.
116. Grosvenor T, Perrigin DM, Perrigin J, Maslovitz B. Houston myopia control study: A randomized clinical trial. Part II. Final report by the patient care team. *Am J Optom Physiol Opt.* 1987;64:482-498.
117. Jensen H. Myopia progression in young school children and intraocular pressure. *Doc Ophthalmol.* 1992;82:249-255.
118. Parssinen O, Hemminki E, Klemetti A. Effect of spectacle use and accommodation on myopic progression: Final results of a three-year randomised clinical trial among schoolchildren. *Br J Ophthalmol.* 1989;73:547-551.
119. Hyman L, Gwiazda J, Hussein M, et al. Relationship of age, sex, and ethnicity with myopia progression and axial elongation in the correction of myopia evaluation trial. *Arch Ophthalmol.* 2005;123:977-987.
120. Fan DS, Lam DS, Lam RF, et al. Prevalence, incidence, and progression of myopia of school children in Hong Kong. *Invest Ophthalmol Vis Sci.* 2004;45:1071-1075.
121. Fan DS, Rao SK, Cheung EY, et al. Astigmatism in chinese preschool children: Prevalence, change, and effect on refractive development. *Br J Ophthalmol.* 2004;88:938-941.
122. Saw SM, Tong L, Chua WH, et al. Incidence and progression of myopia in Singaporean school children. *Invest Ophthalmol Vis Sci.* 2005;46:51-57.
123. Shih YF, Chen CH, Chou AC, et al. Effects of different concentrations of atropine on controlling myopia in myopic children. *J Ocul Pharmacol Ther.* 1999;15:85-90.
124. Shih YF, Hsiao CK, Chen CJ, et al. An intervention trial on efficacy of atropine and multi-focal glasses in controlling myopic progression. *Acta Ophthalmol Scand.* 2001;79:233-236.
125. Zhao J, Mao J, Luo R, et al. The progression of refractive error in school-age children: Shunyi District, China. *Am J Ophthalmol.* 2002;134:735-743.
126. Gudmundsdottir E, Jonasson F, Jonsson V, et al. Iceland-Japan Co-Working Study Groups. "With the rule" astigmatism is not the rule in the elderly. Reykjavik Eye Study: A population based study of refraction and visual acuity in citizens of Reykjavik 50 years and older. *Acta Ophthalmol Scand.* 2000;78:642-646.
127. Montes-Mico R. Astigmatism in infancy and childhood. *J Pediatr Ophthalmol Strabismus.* 2000;37:349-353.
128. Guzowski M, Wang JJ, Rochtchina E, et al. Five-year refractive changes in an older population: The Blue Mountains Eye Study. *Ophthalmology.* 2003;110:1364-1370.
129. Gudmundsdottir E, Arnarsson A, Jonasson F. Five-year refractive changes in an adult population: Reykjavik Eye Study. *Ophthalmology.* 2005;112:672-677.

130. Liu HH, Xu L, Wang YX, et al. Prevalence and progression of myopic retinopathy in Chinese adults: The Beijing eye study. *Ophthalmology.* 2010;117:1763-1768.
131. Vongphanit J, Mitchell P, Wang JJ. Prevalence and progression of myopic retinopathy in an older population. *Ophthalmology.* 2002;109:704-711.
132. Asakuma T, Yasuda M, Ninomiya T, et al. Prevalence and risk factors for myopic retinopathy in a Japanese population: The Hisayama study. *Ophthalmology.* 2012;119:1760-1765.
133. Healey PR, Mitchell P, Gilbert CE, et al. The inheritance of peripapillary atrophy. *Invest Ophthalmol Vis Sci.* 2007;48:2529-2534.
134. Koh VT, Nah GK, Chang L, et al. Pathologic changes in highly myopic eyes of young males in Singapore. *Ann Acad Med Singapore.* 2013;42:216-224.
135. Eye Disease Case-Control Study Group. Risk factors for idiopathic rhegmatogenous retinal detachment. *Am J Epidemiol.* 1993;137:749-757.
136. Lim R, Mitchell P, Cumming RG. Refractive associations with cataract: The Blue Mountains Eye Study. *Invest Ophthalmol Vis Sci.* 1999;40:3021-3026.
137. Grodum K, Heijl A, Bengtsson B. Refractive error and glaucoma. *Acta Ophthalmol Scand.* 2001;79:560-566.
138. Wong TY, Klein BE, Klein R, et al. Refractive errors, intraocular pressure, and glaucoma in a white population. *Ophthalmology.* 2003;110:211-217.
139. Chen H, Wen F, Li H, et al. The types and severity of high myopic maculopathy in Chinese patients. *Ophthalmic Physiol Opt.* 2012;32:60-67.
140. Gao LQ, Liu W, Liang YB, et al. Prevalence and characteristics of myopic retinopathy in a rural Chinese adult population: The Handan Eye Study. *Arch Ophthalmol.* 2011;129:1199-1204.
141. Cheung CMG, Arnold JJ, Holz FG, et al. Myopic choroidal neovascularization: Review, guidance, and consensus statement on management. *Ophthalmology.* 2017;124:1690-1711.
142. Willis JR, Vitale S, Morse L, et al. The prevalence of myopic choroidal neovascularization in the United States: Analysis of the IRIS data registry and NHANES. *Ophthalmology.* 2016;123:1771-1782.
143. Marcus MW, de Vries MM, Montolio FG, Jansonius NM. Myopia as a risk factor for open-angle glaucoma: A systematic review and meta-analysis. *Ophthalmology.* 2011;118:1989-1994.
144. Ohno-Matsui K, Shimada N, Yasuzumi K, et al. Long-term development of significant visual field defects in highly myopic eyes. *Am J Ophthalmol.* 2011;152:256-265.
145. Shen L, Melles RB, Metlapally R, et al. The association of refractive error with glaucoma in a multiethnic population. *Ophthalmology.* 2016;123:92-101.
146. Kim MJ, Kim HS, Jeoung JW, Park KH. Risk factors for open-angle glaucoma with normal baseline intraocular pressure in a young population: The Korea national health and nutrition examination survey. *Clin Exp Ophthalmol.* 2014;42:825-832.
147. Chon B, Qiu M, Lin SC. Myopia and glaucoma in the South Korean population. *Invest Ophthalmol Vis Sci.* 2013;54:6570-6577.
148. Qiu M, Wang SY, Singh K, Lin SC. Association between myopia and glaucoma in the United States population. *Invest Ophthalmol Vis Sci.* 2013;54:830-835.
149. Pan CW, Cheung CY, Aung T, et al. Differential associations of myopia with major age-related eye diseases: The Singapore Indian eye study. *Ophthalmology.* 2013;120:284-291.
150. Iglesias AI, Ong JS, Khawaja AP, et al. Determining possible shared genetic architecture between myopia and primary open-angle glaucoma. *Invest Ophthalmol Vis Sci.* 2019;60:3142-3149.
151. Lowe RF. Causes of shallow anterior chamber in primary angle-closure glaucoma. Ultrasonic biometry of normal and angle-closure glaucoma eyes. *Am J Ophthalmol.* 1969;67:87-93.
152. Hainsworth DP, Gao X, Bebu I, et al. Refractive error and retinopathy outcomes in type 1 diabetes: The diabetes control and complications trial/epidemiology of diabetes interventions and complications study. *Ophthalmology.* 2021;128:554-560.
153. Kader MA. Electrophysiological study of myopia. *Saudi J Ophthalmol.* 2012;26:91-99.
154. Wood A, Guggenheim JA. Refractive error has minimal influence on the risk of age-related macular degeneration: A mendelian randomization study. *Am J Ophthalmol.* 2019;206:87-93.
155. Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia aetiology. *Prog Retin Eye Res.* 2012;31:622-660.
156. Smith TS, Frick KD, Holden BA, et al. Potential lost productivity resulting from the global burden of uncorrected refractive error. *Bull World Health Organ.* 2009;87:431-437.
157. Holden B, Sankaridurg P, Smith E, et al. Myopia, an underrated global challenge to vision: Where the current data takes us on myopia control. *Eye (Lond).* 2014;28:142-146.
158. Naidoo KS, Fricke TR, Frick KD, et al. Potential lost productivity resulting from the global burden of myopia: Systematic review, meta-analysis, and modeling. *Ophthalmology.* 2019;126:338-346.

159. Sankaridurg P, Tahhan N, Kandel H, et al. IMI impact of myopia. *Invest Ophthalmol Vis Sci.* 2021;62:2.
160. Cruz OA, Repka MX, Hercinovic A, et al. Amblyopia Preferred Practice Pattern. *Ophthalmology.* 2022.
161. Sankaridurg P, Bakaraju RC, Naduvilath T, et al. Myopia control with novel central and peripheral plus contact lenses and extended depth of focus contact lenses: 2 year results from a randomised clinical trial. *Ophthalmic Physiol Opt.* 2019;39:294-307.
162. Zhang HY, Lam CSY, Tang WC, et al. Defocus incorporated multiple segments spectacle lenses changed the relative peripheral refraction: A 2-year randomized clinical trial. *Invest Ophthalmol Vis Sci.* 2020;61:53.
163. Mutti DO, Gwiazda J, Norton TT, et al. Myopia--yesterday, today, and tomorrow. *Optom Vis Sci.* 2013;90:1161-1164.
164. Modjtahedi BS, Abbott RL, Fong DS, et al. Reducing the global burden of myopia by delaying the onset of myopia and reducing myopic progression in children: The Academy's Task Force on Myopia. *Ophthalmology.* 2021;128:816-826.
165. Hutchinson AK, Morse CL, Hercinovic A, et al. Pediatric Eye Evaluations Preferred Practice Pattern. *Ophthalmology.* 2022.
166. Chuck RS, Dunn SP, Flaxel CJ, et al. Comprehensive Adult Medical Eye Evaluation Preferred Practice Pattern. *Ophthalmology.* 2020;128:1-29.
167. Zadnik K, Mutti DO, Adams AJ. The repeatability of measurement of the ocular components. *Invest Ophthalmol Vis Sci.* 1992;33:2325-2333.
168. Goss DA, Grosvenor T. Reliability of refraction--a literature review. *J Am Optom Assoc.* 1996;67:619-630.
169. Hofmeister EM, Kaupp SE, Schallhorn SC. Comparison of tropicamide and cyclopentolate for cycloplegic refractions in myopic adult refractive surgery patients. *J Cataract Refract Surg.* 2005;31:694-700.
170. Jacobs DS, Lee JK, Shen TT, et al. Refractive Surgery Preferred Practice Pattern. *Ophthalmology.* 2022.
171. McCarty CA. Uncorrected refractive error. *Br J Ophthalmol.* 2006;90:521-522.
172. Sprunger DT, Lambert SR, Hercinovic A, et al. Esotropia and Exotropia Preferred Practice Pattern. *Ophthalmology.* 2022.
173. American Academy of Pediatrics and American Academy of Ophthalmology. Joint policy statement. Protective eyewear for young athletes. San Francisco, CA: American Academy of Ophthalmology; 2013. https://www.aao.org/clinical-statement/protective-eyewear-young-athletes. Accessed August 25, 2022.
174. Vinger PF, Parver L, Alfaro DV, 3rd, et al. Shatter resistance of spectacle lenses. *JAMA.* 1997;277:142-144.
175. Nichols JJ, Willcox MD, Bron AJ, et al. Members of the TFOS International Workshop on Contact Lens Discomfort. The TFOS international workshop on contact lens discomfort: Executive summary. *Invest Ophthalmol Vis Sci.* 2013;54:TFOS7-TFOS13.
176. Efron N, Morgan PB, Woods CA. International survey of rigid contact lens fitting. *Optom Vis Sci.* 2013;90:113-118.
177. Nichols JJ. Contact lenses 2015. *Contact lens spectrum* 2016;31:18-23, 55. https://www.clspectrum.com/issues/2016/january-2016/contact-lenses-2015. Accessed August 25, 2022.
178. Collier SA, Gronostaj MP, MacGurn AK, et al. Estimated burden of keratitis--United States, 2010. *MMWR Morb Mortal Wkly Rep.* 2014;63:1027-1030.
179. Asbell PA, Wasserman D. Contact lens-induced corneal warpage. *Int Ophthalmol Clin.* 1991;31:121-126.
180. Macsai MS, Varley GA, Krachmer JH. Development of keratoconus after contact lens wear. Patient characteristics. *Arch Ophthalmol.* 1990;108:534-538.
181. Elhers WH, Donshik PC. Giant papillary conjunctivitis. *Curr Opin Allergy Clin Immunol.* 2008;8:445-449.
182. Jeng BH, Halfpenny CP, Meisler DM, Stock EL. Management of focal limbal stem cell deficiency associated with soft contact lens wear. *Cornea.* 2011;30:18-23.
183. Martin R. Corneal conjunctivalisation in long-standing contact lens wearers. *Clin Exp Optom.* 2007;90:26-30.
184. Jalbert I, Sweeney DF, Stapleton F. The effect of long-term wear of soft lenses of low and high oxygen transmissibility on the corneal epithelium. *Eye (Lond).* 2009;23:1282-1287.
185. Chan CC, Holland EJ. Severe limbal stem cell deficiency from contact lens wear: Patient clinical features. *Am J Ophthalmol.* 2013;155:544-549.
186. Kim BY, Riaz KM, Bakhtiari P, et al. Medically reversible limbal stem cell disease: Clinical features and management strategies. *Ophthalmology.* 2014;121:2053-2058.
187. Liu Z, Pflugfelder SC. The effects of long-term contact lens wear on corneal thickness, curvature, and surface regularity. *Ophthalmology.* 2000;107:105-111.
188. Lei Y, Zheng X, Hou J, et al. Effects of long-term soft contact lens wear on the corneal thickness and corneal epithelial thickness of myopic subjects. *Mol Med Rep.* 2015;11:2020-2026.
189. Sel S, Trau S, Knak M, et al. Evaluation of central corneal thickness after cataract surgery, penetrating keratoplasty and long-term soft contact lens wear. *Cont Lens Anterior Eye.* 2013;36:238-242.

190. MacRae SM, Matsuda M, Shellans S, Rich LF. The effects of hard and soft contact lenses on the corneal endothelium. *Am J Ophthalmol.* 1986;102:50-57.
191. MacRae SM, Matsuda M, Shellans S. Corneal endothelial changes associated with contact lens wear. *CLAO J.* 1989;15:82-87.
192. MacRae SM, Matsuda M, Phillips DS. The long-term effects of polymethylmethacrylate contact lens wear on the corneal endothelium. *Ophthalmology.* 1994;101:365-370.
193. Baum J, Barza M. Pseudomonas keratitis and extended-wear soft contact lenses. *Arch Ophthalmol.* 1990;108:663-664.
194. Koidou-Tsiligianni A, Alfonso E, Forster RK. Ulcerative keratitis associated with contact lens wear. *Am J Ophthalmol.* 1989;108:64-67.
195. Cohen EJ, Laibson PR, Arentsen JJ, Clemons CS. Corneal ulcers associated with cosmetic extended wear soft contact lenses. *Ophthalmology.* 1987;94:109-114.
196. Wilson LA, Ahearn DG. Association of fungi with extended-wear soft contact lenses. *Am J Ophthalmol.* 1986;101:434-436.
197. Wilhelmus KR, Robinson NM, Font RA, et al. Fungal keratitis in contact lens wearers. *Am J Ophthalmol.* 1988;106:708-714.
198. Moore MB, McCulley JP, Luckenbach M, et al. Acanthamoeba keratitis associated with soft contact lenses. *Am J Ophthalmol.* 1985;100:396-403.
199. Stehr-Green JK, Bailey TM, Visvesvara GS. The epidemiology of acanthamoeba keratitis in the united states. *Am J Ophthalmol.* 1989;107:331-336.
200. Stern GA, Zam SZ. The pathogenesis of contact lens-associated pseudomonas aeruginosa corneal ulceration. 1. The effect of contact lens coatings on adherence of pseudomonas aeruginosa to soft contact lenses. *Cornea.* 1986;5:41-45.
201. Schein OD, Glynn RJ, Poggio EC, et al. Microbial Keratitis Study Group. The relative risk of ulcerative keratitis among users of daily-wear and extended-wear soft contact lenses: A case-control study. *N Engl J Med.* 1989;321:773-778.
202. Poggio EC, Glynn RJ, Schein OD, et al. The incidence of ulcerative keratitis among users of daily-wear and extended-wear soft contact lenses. *N Engl J Med.* 1989;321:779-783.
203. Schein OD, Buehler PO, Stamler JF, et al. The impact of overnight wear on the risk of contact lens-associated ulcerative keratitis. *Arch Ophthalmol.* 1994;112:186-190.
204. Nilsson SE, Montan PG. The annualized incidence of contact lens induced keratitis in Sweden and its relation to lens type and wear schedule: Results of a 3-month prospective study. *CLAO J.* 1994;20:225-230.
205. Poggio EC, Abelson M. Complications and symptoms in disposable extended wear lenses compared with conventional soft daily wear and soft extended wear lenses. *CLAO J.* 1993;19:31-39.
206. Nilsson SE, Montan PG. The hospitalized cases of contact lens induced keratitis in sweden and their relation to lens type and wear schedule: Results of a three-year retrospective study. *CLAO J.* 1994;20:97-101.
207. Laibson PR, Cohen EJ, Rajpal RK. Conrad Berens Lecture. Corneal ulcers related to contact lenses. *CLAO J.* 1993;19:73-78.
208. Maguen E, Tsai JC, Martinez M, et al. A retrospective study of disposable extended-wear lenses in 100 patients. *Ophthalmology.* 1991;98:1685-1689.
209. Cohen EJ, Fulton JC, Hoffman CJ, et al. Trends in contact lens-associated corneal ulcers. *Cornea.* 1996;15:566-570.
210. Yildiz EH, Airiani S, Hammersmith KM, et al. Trends in contact lens-related corneal ulcers at a tertiary referral center. *Cornea.* 2012;31:1097-1102.
211. Lee YS, Tan HY, Yeh LK, et al. Pediatric microbial keratitis in Taiwan: Clinical and microbiological profiles, 1998-2002 versus 2008-2012. *Am J Ophthalmol.* 2014;157:1090-1096.
212. Poggio EC, Abelson MB. Complications and symptoms with disposable daily wear contact lenses and conventional soft daily wear contact lenses. *CLAO J.* 1993;19:95-102.
213. Chalmers RL, Keay L, McNally J, Kern J. Multicenter case-control study of the role of lens materials and care products on the development of corneal infiltrates. *Optom Vis Sci.* 2012;89:316-325.
214. Chalmers RL, Hickson-Curran SB, Keay L, et al. Rates of adverse events with hydrogel and silicone hydrogel daily disposable lenses in a large postmarket surveillance registry: The TEMPO registry. *Invest Ophthalmol Vis Sci.* 2015;56:654-663.
215. Imayasu M, Petroll WM, Jester JV, et al. The relation between contact lens oxygen transmissibility and binding of pseudomonas aeruginosa to the cornea after overnight wear. *Ophthalmology.* 1994;101:371-388.
216. Ren DH, Petroll WM, Jester JV, et al. The relationship between contact lens oxygen permeability and binding of pseudomonas aeruginosa to human corneal epithelial cells after overnight and extended wear. *CLAO J.* 1999;25:80-100.

217. Ren DH, Yamamoto K, Ladage PM, et al. Adaptive effects of 30-night wear of hyper-o(2) transmissible contact lenses on bacterial binding and corneal epithelium: A 1-year clinical trial. *Ophthalmology.* 2002;109:27-39; discussion 39-40.
218. Ladage PM, Yamamoto K, Ren DH, et al. Effects of rigid and soft contact lens daily wear on corneal epithelium, tear lactate dehydrogenase, and bacterial binding to exfoliated epithelial cells. *Ophthalmology.* 2001;108:1279-1288.
219. Schein OD, McNally JJ, Katz J, et al. The incidence of microbial keratitis among wearers of a 30-day silicone hydrogel extended-wear contact lens. *Ophthalmology.* 2005;112:2172-2179.
220. Dart JK, Radford CF, Minassian D, et al. Risk factors for microbial keratitis with contemporary contact lenses: A case-control study. *Ophthalmology.* 2008;115:1647-1654.
221. Stapleton F, Keay L, Edwards K, et al. The incidence of contact lens-related microbial keratitis in Australia. *Ophthalmology.* 2008;115:1655-1662.
222. Stapleton F, Edwards K, Keay L, et al. Risk factors for moderate and severe microbial keratitis in daily wear contact lens users. *Ophthalmology.* 2012;119:1516-1521.
223. Lim CH, Carnt NA, Farook M, et al. Risk factors for contact lens-related microbial keratitis in Singapore. *Eye (Lond).* 2016;30:447-455.
224. American Academy of Ophthalmology. Information Statement. Extended wear of contact lenses. San Francisco, CA: American Academy of Ophthalmology; 2013. https://www.aao.org/clinical-statement/extended-wear-of-contact-lenses. Accessed August 25, 2022.
225. Morgan PB, Brennan NA, Maldonado-Codina C, et al. Central and peripheral oxygen transmissibility thresholds to avoid corneal swelling during open eye soft contact lens wear. *J Biomed Mater Res B Appl Biomater.* 2010;92:361-365.
226. Diec J, Tilia D, Thomas V. Comparison of silicone hydrogel and hydrogel daily disposable contact lenses. *Eye Contact Lens.* 2018;44 Suppl 1:S167-S172.
227. Stapleton F, Lim CHL, Kweon S, et al. Cosmetic contact lens-related corneal infections in Asia. *Am J Ophthalmol.* 2021;229:176-183.
228. Nilsson SE. Seven-day extended wear and 30-day continuous wear of high oxygen transmissibility soft silicone hydrogel contact lenses: A randomized 1-year study of 504 patients. *CLAO J.* 2001;27:125-136.
229. Szczotka-Flynn L, Debanne SM, Cheruvu VK, et al. Predictive factors for corneal infiltrates with continuous wear of silicone hydrogel contact lenses. *Arch Ophthalmol.* 2007;125:488-492.
230. Szczotka-Flynn L, Lass JH, Sethi A, et al. Risk factors for corneal infiltrative events during continuous wear of silicone hydrogel contact lenses. *Invest Ophthalmol Vis Sci.* 2010;51:5421-5430.
231. Szczotka-Flynn L, Jiang Y, Raghupathy S, et al. Corneal inflammatory events with daily silicone hydrogel lens wear. *Optom Vis Sci.* 2014;91:3-12.
232. Lin MC, Polse KA. Hypoxia, overnight wear, and tear stagnation effects on the corneal epithelium: Data and proposed model. *Eye Contact Lens.* 2007;33:378-381; discussion 382.
233. Radford CF, Minassian D, Dart JK, et al. Risk factors for nonulcerative contact lens complications in an ophthalmic accident and emergency department: A case-control study. *Ophthalmology.* 2009;116:385-392.
234. Diec J, Papas E, Naduvilath T, et al. Combined effect of comfort and adverse events on contact lens performance. *Optom Vis Sci.* 2013;90:674-681.
235. Ozkan J, Willcox MD, Rathi VM, et al. Effect of antibiotic drops on adverse events during extended lens wear. *Optom Vis Sci.* 2014;91:13-23.
236. Richdale K, Lam DY, Wagner H, et al. Case-control pilot study of soft contact lens wearers with corneal infiltrative events and healthy controls. *Invest Ophthalmol Vis Sci.* 2016;57:47-55.
237. Zimmerman AB, Emch AJ, Geldis J, et al. Contact lens corneal inflammatory events in a university population. *Optom Vis Sci.* 2016;93:42-49.
238. Lazon de la Jara P, Papas E, Diec J, et al. Effect of lens care systems on the clinical performance of a contact lens. *Optom Vis Sci.* 2013;90:344-350.
239. Mondino BJ, Weissman BA, Farb MD, Pettit TH. Corneal ulcers associated with daily-wear and extended-wear contact lenses. *Am J Ophthalmol.* 1986;102:58-65.
240. Cope JR, Konne NM, Jacobs DS, et al. Corneal infections associated with sleeping in contact lenses - six cases, United States, 2016-2018. *MMWR Morb Mortal Wkly Rep.* 2018;67:877-881.
241. Alfonso EC, Cantu-Dibildox J, Munir WM, et al. Insurgence of fusarium keratitis associated with contact lens wear. *Arch Ophthalmol.* 2006;124:941-947.
242. Bernal MD, Acharya NR, Lietman TM, et al. Outbreak of fusarium keratitis in soft contact lens wearers in San Francisco. *Arch Ophthalmol.* 2006;124:1051-1053.
243. Chang DC, Grant GB, O'Donnell K, et al. Multistate outbreak of fusarium keratitis associated with use of a contact lens solution. *JAMA.* 2006;296:953-963.

244. Joslin CE, Tu EY, McMahon TT, et al. Epidemiological characteristics of a Chicago-area acanthamoeba keratitis outbreak. *Am J Ophthalmol.* 2006;142:212-217.
245. Joslin CE, Tu EY, Shoff ME, et al. The association of contact lens solution use and acanthamoeba keratitis. *Am J Ophthalmol.* 2007;144:169-180.
246. Khor WB, Aung T, Saw SM, et al. An outbreak of fusarium keratitis associated with contact lens wear in Singapore. *JAMA.* 2006;295:2867-2873.
247. Margolis TP, Whitcher JP. Fusarium--a new culprit in the contact lens case. *JAMA.* 2006;296:985-987.
248. Thebpatiphat N, Hammersmith KM, Rocha FN, et al. Acanthamoeba keratitis: A parasite on the rise. *Cornea.* 2007;26:701-706.
249. Saw SM, Ooi PL, Tan DT, et al. Risk factors for contact lens-related fusarium keratitis: A case-control study in Singapore. *Arch Ophthalmol.* 2007;125:611-617.
250. Update: Fusarium keratitis--United States, 2005-2006. *MMWR Morb Mortal Wkly Rep.* 2006;55:563-564.
251. Alfonso EC, Miller D, Cantu-Dibildox J, et al. Fungal keratitis associated with non-therapeutic soft contact lenses. *Am J Ophthalmol.* 2006;142:154-155.
252. Anger C, Lally JM. Acanthamoeba: A review of its potential to cause keratitis, current lens care solution disinfection standards and methodologies, and strategies to reduce patient risk. *Eye Contact Lens.* 2008;34:247-253.
253. Butcko V, McMahon TT, Joslin CE, Jones L. Microbial keratitis and the role of rub and rinsing. *Eye Contact Lens.* 2007;33:421-423; discussion 424-425.
254. Dyavaiah M, Ramani R, Chu DS, et al. Molecular characterization, biofilm analysis and experimental biofouling study of fusarium isolates from recent cases of fungal keratitis in New York state. *BMC Ophthalmol.* 2007;7:1.
255. Hall BJ, Jones L. Contact lens cases: The missing link in contact lens safety? *Eye Contact Lens.* 2010;36:101-105.
256. Levy B, Heiler D, Norton S. Report on testing from an investigation of fusarium keratitis in contact lens wearers. *Eye Contact Lens.* 2006;32:256-261.
257. Lindsay RG, Watters G, Johnson R, et al. Acanthamoeba keratitis and contact lens wear. *Clin Exp Optom.* 2007;90:351-360.
258. American Society of Cataract and Refractive Surgery Infectious Disease Task Force. ASCRS white paper. Special report: Acanthamoeba keratitis. July 2007.
259. Acanthamoeba keratitis multiple states, 2005-2007. *MMWR Morb Mortal Wkly Rep.* 2007;56:532-534.
260. Gower EW, Keay LJ, Oechsler RA, et al. Trends in fungal keratitis in the United States, 2001 to 2007. *Ophthalmology.* 2010;117:2263-2267.
261. Iyer SA, Tuli SS, Wagoner RC. Fungal keratitis: Emerging trends and treatment outcomes. *Eye Contact Lens.* 2006;32:267-271.
262. Tu EY, Joslin CE. Recent outbreaks of atypical contact lens-related keratitis: What have we learned? *Am J Ophthalmol.* 2010;150:602-608.
263. Tuli SS, Iyer SA, Driebe WT, Jr. Fungal keratitis and contact lenses: An old enemy unrecognized or a new nemesis on the block? *Eye Contact Lens.* 2007;33:415-417; discussion 424-415.
264. Scanzera AC, Tu EY, Joslin CE. Acanthamoeba keratitis in minors with orthokeratology (OK) lens use: A case series. *Eye Contact Lens.* 2021;47:71-73.
265. Yoder JS, Verani J, Heidman N, et al. Acanthamoeba keratitis: The persistence of cases following a multistate outbreak. *Ophthalmic Epidemiol.* 2012;19:221-225.
266. Cope JR, Collier SA, Schein OD, et al. Acanthamoeba keratitis among rigid gas permeable contact lens wearers in the United States, 2005 through 2011. *Ophthalmology.* 2016;123:1435-1441.
267. Arshad M, Carnt N, Tan J, et al. Water exposure and the risk of contact lens-related disease. *Cornea.* 2019;38:791-797.
268. Stellwagen A, MacGregor C, Kung R, et al. Personal hygiene risk factors for contact lens-related microbial keratitis. *BMJ Open Ophthalmol.* 2020;5:e000476.
269. Carnt N, Hoffman JM, Verma S, et al. Acanthamoeba keratitis: Confirmation of the UK outbreak and a prospective case-control study identifying contributing risk factors. *Br J Ophthalmol.* 2018;102:1621-1628.
270. O'Donnell K, Sarver BA, Brandt M, et al. Phylogenetic diversity and microsphere array-based genotyping of human pathogenic fusaria, including isolates from the multistate contact lens-associated U.S. keratitis outbreaks of 2005 and 2006. *J Clin Microbiol.* 2007;45:2235-2248.
271. U.S. Food and Drug Administration. Consumer health information. Ensuring safe use of contact lens solution. 2009.
272. Centers for Disease Control and Prevention. Healthy contact lens wear. 2016.

273. Cope JR, Collier SA, Nethercut H, et al. Risk behaviors for contact lens-related eye infections among adults and adolescents - United States, 2016. *MMWR Morb Mortal Wkly Rep.* 2017;66:841-845.
274. U.S. Food and Drug Administration. Guidance for industry, FDA staff, eye care professionals, and consumers. Decorative, non-corrective contact lenses. November 24, 2006. https://www.fda.gov/regulatory-information/search-fda-guidance-documents/decorative-non-corrective-contact-lenses. Accessed August 25, 2022.
275. American Academy of Ophthalmology. Eye health. Colored contact lenses; 2015. https://www.aao.org/eye-health/glasses-contacts/colored-lenses. Accessed August 25, 2022.
276. Federal Trade Commission. Contact lens rule. 2016. https://www.ftc.gov/legal-library/browse/rules/contact-lens-rule. Accessed August 25, 2022.
277. Bowden FW, III, Cohen EJ, Arentsen JJ, Laibson PR. Patterns of lens care practices and lens product contamination in contact lens associated microbial keratitis. *CLAO J.* 1989;15:49-54.
278. Cavanagh HD, Robertson DM, Petroll WM, Jester JV. Castroviejo lecture 2009: 40 years in search of the perfect contact lens. *Cornea.* 2010;29:1075-1085.
279. Johnston SP, Sriram R, Qvarnstrom Y, et al. Resistance of acanthamoeba cysts to disinfection in multiple contact lens solutions. *J Clin Microbiol.* 2009;47:2040-2045.
280. Hughes R, Kilvington S. Comparison of hydrogen peroxide contact lens disinfection systems and solutions against acanthamoeba polyphaga. *Antimicrob Agents Chemother.* 2001;45:2038-2043.
281. Acanthamoeba keratitis associated with contact lenses--United States. *MMWR Morb Mortal Wkly Rep.* 1986;35:405-408.
282. Zimmerman AB, Richdale K, Mitchell GL, et al. Water exposure is a common risk behavior among soft and gas-permeable contact lens wearers. *Cornea.* 2017;36:995-1001.
283. Wu YT, Zhu H, Willcox M, Stapleton F. The effectiveness of various cleaning regimens and current guidelines in contact lens case biofilm removal. *Invest Ophthalmol Vis Sci.* 2011;52:5287-5292.
284. U.S. Food and Drug Administration. Consumer health information. Ensuring safe use of contact lens solution; 2009.
285. Stehr-Green JK, Bailey TM, Brandt FH, et al. Acanthamoeba keratitis in soft contact lens wearers. A case-control study. *JAMA.* 1987;258:57-60.
286. Keay L, Stapleton F, Schein O. Epidemiology of contact lens-related inflammation and microbial keratitis: A 20-year perspective. *Eye Contact Lens.* 2007;33:346-353, discussion 362-343.
287. Stapleton F, Keay L, Edwards K, Holden B. The epidemiology of microbial keratitis with silicone hydrogel contact lenses. *Eye Contact Lens.* 2013;39:79-85.
288. Forister JF, Forister EF, Yeung KK, et al. Prevalence of contact lens-related complications: UCLA contact lens study. *Eye Contact Lens.* 2009;35:176-180.
289. Bui TH, Cavanagh HD, Robertson DM. Patient compliance during contact lens wear: Perceptions, awareness, and behavior. *Eye Contact Lens.* 2010;36:334-339.
290. Robertson DM, Cavanagh HD. Non-compliance with contact lens wear and care practices: A comparative analysis. *Optom Vis Sci.* 2011;88:1402-1408.
291. Efron N. Obituary--rigid contact lenses. *Cont Lens Anterior Eye.* 2010;33:245-252.
292. Suchecki JK, Ehlers WH, Donshik PC. A comparison of contact lens-related complications in various daily wear modalities. *CLAO J.* 2000;26:204-213.
293. Binder PS, May CH, Grant SC. An evaluation of orthokeratology. *Ophthalmology.* 1980;87:729-744.
294. Polse KA, Brand RJ, Vastine DW, Schwalbe JS. Corneal change accompanying orthokeratology. Plastic or elastic? Results of a randomized controlled clinical trial. *Arch Ophthalmol.* 1983;101:1873-1878.
295. Carkeet NL, Mountford JA, Carney LG. Predicting success with orthokeratology lens wear: A retrospective analysis of ocular characteristics. *Optom Vis Sci.* 1995;72:892-898.
296. Nichols JJ, Marsich MM, Nguyen M, et al. Overnight orthokeratology. *Optom Vis Sci.* 2000;77:252-259.
297. Rah MJ, Jackson JM, Jones LA, et al. Overnight orthokeratology: Preliminary results of the lenses and overnight orthokeratology (LOOK) study. *Optom Vis Sci.* 2002;79:598-605.
298. Sorbara L, Fonn D, Simpson T, et al. Reduction of myopia from corneal refractive therapy. *Optom Vis Sci.* 2005;82:512-518.
299. Walline JJ, Holden BA, Bullimore MA, et al. The current state of corneal reshaping. *Eye Contact Lens.* 2005;31:209-214.
300. Walline JJ, Rah MJ, Jones LA. The children's overnight orthokeratology investigation (COOKI) pilot study. *Optom Vis Sci.* 2004;81:407-413.
301. Ozyol P, Ucakhan-Gunduz O, Ozyol E, Kanpolat A. Overnight orthokeratology with two brands of reverse-geometry contact lenses. *Cont Lens Anterior Eye.* 2013;36:106-112.
302. Watt K, Swarbrick HA. Microbial keratitis in overnight orthokeratology: Review of the first 50 cases. *Eye Contact Lens.* 2005;31:201-208.

303. Young AL, Leung AT, Cheng LL, et al. Orthokeratology lens-related corneal ulcers in children: A case series. *Ophthalmology.* 2004;111:590-595.
304. Kam KW, Yung W, Li GKH, et al. Infectious keratitis and orthokeratology lens use: A systematic review. *Infection.* 2017.
305. Bullimore MA, Sinnott LT, Jones-Jordan LA. The risk of microbial keratitis with overnight corneal reshaping lenses. *Optom Vis Sci.* 2013;90:937-944.
306. Chen KH, Kuang TM, Hsu WM. Serratia marcescens corneal ulcer as a complication of orthokeratology. *Am J Ophthalmol.* 2001;132:257-258.
307. Macsai MS. Corneal ulcers in two children wearing paragon corneal refractive therapy lenses. *Eye Contact Lens.* 2005;31:9-11.
308. Watt KG, Swarbrick HA. Trends in microbial keratitis associated with orthokeratology. *Eye Contact Lens.* 2007;33:373-377; Discussion 382.
309. Van Meter WS, Musch DC, Jacobs DS, et al. Safety of overnight orthokeratology for myopia: A report by the American Academy of Ophthalmology. *Ophthalmology.* 2008;115:2301-2313.
310. Liu YM, Xie P. The safety of orthokeratology--a systematic review. *Eye Contact Lens.* 2016;42:35-42.
311. Jakobsen TM, Moller F. Control of myopia using orthokeratology lenses in Scandinavian children aged 6 to 12 years. Eighteen-month data from the Danish randomized study: Clinical study of near-sightedness; treatment with orthokeratology lenses (CONTROL study). *Acta Ophthalmol.* 2022;100:175-182.
312. Goto T, Shiraishi A, Ohashi Y, et al. A multicenter clinical trial of orthokeratology in school-aged children and adolescents in Japan. *Jpn J Ophthalmol.* 2021;65:624-631.
313. VanderVeen DK, Kraker RT, Pineles SL, et al. Use of orthokeratology for the prevention of myopic progression in children: A report by the American Academy of Ophthalmology. *Ophthalmology.* 2019;126:623-636.
314. Xu J, Gao B, Tian Q, et al. Effects of orthokeratology on axial length elongation in anisometropes. *Ophthalmic Res.* 2021;64:991-1001.
315. Saw SM, Shih-Yen EC, Koh A, Tan D. Interventions to retard myopia progression in children: An evidence-based update. *Ophthalmology.* 2002;109:415-421; discussion 422-414.
316. Li SM, Wu SS, Kang MT, et al. Atropine slows myopia progression more in Asian than white children by meta-analysis. *Optom Vis Sci.* 2014;91:342-350.
317. Walline JJ, Lindsley KB, Vedula SS, et al. Interventions to slow progression of myopia in children. *Cochrane Database Syst Rev.* 2020;1:CD004916.
318. Huang J, Wen D, Wang Q, et al. Efficacy comparison of 16 interventions for myopia control in children: A network meta-analysis. *Ophthalmology.* 2016;123:697-708.
319. Walline JJ. Myopia control: A review. *Eye Contact Lens.* 2016;42:3-8.
320. Chia A, Chua WH, Cheung YB, et al. Atropine for the treatment of childhood myopia: Safety and efficacy of 0.5%, 0.1%, and 0.01% doses (atropine for the treatment of myopia 2). *Ophthalmology.* 2012;119:347-354.
321. Chia A, Lu QS, Tan D. Five-year clinical trial on atropine for the treatment of myopia 2: Myopia control with atropine 0.01% eyedrops. *Ophthalmology.* 2016;123:391-399.
322. Swarbrick HA, Alharbi A, Watt K, et al. Myopia control during orthokeratology lens wear in children using a novel study design. *Ophthalmology.* 2015;122:620-630.
323. Cheng X, Xu J, Chehab K, et al. Soft contact lenses with positive spherical aberration for myopia control. *Optom Vis Sci.* 2016;93:353-366.
324. Chia A, Chua WH, Wen L, et al. Atropine for the treatment of childhood myopia: Changes after stopping atropine 0.01%, 0.1% and 0.5%. *Am J Ophthalmol.* 2014;157:451-457.
325. Pineles SL, Kraker RT, VanderVeen DK, et al. Atropine for the prevention of myopia progression in children: A report by the American Academy of Ophthalmology. *Ophthalmology* 2017;124:1857-1866.
326. Yang N, Bai J, Liu L. Low concentration atropine combined with orthokeratology in the treatment of axial elongation in children with myopia: A meta-analysis. *Eur J Ophthalmol.* 2022;32:221-228.
327. Lam CS, Tang WC, Tse DY, et al. Defocus incorporated soft contact (DISC) lens slows myopia progression in Hong Kong Chinese schoolchildren: A 2-year randomised clinical trial. *Br J Ophthalmol.* 2014;98:40-45.
328. Shah RL, Huang Y, Guggenheim JA, Williams C. Time outdoors at specific ages during early childhood and the risk of incident myopia. *Invest Ophthalmol Vis Sci.* 2017;58:1158-1166.
329. Xiong S, Sankaridurg P, Naduvilath T, et al. Time spent in outdoor activities in relation to myopia prevention and control: A meta-analysis and systematic review. *Acta Ophthalmol.* 2017;95:551-566.
330. Wu PC, Chen CT, Lin KK, et al. Myopia prevention and outdoor light intensity in a school-based cluster randomized trial. *Ophthalmology.* 2018;125:1239-1250.

331. Yao L, Qi LS, Wang XF, et al. Refractive change and incidence of myopia among a group of highly selected senior high school students in China: A prospective study in an aviation cadet prerecruitment class. *Invest Ophthalmol Vis Sci.* 2019;60:1344-1352.
332. Grzybowski A, Kanclerz P, Tsubota K, et al. A review on the epidemiology of myopia in school children worldwide. *BMC Ophthalmol.* 2020;20:27.
333. He X, Sankaridurg P, Xiong S, et al. Shanghai time outside to reduce myopia trial: Design and baseline data. *Clin Exp Ophthalmol.* 2019;47:171-178.
334. Walline JJ, Walker MK, Mutti DO, et al. Effect of high add power, medium add power, or single-vision contact lenses on myopia progression in children: The BLINK randomized clinical trial. *JAMA.* 2020;324:571-580.
335. Chamberlain P, Peixoto-de-Matos SC, Logan NS, et al. A 3-year randomized clinical trial of MiSight lenses for myopia control. *Optom Vis Sci.* 2019;96:556-567.
336. Ong E, Grice K, Held R, et al. Effects of spectacle intervention on the progression of myopia in children. *Optom Vis Sci.* 1999;76:363-369.
337. Vasudevan B, Esposito C, Peterson C, et al. Under-correction of human myopia--is it myopigenic?: A retrospective analysis of clinical refraction data. *J Optom.* 2014;7:147-152.
338. Fulk GW, Cyert LA, Parker DE. A randomized trial of the effect of single-vision vs. bifocal lenses on myopia progression in children with esophoria. *Optom Vis Sci.* 2000;77:395-401.
339. Leung JT, Brown B. Progression of myopia in Hong Kong Chinese schoolchildren is slowed by wearing progressive lenses. *Optom Vis Sci.* 1999;76:346-354.
340. Gwiazda J, Hyman L, Hussein M, et al. A randomized clinical trial of progressive addition lenses versus single vision lenses on the progression of myopia in children. *Invest Ophthalmol Vis Sci.* 2003;44:1492-1500.
341. Li SM, Ji YZ, Wu SS, et al. Multifocal versus single vision lenses intervention to slow progression of myopia in school-age children: A meta-analysis. *Surv Ophthalmol.* 2011;56:451-460.
342. Cheng D, Woo GC, Drobe B, Schmid KL. Effect of bifocal and prismatic bifocal spectacles on myopia progression in children: Three-year results of a randomized clinical trial. *JAMA Ophthalmol.* 2014;132:258-264.
343. Kaphle D, Atchison DA, Schmid KL. Multifocal spectacles in childhood myopia: Are treatment effects maintained? A systematic review and meta-analysis. *Surv Ophthalmol.* 2020;65:239-249.
344. Lam CSY, Tang WC, Tse DY, et al. Defocus incorporated multiple segments (DIMS) spectacle lenses slow myopia progression: A 2-year randomised clinical trial. *Br J Ophthalmol.* 2020;104:363-368.
345. Oishi T, Lauber JK. Chicks blinded with formoguanamine do not develop lid suture myopia. *Curr Eye Res.* 1988;7:69-73.
346. Tigges M, Iuvone PM, Fernandes A, et al. Effects of muscarinic cholinergic receptor antagonists on postnatal eye growth of rhesus monkeys. *Optom Vis Sci.* 1999;76:397-407.
347. Lind GJ, Chew SJ, Marzani D, Wallman J. Muscarinic acetylcholine receptor antagonists inhibit chick scleral chondrocytes. *Invest Ophthalmol Vis Sci.* 1998;39:2217-2231.
348. Yen MY, Liu JH, Kao SC, Shiao CH. Comparison of the effect of atropine and cyclopentolate on myopia. *Ann Ophthalmol.* 1989;21:180-187.
349. Chua WH, Balakrishnan V, Chan YH, et al. Atropine for the treatment of childhood myopia. *Ophthalmology.* 2006;113:2285-2291.
350. Yam JC, Li FF, Zhang X, et al. Two-year clinical trial of the low-concentration atropine for myopia progression (LAMP) study: Phase 2 report. *Ophthalmology.* 2020;127:910-919.
351. Yam JC, Zhang XJ, Zhang Y, et al. Three-year clinical trial of low-concentration atropine for myopia progression (LAMP) study: Continued versus washout: Phase 3 report. *Ophthalmology.* 2022;129:308-321.
352. Chiang MF, Kouzis A, Pointer RW, Repka MX. Treatment of childhood myopia with atropine eyedrops and bifocal spectacles. *Binocul Vis Strabismus Q.* 2001;16:209-215.
353. Syniuta LA, Isenberg SJ. Atropine and bifocals can slow the progression of myopia in children. *Binocul Vis Strabismus Q.* 2001;16:203-208.
354. Kennedy RH, Dyer JA, Kennedy MA, et al. Reducing the progression of myopia with atropine: A long term cohort study of Olmsted County students. *Binocul Vis Strabismus Q.* 2000;15:281-304.
355. Ha A, Kim SJ, Shim SR, et al. Efficacy and safety of 8 atropine concentrations for myopia control in children: A network meta-analysis. *Ophthalmology.* 2022;129:322-333.
356. Luu CD, Lau AM, Koh AH, Tan D. Multifocal electroretinogram in children on atropine treatment for myopia. *Br J Ophthalmol.* 2005;89:151-153.
357. Schwartz JT. Results of a monozygotic cotwin control study on a treatment for myopia. *Prog Clin Biol Res.* 1981;69 Pt C:249-258.
358. Siatkowski RM, Cotter S, Miller JM, et al. Safety and efficacy of 2% pirenzepine ophthalmic gel in children with myopia: A 1-year, multicenter, double-masked, placebo-controlled parallel study. *Arch Ophthalmol.* 2004;122:1667-1674.

359. Tan DT, Lam DS, Chua WH, et al. One-year multicenter, double-masked, placebo-controlled, parallel safety and efficacy study of 2% pirenzepine ophthalmic gel in children with myopia. *Ophthalmology.* 2005;112:84-91.
360. Zhao C, Cai C, Ding Q, Dai H. Efficacy and safety of atropine to control myopia progression: A systematic review and meta-analysis. *BMC Ophthalmol.* 2020;20:478.
361. Gao C, Wan S, Zhang Y, Han J. The efficacy of atropine combined with orthokeratology in slowing axial elongation of myopia children: A meta-analysis. *Eye Contact Lens.* 2021;47:98-103.
362. Jessen GN. Contact lenses as a therapeutic device. *Am J Optom Arch Am Acad Optom.* 1964;41:429-435.
363. Morrison RJ. The use of contact lenses in adolescent myopic patients. *Am J Optom Arch Am Acad Optom.* 1960;37:165-168.
364. Stone J. Contact lens wear in the young myope. *Br J Physiol Opt.* 1973;28:90-134.
365. Stone J. The possible influence of contact lenses on myopia. *Br J Physiol Opt.* 1976;31:89-114.
366. Grosvenor T, Goss DA. The role of bifocal and contact lenses in myopia control. *Acta Ophthalmol Suppl.* 1988;185:162-166.
367. Grosvenor T, Perrigin J, Perrigin D, Quintero S. Use of silicone-acrylate contact lenses for the control of myopia: Results after two years of lens wear. *Optom Vis Sci.* 1989;66:41-47.
368. Perrigin J, Perrigin D, Quintero S, Grosvenor T. Silicone-acrylate contact lenses for myopia control: 3-year results. *Optom Vis Sci.* 1990;67:764-769.
369. Andreo LK. Long-term effects of hydrophilic contact lenses on myopia. *Ann Ophthalmol.* 1990;22:224-227, 229.
370. Katz J, Schein OD, Levy B, et al. A randomized trial of rigid gas permeable contact lenses to reduce progression of children's myopia. *Am J Ophthalmol.* 2003;136:82-90.
371. Walline JJ, Jones LA, Mutti DO, Zadnik K. A randomized trial of the effects of rigid contact lenses on myopia progression. *Arch Ophthalmol.* 2004;122:1760-1766.
372. Horner DG, Soni PS, Salmon TO, Swartz TS. Myopia progression in adolescent wearers of soft contact lenses and spectacles. *Optom Vis Sci.* 1999;76:474-479.
373. Woods J, Jones D, Jones L, et al. Ocular health of children wearing daily disposable contact lenses over a 6-year period. *Cont Lens Anterior Eye.* 2021;44:101391.
374. Santodomingo-Rubido J, Villa-Collar C, Gilmartin B, et al. Long-term efficacy of orthokeratology contact lens wear in controlling the progression of childhood myopia. *Curr Eye Res.* 2017;42:713-720.
375. Cho P, Cheung SW, Edwards M. The longitudinal orthokeratology research in children (LORIC) in Hong Kong: A pilot study on refractive changes and myopic control. *Curr Eye Res.* 2005;30:71-80.
376. Davis RL, Eiden SB, Bennett ES, et al. Stabilizing myopia by accelerating reshaping technique (SMART)-study three year outcomes and overview. *Adv Ophthalmol Vis Syst.* 2015;2:1-8.
377. Berntsen DA, Kramer CE. Peripheral defocus with spherical and multifocal soft contact lenses. *Optom Vis Sci.* 2013;90:1215-1224.
378. Jensen H. Timolol maleate in the control of myopia. A preliminary report. *Acta Ophthalmol Suppl.* 1988;185:128-129.
379. Jensen H. Myopia progression in young school children. A prospective study of myopia progression and the effect of a trial with bifocal lenses and beta blocker eye drops. *Acta Ophthalmol Suppl.* 1991:1-79.
380. American Academy of Ophthalmology. Complementary therapy assessment. Visual training for refractive errors. San Francisco, CA: American Academy of Ophthalmology; 2013. https://www.aao.org/complimentary-therapy-assessment/visual-training-refractive-errors-cta--october-200. Accessed August 25, 2022.
381. Bates WH. The cure of imperfect sight by treatment without glasses. New York: Central Fixation Publishing Co., 1920.
382. Lim KL, Fam HB. Neurovision treatment for low myopia following lasik regression. *J Refract Surg.* 2006;22:406-408.
383. Barrett BT. A critical evaluation of the evidence supporting the practice of behavioural vision therapy. *Ophthalmic Physiol Opt.* 2009;29:4-25.
384. Rawstron JA, Burley CD, Elder MJ. A systematic review of the applicability and efficacy of eye exercises. *J Pediatr Ophthalmol Strabismus.* 2005;42:82-88.
385. Wei ML, Liu JP, Li N, Liu M. Acupuncture for slowing the progression of myopia in children and adolescents. *Cochrane Database Syst Rev.* 2011:CD007842.
386. Al-Khersan H, Flynn HW, Jr., Townsend JH. Retinal detachments associated with topical pilocarpine use for presbyopia. *Am J Ophthalmol.* 2022;242:52-55.
387. Flaxman SR, Bourne RRA, Resnikoff S, et al. Global causes of blindness and distance vision impairment 1990-2020: A systematic review and meta-analysis. *Lancet Glob Health.* 2017;5:e1221-e1234.
388. GBD 2019 Blindness and Vision Impairment Collaborators, Vision Loss Expert Group of the Global Burden of Disease Study. Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of

avoidable blindness in relation to vision 2020: The right to sight: An analysis for the global burden of disease study. *Lancet Glob Health.* 2021;9:e144-e160.
389. Varma R, Vajaranant TS, Burkemper B, et al. Visual impairment and blindness in adults in the United States: Demographic and geographic variations from 2015 to 2050. *JAMA Ophthalmol.* 2016;134:802-809.
390. Fricke TR, Tahhan N, Resnikoff S, et al. Global prevalence of presbyopia and vision impairment from uncorrected presbyopia: Systematic review, meta-analysis, and modelling. *Ophthalmology.* 2018;125:1492-1499.
391. Kandel H, Khadka J, Goggin M, Pesudovs K. Patient-reported outcomes for assessment of quality of life in refractive error: A systematic review. *Optom Vis Sci.* 2017;94:1102-1119.
392. Rose K, Harper R, Tromans C, et al. Quality of life in myopia. *Br J Ophthalmol.* 2000;84:1031-1034.
393. Chen CY, Keeffe JE, Garoufalis P, et al. Vision-related quality of life comparison for emmetropes, myopes after refractive surgery, and myopes wearing spectacles or contact lenses. *J Refract Surg.* 2007;23:752-759.
394. Cuq C, Lafuma A, Jeanbat V, Berdeaux G. A European survey of patient satisfaction with spectacles after cataract surgery and the associated costs in four European countries (France, Germany, Spain, and Italy). *Ophthalmic Epidemiol.* 2008;15:234-241.
395. Leske DA, Hatt SR, Castaneda YS, et al. Eye-related quality of life and functional vision in children wearing glasses. *J AAPOS.* 2020;24:91 e91-91 e96.
396. Kandel H. Quality-of-life outcomes of long-term contact lens wear: A systematic review. *Cont Lens Anterior Eye.* 2021:101521.
397. Wittenborn JS, Rein DB. Cost of vision problems: The economic burden of vision loss and eye disorders in the United States. Prevent Blindness America. 2013:14, 64. https://preventblindness.org/wp-content/uploads/2020/04/Economic-Burden-of-Vision-Final-Report_130611_0.pdf. Accessed August 25, 2022.
398. Fricke TR, Holden BA, Wilson DA, et al. Global cost of correcting vision impairment from uncorrected refractive error. *Bull World Health Organ.* 2012;90:728-738.
399. Barr JT. Annual report: Contact lenses 2005. Contact Lens Spectrum January 2006. Available at: https://www.clspectrum.com/issues/2006/january-2006/contact-lens-2005. Accessed August 25, 2022.
400. Sperduto RD, Seigel D, Roberts J, Rowland M. Prevalence of myopia in the United States. *Arch Ophthalmol.* 1983;101:405-407.
401. Tarczy-Hornoch K, Ying-Lai M, Varma R. Myopic refractive error in adult Latinos: The Los Angeles Latino Eye Study. *Invest Ophthalmol Vis Sci.* 2006;47:1845-1852.
402. Wensor M, McCarty CA, Taylor HR. Prevalence and risk factors of myopia in Victoria, Australia. *Arch Ophthalmol.* 1999;117:658-663.
403. Wu SY, Nemesure B, Leske MC. Refractive errors in a Black adult population: The Barbados Eye Study. *Invest Ophthalmol Vis Sci.* 1999;40:2179-2184.
404. Varma R, Torres M, McKean-Cowdin R, et al. Chinese American eye study group. Prevalence and risk factors for refractive error in adult Chinese Americans: The Chinese American Eye Study. *Am J Ophthalmol.* 2017;175:201-212.
405. Cheng CY, Hsu WM, Liu JH, et al. Refractive errors in an elderly Chinese population in Taiwan: The Shihpai Eye Study. *Invest Ophthalmol Vis Sci.* 2003;44:4630-4638.
406. Saw SM, Gazzard G, Koh D, et al. Prevalence rates of refractive errors in Sumatra, Indonesia. *Invest Ophthalmol Vis Sci.* 2002;43:3174-3180.
407. Xu L, Li J, Cui T, et al. Refractive error in urban and rural adult Chinese in Beijing. *Ophthalmology.* 2005;112:1676-1683.
408. Liang YB, Wong TY, Sun LP, et al. Refractive errors in a rural Chinese adult population the Handan Eye Study. *Ophthalmology.* 2009;116:2119-2127.
409. Li Z, Sun D, Cuj H, et al. Refractive error among the elderly in rural Southern Harbin, China. *Ophthalmic Epidemiol.* 2009;16:388-394.
410. Sawada A, Tomidokoro A, Araie M, et al. Refractive errors in an elderly Japanese population: The Tajimi study. *Ophthalmology.* 2008;115:363-370.
411. Quek TP, Chua CG, Chong CS, et al. Prevalence of refractive errors in teenage high school students in Singapore. *Ophthalmic Physiol Opt.* 2004;24:47-55.
412. Woo WW, Lim KA, Yang H, et al. Refractive errors in medical students in Singapore. *Singapore Med J.* 2004;45:470-474.
413. Saw SM, Chan YH, Wong WL, et al. Prevalence and risk factors for refractive errors in the Singapore Malay Eye Survey. *Ophthalmology.* 2008;115:1713-1719.
414. Nangia V, Jonas JB, Sinha A, et al. Refractive error in Central India: The Central India eye and medical study. *Ophthalmology.* 2010;117:693-699.
415. Dandona R, Dandona L, Srinivas M, et al. Population-based assessment of refractive error in India: The Andhra Pradesh Eye Disease Study. *Clin Experiment Ophthalmol.* 2002;30:84-93.

416. Shah SP, Jadoon MZ, Dineen B, et al. Pakistan National Eye Survey Study Group. Refractive errors in the adult Pakistani population: The National Blindness and Visual Impairment Survey. *Ophthalmic Epidemiol.* 2008;15:183-190.
417. Ezelum C, Razavi H, Sivasubramaniam S, et al. Refractive error in Nigerian adults: Prevalence, type, and spectacle coverage. *Invest Ophthalmol Vis Sci.* 2011;52:5449-5456.
418. Theophanous C, Modjtahedi BS, Batech M, et al. Myopia prevalence and risk factors in children. *Clin Ophthalmol.* 2018;12:1581-1587.
419. Dandona R, Dandona L, Srinivas M, et al. Refractive error in children in a rural population in India. *Invest Ophthalmol Vis Sci.* 2002;43:615-622.
420. Goh PP, Abqariyah Y, Pokharel GP, Ellwein LB. Refractive error and visual impairment in school-age children in Gombak District, Malaysia. *Ophthalmology.* 2005;112:678-685.
421. He M, Zeng J, Liu Y, et al. Refractive error and visual impairment in urban children in Southern China. *Invest Ophthalmol Vis Sci.* 2004;45:793-799.
422. Murthy GV, Gupta SK, Ellwein LB, et al. Refractive error in children in an urban population in New Delhi. *Invest Ophthalmol Vis Sci.* 2002;43:623-631.
423. Saw SM, Goh PP, Cheng A, et al. Ethnicity-specific prevalences of refractive errors vary in Asian children in neighbouring Malaysia and Singapore. *Br J Ophthalmol.* 2006;90:1230-1235.
424. Zhu D, Wang Y, Yang X, et al. Pre- and postcycloplegic refractions in children and adolescents. *PLoS One.* 2016;11:e0167628.
425. Zhan MZ, Saw SM, Hong RZ, et al. Refractive errors in Singapore and Xiamen, China--a comparative study in school children aged 6 to 7 years. *Optom Vis Sci.* 2000;77:302-308.
426. Matsumura H, Hirai H. Prevalence of myopia and refractive changes in students from 3 to 17 years of age. *Surv Ophthalmol.* 1999;44 (Suppl 1):S109-115.
427. Harrington SC, Stack J, Saunders K, O'Dwyer V. Refractive error and visual impairment in Ireland schoolchildren. *Br J Ophthalmol.* 2019;103:1112-1118.
428. Fu A, Watt K, B MJ, et al. Prevalence of myopia among disadvantaged Australian schoolchildren: A 5-year cross-sectional study. *PLoS One.* 2020;15:e0238122.
429. Yang L, Vass C, Smith L, et al. Thirty-five-year trend in the prevalence of refractive error in Austrian conscripts based on 1.5 million participants. *Br J Ophthalmol.* 2020;104:1338-1344.
430. Sharma IP, Lepcha NT, Lhamo T, et al. Visual impairment and refractive error in school children in Bhutan: The findings from the Bhutan School Sight Survey (BSSS 2019). *PLoS One.* 2020;15:e0239117.
431. Khoshhal F, Hashemi H, Hooshmand E, et al. The prevalence of refractive errors in the Middle East: A systematic review and meta-analysis. *Int Ophthalmol.* 2020;40:1571-1586.
432. Hashemi H, Fotouhi A, Yekta A, et al. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. *J Curr Ophthalmol.* 2018;30:3-22.
433. Ip JM, Robaei D, Kifley A, et al. Prevalence of hyperopia and associations with eye findings in 6- and 12-year-olds. *Ophthalmology.* 2008;115:678-685.
434. Borchert MS, Varma R, Cotter SA, et al. Risk factors for hyperopia and myopia in preschool children: The Multi-Ethnic Pediatric Eye Disease and Baltimore Pediatric Eye Disease studies. *Ophthalmology.* 2011;118:1966-1973.
435. Chang MA, Congdon NG, Bykhovskaya I, et al. The association between myopia and various subtypes of lens opacity: SEE (Salisbury eye evaluation) project. *Ophthalmology.* 2005;112:1395-1401.
436. Wang X, Liu D, Feng R, et al. Refractive error among urban preschool children in Xuzhou, China. *Int J Clin Exp Pathol.* 2014;7:8922-8928.
437. Pan CW, Zheng YF, Anuar AR, et al. Prevalence of refractive errors in a multiethnic Asian population: The Singapore epidemiology of eye disease study. *Invest Ophthalmol Vis Sci.* 2013;54:2590-2598.
438. Wolfram C, Hohn R, Kottler U, et al. Prevalence of refractive errors in the European adult population: The Gutenberg health study (GHS). *Br J Ophthalmol.* 2014;98:857-861.
439. Yoo YC, Kim JM, Park KH, et al. Refractive errors in a rural Korean adult population: The Namil study. *Eye (Lond).* 2013;27:1368-1375.
440. Williams KM, Verhoeven VJ, Cumberland P, et al. Prevalence of refractive error in Europe: The European Eye Epidemiology (E(3)) Consortium. *Eur J Epidemiol.* 2015;30:305-315.
441. Sandhu RK, Munoz BE, Swenor BK, West SK. Refractive error and visual function difficulty in a Latino population. *Ophthalmology.* 2012;119:1731-1736.
442. Huynh SC, Kifley A, Rose KA, et al. Astigmatism and its components in 6-year-old children. *Invest Ophthalmol Vis Sci.* 2006;47:55-64.
443. Harvey EM, Dobson V, Clifford-Donaldson CE, et al. Prevalence of astigmatism in Native American infants and children. *Optom Vis Sci.* 2010;87:400-405.

444. Lai YH, Hsu HT, Wang HZ, et al. Astigmatism in preschool children in Taiwan. *J AAPOS.* 2010;14:150-154.
445. Barba-Gallardo LF, Salas-Hernandez LH, Villafan-Bernal JR, et al. Refractive status of patients attending eye clinics of the public health system from Aguascalientes, Mexico. *J Optom.* 2021;14:328-334.
446. Holladay JT, Rubin ML. Avoiding refractive problems in cataract surgery. *Surv Ophthalmol.* 1988;32:357-360.
447. Milder B, Rubin ML. The fine art of prescribing glasses without making a spectacle of yourself. 3rd ed. Gainesville: Triad Publishing Company; 2004.
448. Kastl PR, ed. Contact lenses: The CLAO guide to basic science and clinical practice, 3rd ed. Dubuque, IA: Kendall/Hunt Publishing Company, 1995.
449. Muhafiz E, Bayhan HA, Sahin S, et al. Evaluation of the ocular surface in different contact lens replacement schedules. *Cornea.* 2019;38:587-594.
450. Chao C, Stapleton F, Willcox MDP, et al. Preinflammatory signs in established reusable and disposable contact lens wearers. *Optom Vis Sci.* 2017;94:1003-1008.
451. Yee A, Walsh K, Schulze M, Jones L. The impact of patient behaviour and care system compliance on reusable soft contact lens complications. *Cont Lens Anterior Eye.* 2021;44:101432.
452. Sauer A, Greth M, Letsch J, et al. Contact lenses and infectious keratitis: From a case-control study to a computation of the risk for wearers. *Cornea.* 2020;39:769-774.
453. Cho P, Cheng SY, Chan WY, Yip WK. Soft contact lens cleaning: Rub or no-rub? *Ophthalmic Physiol Opt.* 2009;29:49-57.
454. Centers for Disease Control and Prevention. Healthy contact lens wear. 2016.
455. Carnt NA, Evans VE, Naduvilath TJ, et al. Contact lens-related adverse events and the silicone hydrogel lenses and daily wear care system used. *Arch Ophthalmol.* 2009;127:1616-1623.
456. Guillon M, Maissa C, Wong S, et al. The influence of lens care systems on eyelid tissue changes during silicone hydrogel contact lens wear. *Cont Lens Anterior Eye.* 2018;41:362-368.
457. U.S. Food and Drug Administration. Consumer products. Types of contact lenses: Extended wear contact lenses; 2015. https://www.fda.gov/medical-devices/contact-lenses/types-contact-lenses Accessed August 25, 2022.
458. American Academy of Ophthalmology. Eye health. Proper care of contact lenses; 2016. https://www.aao.org/eye-health/glasses-contacts/contact-lens-care. Accessed August 25, 2022.
459. American Academy of Optometry and American Academy of Ophthalmology Hoskins Center for Quality Eye Care. Cosmetic contact lenses: Potential threat to vision health. October 2018. https://www.aao.org/clinical-statement/cosmetic-contact-lenses-potential-threat-to-vision. Accessed August 25, 2022.