IJSCIA

International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 6 | Issue: 2 | Mar – Apr 2025 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v6i2.14

Efficacy of Orthokeratology Lenses in Adults: A Literature Review

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ABSTRACT

Purpose: To evaluate the efficacy of orthokeratology lenses in adults with the hopes of providing an alternative for those who seek a less invasive method for myopia control. ***Methods:*** A comprehensive search was performed on Science Direct, PubMed, Ophthalmology Advance, and Scientific Reports using the terms "Orthokeratology in Adults", "Efficacy", "Visual Acuity", and "Complications" in various combinations. ***Results:*** From the study by Gifford et al., an efficacy index of 1.02 was found after 1 month of usage and an efficacy index of 0.96 after 6 and 12 months of usage. From the study by Lam et al, the efficacy index was 0.80 after 6 months of usage. From the study by Gispets, the efficacy index was 0.98 for children and 1.00 for adults. A study by Ren et al. only reported the preliminary result. Longer follow-ups at 6 months and 1 year are currently ongoing. The efficacy index between conventional (0.75 D) was 1.05 and the increased compression factor (1.75 D) was 0.91. The most common ones experienced were corneal staining, erosion, and infiltration. The most feared complication, MK, did not occur. ***Conclusion:*** Orthokeratology lenses are suitable for those who want a less invasive method. Orthokeratology is a less invasive and safe method of improving visual acuity with the most common complication being corneal staining.

Keywords: orthokeratology; myopia; efficacy index; visual acuity.

INTRODUCTION

Orthokeratology is a method aimed at creating a temporary reduction in myopia by wearing flat-fitting rigid contact lenses to reshape the anterior cornea. [1] By wearing flat rigid contact lenses, the corneal is flattened, thereby reducing the patient's myopia. The first study on the use of orthokeratology dates back to the 1970s, when Kerns fitted contact lenses 0.25 to 0.50 D flatter than the flattest corneal meridian.[2,3] This was later followed by the study of Binder et al. and Polse et al.[4,5] Although all of them found a reduction in myopia, they concluded that the reduction was unpredictable. Hence, orthokeratology lost its appeal during the 1980s.

There were several technological limitations during those periods that hindered the success of orthokeratology. The main problems in those early studies were the centration of the lens on the cornea and corneal edema during overnight usage. To address this problem, reverse geometry contact lenses were developed. These lenses had a base curve radius flatter than the central corneal curvature and a secondary curve steeper than the base curve radius, hence creating a reverse geometry lens. The design of these lenses allowed a tear to perform a reservoir and produced lenses with better stability.[6,7] Poor oxygen transmissibility of the early lenses was thought to be the cause of corneal edema. The development of new material in the 1990s addressed this issue by having better oxygen transmissibility, hence reducing hypoxic stress and corneal edema. Lastly, the development of corneal topography allows ophthalmologists to map the cornea's curvature accurately. This allowed the development of a patient-specific orthokeratology lens.[8] The advent of those technologies allowed orthokeratology to produce a more consistent result. This sparked a renewed interest in the field of orthokeratology.

Initially, orthokeratology lenses were used to control myopia in children. However, the ability to reduce myopia, and hence, remove the need for daytime visual correction aids seems attractive for adults. Although the improvement is not permanent, orthokeratology lenses offer a less invasive method of improving visual acuity when compared to the likes of Laser-Assisted in Situ Keratomileusis (LASIK) surgery. This article aimed to evaluate the efficacy of orthokeratology lenses in adults with the hopes of providing an alternative for those who seek a less invasive method for myopia control.

Orthokeratology lenses achieved their desired effect by inducing corneal flattening. Swarbrick et al., Nichols et al., and Hague et al. all found overnight usage of orthokeratology lenses reduced the thickness of central corneal epithelium by a maximum of 13.5%.[9–11] On the other hand, Reinstein et al. and Qian et al. found that alongside central corneal epithelial thinning, there was an increase in the thickness of the superior and mid-peripheral corneal epithelium.[12,13]

Another structural change occurred in the anterior chamber, where Gonzales-Mesa et al. and Lau et al. found a reduction in the anterior chamber's depth.[14,15] The central thinning and mid-peripheral thickening induce the corneal flattening seen after the usage of orthokeratology lenses. A flattened cornea would then reduce the degree of the patient's myopia.

METHODS

A comprehensive search was performed on Science Direct, PubMed, Ophthalmology Advance, and Scientific Reports using the terms "Orthokeratology in Adults", "Efficacy", "Visual Acuity", and "Complications" in various combinations. The search was conducted on the 13th of May 2023. We included ten years old literature from all levels of evidence. All selected articles were reviewed thoroughly to review current applications of orthokeratology lenses in adults.

DISCUSSION

Gifford et al. performed a study on twelve children and eight adults. The adults, aged 18 to 29 years old, had a mean spherical equivalent refraction (SER) of -2.28 ± 1.02 D for the right eye and -1.78 ± 0.67 D for the left eye at baseline. They were fitted with Contex E-series OK lenses (Contex, California, USA) and were followed for 12 months. In that study, they found an improvement in SER. SER was -0.81 ± 0.45 D at 1 month and -0.83 ± 0.75 D after 12 months. They also found that 1-month wear of orthokeratology lenses shifted the relative peripheral refraction (RPR) in the myopic direction and was stable thereafter. At baseline they had an acuity of -0.08 ± 0.03logMAR and -0.09 ± 0.04logMAR at 1 month, -0.06 ± 0.06logMAR at 6 months, and -0.06 ± 0.06logMAR at 12 months. Nevertheless, this shift in RPR did not correlate with myopia progression.[16] The compression factor used in this study was 0.75D (Jessen Factor). We also calculated the efficacy index by using the formula outlined by Gomel et al, dividing post-treatment uncorrected visual acuity (UCVA) with baseline best corrected visual acuity (BCVA). They used 0.8 as the cut-off value for a successful treatment.[17] From the study by Gifford et al., we found an efficacy index of 1.02 after 1 month of usage and an efficacy index of 0.96 after 6 and 12 months of usage.[16] Gifford et al. also performed another research with 34 adults aged 18 to 30 years old, where they found that wearer of orthokeratology lenses had better SER (right: -2.09±1.23D; left: -2.00±1.35D) than wearer of soft contact lenses (right: -2.41±1.56D; left: -2.46±1.45D), although their baseline SER was similar. However, their p-value was not significant.[18]

Another study by Lam et al. found a different result. In their study, they fitted 59 adults aged 18 to 30 years old with orthokeratology lenses with a compression factor of 0.75D, with 37 participants completing the 6-month follow-up. SER improved from -4.69 ± 0.32D at baseline to -0.26 ± 0.64D after 6 months, and the difference was statistically significant ($p < 0.001$). Their participants' baseline BCVA was -0.10 ± 0.10logmar. They also found an improvement in uncorrected visual acuity (UCVA). The participants' UCVA was 1.02 ± 0.16logmar at baseline and 0.00 ± 0.16logmar after 6 months. They also found that participants with a poor response to orthokeratology lenses had a lower tangent modulus value (0.474 MPa vs. 0.536 MPa). In participants with a good response, a higher corneal stiffness correlated to a greater myopia reduction. The efficacy index was 0.80 after 6 months of usage.[19]

Gispets et al. performed a large study with 300 participants aged 7 to 53 years old. The participants were followed for 18 years. After the end of the study period, 79.4% of children and 46.4% of adults were still using their orthokeratology lenses. The baseline median SER was -2.50 D for both the children and adults. They found that 88.6% of participants had SER within ± 0.5D of target emmetropia. They also measured efficacy, which was defined as the ratio of post-orthokeratology lenses uncorrected distance visual acuity (UDVA) to pre-orthokeratology lenses distance corrected visual acuity (DCVA). They found an efficacy of 0.98 for children and 1.00 for adults.[20]

Several studies have pointed out that correction achieved by orthokeratology lenses might not be sustained throughout the day. Therefore, an initial over-correction might be required. The extra correcting power added to the manifest refractive error is called the compression factor. The conventional compression factor is usually 0.50D to 0.75D. To study the efficacy of using a higher compression factor, Wan et al. compared orthokeratology lenses with a compression factor of 0.75D and 1.75D in 25 children aged 6 to 11 years old. They found that 80% of participants fitted with a higher compression factor achieved their target within 4 weeks, while only 60% of participants with a conventional compression factor achieved their target. However, they did not find any differences in the first fit success rate and external ocular health.[21] Seeing the benefit in children, Ren et al. tried to investigate the effect of increasing the compression factor. They enrolled 54 adults aged 20 to 36 years old. However, they found conflicting results. They did not find a difference in SER reduction between participants fitted with lenses with a conventional and increased compression factor. They indeed found better uncorrected visual acuity after one month (-0.06 vs. 0.00), but the difference was not statistically significant. The baseline best corrected visual acuity was -0.04. This study from Ren et al. only reported the preliminary result. Longer follow-ups at 6 months and 1 year are currently ongoing. The efficacy index between conventional (1.05) and increased compression factor (0.91) was comparable.[22] Therefore, further studies should be conducted to confirm this finding. The summary of study results is shown in Table 1.

There are several complications related to orthokeratology lenses, such as microbial keratitis (MK), corneal staining and erosion, lens binding, tear film stability, and epithelial iron deposit. Gispets et al. in their study reported that 34.3% of the children and 44.6% of the adults experienced some form of complications.

The most common ones experienced were corneal staining, erosion, and infiltration. The most feared complication, MK, did not occur. Nevertheless, none of the complications caused significant visual acuity disturbance. Regarding corneal staining, they found that most instances were grade 1 or 2. Risk factors for corneal staining included higher myopia, higher corneal eccentricity, smaller anterior horizontal radius, and lens cleaning with protein removal.[20] Lam et al. also reported one significant corneal staining that resulted in that patient withdrawing from the study. However, they did not report the occurrence of corneal staining in those subjects who continued to participate in the study.[19] Ren et al. found that there was no difference in the occurrence of corneal staining between the low and high compression factor groups. However, there was a statistically significant increase in the incidence of corneal staining between baseline and 1 month. In the low compression factor group, corneal staining increased from 35% to 77%, and in the high compression factor group it increased from 33% to 79%.[22] Gifford et al. did not report the complications occurring in their study. One systematic review by Liu et al. also found that corneal staining was the most common complication associated with orthokeratology lenses. The incidence of the most threatening complication, MK, was 7.7 cases per 10,000 patient-years (95% CI 0.9 – 27.8), similar to other overnight modalities.[23]

This review attempts to understand if orthokeratology is a viable alternative treatment for adults who were uncomfortable with their soft contact lenses and wanted a less invasive treatment for myopia. To determine whether orthokeratology could effectively reduce myopia in adults, we used an efficacy index outlined by Gomel et al. The efficacy index was calculated by dividing post-treatment uncorrected visual acuity (UCVA) with baseline best corrected visual acuity (BCVA). The cut-off value for a successful treatment was 0.8. The summary results from Table 1. show that all efficacy index was 0.8 and above with only one study showing an efficacy index of 0.8. Based on the results, orthokeratology provided an effective reduction in myopia. The duration of orthokeratology treatment varies in each study. Long-term use of orthokeratology didn't show better results but was still effective. The compression factor mostly used by the studies was 0.75D but there was one study by Ren et al. using a compression factor of 1.75D. A higher compression factor didn't provide a better result in post-treatment uncorrected visual acuity (UCVA).

CONCLUSION

Orthokeratology lenses have a good ability to reduce myopia in adults. Therefore, orthokeratology lenses can serve as an alternative to daytime wear of visual correction aids. As the correction was comparable to LASIK surgery, orthokeratology lenses are suitable for those who want a less invasive method. Orthokeratology is a less invasive and safe method of improving visual acuity with the most common complication is corneal staining. However, most of the studies on orthokeratology lenses are retrospective and only analysed a small number of samples. Seeing the good potential of orthokeratology lenses, larger prospective studies are warranted.

DISCLOSURE

A. Conflict of Interests

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

B. Funding

This manuscript did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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TABLE 1: Summary of study results.

Author	Year	Location	Study design	Samples	Treatments compared	Outcome	Efficacy Index
Gifford et al.[15]	2020	Australia	Retrospective cohort	8 adults with myopia between -0.75 to -0.45 D aged 18 - 29 years old.	OK lenses only	Baseline SER OD -2.28 ± 1.02 D, OS -1.78 ± 0.67 D; 1-month SER -0.81 ± 0.45 D; 12-month SER -0.83 ± 0.75 D Baseline acuity -0.08 ± 0.03logMAR; 1-month acuity -0.09 ± 0.04logMAR; 6-month acuity -0.06 ± 0.05logMAR; 12-month acuity -0.06 ± 0.06logMAR.	1-month 1.02; 6-month 0.96; 12-month 0.96
Lam et al.[18]	2019	Hongkong	Prospective cohort	37 adults	OK lenses only (CF 0.75D)	Baseline SER -4.69 ± 0.32 D; 6-month SER -0.26 ± 0.64 D; $p < 0.001$. Baseline BCVA -0.10 ± 0.10logmar; 6-month UCVA 0.00 ± 0.16logmar; $p < 0.01$	6-month 0.80
Gispets et al.[19]	2021	Spain	Retrospective cohort	300 adults	OK lenses only	18-year UDVA : DCVA 1.00	18-year 1.00
Ren et al.[21]	2020	China	Randomized-controlled trial	50 adults	OK lenses with a CF of 0.75 D vs. 1.75 D	Baseline BCVA -0.04 ± 0.05; CCF 1-month UCVA -0.06 (-0.18 – 0.42); ICF 1-month UCVA 0.00 (-0.16 – 0.52); $p > 0.05$	0.75 D CF: 1.05; 1.75 D CF: 0.91

CF compression factor; *CCF* conventional compression factor; *DCVA* distance corrected visual acuity; *ICF* increased compression factor; *LASIK* Laser-Assisted in Situ Keratomileusis; *OK* orthokeratology; *SER* spherical equivalent refraction; *UCVA* uncorrected visual acuity; *UDVA* uncorrected distance visual acuity; *VA* visual acuity.