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Review

Retardation of Myopia Progression by Multifocal Soft Contact Lenses

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Abstract

Myopia is an important public health problem due to its prevalence and significant public health cost. Elevating levels of myopia increase the risk of vision impairment, and therefore, high myopia has become one of the main causes of untreatable vision loss throughout the world due to its irreversible complications. At present, many options for slowing progression of myopia have already been proposed and evaluated such as progressive addition of executive bifocal spectacle lenses, peripheral defocusing lenses, overnight orthokeratology, pharmacological agents such as atropine eye drops, and multifocal soft contact lenses (MFSCLs). Use of MFSCLs has especially increased in recent years due to the growing demand to slow myopia progression during patient's adolescent growth period to avoid pathological myopia in adulthood. Compared with the other traditional methods of controlling myopia, MFSCLs allow myopic patients to better maintain their clear visual quality and slow myopia progression. In this manuscript, we aim to review the basics of myopia, recent advances in contact lenses to control myopia with emphasis on MFSCLs, define the elements for proper MFSCL fittings (such as pupil size, aberrations, accommodation and centering), discuss the potential rebound effect after discontinuation of contact lenses, and future directions for improvements of contact lenses for the control of myopia.

Key words: Multifocal soft contact lenses, Myopia, Progression

Prevalence and Risking Factors of Myopia

Myopia is traditionally considered as mere refractive error. However, recent increased prevalence in the world, especially in Asia, has forced the scientific society to view it differently [1-5]. The incidence of myopia is ~ 95% in the youngster population from China/ Korea [1, 2] and can occur when children are as young as 5–6 years old [6-8]. The most common form of myopia worldwide is secondary to elongation of the axial length of the eye, termed axial myopia. This axial lengthening process begins in childhood and progresses remarkably during the adolescent growth period [9]. Data from China, Taiwan and Japan indicate that severe axial myopia has become one of the main causes of untreatable vision loss throughout the world, often due to its irreversible complications, such as retinal detachment, macular degeneration, macular hemorrhage, choroidal neovascularization and open angle glaucoma [10, 11]. It was estimated that 1.5 billion people were affected in 2010, but this number is expected to rise to 5 billion by 2050 [4]. Unfortunately, this disease has no definitive cure by traditional optical interventions.

Historical Treatments of Myopia

At present, many options for slowing progression of myopia have been proposed and evaluated, such as progressive addition of executive bifocal spectacle lenses [12-14], peripheral defocusing lenses [15], contact lenses [16], outdoor activities [17], pharmacological agents such as atropine eyedrops [18],overnight orthokeratology [19-21], and multifocal soft contact lenses [22]. However a Cochrane Database Systematic Review in 2011 concluded that bifocals, progressive addition lenses and contact lenses yield disappointing long term results for myopia control [15] and specially designed spectacle lenses have minimal effect [23]. Atropine eyedrops which seem to be an effective way to slow the progression of myopia are also limited by drug side effects such as photophobia, abnormal accommodation and myopic rebound. Another alternative are certain specially designed contact lenses including orthokeratology and multifocal soft contact lenses (MFSCLs) which have been shown to delay induced myopia progression by generally incorporating 'positive power' to reduce the hyperopic defocus and/or impose myopic defocus in peripheral retina [24-27]. A study showed lenses with myopic defocus in the peripheral retina delay axial length elongation [28], while lenses imposing peripheral hyperopic defocus have the opposite effect, increasing the rate of elongation [24, 27]. These findings encourage the use of the optical devices for myopia control. While orthokeratology is an effective tool in delaying axial elongation [19, 29], children have to sleep with lenses at least 8-10 hours for necessary corneal curvature and orthokeratology is only applicable to the children with low and moderate myopia.

Slowing Myopia Progression by Use of Contact Lenses

Among all treatment options for myopia, soft contact lenses (SCLs) have been extensively investigated for their effect on retarding myopia progression since 1970s [30]. As early as 1975, contact lenses were considered to slow myopia progression when rigid contact lenses were shown to slow down myopia progression compared to spectacles as the control [31]. A later study in 1990s suggested rigid gas-permeable (RGP) contact lenses slowed myopia progression compared to spectacle lenses. More recently, SCLs designed with new materials and technologies (e.g. concentric ring bifocal SCLs [32-34] or peripheral add multifocal SCLs [35-39]) have achieved significant success in retarding myopia progression in pre-school- and school-age children. The design of concentric ring bifocal SCLs consists of a central distance zone surrounded by correction zones with near addition, while peripheral add multifocal SCLs arecomposed of a central zone for distance vision surrounded by progressively-increased relative positive power in peripheral zones. These specifically-designed SCLs are promising.

Although contact lenses are a promising, effective and attractive method for myopia control, wearing contact lenses is not always beneficial. The key controversial issue of wearing contact lenses is associated with safety. In children with contact lenses, drawbacks have been noted, similar to those reported in adult contact lenses wearers [40-43]. One of the most common risks is microbial keratitis as observed in many overnight wearers. Furthermore, discomfort could complicate the effective usage of contact lenses for control of myopia [44]. In fact, compliance with wearing lenses was found to be critical in retarding progression of myopia [45]. Among non-presbyopic myopic wearers, lenses featuring multifocality might decrease visual performance due to large power variations in the optic zone or when the lenses were decentered [46].

Better Control of Myopia by Defocus of Multifocal Soft Contact Lenses

Contact lenses are ideal for myopic defocus of 360° in the periphery area since the lenses are relatively centered during eye movements. Investigations in myopic children with orthokeratology lenses have suggested decreases in axial elongation [47-51]. The decrease of axial growth with orthokeratology is probably due to myopic shift in the peripheral area of retinal defocus led by changes of corneal shape stimulated by the lenses [52-54]. Other reports have suggested that soft bifocal contact lenses might slow down myopia progression in a short period in school children [55, 56]. However, no results from a multi-year clinical trial with soft bifocal contact lenses are currently available, and myopic shift due to peripheral defocus by soft bifocal contact lenses has been debated previously [54, 57].

Hyperopic retinal defocus in the peripheral area was first indicated as a potential mechanism for myopia progression in the 1970s [58]. Since that time, the results from several animal and human clinical studies have strongly suggested that retinal defocus in the peripheral area might mediate eye growth even under a clear foveal image [24, 59], and optical lenses eliminating hyperopic defocus in the peripheral area or inducing myopic defocus in the peripheral area might retard the progression of myopia in school children [60]. These results indicate that optical designs with myopic defocus may be a feasible option for delaying myopia progression.

Although eye response to optical defocus has been described in animal studies, it is still unknown how the optical signals are activated or inhibited in choroid, retina and sclera, and how the signals control structural changes that cause increased axial length. Until recently, various hypotheses have been proposed to explain the myopia control effect of these lenses, including:

1. reduction and correction of accommodative lag [61];
2. positional alteration of the peripheral retinal image for decrease of hyperopic defocus [56];
3. imposition of extended myopic defocus in the retina [45, 55];
4. elimination of the hyperopic blur induced by negative spherical aberration in accommodation [40];
5. alteration and optimization of the quality of retinal image for the points in front of the retina and degrading quality of retinal image for the points behind the retina [62].

These hypotheses require further investigations, of course.

Contact Lens Designs

Some multi-zone, presbyopic contact lenses have been developed for myopia control through removing hyperopic defocus [55, 61, 63, 64]. However, the ability to remove hyperopic defocus by such multizone contact lenses mainly depends on the behavior in eyes with these lenses [55, 65]. That is, when the eyes relax their accommodation, the anticipated defocus may not happen. Nevertheless, compared to the power transition from distance to near that happens with spectacles, MFSCLs can provide near and distance correction in the pupil, therefore, offering constant exposure to the treatment zone and at the same time, correcting the compliance shortcoming of spectacle options. In fact, increased accommodative lag is associated with myopia progression [66-69], indicating that accommodative lag may promote progression of myopia.

Extended depth of focus (EDOF) through manipulation of contact lenses magnitude may further improve contact lenses [70]. EDOF [70] design has the advantage that power distribution changes gradually from distance to near power, in contrast to the power distribution of center-distance and center-near aspheric multifocal contact lenses, monotonic in nature. For example, EDOF lenses have provided significant improvement of intermediate and near vision without adversely affecting distance vision [70]. Moreover, progressive designs [56] of multifocal soft contact lenses with ADD (which manipulate the distance correction towards the peripheral area) have been adopted recently [45, 55]. MFSCLs are advantageous compared to overnight orthokeratology and atropine eyedrops as they reduce the risk of microbial keratitis and reduce side effects, respectively.

Parameters that may Affect Fitting and Clinical Outcome, Limitations and Future Directions

Parameters that may Affect Fitting and Clinical Outcome: (1) Wearing Time: Wearing time is an important factor to retard myopia progression by MFSCLs [45]. In this article, it is suggested that the optimal wearing time for the MFSCLs lens is 7-8 hours per day to achieve the retardation up to 58%. **(2) Different ADD:** It is reported that the better myopia control effect may be achieved with higher add powers [71]. **(3) Pupil size:** Pupil size has a significant effect on MFSCLs performance [72]. Previous studies [73-75] have suggested that the refractive power by MFSCLs varies with the pupil size and across individuals. This is critical since people with the same visual requirements may have varying visual performance when fitted with the same MFSCLs as a result of different pupil size.

Limitations: Potential limitations include: randomized controlled trials have different parameters and bias is present [76]. Bias may also come from ethnicity. For example, the effect of SCLs on retarding myopia in Asian children is more significant [77, 78]. As most of the studies have suggested, children with low myopia are often included and observed them with various follow-up periods.

Future Directions: Regarding to rebound of myopia due to discontinuation of lens wear, no reports have been noted for monitoring the progression of myopia due to discontinuation of wear of soft contact lens. Further studies are required for myopia rebound due to discontinuation of wear of soft contact lens. In addition, the safety of MFSCLs requires further studies. Furthermore, MFSCLs should be carefully designed with lower compromising for image quality.

Conclusion

Multifocal contact lenses slow progression of myopia and are one of the most effective methods to control myopia to date. Nevertheless, questions remain on the mechanism of how these lenses improve and retain vision. Further research and development is needed in designing contact lenses for younger patients, as there is an elevated prevalence of myopia in school-age children. Eye doctors should consider the benefits and risks of multifocal contact lenses compared to other options.

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Competing Interests

The authors have declared that no competing interest exists.

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