CHAPTER 19

MYOPIA CONTROL

INTRODUCTION

Myopia is no longer considered a benign refractive error, corrected with spectacles or contact lenses. Recent research has shown that myopia has become an epidemic and is potentially sight-threatening, due to its association with significant ocular pathologies, such glaucoma, maculopathy and retinal detachment. Myopia is more prevalent, it's progressing and we (individuals, eye care providers and society) are all part of the problem. Industrialised societies are creating myopigenic environments, practitioners are not proactive in taking care of the "garden variety" school myopia and individuals do not educate themselves on how to avoid becoming myopic, fostering the creation and progression of myopia. With our current understanding of myopia control, it is nearly within our reach to keep most myopes around -1.00D, which translates to huge lifestyle and ocular health advantages for our patients.

CLASSIFICATION AND AETIOLOGY

Myopia can be classified according to the age of onset [490]. Between birth and the age of 4 years, myopia is classified as congenital. It may be associated with prematurity, general systemic problems at birth or systemic syndromes that have a genetic basis. Congenital myopia constitutes less than 1% of all myopia, and due to the high levels of myopia, that remain stable over time, these eyes are at greater risk for associated ocular pathology. Early onset myopia starts around the ages of 4–5 years and constitute around 2% of all myopia. It generally reaches levels (< -6.00D) that puts the eye at risk in terms of pathology and the aetiology is genetic with traceable chromosomal locations [491]. School or juvenile myopia occurs around the ages of 6–10 years and results in more modest levels of myopia (around -2.50). It constitutes 75% of all myopia and is predominantly a disorder caused by abnormal environmental exposures that promote axial elongation that cannot be overcome by emmetropisation [491]. On average, myopia progression rates are -0.55D per year among Caucasian children and -0.82D among Asian children [492]. Late onset myopia occurs after the age of 15 years, when all co-ordinated eye growth should have stopped [493]. It constitutes 15% of all myopia and results in low levels of myopia (-1.00 to -2.00D). Late adult onset myopia occurs, when there is a rapid increase of -1.00D, during the incipient phase of presbyopia (35–45 years). It constitutes 5% of all myopia and is due to an increase in axial length [494].

Myopia can also be classified as pathological, physiological and intermediate, by degree low (< -3D), moderate (3–6D), very high (> -6D) and very high (> -10D). Other forms include anomalous myopias, such as pseudo-myopia or near work induced transient myopia (NITM), night myopia and instrument myopia.

Holistically urbanisation of modern society creates a myopigenic environment, which promotes the development and progression of myopia. This myopigenic environment affects what we eat, how much time we spend doing near work task, our outdoor activity, our genetics through gene expressions and their mutations and a host of other factors. Myopia is a polygenic multifactorial disease governed by both genetic and environmental factors [495].

PREVALENCE

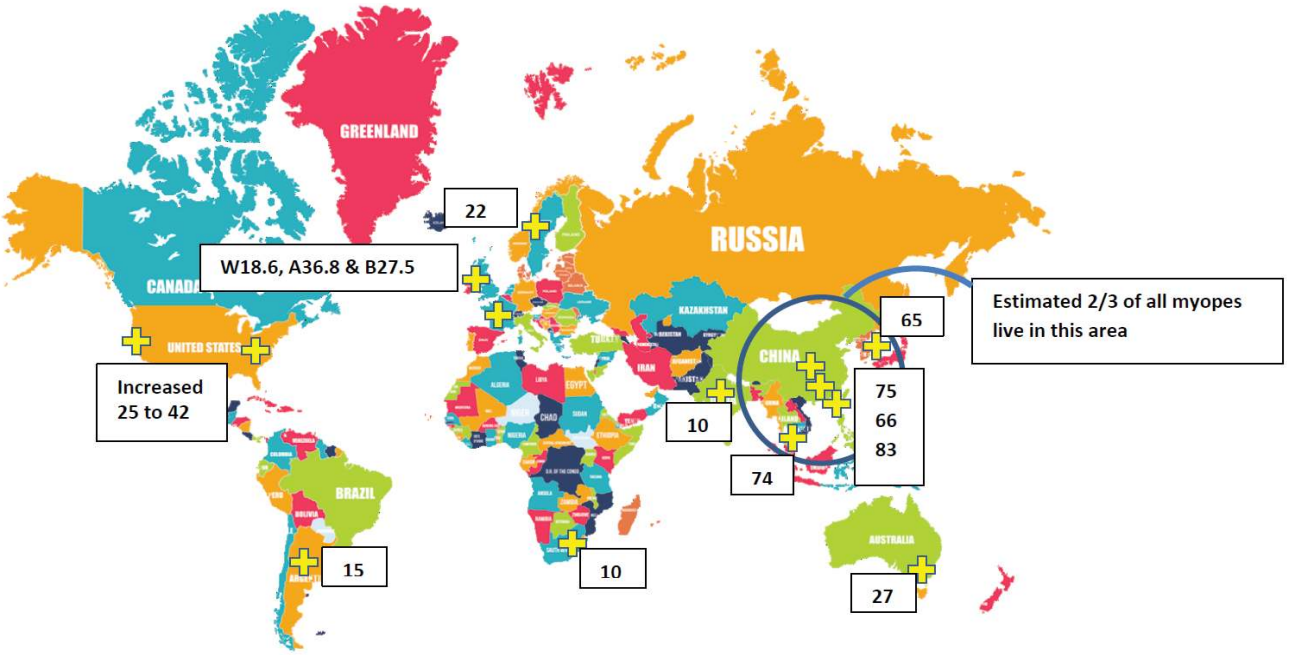

Figure 121: World-wide % prevalence of myopia ~ 15+ years, urban population, cycloplegic refraction [491].

In the USA, myopia defined as MSE < 0D, increased by 66.4% among 12–54-year-olds over a 30-year period (prevalence from 25% to 41.6%) [496]. In the UK myopia defined as MSE ≤ -0.50D the prevalence among whites was 18.6%, South Asians 36.8% and Black African Caribbean's 27.5% [497]. In Europe, myopia prevalence has increased from 25% to 47.2% of young adults [498]. However, Asian countries show highest prevalence rates of myopia. In Hong Kong, 18.3% of 6 year old children are myopic, 0.7% are highly myopic [499]. By age 12 years the figures reach 61.5% and 3.8% [499]. In Taiwan, myopia prevalence surpasses 80% by 18 years of age affecting more females than males [500] and in Korea 96.5% of 19 year olds are myopic [501]. The prevalence of myopia in Beijing among 17–18-year olds is 74% and in rural China this drops to 5% among the 5–15-year-old children [502]. Likewise in New-Delhi, the prevalence among 15 year olds is 10.8% [503].

SHOULD WE BE CONCERNED?

According to the late Prof. Brien Holden, "Myopia represents a significant risk factor for the development of ocular pathology, if nothing is done myopia will become a major cause of blindness around the world" [504]. High myopia (>6.00D) predisposes the eye to the following pathologies [505]:

- Temporal crescents occur in all eyes longer than 28 mm [505]
- Chorioretinal atrophy
- Choroidal Neo-vascular membranes, lacquer cracks leads to severe vision loss in 0.1–0.5% of myopic patients in Europe and 0.2–1.4% in Asia [506]
- Myopic patients have an 8x greater risk of developing macular degeneration and Foster-Fuchs spots [507]
- Posterior staphylomas occur in 20% of eyes longer than 26.5 mm [505]
- Posterior vitreous detachments, lattice degeneration and rhegmatogenous retinal detachments are common in myopes. Up to 50% of all retinal detachments occur in myopes and the risk is increased with cataract surgery [505]
- Myopic patients have a 3x greater risk of developing early onset cataracts [507]

- Myopic patients are 18x more likely to develop glaucoma and the odds ratios are 3:1 for myopia above -5.00 and 1:3 for low myopia (-0.25 to -5D) [507]

Not only should we be preventing the progression of myopia, we should also include mydratic fundus examination in the routine care of our existing myopic patients, in to diagnose and treat associated pathologies.

THE NATURE OF EYE GROWTH AND WHAT DRIVES EXCESSIVE EYE GROWTH IN MYOPIA?

Is eye growth due to global expansion, axial stretch or posterior pole axial stretch? Magnetic resonance studies show that posterior pole axial stretch predominates and that most of the change occurs in the last 20% to 25% along the optical axis or 70% to 80% of the distance along the optical axis from the front of the eye [508, 509].

The catalyst for the use of animal models in myopia development came over 30 years ago with the work of Hubel and Wiesel concerning information processing in the visual system (they shared The Nobel Prize in Physiology / Medicine in 1981). Their work on animals concerned mechanisms for amblyopia, which meant depriving the animals of visual stimulation (i.e. degradation of visual feedback). Somewhat by chance they noticed that the visual deprivation they used (i.e. lid occlusion) caused the animals eyes to become substantially myopic. It is now widely accepted that the quality of the retinal image can modulate axial eye growth.

It appears that the changes in axial length associated with defocus are modulated by changes in both scleral growth and choroidal thickness in both avian and primate models. Myopic defocus leads to the thickening of the choroid and decreased scleral growth rate, the former resulting in an anterior movement of the retina towards the image plane. Hyperopic defocus leads to a thinning of the choroid and an increase in scleral growth rate, the former resulting in a posterior movement of the retina towards the image plane. Hyperopic blur seems to drive eye growth. [510].

The aetiological link between the choroid and sclera is currently receiving a lot of attention in the animal myopia literature, the principal point being that transient changes in choroidal thickness are mechanistically linked to scleral synthesis of macromolecules, and thus have an important role in homeostatic control of eye growth in myopia [511]. From the literature, it seems that the amacrine cells at level of the inner plexiform layer of the retina are probably responsible for detecting the sign of defocus, thereby modulating eye growth [511]. Choroidal thickness changes can occur rapidly, within minutes of exposure, but it appears that they are always a precursor to subsequent growth change mediated by the sclera.

Abnormal oculomotor factors, including lag of accommodation and increased response AC/A ratios may contribute to myopigenesis by producing hyperopic retinal defocus when a child is engaged in near-viewing tasks [512, 513]. Emmetropisation is a 'vision-dependent' phenomenon and it is reasonable and expedient to adopt the quality of the retinal image as a primary aetiological candidate for the onset and development of myopia [514]. This is of particular importance, as optical methods of myopia control are currently likely to be the most appropriate treatment methods for use in general clinical practice.

PREDICTING MYOPIA ONSET AND PROGRESSION

Intrinsic Factors:

Children with two myopic parents were 6.42x more likely to be myopic than children with no myopic parents [515]. The development of myopia in children is much more likely when one or both parents have myopia, this seems to indicate a genetic component, but one also needs to consider the myogenic environment created by two myopic parents as a cause of juvenile myopia [516–519].

Outdoor Activity:

The amount of outdoor activity was significantly different between subjects, who became myopic and emmetropes and this difference was present up to 4 years before myopia onset [520]. Furthermore, near work was significantly greater in those subjects that became myopic 1 year before onset of myopia [517, 521]. The greater the amount of outdoor activity at 8/9 years of age the lower the risk of myopia at 13/14 years of age [517, 520]. From the literature, it is clear that outdoor activity has a protective effect, when parental myopia is present. One hour spent outdoors per week during childhood reduces the risk of developing myopia by 2% (10 hours per week by 20%) [522]. Non-myopes spend approximately 33% more time outdoors (30minutes per day) than myopes [521].

Ocular Factors:

For MSE > +0.75D at age 8/9 years (3rd grade) the sensitivity and specificity for predicting myopia in the 8th grade (age 14 years) were 86.7% and 73.3% respectively [523].

Jones-Jordan et al. 2010 looked at refractive error in younger children (6 years old) and parental history of myopia as predictors of the onset of myopia by the 8th grade (age 14 years). If the cycloplegic MSE at age 6 years was ≤ +0.75D the child has a high risk of developing myopia at age 14 years. The combination of MSE ≤ +0.75D and parental history gave a sensitivity of 62.5% and specificity of 81.9% for predicting myopia [516].

Myopic eyes are clearly different from emmetropic eyes before the onset of myopia. Compared to emmetropic children, children that developed myopia were [524]:

- Less hyperopic at least 4 years before onset of myopia
- Had longer axial length at least 3 years before onset of myopia
- More hyperopic peripheral refractive error at least 2 years before onset of myopia
- The fastest interval for change in all three components was in the year before onset of myopia
- The fastest rate of change occurred in the year prior and the year after onset of myopia

The ratio of axial length and corneal radius can also be used as a predictive index for the development of myopia. If an emmetropic child has a ratio of > 3 the child is predisposed to develop myopia [525].

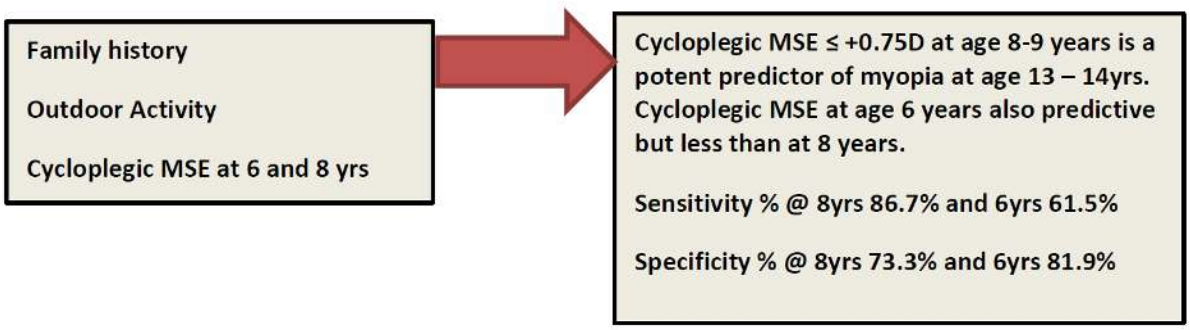

Figure 122: Optometrists ability to predict myopia

MYOPIA CONTROL STRATEGIES

To prevent the development of myopia or its progression optical, pharmaceutical and behavioural strategies can be employed. Optical strategies, include the use of under correction, single vision spectacle lenses, radial refractive gradient spectacle lenses, bifocal spectacle lenses, progressive addition spectacle lenses, contact lenses (both soft and RGP) and corneal reshaping technology (orthokeratology).

As clinicians we often hear from our patients "that wearing spectacle will make their eyes worse". In fact, no evidence exists that it does, but the literature is clear that optimum correction for both distance and near is the most appropriate clinical management for myopia [526]. Applying the principle from animal studies that blur drives growth it was thought that under correction would inhibit growth of the eye and slow myopic progression. A study by Chung et al., 2002 tested this hypothesis by under correcting the distance refraction in patients with juvenile myopia by +0.75D. The authors found that under correction produced rapid progression in myopia, which correlated well with changes in axial length [527].

The use of bifocal lenses (with and without base in prism) to control the progression of myopia have been studied and compared to the effectiveness of single vision, as well as progressive addition lenses. Cheng et al., 2001 found that large segment executive bifocal spectacle lenses produced a myopic shift in the peripheral image shells for the inferior field, as well as the central field. It is their theory that this is the reason for the significant treatment effect (0.70D over a 3-year period) with the executive bifocals compared to single vision lenses. They also found that base in prism control made little difference while other authors found the opposite [528].

The COMET 1 & 2 (Correction of myopia evaluation trial) compared the use of progressive addition spectacle lenses (Varilux Comfort with +2.00 addition) and single vision spectacle lenses to control the progression of juvenile myopia. COMET 1 showed a modest effect, which was not clinically significant, and the trial was ceased after the first year. However, specific sub-groups in the trial did show significant effects [529]. The COMET 2 trial specifically looked at these sub-groups, which included children with low baseline myopia (-0.75 to -2.75), accommodative lag ≥ 0.50D and near esophoria ≥ 2PD. Disappointingly, the outcomes were similar to the COMET 1 study with a modest effect that was not clinically significant [530].

The CLAMP (Contact Lens and Myopia Progression) study, compared the use of RGP and Soft contact lenses to slow the progression of myopia in children with moderate myopia. This 3-year trial found that the increase in myopia was less with the RGP lenses (clinically significant difference) than soft lenses. The effect was attributed to corneal flattening with the RGP lenses and was not maintained after cessation of RGP wear [531]. Orthokeratology or corneal reshaping technology (CRT) significantly slows eye growth [532]. The mechanism seems to be due to the peripheral retinal image shells caused by the "peripheral annular knuckle" created on the cornea by the reverse geometry RGP design [533]. This produces a relative peripheral myopic defocus, which slows the progression of myopia significantly. Laser refractive surgery, results in similar corneal topography changes, and it therefore begs the question if the effect on myopia progression would be similar to orthokeratology? Of all the optical treatment strategies employed to slow myopia progression, CRT seems to have the greatest treatment effect [534].

Soft bifocal (centre distance) contact lenses or dual focus lenses have also been used to treat and prevent progression of myopia. It is generally accepted that the addition power of the bifocal should be the maximum that the child can tolerate. These lenses also create myopic peripheral image shells and defocus to slow the progression of myopia. However, if the child uses the near zones not to accommodate, peripheral hyperopic defocus will not be eliminated. Tarrant et al., 2005 showed that young patients over accommodate at all distances using bifocal contact lenses, and therefore myopic peripheral defocus is maintained [535]. Aller and Wildsoet, 2008 used soft bifocal lenses in twins to study the effect of the lenses on myopia progression and found that bifocal wear stabilised the myopia in both girls [536]. Anstice and Phillips, 2011 compared dual focus soft lenses with single vision soft contact lenses and found that in 70% of their cohort myopia progression was reduced by 30% or more in the eye wearing the DF lens relative to the eye wearing the SV lens [537].

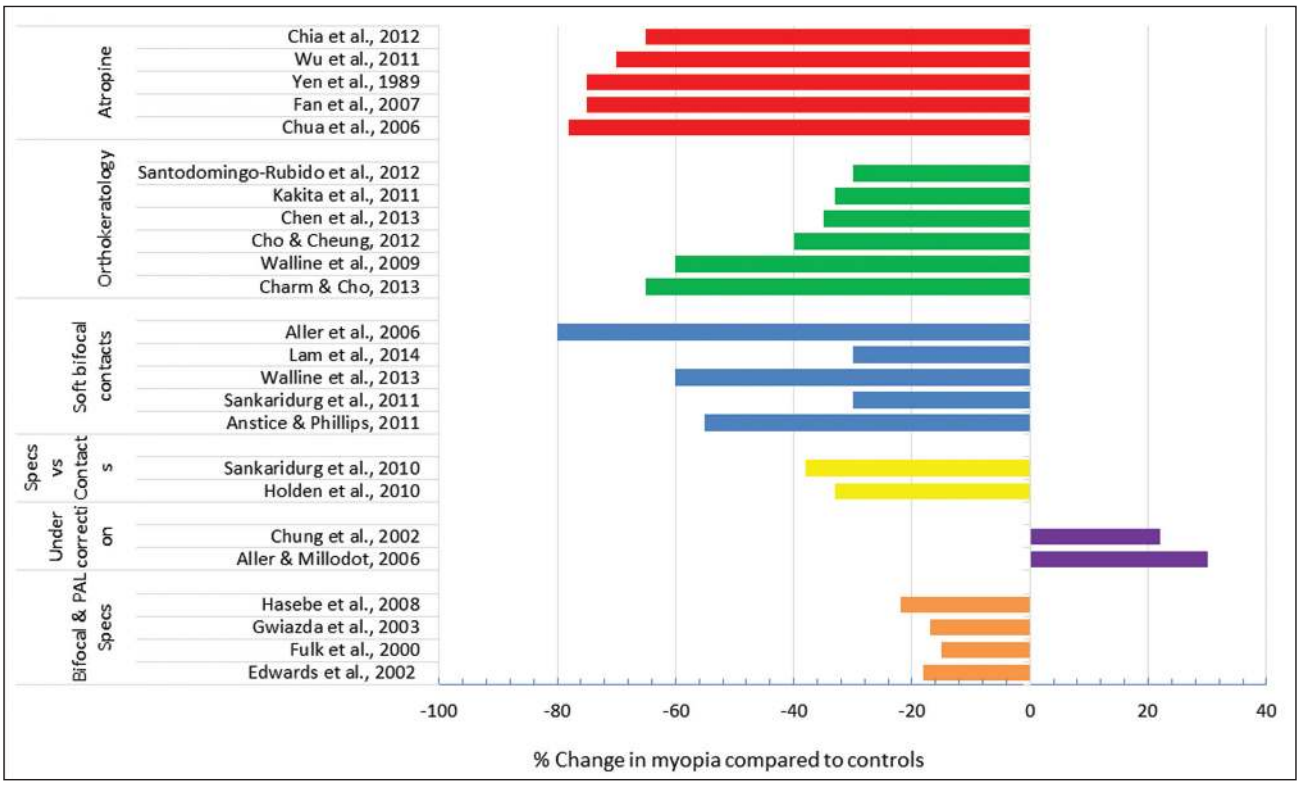

Figure 123: The bar graph shows that atropine treatment closely followed by orthokeratology results in the least amount of increase in myopia and axial length

Soft bifocal contact lenses also have beneficial effects on limiting myopia progression. It is clear that under correction is not an option to control myopia progression. A word of caution when interpreting the graph. Although % changes may look impressive, they are derived from relatively low levels of dioptric difference between treatment and control groups – typically 0.20 to 0.70D. References in order: Atropine [538–542], orthokeratology [270, 272, 273, 533, 543, 544], soft bifocal contact lenses [537, 545–548], spectacles vs contact lenses [549, 550], under correction [527, 551] and bifocal and PAL spectacles [529, 552–554]

Currently, no drugs are approved by USA FDA, UK MHRA/CSM for use as a treatment for myopia. The drugs discussed in this review have been used in various clinical trials mainly in the East and act on the autonomic nervous system. Atropine is a non-selective anti-muscarinic drug that blocks all muscarinic receptors. It results in cycloplegia, mydriasis and it has an indirect effect on oculomotor balance through the AC/A ratio. It was postulated that atropine worked by blocking accommodation, but recent work suggests that atropine has biochemical effects on the retina and sclera inhibiting axial myopia [555]. Pirenzepine is a partially selective M1/M4 anti-muscarinic drug that does not affect accommodation or pupil size. The efficacy of atropine is more than that of pirenzepine. Both pirenzepine and atropine have been shown to slow myopia progression. Studies in the United States and Singapore showed that pirenzepine slows myopia progression by 51% [556] and 77% [557], respectively. The ATOM 1 & 2 studies used atropine in two different concentrations to control myopia progression. In the ATOM 1 (Atropine in the Treatment of Myopia) study, 1% atropine drops were used in one eye at night, over a 2-year period in a group of myopic East Asian children, aged 6–12 years. No serious adverse effects were reported and the results showed that atropine prevented an increase in myopia, as well as axial length of 0.92D and 0.40 mm respectively, compared to the placebo group [542]. After cessation, eyes treated with atropine initially demonstrated higher rates of progression than placebo group, but after 3 years absolute myopia progression was less than placebo treated group [558]. The safety profile of atropine and its effect on pupil size and accommodation is a major source of concern, limiting its widespread use as a preventative treatment for myopia progression. The ATOM 2 study examined the

efficacy of lower doses of atropine at night (both eyes) in a group of East Asian children between 6–12 years of age over a two-year period. The dosages of atropine chosen were 0.5%, 0.1% and 0.01%. Although the lower doses reduced efficacy, all three doses reduced myopia progression significantly. Atropine 0.01% had negligible effects on the pupil accommodation and no effects on the retina or near vision [538]. After cessation of treatment there was a myopic rebound and it was greater in eyes that had received 0.5% and 0.1% atropine. The 0.01% atropine effect, however, was more modulated and sustained [559].

Mutti et al., 2007 first reported the association between outdoor time and lower likelihood of myopic refractive error [517], and that effect has been reported in several subsequent studies [520, 521, 560–565]. Mutti and Marks, 2011 postulated that time outdoors would enhance the level of vitamin D and this may be the protective agent slowing myopia progression. The results of the study showed that myopes have lower levels of vitamin D than emmetropes [566]. Greater outdoor activity at age 8/9 years lowers the risk of myopia at age 13/14 years even if both parents are myopic [517]. It is still unclear how outdoor activities impact myopia and several hypotheses have been explored. Recent studies suggest interactions between light conditions and myopia development. Higher light intensity outdoors result in constricted pupils, greater depth of field, less image blur, and therefore, less myopia progression [560]. Another hypothesis suggests that dopamine is released from the retina under conditions of blue light exposure (460–500 nm). Dopamine inhibits growth preventing myopia progression [567].

Behavioural optometrists are enthusiastic advocates of their approach to optometry and they seem to get great satisfaction from the work they conduct. However, the lack of controlled clinical trials of behavioural management strategies, represents a major challenge to the credibility of the theory and practice of behavioural optometry and claims regarding the effectiveness of such behavioural vision therapy should be viewed with caution [568].

Although nutrition is important for many ocular structures there are no direct studies that implicate diet with myopia progression. High consumption of refined carbohydrates affects glycaemic control and promotes insulin resistance. This results in compensatory hyperinsulinemia, an increase in IGF-1 (insulin growth factor) and a decrease in retinoid receptor signalling, which result in unregulated enhanced tissue growth [569].

SUGGESTED MYOPIA PROTOCOL

The goal of any intervention or treatment is to slow or stop further progression into myopia and if the child is already myopic to prevent progression beyond minus one (Done at Minus One™), which will alleviate future eye health problems associated with myopia. In order to achieve these goals, I use the following protocol.

Yearly cycloplegic examinations starting at age 4, which include ocular health screening, near phorias, lag of accommodation, corneal topography, pupil diameter, uncorrected visual acuity, as well as best corrected visual acuity. If an A-scan ultrasound is available, the axial length should be measured. The expected refractive error at age 4 is MSE +0.50 ± 0.60D [523]. If this is the case and the other risk factors for myopia are not present, the parents and patient should be counselled on how to avoid becoming myopic.

- Counsel about the benefit of outdoor activities (2–3 hours daily)
- Counsel on proper nutrition (reduce carbohydrates, refined sugars, and grains)
- Discuss risk factors for myopia progression

If the MSE at age 4 years with cycloplegia is ≤ +0.50 to -0.25D and the patient is esophoric with an accommodative lag > 0.50D at 33 cm and has two myopic parents, treatment should be instituted. This includes:

- Counselling on need for 2–3 hours of outdoor activities
- Counselling on the use of the prescription lenses supplied and why the lenses are needed

- Devices for creating more peripheral myopia are desired, these devices include executive bifocal and or progressive addition lenses or radial refractive gradient lenses for continuous wear. An addition of +2.00D has been shown to be most efficient with up to 62% reduction in myopia [570].
- See every 6 months for follow-up examinations

If the patient is a juvenile (older than 4 years) and the MSE with cycloplegia is ≥ -0.50D steadily increasing over the past 1–2 years and other risk factors are present, treatment should include the most aggressive creation of peripheral myopia possible either via ortho-teratology, bifocal soft contact lenses with maximum addition tolerable, radial refractive gradient spectacles and executive bifocal lenses. It is worth keeping in mind that the younger the patient, the more the myopia is expected to progress and the older the patient, the faster myopia is expected to progress.

- Review risk factors, and modify outdoor time
- Counsel on proper nutrition (reduce carbohydrates, refined sugars, and grains)
- Consider the addition of pharmacological intervention (0.01% atropine)
- See every 3–6 months for follow-up examinations

CONCLUSION

Research has shown that it is possible to significantly slow the progression, and in some cases even prevent juvenile or school myopia using treatment strategies available to every practicing eye care professional. It is time to realise what the statement means that “Optometry is the Art and Science of Vision Care”.