Refractive error change and vision improvement in moderate to severe hyperopic amblyopia after spectacle correction: Restarting the emmetropization process?

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Abstract

Purpose
The aims of the study were to develop guidelines for prescribing spectacles for patients with moderate to severe hyperopic amblyopia and to demonstrate how emmetropization progresses.

Methods
Children with hyperopic amblyopia who had a spherical equivalent of ≥ +4.0 diopters (D) or more were included, while those who had astigmatism of > 2.0 D or anisometropia of > 2.0 D were excluded. The patients were divided into a full correction group and an under-correction group according to the amount of hyperopia correction applied. The under-correction group was further subdivided into a fixed under-correction group and a post-cycloplegic refraction (PCR) under-correction group. The duration of amblyopia treatment and changes in initial hyperopia were compared between the groups.

Results
In total, 76 eyes of 38 patients were analyzed in this study. The full correction group and under-correction group were subjected to 5.5 months and 5.9 months of amblyopia treatment, respectively (P = 0.570). However, the PCR under-correction group showed more rapid improvement (2.9 months; P = 0.001). In the under-correction group, initial hyperopia was decreased by -0.28 D and -0.49 D at 6 months and 12 months, respectively, after initial cycloplegic refraction. Moreover, the amount of hyperopia under-correction was correlated with the amount of hyperopia reduction (P = 0.010).

Conclusion
The under-correction of moderate to severe hyperopic amblyopia has beneficial effects for treating amblyopia and activating emmetropization. PCR under-correction can more rapidly
improve visual acuity, while both fixed under-correction and PCR under-correction can induce emmetropization and effectively reduce initial hyperopia.

**Introduction**

Prescribing spectacles for hyperopia is challenging for most pediatric ophthalmologists and optometrists. When spectacles are prescribed for children with hyperopic amblyopia, three aspects of the spectacles should be considered. First, one must assess how quickly and successfully the spectacle correction can achieve corrected visual acuity. Second, one should determine whether there is any possibility of developing strabismus. Finally, one should evaluate whether the hyperopia will change in the future, which is related to the issue of emmetropization.

Hyperopia is correlated with amblyopia and strabismus. Atkinson et al. [1] demonstrated that children with more than moderate hyperopia have a greater risk of developing amblyopia and strabismus. The authors also reported that partial spectacle correction of hyperopia can reduce the risk ratios of amblyopia and strabismus [1]. However, Ingram et al. [2] investigated the effect of early spectacle correction of hyperopia at 6 months of age and reported that the incidences of strabismus and amblyopia were not reduced by early spectacle correction [2]. Atkinson et al. [1] explained that the difference might be due to differences in the methods for prescribing spectacles or in compliance with the treatment. However, Ingram et al. [3] suggested that the children with hyperopia and who later developed strabismus could not recognize a stimulus of blurred vision because of a congenital lesion. Therefore, spectacle correction could not change the development of strabismus in these children.

Spectacle correction of hyperopia is related to emmetropization, which refers to changes in neonatal refractive errors during eye growth [4]. Although emmetropization has been hypothesized to progress passively with the growth of the ocular components [5], evidence indicates that active emmetropization process is regulated by an active visual feedback control system to compensate for detected refractive errors [6–9]. Human infants usually exhibit hyperopia, after which, ocular development towards emmetropia occurs [10,11]. However, Morgan et al. [12] have argued that the preferred final endpoint of emmetropization is mild hyperopia rather than emmetropia because in areas with a low prevalence of myopia, populations tend to remain predominantly mildly hyperopic. They proved that the early onset of emmetropia is a major risk factor for myopia progression. Therefore, after the achievement of emmetropia, there is the potential for progression to myopia [12–14].

Optical blurring and accommodation induced by hyperopic defocusing promote emmetropization [4]. Atkinson et al. [15] reported that partial spectacle correction for infantile hyperopia does not impede emmetropization. However, Ingram et al. [3] demonstrated that decreases in hyperopia are impeded by partial spectacle correction for hyperopia. Emmetropization between 3 months and 12 or 24 months of age occurs under active visual feedback control and through coordinated changes in corneal power and axial length. During that period, the normal distribution of refractive errors at birth changes to a highly peaked, leptokurtic distribution, with mean values that are mild hyperopic [12,16–19]. However, several investigators have suggested that emmetropization may continue throughout life, although little evidence supports this idea [20–22]. Little is known about how emmetropization in childhood hyperopia progresses and how it is influenced by spectacle correction.

The present study thus examined hyperopia changes according to the method of spectacle correction. The aim of this study was to provide guidelines for prescribing spectacles for moderate to severe hyperopia and thus for safely achieving emmetropization progress.
Materials and methods

This study was approved by the Inje University Ilsan Paik Hospital Institutional Review Board and was conducted in accordance with the Declaration of Helsinki ethical principles for medical research. Detailed medical records for all patients who were diagnosed as having hyperopic amblyopia between 2010 and 2015 were reviewed retrospectively. All medical records were completely anonymized, de-identified and aggregated before access to analyze the data. The patients between the age of 3 years and 11 years whose visual acuity could be measured with a Snellen acuity chart were included. Full ophthalmic evaluations at initial presentation included visual acuity measurement, slit-lamp examination of the anterior segments, intraocular pressure measurement and fundus examination. A cover uncover test and an alternate cover test were performed to identify strabismus. Amblyopia was defined separately according to the age at initial presentation: < 20/50 between the ages of ≥ 3 and < 4 years, < 20/40 between the ages of ≥ 4 and < 5, < 20/30 between the ages of ≥ 5 and < 6, and < 20/25 at ages of ≥ 6. When the patients met the suggested criteria for amblyopia, as well as if there were two or more lines of decrease in visual acuity based on the above definitions, immediate cycloplegic refraction was performed and spectacle correction was planned. If there was one line of decrease in visual acuity based on the above definitions, the child was followed up, and visual acuity was checked within the next two or three months. If there was no improvement in visual acuity, cycloplegic refraction was performed and spectacle correction was prescribed. For cycloplegic refraction, 1% cyclopentolate was applied three times at ten-minute intervals, followed by a ten-minute waiting period before examination. When the cycloplegia was inadequate, two more drops were added at ten-minute intervals, followed by a ten-minute waiting period. After confirming that cycloplegia was adequate, refraction was performed via retinoscopic examinations by the same ophthalmologist (JWC). The success of an amblyopia treatment was defined as an improvement in visual acuity of ≥ 20/30 under the age of 6 years or of ≥ 20/25 at the age of 6 years or older. Hyperopic children with a spherical equivalent (SE) of +4.0 diopters (D) or more after cycloplegic refraction were included in this study. To investigate the course of hyperopia alone and to exclude any confounding effects of astigmatism or anisometropia, cases were excluded if astigmatism > 2.0 D or anisometropia > 2.0 D of SE was present between each eye. Additionally, cases in which there were any other ocular abnormalities or systemic diseases that affected visual acuity were excluded.

Based on the method of hyperopia correction, patients were divided into the full correction group, if the full amount of hyperopia was prescribed, or the under-correction group, if a partial amount of hyperopia was prescribed. The under-correction group was further subdivided into two subgroups based on the under-correction method. In the fixed under-correction group, the initial refractive error was reduced by a determined amount ranging from 1.0 D to 1.5 D following the recommendation of the Pediatric Eye Disease Investigator Group [23]. In the post-cycloplegic refraction (PCR) under-correction group, at one week after cycloplegic refraction, the spectacle prescription was intended to achieve the best corrected visual acuity initially with partial hyperopia correction. Therefore, the initial full correction of hyperopia was reduced by 0.25 D stepwise until no additional corrected visual acuity improvement was achieved. If constant esotropia was manifested at the initial visit, then a full correction of hyperopia was performed. If residual esotropia was observed after full correction, the patients were excluded. In all cases in the under-correction group, a cover uncover test and an alternate cover test were performed to evaluate the development of esotropia at each visit. After the spectacles were applied, each patient’s visual acuity was examined every 2 months and cycloplegic refraction was carried out every 6 months. Patients who were followed up for more than 12 months were included in this study.
Statistical methods

To examine the differences and compare the changes between two groups, such as the full correction group and the under-correction group, or to compare changes among the three groups, such as the full correction group, the fixed under-correction group and the PCR under-correction group, a Mann-Whitney test and a Kruskal-Wallis test were used. To investigate the amount of under-correction and the decrease in hyperopia, a linear regression analysis was performed using SPSS software (version 18.0, SPSS Inc., Chicago, IL). All data for each group are presented as the mean ± standard deviation. A value of $P < 0.05$ was considered statistically significant.

Results

The seventy-six eyes of thirty-eight patients who met the inclusion criteria were analyzed in this study. Mean initial cycloplegic refraction and spectacle correction were performed at 66.5 months of age, and the mean follow-up period was 30.5 months. Mean SE at the initial visit was 5.78 D (4.0–11.25 D; Table 1). There was no significant difference between the full correction group and the under-correction group. However, when comparing the 3 groups, the age of the PCR under-correction group at the initial visit was greater than those of the other groups. In the under-correction group, spectacles were prescribed with a reduction of 1.90 D. The amounts of spectacle reduction in the fixed under-correction group and the PCR under-correction group were 1.17 D and 2.62 D, respectively (Table 2). The improvement in visual acuity and the duration of amblyopia treatment did not differ between the full correction group and the under-correction group ($P = 0.570$, Mann-Whitney test). Improvements were achieved in 5.5 months and 5.9 months in the full correction group and the under-correction group, respectively. However, when comparing the 3 groups after dividing the under-correction group, the PCR under-correction group achieved successful amblyopia treatment faster than the other groups, reaching an improvement in 2.9 months ($P = 0.001$, Kruskal-Wallis test). Additionally, a decrease in hyperopia was observed during the follow-up period. At 6 months and 12 months after initial cycloplegic refraction, SE decreases of 0.07 D and 0.17 D, respectively, were observed. There was a significant decrease in hyperopia in the under-correction group compared with the decrease in the full correction group at the 6-month and 12-month examinations ($P < 0.001$, Mann-Whitney test). However, in the under-correction group.
There was no significant difference in hyperopia reduction between the fixed and the PCR under-correction groups at the 6-month and 12-month examinations ($P = 0.070$ and $P = 0.755$, respectively, Fig 1). However, the amount of hyperopia under-correction was correlated with the amount of hyperopia reduction at the 6-month and 12-month examinations ($R^2 = 0.126$, $P = 0.010$ at 6 months, $R^2 = 0.149$, $P = 0.005$ at 12 months, Fig 2).

**Discussion**

The under-correction of hyperopia in children without strabismus has shown benefits compared with the full correction. In the present study, the under-correction group showed a more rapid improvement in visual acuity and a greater reduction of hyperopia than the full correction group. Therefore, the under-correction of hyperopia can promote emmetropization even in childhood, and if the under-correction is performed safely, more emmetropization can be expected.

The incidence of hyperopia corresponding to an SE of more than +4.0 D is less than 1% [24–26]. In addition, uncorrected hyperopia of more than +4.0 D has a significant relationship with the degradation of visual acuity [25,26]. Atkinson et al. [1] demonstrated that children with hyperopia over +3.5 D in at least one meridian have a 6 times greater risk of developing amblyopia and a 13 times greater risk of developing strabismus. The authors also reported that partial spectacle correction of hyperopia could reduce the risk ratios of amblyopia and strabismus to 2.5:1 and 4:1, respectively. Although such uncorrected hyperopia correlates with a high risk of vision development impairment and although some of these patients require spectacle correction, guidelines for prescribing spectacles for hyperopic children differ, and most guidelines are based on the experiences and surveys of practitioners [27,28]. Based on a review of the literature, the American Academy of Pediatric Ophthalmology and Strabismus Vision Screening Committee has proposed standard risk factors for amblyopia that should be

### Table 2. The amount of hyperopia reduction with spectacle correction in the under-correction group.

|                        | Total under-correction group | Fixed under-correction group | PCR under-correction group | P value |
|------------------------|-------------------------------|------------------------------|----------------------------|---------|
| **Mean**               | 1.90 ± 1.03 D                 | 1.17 ± 0.24 D                | 2.62 ± 1.01 D              | < 0.001 |
| **Range**              | 1.0–4.0 D                     | 1.0–1.5 D                    | 1.5–4.0 D                  |         |

PCR = post-cycloplegic refraction.

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![Fig 1. Changes in hyperopia and the progression of emmetropization in the full correction and under-correction groups.](https://doi.org/10.1371/journal.pone.0175780.g001)

(A) Initial hyperopia was significantly reduced in the under-correction group during follow-up ($P < 0.001$). (B) The amount of hyperopia under-correction was correlated with the amount of hyperopia reduction ($P = 0.010$).

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detected in preschool vision screening [29,30], but this committee has not suggested a protocol for prescribing spectacles for hyperopia.

Previous studies on the correction of hyperopia have focused on the success rate of amblyopia treatment or on the correlation with the development of strabismus. In contrast, in the present study, the speed of improvements of visual acuity in children with amblyopia and the progression of emmetropization were evaluated according to the method of hyperopia correction. Moreover, to confirm the correlation between the amount of hyperopia under-correction and the amount of progression of emmetropization, a greater amount of conventional under-correction was employed. In the fixed under-correction group, the amount of under-correction did not exceed 1.5 D, based on the recommendation of the Pediatric Eye Disease Investigator Group [23]. However, in the PCR under-correction group, in which an under-correction of more than 1.5 D was employed, more caution was needed because there is a greater risk of developing strabismus. MacEwen et al.[31] demonstrated that under-correction in fully accommodative esotropia can increase esotropia and that affected children can decompensate to manifest esotropia. Therefore, in the current study, the children in the PCR under-correction group were recruited if strabismus was not observed at the initial visit to avoid the development of strabismus. PCR under-correction was performed after one week of cycloplegic refraction to determine the partial amount of under-correction of hyperopia required to achieve the best corrected vision without inducing strabismus. Although there was still a risk of developing strabismus during the follow-up period, none of the children in this group developed strabismus. In the fixed under-correction group, an under-correction of 1.17 D (1.0–1.5
D) was employed, and in the PCR under-correction group, an under-correction of 2.62 D (1.5–4.0 D) was safely achieved. The demographic characteristics of the children in the different groups were not significantly different, except for their age at the initial visit: the PCR under-correction group was older than the other groups. However, this difference did not seem to influence the results because an older age correlates with disadvantages in terms of improvements in visual acuity and changes in hyperopia.

There were several advantages to using under-correction in treating moderate to severe hyperopia. First, children achieved normal visual acuity more rapidly. Although there was no difference in the duration of amblyopia treatment, the children achieved normal visual acuity more quickly after PCR under-correction because the minimum amount of under-correction required for the best corrected vision was applied in this group. Second, the children were more comfortable with spectacles that provided under-correction, and therefore, compliance was higher. Third, hyperopia showed a greater decrease, which is considered to indicate the promotion of emmetropization. There was no difference in hyperopia reduction between the fixed and the PCR under-correction groups. However, there was a negative correlation between the amount of hyperopia under-correction and hyperopia reduction ($R^2 = 0.126$, $P = 0.010$ at 6 months, $R^2 = 0.149$, $P = 0.005$ at 12 months, Fig 2). This result indicates that hyperopia under-correction can induce emmetropization even in childhood and that the amount of under-correction may correlate with the amount of emmetropization. These findings are compatible with the results of previous animal experiments showing that negative lens induced hyperopic defocus during the neonatal period actively regulated ocular growth and refraction to compensate for hyperopia [32,33]. This active regulation of induced defocus also appeared in myopic defocus. In myopic defocus with positive lenses, ocular growth was inhibited and myopia was decreased [34]. Based on those results, other studies have revealed that the under-correction of myopia slows the progression of myopia in children [35–37], although other studies had shown conflicting results [38,39]. The exact mechanism by which hyperopia under-correction induces emmetropization in childhood is unclear. However, in the present study, the children with moderate to severe amblyopia might not have experienced normal emmetropization process due to a greater degree of hyperopia at an earlier period and may have failed to move towards the target refractive error, emmetropia or mild hyperopia. As a result, these children could not achieve normal visual development and developed amblyopia. The initial mean refractive error was approximately 5.8 D in the full correction group and under-correction group, without a significant difference. After spectacle correction, there was no change in hyperopia in the full correction group, whereas there was a significant reduction in hyperopia in the under-correction group. Therefore, the under-correction of hyperopia not only aids in treating amblyopia but also promotes emmetropization process.

The exact mechanism by which the under-correction of moderate to severe hyperopic amblyopia promotes emmetropization in childhood is not known. One possibility is that accommodation promotes emmetropization. Emmetropization in hyperopia is considered to progress by not only optical defocusing and blurring but also accommodation [40]. Even if optical blurring and defocusing occur before optical correction, accommodation is not activated in uncorrected states, and this status may be responsible for amblyopia. Therefore, prior to spectacle correction, the children with moderate to severe hyperopic amblyopia in the present study might exhibit only optical defocusing and blurring, and they did not undergo accommodation because it was out of range. However, after wearing spectacles, hyperopia under-correction stimulated accommodation and resulted in a recovery of emmetropization. In contrast, with the full correction of hyperopia, accommodation was not activated, and emmetropization did not progress. Among the various types of accommodation [41], tonic accommodation may have been responsible for emmetropization in this study [42]. This type
refers to baseline accommodation of the resting state in hyperopia and is activated to compensate for sustained accommodative demands to overcome ongoing hyperopia but does not induce convergence [41,42]. Therefore, a remnant hyperopia of more than 1.5 D have not produced esotropia. Another possible mechanism is the re-activation of the visual feedback control system in that period. Children with moderate to severe hyperopia are thought to have failed to undergo emmetropization process at an earlier developmental stage due to unknown causes. The under-correction of hyperopia could re-activate the visual feedback control system and promote emmetropization. However, the exact mechanism by which the visual feedback control system could be re-activated during childhood after spectacle correction is unclear. Therefore, further studies should be conducted.

There were some limitations in this study. First, due to the study’s retrospective design, the patients were not randomized. Although there was no significant difference in the demographic characteristics of each group, there could have been a bias when determining hyperopia correction methods. Second, even though the progression of emmetropization in childhood was identified in the hyperopia under-correction group, the exact mechanism was not verified.

**Conclusion**

Based on this study, the under-correction of moderate to severe hyperopic amblyopia has beneficial effects for treating amblyopia and activating emmetropization. In particular, PCR under-correction can improve visual acuity quickly, while both fixed and PCR under-correction can induce emmetropization and effectively reduce initial hyperopia. Therefore, although PCR under-correction is time-consuming, it is safe and effective for the treatment of moderate to severe hyperopic amblyopia. However, because there is a risk of developing esotropia during the under-correction period, one should exercise caution in selecting subjects for under-correction. The possible development of esotropia and the decompensation of binocularity should also be carefully monitored.

**Supporting information**

S1 File.
(XLSX)

**Author Contributions**

Conceptualization: JWC.
Data curation: JWC.
Formal analysis: JWC.
Funding acquisition: JWC.
Methodology: JWC.
Project administration: JWC.
Resources: JWC.
Software: JWC.
Supervision: JWC.
Validation: JWC.
References

1. Atkinson J, Braddick O, Robier B, Ehrlich D, King J, et al. Two infant vision screening programmes: prediction and prevention of strabismus and amblyopia from photo- and videorefractive screening. Eye. 1996; 10: 189–198. https://doi.org/10.1038/eye.1996.46 PMID: 8776448
2. Ingram RM, Arnold PE, Dally S, Lucas J. Results of a randomised trial of treating abnormal hypermetropia from the age of 6 months. Br J Ophthalmol. 1990; 74: 158–159. PMID: 2182103
3. Ingram RM, Gill LE, Lambert TW. Effect of spectacles on changes of spherical hypermetropia in infants who did, and did not, have strabismus. Br J Ophthalmol. 2000; 84: 324–326. https://doi.org/10.1136/bjo.84.3.324 PMID: 10684846
4. Troilo D. Neonatal eye growth and emmetropisation—a literature review. Eye. 1992; 6: 154–160. https://doi.org/10.1038/eye.1992.31 PMID: 1624037
5. Glickstein M, Millodot M. Retinoscopy and eye size. Science. 1970; 168: 605–606. PMID: 5436596
6. Medina A. A model for emmetropization. The effect of corrective lenses. Acta Ophthalmol. 1987; 65: 565–571.
7. Wildsoet CF. Active emmetropization—evidence for its existence and ramifications for clinical practice. Ophthalmic Physiol Opt. 1997; 17: 279–290. PMID: 9390372
8. McBrien NA, Gentle A, Cottriall C. Optical correction of induced axial myopia in the tree shrew: implications for emmetropization. Optom Vis Sci. 1999; 76: 419–427. PMID: 10416997
9. Ai L, Li J, Guan H, Wildsoet CF. Emmetropization and eye growth in young aphakic chickens. Invest Ophthalmol Vis Sci. 2009; 50: 295–304. https://doi.org/10.1177/0019266108326601 PMID: 18719085
10. Ingram RM, Arnold PE, Dally S, Lucas J. Emmetropisation, squint, and reduced visual acuity after treatment. Br J Ophthalmol. 1991; 75: 414–416. PMID: 1854694
11. Ehrlich DL, Braddick OJ, Atkinson J, Anker S, Weeks F, Hartley T, et al. Infant emmetropization: longitudinal changes in refraction components from nine to twenty months of age. Optom Vis Sci. 1997; 74: 822–843. PMID: 9383797
12. Morgan IG, Rose KA, Ellwein LB. Is emmetropia the natural endpoint for human refractive development? An analysis of population-based data from the refractive error study in children (RESC). Acta Ophthalmol. 2010; 88: 787–884. https://doi.org/10.1111/j.1755-3768.2009.01800.x PMID: 19958289
13. Zadnik K, Mutti DO, Friedman NE, Qualella PA, Jones LA, Qui P, et al. Ocular predictors of the onset of juvenile myopia. Invest Ophthalmol Vis Sci. 1999; 40: 1936–1943. PMID: 10440246
14. Thorn F, Gwiazda J, Held R. Myopia progression is specified by a double exponential growth function. Optom Vis Sci. 2005; 82: 286–297. PMID: 15829846
15. Atkinson J, Anker S, Bobier W, Braddick O, Durden K, Nardini M, et al. Normal emmetropization in infants with spectacle correction for hyperopia. Invest Ophthalmol Vis Sci. 2000; 41: 3726–3731. PMID: 11053269
16. Pennie FC, Wood IC, Olsen C, White S, Charman WN. A longitudinal study of the biometric and refractive changes in full-term infants during the first year of life. Vision Res. 2001; 41: 2799–2810. PMID: 11587728
17. Mayer DL, Hansen RM, Moore BD, Kim S, Fulton AB. Cycloplegic refractions in healthy children aged 1 through 48 months. Arch Ophthalmol. 2001; 119: 1625–1628. PMID: 11709012
18. Mutti DO, Mitchell GL, Jones LA, Friedman NE, Frane SL, Lin WK, et al. Refractive astigmatism and the toricity of ocular components in human infants. Optom Vis Sci. 2004; 81: 753–761. PMID: 15557849
19. Mutti DO, Mitchell GL, Jones LA, Friedman NE, Frane SL, Lin WK, et al. Axial growth and changes in lenticular and corneal power during emmetropization in infants. Invest Ophthalmol Vis Sci. 2005; 46: 3074–3080. https://doi.org/10.1177/0019266105460312 PMID: 16123404
20. Ooi CS, Grosvenor T. Mechanisms of emmetropization in the aging eye. Optom Vis Sci. 1995; 72: 60–66. PMID: 7753529
21. Sorsby A, Benjamin B, Sheridan M, Stone J, Leary GA. Refraction and its components during the growth of the eye from the age of three. Memo Med Res Counc. 1961; 301: 1–67. PMID: 13915328
22. Grosvenor T. Reduction in axial length with age: an emmetropizing mechanism for the adult eye? Am J Optom Physiol Opt. 1987; 64: 657–663. PMID: 3686185
23. Pediatric Eye Disease Investigator Group. A randomized trial of atropine vs. patching for treatment of moderate amblyopia in children. Arch Ophthalmol. 2002; 120: 268–278. PMID: 11879129
24. Kutschke PJ, Scott WE, Keech RV. Anisometropic amblyopia. Ophthalmology. 1991; 98: 258–263. PMID: 2008287
25. Donahue SP. Prescribing spectacles in children: a pediatric ophthalmologist’s approach. Optom Vis Sci. 2007; 84: 110–114. https://doi.org/10.1097/OPX.0b013e318031b09b PMID: 17299340
26. Robaei D, Rose K, Ojaimi E, Kifley A, Huynh S, Mitchell P. Visual acuity and the causes of visual loss in a population-based sample of 6-year-old Australian children. Ophthalmology. 2005; 112: 1275–1282. https://doi.org/10.1016/j.ophtha.2005.01.052 PMID: 15921756
27. Lyons SA, Jones LA, Walline JJ, Bartolone AG, Carlson NB, Kattouf V, et al. A survey of clinical prescribing philosophies for hyperopia. Optom Vis Sci. 2004; 81: 233–237. PMID: 15097764
28. Miller JM, Harvey EM. Spectacle prescribing recommendations of AAPOS members. J Pediatr Ophthalmol Strabismus. 1998; 35: 51–52. PMID: 9503319
29. Donahue SP, Arnold RW, Ruben JB. Preschool vision screening: what should we be detecting and how should we report it? Uniform guidelines for reporting results of preschool vision screening studies. J AAPOS. 2003; 7: 314–316. https://doi.org/10.1016/S1091853103001824 PMID: 14566312
30. Donahue SP, Arthur B, Neely DE, Arnold RW, Silibert D, Ruben JB. Guidelines for automated preschool vision screening: a 10-year, evidence-based update. J AAPOS. 2013; 17: 4–8. https://doi.org/10.1016/j.jaapos.2012.09.012 PMID: 23360915
31. MacEwen CJ, Lymburn EG, Ho WO. Is the maximum hypermetropic correction necessary in children with fully accommodative esotropia? Br J Ophthalmol. 2008; 92: 1329–1332. https://doi.org/10.1136/bjo.2007.126417 PMID: 18408081
32. Schaeffel F, Glasser A, Howland HC. Accommodation, refractive error and eye growth in chickens. Vision Res. 1988; 28: 639–657. PMID: 3195068
33. Troilo D, Wallman J. The regulation of eye growth and refractive state: an experimental study of emmetropization. Vision Res. 1991; 31: 1237–1250. PMID: 1891815
34. Smith EL 3rd, Hung LF, Huang J, Anumugam B. Effects of local myopic defocus on refractive development in monkeys. Optom Vis Sci. 2013; 90: 1176–1186. https://doi.org/10.1097/OPX.0000000000000308 PMID: 24061154
35. Li SY, Li SM, Zhou YH, Liu LR, Li H, Kang MT, et al. Effect of undercorrection on myopia progression in 12-year-old children. Graefes Arch Clin Exp Ophthalmol. 2015; 253: 1363–1368. https://doi.org/10.1007/s00417-015-3053-8 PMID: 26032395
36. Sun YY, Li SM, Ly SY, Kang MT, Liu LR, Meng B, et al. Effect of uncorrection versus full correction on myopia progression in 12-year-old children. Graefes Arch Clin Exp Ophthalmol. 2017; 255: 189–195. https://doi.org/10.1007/s00417-016-3529-1 PMID: 27796670
37. Li SM, Ly SY, Liu LR, Guo JY, Chen W, Wang NL, et al. Full correction and Undercorrection of Myopia Evaluation Trial: design and baseline data of a randomized, controlled, double-blind trial. Clin Exp Ophthalmol. 2013; 41: 329–338. https://doi.org/10.1111/j.1442-9071.2012.02884.x PMID: 23090377
38. Chung K, Mohdin N, O'Leary DJ. Undercorrection of myopia enhances rather than inhibits myopia progression. Vision Res. 2002; 42: 2555–2559. PMID: 12448649
39. Adler D, Millodot M. The possible effect of undercorrection on myopic progression in children. Clin Exp Optom. 2006; 89: 315–321. https://doi.org/10.1111/j.1444-0938.2006.00555.x PMID: 16907670
40. Mutti DO, Mitchell GL, Jones LA, Friedman NE, Frane SL, Lin WK, et al. Accommodation, acuity, and their relationship to emmetropization in infants. Optom Vis Sci. 2009; 86: 666–676. https://doi.org/10.1097/OPX.0b013e3181a6174f PMID: 19417711
41. Heath GG. Components of accommodation. Am J Optom Arch Am Acad Optom. 1956; 33: 569–579. PMID: 13372735
42. Babinsky E, Candy TR. Why do only some hyperopes become strabismic? Invest Ophthalmol Vis Sci. 2013; 54: 4941–4955. https://doi.org/10.1167/iovs.12-10670 PMID: 23883788