The Effect of Orthokeratology Lens on the Axial Length of Globe in Children with Myopia in Asia

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ABSTRACT

The aim of this meta-analysis was to determine the effect of orthokeratology (OK) lens on the axial length of the eye globe of Asian children with myopia of low and moderate degree compared with children treated with glasses. PubMed, Embase, Web of Science, and Cochrane Library were searched to collect relative researches on the treatment of OK lens in myopia children from January 2000 to July 2021. The authors adopted the standardised mean difference (SMD) as effect size, to estimate the pooled changes of axial length in Asian myopic children. Seven articles were identified. In Asian children with myopia of low to a moderate degree, compared with glasses treatment, axial length decreased significantly in the OK Lens group (SMD = -0.84, 95%CI: -1.10 ~ -0.58), with a p-value less than 0.05. According to the follow-up time, the subgroup analysis demonstrated that, SMD = -0.68 (95%CI: -1.43 ~ 0.08, p>0.05) for six months; SMD = -1.00 (95 %CI: -1.38~-0.62, p<0.05) for 12 months; SMD=-0.71 (95%CI: -1.20~-0.21, p<0.05) for two years. In conclusion, in the early treatment, compared with glasses, children with low and moderate myopia wearing OK lenses were more effective in reducing axial elongation in Asia.

Key Words: *Axial length, Orthokeratology, Myopia, Meta-analysis*.

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INTRODUCTION

In recent years, the global incidence of myopia has increased dramatically.[1] So far, it is estimated that about 30% of the world's population suffers from myopia, and this figure will rise to 50% by 2050.[2] The prevalence of myopia in adolescents is also increasing, and now around 70% of high school students in China are diagnosed with myopia.[3] With further development of myopia, severe eye complications such as retinal detachment, cataracts, and glaucoma may occur, which pose a serious threat to vision and even lead to blindness.[4-6] The appropriate treatments to control and delay the progression of myopia mainly include drug therapy (*e.g.*, atropine), non-surgical correction (*e.g.*, single-vision spectacles), and surgical correction (*e.g.*, refractive surgery).[7,8] Southeast Asia, South Asia, and East Asia account for the largest potential loss in their economic activities, in which the financial burden of East Asia is the largest.[9] For these reasons, methods to prevent myopia and control its progression are urgently needed.

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Currently, the orthokeratology (OK) lens is considered one of the most promising approaches to control the development of myopia in children.[10] In China, 1.5 million adolescents have chosen this treatment method.[11] The safety and effectiveness of long-term wearing of the OK lens have always been the focus of attention. OK lens is a specially designed rigid contact lens with high oxygen permeability. In the middle of the last century, the emergence of a new glass material, polymethyl methacrylate (PMMA), provided the raw materials for ophthalmologists to manufacture contact lenses. It was found that contact lenses can affect the cornea's curvature, change the degree of myopia and astigmatism, and affect vision.[12] There are many ways to classify myopia, which can be divided into axial and refractive according to its refractive components. For now, axial myopia is dominant in myopia, which is mainly manifested by an increase in the axial length of the eye. Thus, the change in axial length is an important indicator to assess the correction and control of myopia with the OK lens. A comparative study of low to moderate myopia by Hiraoka *et al.* in 2012 showed that the axial length of the OK lens group increased by (0.99 ± 0.47) mm, while that of the ordinary frame glasses group increased by (1.41 ± 0.68) mm, and that the OK lens could slow down the growth of the eyeball.[13] However, the results of 2-year follow-up conducted by Cheung *et al.* suggested that the effect of the OK lens on the axis of the eye compared with the control group had no difference.[14]

Therefore, in this meta-analysis, the authors compared the effects of OK lenses with glasses treatments on the axial length to evaluate the advantages of OK lenses in treating Asian children with low and moderate myopia. To the best of author' knowledge, this is the first meta-analysis to systematically evaluate axial elongation after OK Lens treatment in Asian children with moderate and low myopia.

METHODOLOGY

This meta-analysis was conducted by following the preferred reporting items for systematic reviews and meta-analyses (PRISMA).[15] The databases of PubMed, Web of Science, Embase, and Cochrane Library, from January 2000 to July 2021, were searched to collect relevant retrospective cohort studies, prospective cohort studies, or randomised controlled trials (RCTs) on the changes of axial length in children with myopia treated by the OK lens. "Myopia", "Orthokeratology", and "Axial Length" were the keywords for conducting the research. Two authors (LQN and XLF) searched the literature independently, with final cross-checking. A disagreement was resolved either through discussion, or a third author (YG) was asked for verification.

Inclusion criteria were as follows (1) The subjects of the studies were children with acquired myopia under the age of 18 years; (2) Research was on the effect of OK lens treatment on axial elongation; (3) Glasses treatment was used as the control group; (4) Literature data including axial length and myopia information such as the degree of refractive error and astigmatism; (5) The axial length was tested by intraocular lens master (IOL Master), optical biometry; (6) Research published in English; (7) The subjects were Asian children with low and moderate myopia. Literature was excluded if it was an abstract, comment, review, and editorial review or case report; research samples were from other ophthalmological diseases; insufficient data, or research in which the relevant raw data could not be extracted and if the follow-up time was less than one year.

The quality of the studies was assessed in accordance with the Newcastle-Ottawa scale (NOS),[16] by two investigators (TSH and XLF) independently, and finally cross-checked. The total NOS scores were nine stars. The study with an NOS score ≥6 was considered high-quality research. We assessed the quality of the RCTs in accordance with Jadad scoring including randomization, blinding procedures, report of withdrawals, and dropouts.[17] The total Jadad scores were five. The study, of which the Jadad score higher than 3 was considered as high-quality research, was included in this meta-analysis.

Two researchers (LQN and XLF) independently extracted the data, and then cross-checked it. The disagreements could be resolved through discussion, or determined by a third author. The following information was extracted: first author, country, publication year, research type, as well as clinical data including follow-up time, axial length, number of samples, age, astigmatism, and degree of myopic refractive error.

The data was processed using Stata 15.0 statistical software. The standardised mean difference (SMD), as well as the corresponding 95% confidence interval (CI), was adopted to pool the variation of axis length between the OK lens group and the glasses group. The heterogeneity across included articles was evaluated through the method of Cochran's Q test and I^2-test. A p-value was less than or equal to 0.05, with I^2 more than or equal to 50%, indicating the existence of heterogeneity, and then a random-effects model (REM) was adopted. Otherwise, the authors utilised a fixed-effects model (FEM) to pool the data. Subgroup analysis was performed according to the follow-up time. A funnel plot, as well as Egger's test, was used to identify publication bias. Finally, we conducted a sensitivity analysis to verify whether the findings are robust or not.

RESULTS

After comprehensively screening, a total of seven articles were identified.[13,14,18-22] The detailed flow chart of articles screening is displayed in Figure 1. The basic characteristics of the included studies, as well as NOS or Jadad quality scores, are shown in Table I.

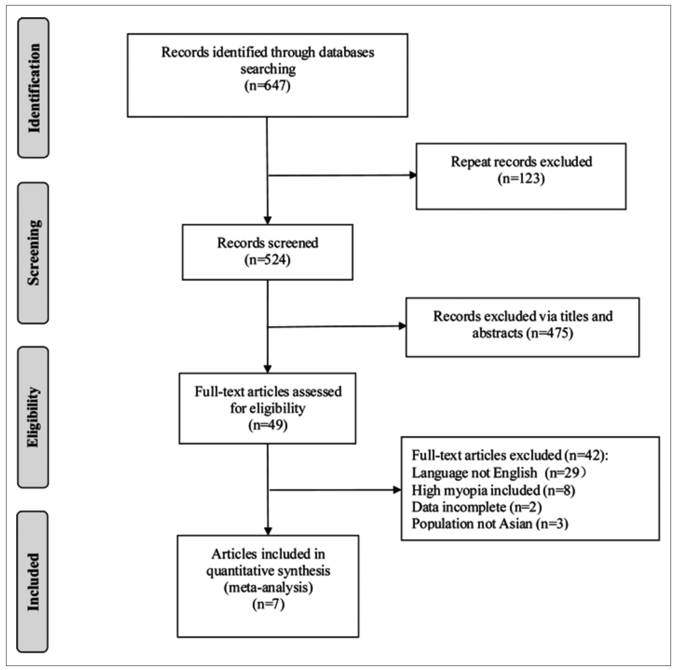

Figure 1: screening flow diagram of document retrieval.

First of all, the changes of axial length in Asian myopic children of low to a moderate degree were analysed after treatment of OK lens. A total of 383 Asian children received OK lens treatment and 299 children served as controls. According to the heterogeneity results (I^2=75.0%, p<0.001), REM was applied for data integration. Comparing OK lenses with glasses treatment, SMD was -0.84 (95%CI: -1.10 ~ -0.58, p<0.001), with difference significant (Figure 2). The p-value of Egger's test was 0.113, with a symmetrical funnel plot (Figure 3), indicating no existence of obvious publication bias.

In order to explore the source of heterogeneity, a subgroup analysis of the follow-up time was conducted. There was no significant decrease in heterogeneity after subgroup analysis according to the follow-up time.

Table I: The basic characteristics of the studies included.

First author	Year	Country	Study design	Follow-up (years)	Group	Number (Cases/Controls)	Age	Myopia	Astigmatism	NOS score	Jadad score
Hiraoka *et al.* [13]	2012	Japan	Re	5	OKs/spectacles	22/21	8-12	-0.5~-5.00D	≤1.50D	9	NA
Cho *et al.*[18]	2012	China	RCT	2	OKs/SV	37/41	6-10	-0.5~-4.00D	<1.25D	NA	4
Chen *et al.*[19]	2013	China	Cohort study	2	OKs/SV	35/23	6-12	0.5~5.00D	<1.50D	7	NA
He M *et al.*[20]	2016	China	Re	1	OKs/SV	141/130	7.0-11.5	-0.5~-6.00D	<1.5D	8	NA
Cheung *et al.* [14]	2016	China	RCT	2	OKs/SV	37/38	7-10	-0.5~-4.00D	<-1.25D	NA	4
Long W *et al.* [21]	2019	China	Re	1	OKs/spectacles	98/37	8-14	-0.5~-6.0D	<3.0	8	NA
Yoo *et al.*[22]	2020	Korea	Re	1	OKs/spectacles	13/9	8-12	-0.75~-4.00D	<1.50D	8	NA

OKs= group wearing orthokeratology lens; SV= group wearing single-vision spectacles; D= Diopter; NOS= Newcastle-Ottawa Scale; NR= Not reported; Re: Retrospective cohort study; Gp= Gaspermeable lens; RCT= Randomised controlled trial; NA: Not applicable.

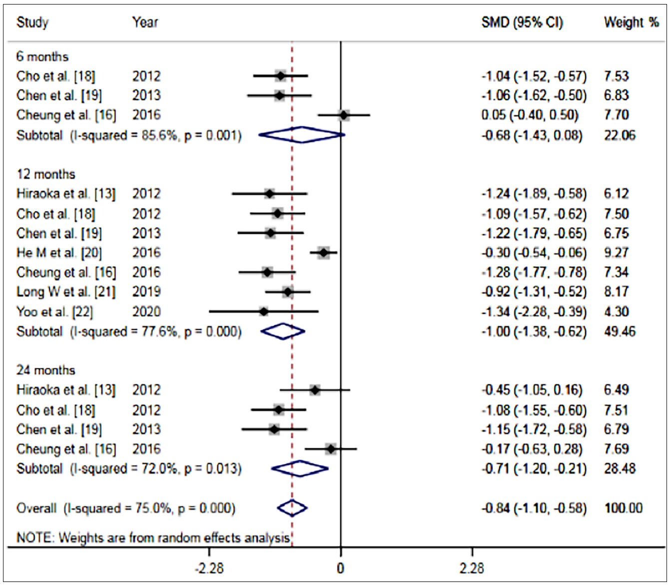

Figure 2: Forest plot of changes in axial length after orthokeratology lens treatment. SMD= Standardised mean difference; CI= Confidence interval.

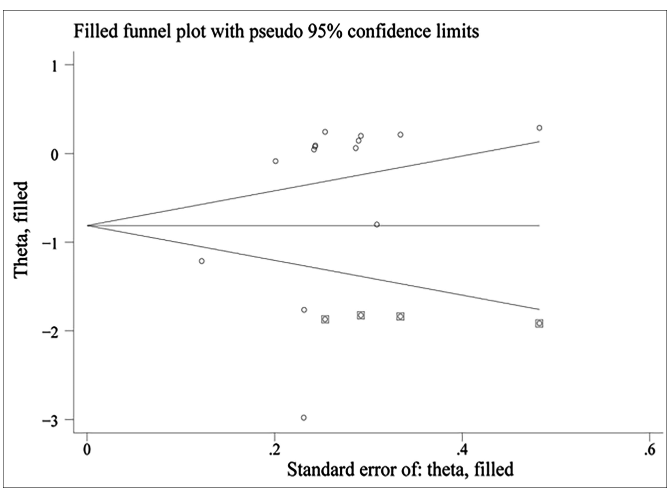

Figure 3: Funnel plot of changes in axial length after orthokeratology lens treatment.

The results (Figure 2) demonstrated that there was no difference in the eye's axial elongation of Asian myopic children of low to a moderate degree after 6 months (SMD = -0.68 (95%CI: -1.43 ~ 0.08, p>0.05). Besides, OK lens controlled the axial length of the eye at 12 (SMD = -1.00 (95%CI: -1.38~-0.62, p<0.001) and 24 months (SMD= -0.71 (95%CI: -1.20~-0.21, p= 0.005) after treatment significantly.

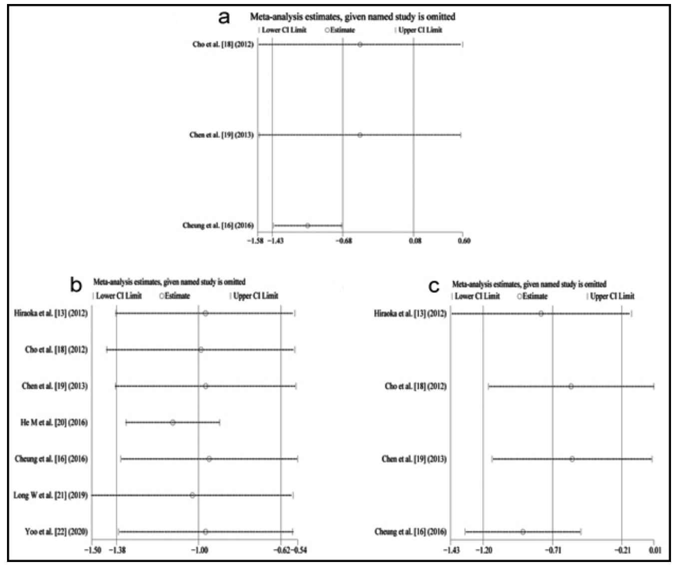

Figure 4: Influence analysis of changes in axial length after orthokeratology lens treatment. (a) 6 months (b) 12 months (c) 24 months.

To confirm the robustness of the findings concluded in this study, sensitivity analysis of the subgroup was performed based on follow-up after myopia treatment. After eliminating each study, a meta-analysis was conducted again to determine the impact of the study on the overall conclusion. After 6 months of treatment (Figure 4a), only one study was omitted,[14] the difference became statistically significant. After 24 months of treatment (Figure 4c), only one study was excluded,[18] the difference again cost statistical significance, indicating the change in conclusion. After 12 months of treatment (Figure 4b), when each study was omitted, the conclusion did not change significantly. This shows that the conclusion that the OK lens slows the axial length in Asian myopia children of low and moderate degree is robust after 12 months of treatment, but the conclusions after 6 and 24 months should be treated with caution.

DISCUSSION

To explore the changes of axis length treated by the OK lens in Asian children with myopia, we conducted a systematic search on the online English database and comprehensively analysed OK lens versus glasses treatment. Also, the change of eye axis length is measured after wearing the OK lens for 6 months, 1 year, and 2 years. The results suggest that there is no difference in the axial length after 6 months between the OK lens and glasses treatment. However, after

1 and 2 years, the OK lens can significantly reduce the axial length. The design of OK lens and the change of OK corneal parameters can affect the development of AL elongation and myopia.[23] In recent years, in addition to OK lenses, the defocus incorporated multiple segments (DIMS) lenses have shown sound treatment effects in correcting myopia in children. Lam *et al*.[24] showed that children who used DIMS lenses for the first 2 years had sustained myopia control in the third year, and children who went from single vision (SV) to DIMS lenses also showed good myopia control.

After the strict screening, seven studies were enrolled in our research. All studies contain control trials and followed up for at least 12 months. The results showed that OK lens compared with glasses treatment, the axial elongation decreased in Asian children with low and moderate myopia. The funnel plot, as well as Egger's test results, indicated no obvious publication bias in this meta-analysis.

Considering the influence of OK lens on myopia patients may change over time, the authors pooled the changes of axial length in Asian myopic children of low and moderate degrees from six months to two years in the OK lens treatments compared with glasses. The results suggest that after 6 months of OK lens treatment, compared with glasses treatment, (SMD=-0.68), the difference was not significant. It suggests that the OK lens treatment did not show a better effect than glasses in controlling the length of the eye axis after 6 months of treatment in Asian myopic children of low and moderate degrees. However, after excluding one study, the difference changed significantly. Therefore, more studies are needed to verify whether the OK lenses slow the axial length more effectively than glasses in treating myopia of low to moderate degrees after 6 months in Asian children.

After 12 months of OK lens treatment for Asian myopic children of low to moderate degree, SMD was -1.00 for the axial changes, with difference significant. Therefore, the effect of OK lens controlling axial length after 12 months is better than that of glasses treatment in Asian myopic children of low to moderate degrees. After excluding any research and performing a meta-analysis, the conclusion has not changed. Sensitivity analysis results confirm this conclusion.

For Asian myopic children of low and moderate degree, the treatment effect of OK lens after 24 months on the change of axial length compared with glasses treatment, the difference is statistically significant (SMD=-0.84). After omitting each study and performing a meta-analysis, we found that one study had an impact on the conclusion. The differences that are originally statistically significant become not significant after eliminating one study. Therefore, the effect of OK lens controlling axial elongation is better than that of glasses after 24 months length in Asian myopic children of low to moderate degree. However, since the sensitivity analysis shows a certain degree of instability, this conclusion must be treated with caution. In 2015, a meta-analysis published by Li *et al.* indicated that the control effect of axial length of OK lens was better than that of the control group at 6, 12 and 24 months after treatment of myopia in children, with the difference statistically significant.[25] Their conclusions are consistent with the present limiting the study to Asian children with mild to moderate myopia after treatments of one and two years. However, after 6 months of treatment, OK lens showed no better effect than the control in this study. Guan *et al.* showed that OK lens performed better than the control group after one and two years for myopia in a meta-analysis in 2020.[26] This is basically consistent with the conclusions of this meta-analysis. Nevertheless, our study more strictly limited the conditions of inclusion, excluding a study whose control did not use spectacles and included more recent studies.[27] It makes the present conclusions more reliable.

Inevitably, this study also had certain limitations. Firstly, the number of included studies was small, with only seven studies eligible. This also resulted in a smaller sample size. The lack of research data may affect the robustness of the obtained conclusions. Secondly, the authors included research published in English only and excluded research published in other languages, which may lead to certain publication bias. Thirdly, four retrospective cohort studies were included in this study. Compared with prospective cohort studies, the quality of retrospective studies was low, which may affect the robustness of the conclusions of this study. In addition, the longest time point analysed was 24 months after OK lens treatment. Thereby, more research is needed on longer time of the OK lens treatment. Finally, there is high heterogeneity in this meta-analysis. Even after the follow-up subgroup analysis, the heterogeneity did not decrease significantly. This suggests that there may be other factors affecting the heterogeneity across studies.

CONCLUSION

In the early myopic children treatment, the OK lens is more effective in delaying eye axis elongation than wearing ordinary glasses in Asia. However, considering the limitations of this study, such as sample size, heterogeneity, *etc*., larger follow-up researches are needed to conclude more accurate findings for the OK lens treatment of children with myopia in Asia.

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Availability of Data and Material:
The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

COMPETING INTERESTS:

The authors declared no competing interest.

AUTHORS' CONTRIBUTION:

GY, ST, SL: Substantial contribution to the conception and design of the work, critical revision, and drafting of the manuscript.

GY, ST, QL, LX: Acquisition, analysis, and interpretation of the data.

All the authors have approved the final version of the manuscript to be published.

REFERENCES

1. Rudnicka AR, Kapetanakis VV, Wathern AK, Logan NS, Gilmartin B, Whincup PH, *et al*. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: Implications for aetiology and early prevention. *Br J Ophthalmol* 2016; **100**: 882-90.doi: 10.1136/bjophthalmol-2015-307724.
2. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, *et al*. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016; **123**:1036-42. doi.10.1016/j.ophtha.2016. 01.006.
3. Kang ZF, Tao FF, Jing J, Xu XM, Su LY, Eye H. A meta-analysis for prevalence of myopia among Chinese teenagers. *J Clin Ophthalmol* 2016; **24**: 395-99. doi: 10.3969/j.issn.1006-8422.2016.05.004.
4. Kim J, Ryu SY, Hong JH, Chung EJ. Incidence and risk factors for retinal detachment after cataract surgery in Korea: A nationwide population-based study from 2011 to 2015. *Graefes Arch Clin Exp Ophthalmol* 2019; **257**:2193-202.DOI: 10.1007/s00417-019-04423-x.
5. Zemborain ZZ, Jarukasetphon R, Tsamis E, De Moraes CG, Ritch R, Hood DC. Optical coherence tomography can be used to assess glaucomatous optic nerve damage in most eyes with high myopia. *J Glaucoma* 2020; **29**:833-45. doi. 10. 1097/IJG.0000000000001631.
6. Tsai ASH, Wong CW, Lim L, Yeo I, Wong D, Wong E, *et al*. Pediatric Retinal detachment in an asian population with high prevalence of myopia: Clinical characteristics, surgical outcomes, and prognostic factors. *Retina-J Ret Vit Dis* 2019; **39**:1751-60. doi. 10.1097/IAE.0000000000002238.
7. Wu PC, Chuang MN, Choi J, Chen H, Wu G, Ohno-Matsui K, *et al*. Update in myopia and treatment strategy of atropine use in myopia control. *Eye (Lond)* 2019; **33**:3-13. doi: 10.1038/s41433-018-0139-7.
8. Gomel N, Negari S, Frucht-Pery J, Wajnsztajn D, Strassman E, Solomon A. Predictive factors for efficacy and safety in refractive surgery for myopia. *Plos One* 2018; **13**:e208608. doi. 10.1371/journal.pone.0208608.
9. Naidoo KS, Fricke TR, Frick KD, Jong M, Naduvilath TJ, Resnikoff S, *et al*. Potential lost productivity resulting from the global burden of myopia: Systematic review, meta-analysis, and modeling. ophthalmology 2019; **126**:338-46. doi. 10.1016/j.ophtha.2018.10.029.
10. Si JK, Tang K, Bi HS, Guo DD, Guo JG, Wang XR. Orthokeratology for myopia control: A meta-analysis. *Optom Vis Sci* 2015; **92**:252-57. doi. 10.1097/OPX.0000000000000505.
11. Xie P, Guo X. Chinese experiences on orthokeratology. *Eye Contact Lens* 2016; **42(1)**:43-7. doi. 10.1097/ICL.00000000 00000190.
12. González-Méijome JM, Peixoto-de-Matos SC, Faria-Ribeiro M, Lopes-Ferreira DP, Jorge J, Legerton J, *et al.* Strategies to regulate myopia progression with contact lenses: A review. *Eye Contact Lens* 2016; **42**:24-34. doi.10.1097/ICL. 0000000000000100.
13. Hiraoka T, Kakita T, Okamoto F, Takahashi H, Oshika T. Long-term effect of overnight orthokeratology on axial length elongation in childhood myopia: A 5-year follow-up study. *Invest Ophthalmol Vis Sci* 2012; **53**:3913-19. doi. 10.1167/iovs.11-8453.
14. Cheung SW, Cho P. Long-term effect of orthokeratology on the anterior segment length. *Cont Lens Anterior Eye* 2016; **39**:262-5. doi. 10.1016/j.clae.2016.02.003.
15. Moher D, Liberati A, Tetzlaff J, Et Al. Preferred reporting items for systematic reviews and meta-analyses: The prisma statement. *J Clin Epidemiol* 2009; **151**:264-69. doi. 10.1016/j.jclinepi.2009.06.005.
16. Stang A. Critical evaluation of the newcastle-ottawa scale for the assessment of the quality of nonrandomised studies in meta-analyses. *Eur J Epidemiol* 2010; **25**:603-05. doi. 10.1007/s10654-010-9491-z.
17. Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJ, Gavaghan DJ EA. Assessing the quality of reports of randomised clinical trials: Is blinding necessary? *Control Clin Trials* 1996; **17**:1-12. doi.10.1016/0197-2456(95)00134-4.
18. Cho Pauline, Cheung Sin-Wan. Retardation of myopia in orthokeratology (ROMIO) study: A 2-year Randomised clinical trial. *Invest Ophthalmol Vis Sci* 2012; **53**:7077-85. doi. 10.1167/iovs.12-10565.
19. Chen C, Cheung SW, Cho P. Myopia control using toric orthokeratology (TO-SEE study). *Invest Ophthalmol Vis* 2013; **54**:6510-17. doi. 10.1167/iovs.13-12527.
20. He M, Du Y, Liu Q, Ren C, Liu J, Wang Q, *et al*. Effects of orthokeratology on the progression of low to moderate myopia in Chinese children. *Bmc Ophthalmol* 2016; **16**:126. doi 10.1186/s12886-016-0302-5.
21. Long W, Li Z, Hu Y, Cui D, Zhai Z, Yang X. Pattern of axial length growth in children myopic anisometropes with orthokeratology treatment. *Curr Eye Res* 2019; **45**:834-8. doi. 10.1080/02713683.2019.1701685.
22. Yoo YS, Kim DY, Byun YS, Ji Q, Yoon G. Impact of peripheral optical properties induced by orthokeratology lens use on myopia progression. *Heliyon* 2020; **6**:e3642. doi.10.1016/j. heliyon.2020.e03642.
23. Pauné J, Fonts S, Rodríguez L, Queirós A. The role of back optic zone diameter in myopia control with orthokeratology lenses. *J Clin Med* 2021; **10**. doi.10.3390/jcm10020336.
24. Lam CS, Tang WC, Lee PH, Zhang HY, Qi H, Hasegawa K, *et al*. Myopia control effect of defocus incorporated multiple segments (DIMS) spectacle lens in Chinese children: Results of a 3-year follow-up study. *Br J Ophthalmol* 2021. doi. 10. 1136/bjophthalmol-2020-317664.
25. Li SM, Kang MT, Wu SS, Liu LR, Li H, Chen Z, *et al*. Efficacy, safety and acceptability of orthokeratology on slowing axial

elongation in myopic children by meta-analysis. *Curr Eye Res* 2015; **41**:600-8. doi: 10.3109/02713683.2015.1050743.

26. Guan M, Zhao W, Geng Y, Zhang Y, Li Y. Changes in axial length after orthokeratology lens treatment for myopia: A meta-analysis. *Int Ophthalmol* 2020; **40(1)**:255-65. doi. 10.1007/s10792-019-01167-9.

27. Na M, Yoo A. The effect of orthokeratology on axial length elongation in children with myopia: Contralateral comparison study. *Jpn J Ophthalmol* 2018; **62**:327-34. doi. 10.1007/s10384-018-0573-x.

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