CLINICAL PERSPECTIVE

Myopia Control: Why Each Diopter Matters

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SIGNIFICANCE: Reducing the incidence or prevalence of any disease by 40% is of huge public health significance. Slowing myopia by 1 diopter may do just that for myopic maculopathy—the most common and serious sight-threatening complication of myopia. There is a growing interest in slowing the progression of myopia due to its increasing prevalence around the world, the sight-threatening consequences of higher levels of myopia, and the growing evidence-based literature supporting a variety of therapies for its control. We apply data from five large population-based studies of the prevalence of myopic maculopathy on 21,000 patients. We show that a 1-diopter increase in myopia is associated with a 67% increase in the prevalence of myopic maculopathy. Restated, slowing myopia by 1 diopter should reduce the likelihood of a patient developing myopic maculopathy by 40%. Furthermore, this treatment benefit accrues regardless of the level of myopia. Thus, while the overall risk of myopic maculopathy is higher in a –6-diopter myope than in a –3-diopter myope, slowing their myopic progression by 1 diopter during childhood should lower the risk by 40% in both.

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There is a growing interest in slowing the progression of myopia. This arises from its increasing prevalence around the world,[1,2] the sight-threatening consequences of higher levels of myopia,[3] and the growing evidence-based literature supporting a variety of therapies for its control.[4] Indeed, recent studies have shown that soft contact lenses,[5,6] overnight orthokeratology,[7] atropine,[8] spectacles,[9] and increased time outdoors[10] can slow myopia progression in children and teenagers, with the support of a growing body of research.[11] Nonetheless, some may say "So what? We can correct myopia with a range of modalities, so why should we worry about slowing it?" We would like to propose some possible, evidence-based answers to this question for practitioners and parents alike while noting that, to date, there are no products approved for myopia control by the U.S. Food and Drug Administration.

As primary health care practitioners, optometrists should care about the long-term visual health of every patient and not just address his or her current visual needs. Thus, there are three broad benefits of lowering a patient's ultimate level of myopia to the long-term care of a patient:

- *Less visual disability when uncorrected*
- *Better options for, and outcomes from, surgical myopia correction*
- *Reduced risk of blindness associated with higher levels of myopia*

Let us consider each in turn.

LESS MYOPIA = LESS VISUAL DISABILITY WHEN UNCORRECTED

The relation between uncorrected visual acuity and myopia is well established: the higher the myopia, the poorer the uncorrected visual acuity.[12,13] This relationship has been extended to other measures of vision. In particular, recent research has demonstrated the relationship between uncorrected myopia and visual functioning or vision-related quality of life.[14] A 2-diopter myope can easily navigate an unfamiliar hotel room or house at night without correction. The task would be more challenging with higher myopia. In summary, patients with uncorrected higher myopia will have poorer visual acuity, have more difficulty performing everyday tasks, and report more challenges related to their vision. Corrected or not, greater refractive error produces greater disability and dependence on whatever mode of correction used.

LESS MYOPIA = BETTER OPTIONS FOR, AND OUTCOMES OF, SURGICAL MYOPIA CORRECTION

Refractive surgeons have a cliché that "the shorter putt is easier to sink." In essence, the lower the level of myopia, the easier it is to achieve minimal residual refractive error: a well-established feature of modern, corneal refractive surgery. Thus, lower levels of myopia are associated with better postoperative uncorrected visual acuity and fewer secondary surgical enhancements. More importantly, postoperative visual quality is poorer with greater levels of preoperative myopia. For example, Bailey et al.[15] demonstrated that laser *in situ* keratomileusis reduced best-corrected low-contrast visual acuity by more than one line in high myopes, whereas it was relatively unchanged in low myopes. Finally, the higher the myopia, the greater the amount of corneal stroma that needs to be removed in laser *in situ* keratomileusis and other ablative procedures. For patients with higher myopia, thinner corneas, or both, this can make them poor candidates for laser *in situ* keratomileusis because of the increased risk of postoperative corneal ectasia,[16] and thus,

they need to seek alternative procedures, such as phakic intraocular lenses, with their attendant increased risks.

LESS MYOPIA = REDUCED RISK OF VISUAL IMPAIRMENT

Higher levels of myopia have long been associated with increased risk of cataract, glaucoma, and retinal detachment, but the greatest myopia-related cause of irreversible vision loss is myopic maculopathy, also referred to as myopic retinopathy or myopic macular degeneration.[17–19]

Myopic maculopathy is characterized by stretched blood vessels, peripapillary atrophy, posterior staphyloma, lacquer cracks in the Bruch membrane, geographic atrophy of the retinal pigment epithelium and choroid, subretinal hemorrhages, and choroidal neovascularization. These sight-threatening retinal changes occur later in life, but the underlying myopia develops during childhood and has often stabilized by the age of 21 years.[20] Unlike other common eye diseases, it is untreatable.

Fricke et al.[21] recently published a systematic review and meta-analysis quantifying blindness and visual impairment associated with myopic maculopathy and predicted future global trends. They estimated that 10 million people had visual impairment from myopic maculopathy in 2015, of whom 3.3 million were blind. By 2050, visual impairment will grow to 55.7 million (1 in 175), 18.5 million of whom will be blind. The risk of myopic maculopathy and its impact on public health are not limited to high myopes. As succinctly stated by Flitcroft,[22] "there is no safe level of myopia." Although the risk of myopic maculopathy escalates with increasing myopia, there are the far more myopes at the low end of the refractive spectrum. In fact, myopes of less than 5 diopters contributed 43% of the cases of myopic maculopathy in the Australian Blue Mountains Eye Study.[23] Thus, myopia control has the potential to reduce the risk of widespread visual impairment in myopes.

There have been five recent large population-based studies of the prevalence myopic maculopathy in older patients.[23–27] Collectively, these studies report data on 21,000 patients, mostly older than 50 years. Fig. 1 plots the prevalence of myopic maculopathy as a function of degree of myopia. Data are taken directly from the publications. Each article presented data for various ranges of myopia, so in constructing the figure, the midpoint of each range was used. The similarity across the five studies is more apparent by plotting prevalence on a logarithmic scale (right side). All five studies show a remarkably similar trajectory, despite being offset vertically by variations in disease definition, age, and underlying risk. Also shown is a family of lines with a slope of 1.67× per diopter. This further emphasizes the similarity in the growing incidence of maculopathy associated with increasing myopia across the five studies. In simple terms, from these published peer-reviewed data, we can state that each 1-diopter increase in myopia is associated with a 67% increase in the prevalence of myopic maculopathy, regardless of the overall incidence in a study population and the criteria used to define the disease. Restated, slowing myopia such that patients' refractive error is lower by 1 diopter should reduce the likelihood of them developing myopic maculopathy by 40%, regardless of race or disease definition. Furthermore, given the apparent constant slope of the data, this treatment benefit accrues regardless of the level of myopia. Thus, although the overall risk of myopic maculopathy is higher in a –6-diopter myope than in a –3-diopter myope, slowing their myopic progression by 1 diopter during childhood should lower the risk by 40% in both.

COMPARISON WITH OTHER PREVENTIVE THERAPIES FOR MACULAR DISEASE

The Age-Related Eye Disease Study evaluated the effect of dietary supplements on the progression of age-related macular degeneration.[28] Eligible patients were randomly assigned to receive daily oral tablets containing antioxidants, zinc, antioxidants plus zinc, or a placebo. There was a statistically significant odds reduction for the development of advanced age-related macular degeneration with antioxidants plus zinc (odds ratio, 0.72; 99% confidence interval, 0.52 to 0.98). This represents a risk reduction of 25% for those taking antioxidants plus zinc for an average of 6.3 years. The reduction for those taking antioxidants alone or zinc alone was 17 and 21%, respectively.

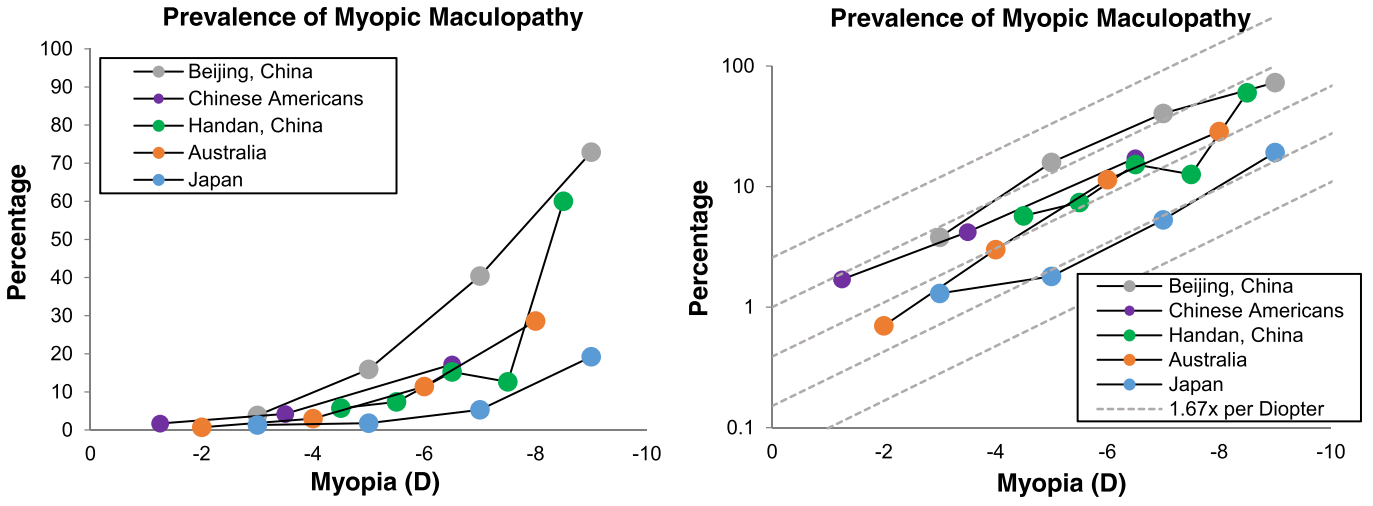

FIGURE 1. The prevalence of myopic maculopathy plotted with both linear (left) and logarithmic (right) scales. The logarithmic scale emphasizes the similar trajectory of each data set, the additional risk associated with each diopter.

Hence, 6 years of supplements reduces the development of advanced age-related macular degeneration progression by 25%, but what about 6 years of myopia control? We do not have much 6-year data for myopia control, but there is a reason to speculate that 1 diopter of slowing is achievable,[8,29,30] although diminution of effect over time and rebound after withdrawal of treatment[31] remain legitimate concerns (Brennan et al. OVS 2018;95:E-Abstract 180084). The long-term visual benefits can be easily inferred from the figure; 1 diopter of control should lower the risk of myopic maculopathy by 40%. Applying this reduction to the projections of Fricke et al.,[21] future visual impairment due to myopic maculopathy could be tapered by tens of millions.

Myopia control modalities under investigation are generally innocuous, with many incorporated into a child's optical correction, and presage a future public health imperative. Therapies will undoubtedly improve, along with our knowledge of how best to implement them. Furthermore, if ongoing clinical trials of atropine in premyopic children demonstrate that the onset of myopia can be delayed, we will have additional options. On top of this, the interventions also correct a child's vision. Does this not sound like a win-win?

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