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The Effect of Orthokeratology on Accommodative and Convergence Function: A Clinic Based Pilot Study

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ABSTRACT

Background: Orthokeratology is a successful treatment for patients with myopia. There has been little research on its effects on accommodation and convergence.

Methods: Eleven subjects presenting for orthokeratology had accommodative and convergence function assessed pre- and post-treatment. Based on the results, patients were categorised as normal or embedded. The pre- and post-treatment results were compared.

Results: This pilot study found that of the 11 subjects, 10 (90.1%) demonstrated an improved accommodative convergence profile after treatment ($p=0.003$). The subject who demonstrated no change was the only one that had a normal profile before treatment. No subject displayed a worse accommodative convergence profile post-treatment.

Conclusion: This suggests that orthokeratology has a positive effect on accommodation and convergence function. More research with larger sample sizes is required to confirm this result.

Keywords: accommodation, myopia, myopia control, orthokeratology

Introduction

Orthokeratology is the practice of using specially designed contact lenses to alter the shape of the cornea for the purpose of changing the refractive power of the eye. It has gained rapid acceptance over the last ten years due to refinements in corneal topography and manufacturing technology.[1,2]

There has been a large amount of research on how orthokeratology changes refractive error, higher order optical aberrations, the effect length,[2,3] which corneal structures are involved,[2-4] contrast sensitivity,[5-8] and the risk of microbial keratitis.[9,10] There has been little research on the effect of orthokeratology on accommodation and convergence function, but one study reported that there was no significant change.[11] Research is beginning to support the use of orthokeratology to reduce myopic progression.[12,13] It has been demonstrated that accommodative convergence function can be abnormal in patients with myopia[14-18] and that near adds may have a positive effect on myopia progression and asthenopia,[16,19] especially in patients with near esophoria and high accommodative lags.[16] One study showed that frequently there is an exophoric shift in the near heterophoria of patients once myopic progression ceases.[20] Considering that accommodative/convergence dysfunction may be associated with myopic progression and orthokeratology may be associated with myopia control, it would be reasonable to hypothesise that orthokeratology may affect accommodative and/or convergence function. This pilot study aims to measure the effect that orthokeratology has on accommodation and convergence function.

Methods

Subjects were recruited from patients presenting to the author's private practice and two other practices. Examinations were conducted by three different optometrists. A comprehensive optometric consultation was performed and suitability for orthokeratology was assessed. Subjects were then fitted with BE Enterprises[a] orthokeratology lenses. Repeated measures of accommodative convergence function were performed between one month and three months of wearing the final custom orthokeratology lenses. All subjects had not previously had orthokeratology performed and had worn a variety of single vision or bifocal/progressive glasses or soft contact lenses. Pre-treatment measurements of near function were performed through the distance subjective refraction measured at the initial consultation. Post-treatment measurements of near function were performed unaided at the review consultation. Patients with presbyopia were excluded.

Pre-treatment refractive error was measured by subjective refraction. Heterophorias were measured using a Howell card at three meters and 33 cm in free space. Near vergence ranges were measured with a prism bar in free space. Near point of convergence was objectively measured clinically by the examiner. Accommodative facility with +/- 2 D flippers was graded as: a) fail both plus and minus, b) pass only plus or minus, and c) pass both plus and minus. The number of cycles per minute was not measured. Accommodative lag using MEM retinoscopy was measured clinically by the examiner.

Table 1: Howell Profiles

Voluntary Accommodation (H1)	Voluntary Convergence (H2)
• Exophoria at near • Plus AC/A – high • Minus AC/A – normal • NPC – normal to reduced • NPA – normal • +/-2 Binoc – fails plus • MEM ret – plano or minus • BO Near – Low • BI Near – High • BO Dist – Low • BI Dist - Low	• Esophoria at near • Plus AC/A – normal • Minus AC/A – high • NPC – normal • NPA – normal to reduced • +/-2 Binoc – fails minus • MEM ret – +0.75 or higher • BO Near – High • BI Near – Low • BO Dist – High? • BI Dist - Low

Table 2: Howell Profiles – Changes to embedded profiles

	Voluntary Convergence H2→	Embedded	Voluntary Accommodation H1→	Embedded
Phoria Near	Esophoria	Ortho to Exo	Low Exophoria	Exophoria
Phoria Dist	Low Esophoria	Ortho	Ortho	Low Exophoria
Plus AC/A	Normal	Low	High	Low?
Minus AC/A	High	Low, blurry	Normal	Low
NPC	Normal	Remote	Normal→	Remote
NPA	Normal→	Remote	Normal	Remote?
+2 D binoc	Pass	Fail?	Fail	Fail
-2 D binoc	Fail	Fail	Pass	Fail?
MEM Ret	Excessive Lag	Excessive Lag	Plano to Lead	Normal to Lag
BO Near	High	Low	Low	Low
BI Near	Low	Low	High?	Low?
BO Dist	High?	Low	Low?	Low
BI Dist	Low	Low	Low?	Low

The author then assessed each subject's collective data and made a clinical determination whether the subject displayed a normal or dysfunctional accommodative convergence profile using Howell's criteria.[21] Howell's criteria categorises patients as normal, H1, H2, or embedded based on the results of clinical measures (Table 1). Howell uses free space techniques with associated normative values. As an adaptation to near point stress with an increased lag of accommodation, patients may develop into H1 or H2 profiles. H1 profiles are defined as the patient using voluntary accommodation to resolve the mismatch between accommodation and convergence due to the accommodative lag, resulting in near exophoria, accommodative excess, low base out ranges at near, and high base in ranges at near. H2 profiles are defined as the patient using voluntary convergence to resolve the mismatch between accommodation and convergence due to the accommodative lag, resulting in near esophoria, accommodative insufficiency, high base out ranges at near, and low base in ranges at near. Without appropriate intervention, H1 and H2 patients continue to adapt to the near point stress, resulting in embedded profiles. Embedded profiles are defined as having near exophoria, accommodative infacility, reduced near point of convergence, reduced near point of accommodation, low base out ranges at near, and low base in ranges at near (Table 2).The author then compared pre- and post-treatment profiles to determine whether the profile had changed clinically using Howell's criteria. Post-treatment refractive errors were determined by the amount of change on the corneal topographic subtractive difference axial map.

Non-parametric statistical tests were used in data analysis due to the small sample size and non-normal distribution of the data. The Wilcoxon Matched Pair Signed Rank Test (WMPSRT) was used with a two tailed test of p<0.05 for statistical significance. OpenStat[22] software was used for the statistical analysis.

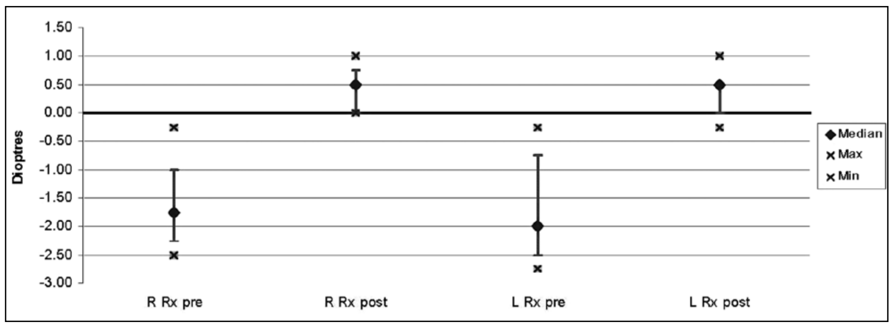

Figure 1: Refractive error pre- and post-treatment (Median, Q1, Q3 and ranges).

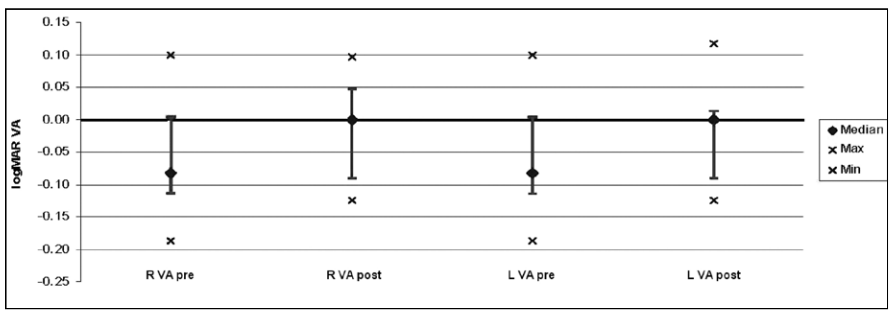

Figure 2: Visual acuity pre- and post-treatment (Median, Q1, Q3 and ranges).

Results

The experimental group consisted of 11 patients (mean age 18.4 years, standard deviation 9.6, range 11.0 to 36.8 years). The results for the different visual parameters measured pre- and post- treatment are shown in Table 3.

Refractive error (Figure 1) improved significantly following orthokeratology treatment (p=0.002). There is no evidence that visual acuity (RE p=0.054, LE p=0.064, Figure 2), distance phoria (p=0.500, Figure 3), or near phoria (p=0.097, Figure 3) changed significantly following treatment. Heterophoria measured with +2, -2, +1, -1 lenses (commonly known as AC/A ratio), was graphed with ratios of pre-treatment 2.2:1 and post-treatment 0.93:1 (Figure 4). Only heterophoria with -1D lenses was significantly different after treatment (p=0.043). The near prism fusional ranges (Figure

Table 3: Visual parameter measurements pre- and post- treatment

Parameter	Pre-treatment (median)	Post-treatment (median)	Significance (WMPSRT)
Refractive error (right eye)	-0.75D (Q1: -2.25; Q3: -1.00)	+0.50D (Q1: 0.00; Q3: +0.75)	p=0.002
Refractive error (left eye)	-2.00D (Q1: -2.50; Q3: -0.75)	+0.50D (Q1: 0.00; Q3: +0.50)	p=0.002
Visual acuity (right eye)	-0.08 logMAR (Q1: -0.11; Q3: 0.00)	0.00 logMAR (Q1: -0.09; Q3: 0.05)	p=0.054
Visual acuity (left eye)	-0.08 logMAR (Q1: -0.11; Q3: 0.00)	0.00 logMAR (Q1: -0.09; Q3: 0.01)	p=0.064
Distance phoria	ortho (Q1: ortho; Q3: 1.0 exo)	ortho (Q1: ortho; Q3: ortho)	p=0.500
Near phoria	0.5 exo (Q1: 0.75 eso; Q3: 2.0 exo)	2.00 exo (Q1: 0.00, Q3: 4.25 exo)	p=0.097
AC/A ratio	2.2 : 1	0.93 : 1	
Heterophoria with:			
+2.00D	6.0 exo (Q1:2.5 exo; Q3:7.5 exo)	4.0 exo (Q1:1.5 exo; Q3:8.0 exo)	p=0.672
+1.00D	2.0 exo (Q1:3.0 eso; Q3:4.0 exo)	2.0 exo (Q1:1.0 exo; Q3:6.0 exo)	p=0.068
-1.00D	1.0 eso (Q1:4.0 eso; Q3:0.3 eso)	0.8 exo (Q1:1.0 eso; Q3:3.0 exo)	p=0.043
-2.00D	3.5 eso (Q1:7.5 eso; Q3:0.3 eso)	Ortho (Q1:4.5 eso; Q3:2.3 exo)	p=0.068
Near prism fusional ranges			
Base out break	20.0 (Q1: 12.5, Q3: 25.0)	22.5 (Q1: 15.0, Q3: 27.5)	p=0.059
Base out recovery	13.5 (Q1:4.5; Q3: 16.3)	15.0 (Q1: 10.0, Q3: 22.5)	p=0.059
Base in break	11.0 (Q1: 8.5, Q3: 15.0)	12.5 (Q1: 9.5, Q3: 16.3)	p=0.446
Base in recovery	5.0 (Q1: 4.75, Q3: 10.0)	9.0 (Q1: 5.75, Q3: 11.25)	p=0.069
Near point of convergence	0 cm (Q1: 0, Q3: 3.8)	0 cm (Q1: 0.0, Q3: 4.5)	p=0.655
Accommodative facility (+/- 2D flippers)	Fail both (Q1: Fail both, Q3: Fail one)	Fail one (Q1: Fail one, Q3: Pass both)	p=0.018
MEM retinoscopy	R: +0.25 (Q1:-0.06, Q3: 1.06)	R: +0.25 (Q1:-0.06, Q3: 0.37)	p=0.080
	L: +0.25 (Q1:-0.06, Q3: 1.06)	L: +0.25 (Q1:-0.06, Q3: 0.50)	p=0.080

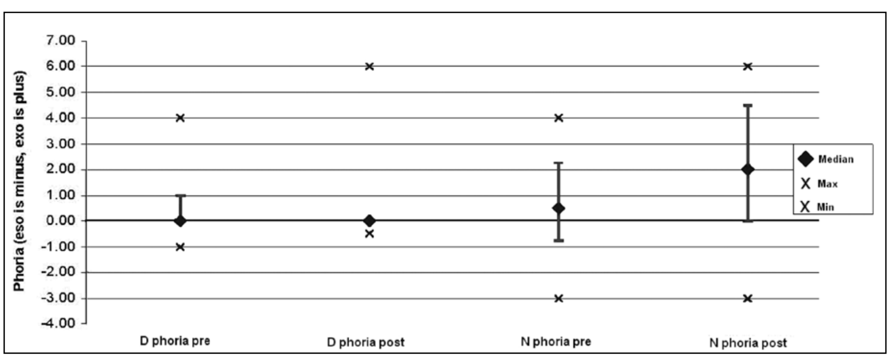

Figure 3: *Heterophoria pre- and post-treatment (Median, Q1, Q3 and ranges).*

5) did not change significantly for base out break (p=0.059), base out recovery (p=0.059), base in break (p=0.446) or base in recovery (p=0.069). The median near point of convergence (p=0.655) and MEM retinoscopy for either right (p=0.080) or left eye (p=0.080) did not change significantly (Figure 6). However, there was a significant improvement in accommodative facility with +/-2D flippers (p=0.018).

Before treatment, one subject (9.1%) was classified as having a normal accommodative convergence profile compared with three (27.3%) classified as normal after treatment, although there is no evidence that this is a significant change (p=0.317, WMPSRT) (Figure 7). Ten patients were categorised as embedded before treatment. Improvement was defined as changing from an embedded profile to an H1 or H2 profile, or from an H1 or H2 profile to a normal profile. Of the 11 subjects, 10 (90.1%) demonstrated an improved accommodative convergence profile after treatment (p=0.003, WMPSRT) with the one subject who demonstrated no change being the only subject having a normal profile before treatment.

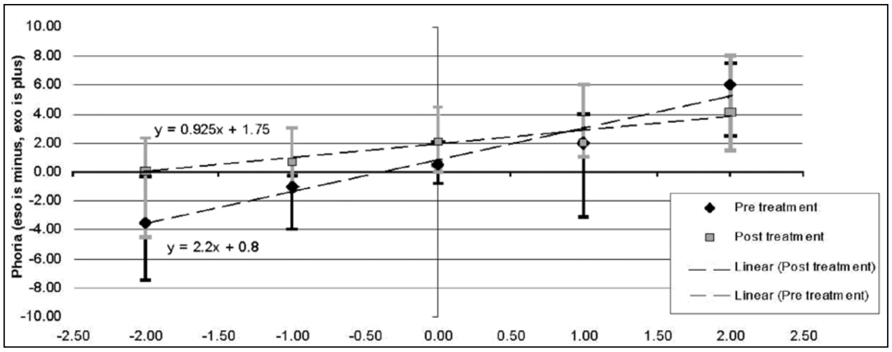

Figure 4: *AC/A pre- and post-treatment (Median, Q1, Q3).*

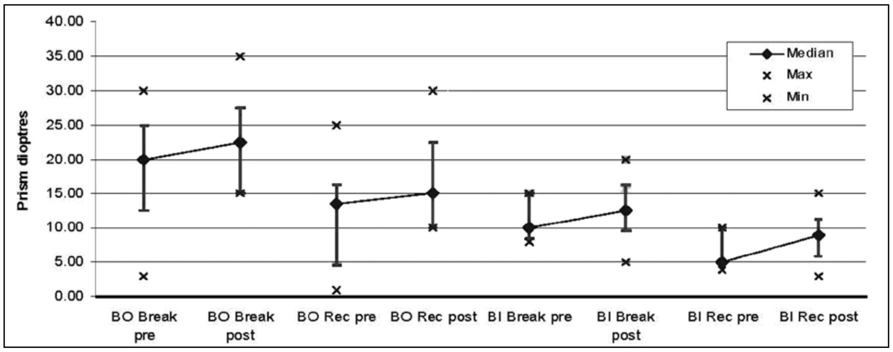

Figure 5: *Near fusional ranges pre- and post-treatment (Median, Q1, Q3 and ranges).*

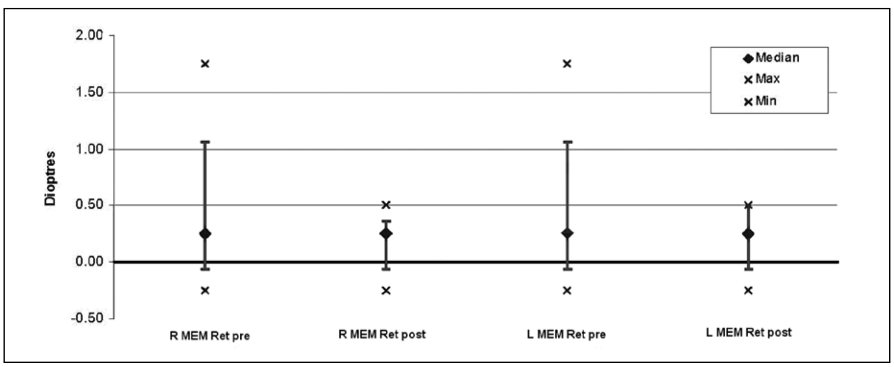

Figure 6: *MEM retinoscopy (Median, Q1, Q3 and ranges).*

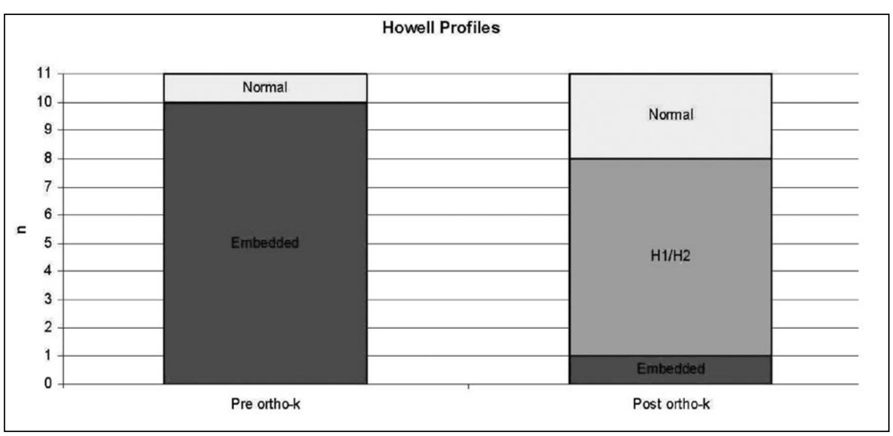

Figure 7: *Howell Profiles.*

No subject displayed a worse accommodative convergence profile post-treatment.

Discussion

This pilot study agrees with previous studies that orthokeratology is an effective treatment for reducing myopic refractive error. Clinically, a patient's visual system is often assessed from a collection of clinical techniques rather than relying on a single measure of near function. Research tends to look at individual clinical measures in isolation. Accommodative facility was the only individual clinical measure found to have had a statistically significant improvement in function. It is noteworthy that every subject that was assessed to have an accommodative convergence dysfunction prior to treatment demonstrated an overall improvement post-treatment. Near point of convergence was clinically normal in all patients pre-treatment, so it would be hard to achieve an improvement in this sample. Near heterophoria, AC/A ratio, base out break, base out recovery, base in recovery, and MEM retinoscopy findings pre- and post-treatment all had p values < 0.10. In this context, the small sample size of this pilot study leaves open the possibility that there may be a change in these measurements after orthokeratology treatment.

Although not reaching the level of statistical significance, most clinical measures moved towards normal findings and had smaller inter-quartile ranges (Figures 1 to 6). Median near heterophoria showed an exo shift which has been shown to be associated with the reduced progression or stabilisation of progressive myopia.[20] It is interesting to note in particular that MEM retinoscopy findings have a reduced inter-quartile range post-treatment (Figure 6). The author would consider the change in the variation of MEM retinoscopy findings to be clinically significant and representing a more normal clinical finding post-treatment.

In summary, the results suggest a shift to less near esophoria, lower accommodative lag, and lower AC/A ratios after orthokeratology treatment. Larger near esophoria, higher accommodative lag, and larger AC/A ratios have all been linked to myopic progression.[14-20] Thus it appears that orthokeratology has a positive effect on factors which have been linked to myopic progression.

This study suggests that there is a change in accommodative convergence function after orthokeratology treatment. One proposed mechanism,[23] based on clinical observation, is that myopic patients habitually remove their distance correction for near work, giving them an effective near add. These patients are habitually functioning with less accommodative demand for a given working distance. Once this effective near add is removed due to elimination of myopia, the visual system requires time to adapt to the increased accommodative demand: a form of passive vision therapy. This study measured initial accommodative convergence function through the full distance correction, regardless of whether the subject habitually functioned in this way.

Consider the following alternate mechanism based on the same principle to explain myopia control with orthokeratology.[24] In an alternative model, the relative steepening of the mid-peripheral cornea corrects relative hyperopic blur in the retinal periphery[20-25] that is often present in myopic eyes.[26] Magno-ganglion cells have a peak density 20° from the fovea.[27] The magnocellular pathway has been linked to ambient visual function and is theorized to contribute to the control of accommodation and convergence.[28,29] The author's hypothesis is that the correction of peripheral retinal hyperopic defocus by a cornea treated with orthokeratology alters ambient visual function in a way that positively affects accommodative convergence function.

This pilot study does suffer from a number of experimental limitations. The sample size is too small, making it difficult to apply meaningful statistical analysis. Measuring many different clinical variables that are not independent can cause difficulties with statistical analysis. Grouping the findings using Howell's clinical profiles may be oversimplifying the analysis and may make it difficult to determine which clinical variables are changing. This inherently goes to the nature of how clinicians assess patients; do we look at heterophoria or MEM retinoscopy in isolation, or do we make a clinical judgement based on the complete optometric assessment? Considering that many clinicians would make a clinical judgment based on the overall assessment, the author feels that it is reasonable to emphasize the finding that 90.1% of subjects displayed an improved overall clinical profile as evidence that orthokeratology has a positive effect on accommodative convergence function. However, as with any treatment, individual responses may vary, and there is no evidence to suggest that orthokeratology treatment would never have a negative effect on accommodative convergence function. Variables which could influence this are the radius of the corneal steepening annulus, which would alter the refractive error changes in the peripheral retina, and differences in the shape of individual eyes.

Conclusion

Orthokeratology is an effective treatment of myopic refractive error. This pilot study provides evidence that it can also improve accommodative convergence function by an unknown mechanism. The results of this pilot study warrant further investigation into the effect of orthokeratology on accommodative and convergence function.

Acknowledgement

The author would like to acknowledge the assistance of Paul Graham and Sally Mason for contributing subjects to this study.

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Appendix: Source List

a Capricornia Contact Lenses, 2/9 Cronulla Court, Slacks Creek, QLD 4127, capricorniacontactlenses.com.au

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Brand P. The effect of orthokeratology on accommodative and convergence function: a clinic based pilot study. Optom Vis Perf 2013;1(5):162-7.

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