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Research Article

Retrospective Review of Corneal changes in overnight Orthokeratology

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Abstract

Purpose: To evaluate the dynamic changes in the cornea, anterior chamber depth (ACD), the pupil diameter (PD), corneal sensitivity, and tear break up time (BUT), after orthokeratology (OK).

Methods: Sixty-one patients with myopia (115 eyes) whose refractive error had been corrected from -0.75 to -5.50 diopter (D) by OK were retrospectively enrolled. Three groups (groups A/B/C) were classified based on their pre-treatment K reading and four subgroups (subgroup 1/2/3/4) were divided in groups A/B/C according to their follow-up time. The surface irregularity index (SIRS) and the mean keratometric reading within 3 mm and 5 mm of the corneal apex, the front radius of corneal curvature (FRCC), the posterior radius of corneal curvature (PRCC), ACD, PD, corneal sensitivity, and tear break up time before and 3, 6, and 24 months after treatment were analyzed.

Results: In group A: there was a significant difference between before and post-treatment (3 mm SIRS: F=62.58, *P*<0.001; 5 mm SIRS F=72.7, P=0.00).
In group B: there were significant differences among the four subgroups (3 mm SIRS: F=75.91, *P*<0.001; 5 mm SIRS:F=80.34, *P*<0.001). There was a significant difference before and post-treatment for 3 mm K readings (F=29.00, *P*<0.001). There were significant differences among the four subgroups in terms of corneal sensitivity (F=8.86, *P*<0.001) but no differences were found between subgroups 1/2 and 3/4.

Conclusion: Changes in OK occurred predominantly at the 3 mm anterior corneal surface within 3 months. The corneal sensitivity decreased at 3 months. No changes were observed in tear BUT.

Keywords: Overnight OK Lens; Cornea; Contact Lens; Curvature Change; Anterior Chamber Depth

Abbreviations

ACD: Anterior Chamber Depth;
BCVA: Best Corrected Vision Acuity;
BUT: Tear Break up Time;
D: Diopter;
Dk: Oxygen Permeability Coefficient;
DS: Diopter Sphere;
FRCC: Front Radius of Corneal Curvature;
K: Keratometric;

OK: Orthokeratology;
PD: Pupil Diameter;
PRCC: Posterior Radius of Corneal Curvature;
Cyl: Refractive Cylinder;
SIRS: Surface Irregularity Index;
SEQ: Spherical Equivalents;
UCVA: Uncorrected Vision Acuity

Introduction

Orthokeratology (OK) is a clinical technique that uses a reverse-geometry lens designed rigid contact lenses to reshape the cornea to temporarily reduce or eliminate refractive error[1]. Reductions in myopic refractive error of up to 6.00 D can be obtained with this technique. Studies from Hiraoka et al [2] and Cho et al[3] indicate that OK can suppress axial length elongation in childhood myopia. Younger children tend to have faster axial elongation and may benefit from early ortho-k treatment.3 OK is used to control the progression of childhood myopia and the treatment under close monitoring is well accepted by children [4].

In order to get the optimum clinical benefit, the patient needs to wear the OK lens every night. The dynamic changes to the anterior surface of the eye after wearing OK lens are not known. This retrospective study evaluated the dynamic changes in the corneal front and posterior surface, anterior chamber depth (ACD), pupil diameter (PD), corneal sensitivity, and tear function after treatment.

Methods

Sixty-one patients with myopia (115 eyes) were enrolled at the Nanchang Eye Hospital and the Third Hospital affiliated to Nanchang University from January 2010 to August 2013. Their refractive errors ranged from -0.75 to -5.50 diopter sphere (DS), refractive cylinder (Cyl) were from -0.25 to -1.50 diopter cylinder (DC)(mean -0.36±0.24 DC), spherical equivalents (SEQ) were from -0.75 to-5.50 DS (mean -2.93±1.09DS). The patients ranged in age from 7 to 15 years (mean 10.23±2.18 years). Uncorrected vision acuity values (UCVA) were from LogMAR 2.0 to 0.2 (mean LogMAR 0.79±0.33) and best corrected vision acuities (BCVA) were from LogMAR 0.1 to -0.5 (mean LogMAR -0.008±0.059). Follow-up time ranged from 1 to 40 months (mean 12.19±9.78 months). The mean keratometric readings (K) were from 40.44D to 45.72D (mean 43.36±1.19D).

Corneal topography measurement

Corneal topography was performed using an Orbscan-II (Bausch and Lomb, Rochester, NY, USA) before and 1 and7 days and 1, 3, 6, 12, 24, and 36 months respectively post treatment. The surface irregularity index (SIRS) and the mean keratometric readings within 3 mm (3 mm K) and 5 mm (5 mm K) of the corneal apex, the front radius of corneal curvature (FRCC), and the posterior radius of corneal curvature (PRCC) were measured. The ACD and the pupil diameter (PD) were collected and used for analysis.

Corneal sensitivity measurement

Cochet-Bonnet (COBO) aesthesiometer (Luneau SA, France) measurements were performed before and 1, 6, and 24 months post treatment. The procedures were performed within 2~5 hours after lens removal. The section of the nylon thread used with the aesthesiometer was S=0.0113 mm^2 (i.e., Ø 12/100 mm) and the length was 60 mm. Measurements were initiated by using the nylon fully extended (scale reading 6). The tip was applied perpendicularly to the corneal surface and a slight pressure was exerted until an inflection deviation of the wire of about 4% was obtained (i.e., the first visible inflection). This procedure was repeated, if necessary, with decreasing lengths and stopped when the initial reaction of the patient was achieved. Nylon lengths were recorded for three separate measurements. The mean nylon lengths were calculated and used for analysis.

Tear break up time (BUT)

Sodium fluorescein as applied in the inferior fornix and the patient was allowed to blink a few times. “Black spots” were observed under the slit lamp with cobalt blue. The elapsed times between when the patient started to open the eye and when black spots occurred were noted for three separate measurements. The mean of these times was calculated and used for analysis.

OK lens material

The basic material was Boston XO and the Dk value was 140 $cm^2/s[mlO^2/(ml.hPa)]$ (using the gas-to-gas approach).

Group

In this retrospective clinical study, three groups were divided based on their pre-treatment K reading: Group A<46~44.1D; Group B, 44~42.1D; Group C, 42~40D. Four subgroups were divided into groups A/B/C according to their follow-up time: Subgroup 1, before treatment; Subgroup 2, 1~3 months post-treatment; Subgroup 3, 3.1~12 months post-treatment; Subgroup 4, 12.1~40 months post-treatment.

Statistical analysis methods

One-way ANOVA and Fisher’s LSD statistical analyses were performed by SPSS software version 13.0 (SPSS, Inc., City, State, USA). A 2-sided P value of less than 0.05 was considered statistically significant.

Results

Case characteristic in subgroup

There were no differences in the FRCC and SEQ in the four subgroups for both group A and B, respectively (group A: F=1.72, 1.46, *P*=0.16, 0.22; group B: F=0.63, 0.37, *P*=0.59, 0.77)(Table 1).

The dynamic changes in the anterior ocular surface

There were differences in 3 mm SIRS, 3 mm K, and 5 mm SIRS in the four subgroups 1/2/3/4 in group A (F=62.58, 10.03, 72.7, all *P*<0.01) (Figure 1A, Figure 1B). There were no differences in 3 mm SIRS, 5 mm SIRS, or 3 mm K among subgroups 2/3/4. There were no differences in 5 mm K (Figure 1B),

Table 1. Comparison of the FRCC and SEQ in four subgroups both group A and B

Groups		Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4	F	*P*
Group A (46～44.1D)	n	28	19	15	20		
	FRCC (mm)	7.53±0.09	7.54±0.08	7.49±0.08	7.54±0.09	1.72	0.16
	SEQ(D)	3.45±1.36	3.46±1.22	3.52±1.16	2.82±0.90	1.46	0.22
Group B (44～42.1D)	n	52	27	35	38		
	FRCC (mm)	7.83±0.10	7.83±0.09	7.80±0.10	7.83±0.11	0.63	0.59
	SEQ(D)	2.82±1.25	2.85±1.32	3.05±1.08	2.78±1.11	0.37	0.77

Table 2. The dynamic changes in the anterior ocular surface in group A

Subgroup	Wear time (months)	3 mm SIRS	3 mm K	5 mm SIRS	5 mm K	PRCC (mm)	ACD (mm)	PD (mm)
1	0	1.16±0.41	44.52±0.83	1.61±0.41	43.97±0.86	6.25±0.14	3.66±0.25	4.34±0.96
2	3.00±0	4.98±2.57●	43.72±1.12●	5.41±2.26●	43.82±1.02	6.29±0.17	3.66±0.30	4.14±0.56
3	7.15±2.79	4.27±1.41●	43.82±1.29●	5.10±1.66●	44.30±0.95	6.24±0.13	3.59±0.28	4.48±0.67
4	20.61±5.70	4.44±2.23●	43.27±0.88●	5.32±2.33●	44.05±0.99	6.29±0.17	3.58±0.18	4.32±0.53
F	104.53	62.58	10.03	72.7	0.85	0.64	0.63	0.46
P	0.000	0.000	0.000	0.000	0.46	0.59	0.59	0.70

•*P* < 0.05 Compare subgroup1 ▲*P* < 0.05 Compare subgroup2 **P* < 0.05 Compare subgroup3

Table 3. The dynamic changes in the anterior ocular surface in group B

Sub-group	Wear time (months)	3 mm SIRS	3 mm K	5 mm SIRS	5 mm K	PRCC (mm)	ACD (mm)	PD (mm)
1	0	1.20±0.46	42.91±0.54	1.50±0.44	42.51±0.58	6.49±0.13	3.77±0.22	4.58±1.05
2	3.00±0.00	2.92±1.54●	41.83±0.99●	3.63±1.46●	42.46±0.96	6.47±0.16	3.75±0.26	4.31±0.56
3	7.05±2.93	3.69±1.48●▲	41.99±0.91●	4.16±1.65●	42.54±0.82	6.46±0.13	3.70±0.25	4.37±0.59
4	23.51±8.66	4.29±2.09●▲★	41.88±0.83●	4.54±2.03●▲★	42.38±0.76	6.48±0.13	3.73±0.21	4.56±0.74
F	101.23	75.91	29.00	80.34	2.26	0.54	0.56	0.87
P	0.000	0.000	0.000	0.000	0.08	0.65	0.63	0.45

•*P* < 0.05 Compared with Subgroup 1▲*P* < 0.05 Compared with Subgroup 2 **P* < 0.05 Compared with Subgroup 3

PRCC, ACD, and PD in the four subgroups 1/2/3/4 in group A (F=0.85, 0.64, 0.63, 0.46, all P>0.05)(Table 2).

There were difference in 3 mm SIRS,3 mm K, and 5 mm SIRS in four subgroups 1/2/3/4 in group B (F=75.91, 29.00, 80.34, all P<0.0=(Figure 1C, Figure 1 D). There were differences in 3 mm SIRS and 5 mm SIRS, but no difference in the 3 mm K among subgroups 2/3/4. There were no differences in 5 mm K (Figure 1D), PRCC, ACD, and PD in the four subgroups 1/2/3/4 in groups B (F=2.26, 0.54, 0.56, 0.87, all P>0.05)(Table 3).

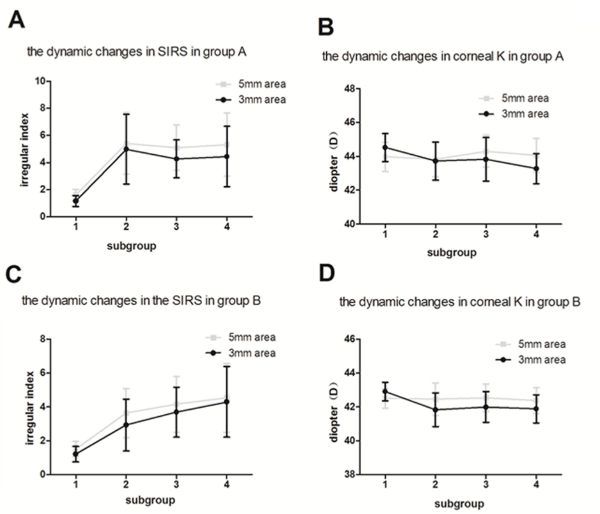
Figure 1. The SIRS and K changes in group A/B

Figure 1A, 3mm and 5mm SIRS increase post-treatment in 3months and no difference after 3months in group A.

Figure 1B, 3mm K decrease in 3months and no difference after 3months. there were no difference in 5mm K in 4 subgroup in group A .

Figure 1C, 3mm and 5mm SIRS increase post-treatment and there were difference in 4 subgroup in group B.

Figure 1D, 3mm K decrease in 3months and no difference after 3months. there were no difference in 5mm K in 4 subgroup in group B.



SIRS= surface irregularity index

K= mean keratometric reading

Corneal Sensitivity Measurement

Compared to subgroup 1, there was no difference in corneal sensitivity in subgroup 2, however there were significant differences in subgroups 3 and 4. There was no difference between subgroup 3 and 4 (Table 4, Figure 2E).

Tear break up time (BUT)

There were no differences in tear BUT in subgroups 1/2/3/4 (F=1.2, *P* = 0.30)(Table 4. Figure 2F).

Table 4. The dynamic changes in the corneal sensitivity and tear BUT

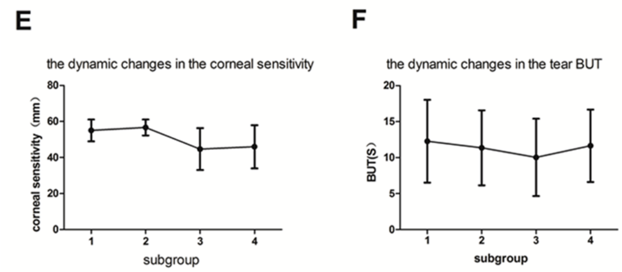
	Wear time (month)	Corneal sensitivity (mm)	Tear BUT (s)
1	0	55.00±6.12(n=29)	12.28±5.75(n=25)
2	0.94±0.55	56.66±4.43(n=12)	11.35±5.21(n=22)
3	5.93±2.05	44.65±11.64•▲(n=29)	10.03±5.37(n=29)
4	22.35±8.57	45.94±11.95•▲(n=32)	11.64±5.03(n=31)
F	123.37	8.86	1.20
P	0.000	0.000	0.30

•*P* < 0.05 Compared with Subgroup 1 ▲*P* < 0.05 Compared with Subgroup 2

Figure 2. The corneal sensitivity and tear BUT changes in subgroup 1/2/3/4

Figure2E, there were no difference in corneal sensitivity between subgroup 1 and 2, there were no difference between subgroup 3 and 4. there was a difference in subgroup 1/ 2 and subgroup 3 /4.

Figure2F, there were difference in BUT in 4 subgroup.



Discussion

Two theories have been considered to explain OK for correcting myopia refractive error. One involves changing the corneal front surface and another involves changing the overall corneal curvature. The findings of Owens et al [5] suggested there was a significant topographic flattening of the corneal front surfaces with OK. There is also a significant flattening of the posterior corneal surface during the early adaptive stages of OK lens wear with the EyeSys corneal topographic system. González-Mesa et al [6] used the pentacam to discover a long period of OK reduces anterior chamber depth (ACD) and AL and changes PRCC over one year. In this study, there was a difference in the FRCC and no difference in the PRCC, ACD, and PD in the 3, 6, and 24 months post-OK compared to pre-OK values, in patients who had low and medium myopia with K readings from 42 to 46 D (OrbscanII data). The same results were obtained using the Zeiss IOLMaster[7] and Pentacam[8] instruments. Most researchers concluded that overnight OK alters the anterior corneal shape rather than the PRCC or the ACD.

Further studies[9-12] using corneal thickness measurements and confocal microscopy, have found that OK causes rapid central corneal epithelial thinning and midperipheral stromal thickening. From this study, the mean 3 mm K changed markedly and the mean 5 mm K did not change post treatment in either group A or group B. This indicated that OK induces 3 mm but not 5 mm corneal anterior surface area changes. From the aspect of dynamic changes, 3 mm K decreased 3 months after the onset of OK and then remained stable during the 24 months of treatment. The corneal biomechanical properties that remain unchanged during the 6 months of follow up visits include corneal hysteresis (CH) and the corneal resistance factor (CRF) [13].

We observed that the 3 mm SIRS increased 3 months after the onset of OK and remained stable during the 24 months of treatment in group A and it continued to increase during the OK treatment in group B. This indicated the cornea continued to undergo micro-changes in the medium K reading scores (group B) and remained stable in the higher K reading scores (group A). These findings might explain the results of Santodomingo-Rubido et al.,[14] in which greater corneal refractive power was a successful treatment option in controlling axial elongation compared to single-vision spectacles in children. Cochet-Bonnet (COBO) aesthesiometry has been the gold-standard measure for corneal sensitivity since 1960. Corneal sensitivity loss has been demonstrated after various periods of eyelid closure in human subjects[15]. In the current study, the corneal sensitivity was measured in awake patients for 3 hours and 2 or 5 hours after removing the OK lens. These results indicated that the corneal sensitivity was not lost within 3 months (mean 0.94±0.55 months) of initiating OK treatment. However, sensitivity was lost after 3 months but then remained relatively stable. Previous studies[16,17] suggested that low oxygen pressure at the corneal surface is mainly responsible for significant changes in corneal sensitivity. However, it is thought that enough oxygen passes through the OK lens to meet corneal metabolic needs. Lum E et al[18]. concluded that central corneal sensitivity was reduced after a single overnight wear of OK lenses but did not change after overnight wear of silicone hydrogel and rigid gas-permeable contact lenses, as measured using the COBO aesthesiometer. These results suggested that the mechanical force exerted by contact lenses may influence corneal sensitivity. However, Hiraoka et al[19]. found that OK significantly reduced corneal sensitivity similarly in the central (mechanical force area) and peripheral regions (no mechanical force area). At present, the clinical significance of this sensory loss and stability after 3 months is not clear. Corneal sensitivity affects epithelial cell properties [20,21]. Moreover, corneal sensitivity loss should be heeded, since the eye is at a greater risk of infection [22,23]. Fortunately, the BUT did not change after treatment in this study.

We did not analyze the patients whose mean K readings ranged from 40 to 42D due to a lack of sufficient follow-up. But from the above data, we concluded that the anterior corneal changes showed a similar trend but the difference occurred in the micro-changes on the front surface of the cornea.

In summary, OK mainly caused changes in the 3 mm anterior corneal surface within 3 months that remained stable at least 24 months. No changes in PRCC, ACD, PD, or BUT were observed. The corneal sensitivity remained stable in the first 3 months and it decreased after 3 months, then stabilized after OK treatment. Loss in corneal sensitivity should be viewed with caution due to the possibility of an increased risk of infection.

References

1.Swarbrick HA. Orthokeratology review and update. *Clin Exp Optom*. 2006, 89(3): 124–143.

2. Hiraoka T1, Kakita T, Okamoto F, Takahashi H, Oshika T et al. 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(7): 3913–3919.

3. Cho P, Cheung SW. Retardation of Myopia in Orthokeratology (ROMIO)Study: A 2-year randomized clinical trial. *Invest Ophthalmol Vis Sci*. 2012, 53(11): 7077–7085.

4. Chan B1, Cho P, Cheung SW. Orthokeratology practice in children in a university clinic in Hong Kong. *Clin Exp Optom*. 2008, 91(5): 453-460.

5. Helen Owens, Leon F. Garner, Jennifer P. Craig. Posterior Corneal Changes with Orthokeratology. *Optom Vis Sci*. 2004, 81(6): 421–426.

6. González-Mesa A1, Villa-Collar C, Lorente-Velázquez A, Nieto-Bona A. Anterior segment changes produced in response to long-term overnight orthokeratology. *Curr Eye Res*. 2013, 38(8): 862-870.

7. Santodomingo-Rubido J1, Villa-Collar C, Gilmartin B, Gutiérrez-Ortega R. Short-term changes in ocular biometry and refraction after discontinuation of long-term orthokeratology. Eye Contact Lens. 2014, 40(2): 84-90.

8. Tsukiyama J1, Miyamoto Y, Higaki S, Fukuda M, Shimomura Y et al. Changes in the anterior and posterior radii of the corneal curvature and anterior chamber depth by orthokeratology. Eye Contact Lens. 2008, 34(1): 17–20.

9. Swarbrick HA, Wong G, O'Leary DJ. Corneal response to orthokeratology. Optom Vis Sci. 1998,75:791–799.

10. Nichols JJ1, Marsich MM, Nguyen M, Barr JT, Bullimore MA et al. Overnight orthokeratology. *Optom Vis Sci*. 2000, 77(5): 252–259.

11. Alharbi A, Swarbrick HA. The effects of overnight orthokeratology lens wear on corneal thickness. *Invest Ophthalmol Vis Sci*. 2003, 44(6): 2518–2523.

12. Nieto-Bona A1, González-Mesa A, Nieto-Bona MP, Villa-Collar C, Lorente-Velázquez A et al. Long-term changes in corneal morphology induced by overnight orthokeratology. *Curr Eye Res*. 2011, 36(10): 895-904.

13. Mao XJ1, Huang CC, Chen L, Lü F. A study on the effect of the corneal biomechanical properties undergoing overnight orthokeratology. *Zhonghua Yan Ke Za Zhi*. 2010, 46(3): 209-213.

14. Santodomingo-Rubido J1, Villa-Collar C, Gilmartin B, Gutiérrez-Ortega R. Factors preventing myopia progression with orthokeratology correction. *Optom Vis Sci*. 2013, 90(11): 1225-1236.

15. Millodot M, O'Leary DJ. Loss of corneal sensitivity with lid closure in humans. *Exp Eye Res.* 1979, 29(4): 417–421.

16. Millodot M, O'Leary DJ. Effect of oxygen deprivation on corneal sensitivity. *Acta Ophthalmol (Copenh)*. 1980, 58(3): 434–439.

17. Bonanno JA, Polse KA. Effect of rigid contact lens oxygen transmissibilityon stromal pH in the living human eye. *Ophthalmology*. 1987, 94(10): 1305–1309.

18. Lum E1, Golebiowski B, Gunn R, Babhoota M, Swarbrick H et al. Corneal Sensitivity with Contact Lenses of Different Mechanical Properties. *Optom Vis Sci.* 2013, 90(9): 954-960.

19. Hiraoka T1, Kaji Y, Okamoto F, Oshika T. Corneal sensation after overnight orthokeratology. *Cornea*. 2009, 28(8): 891-895.

20. Martin XY, Safran AB. Corneal hypoesthesia. *Surv Ophthalmol*. 1988, 33(1): 28–40.

21. Beuerman RW, Schimmelpfennig B. Sensory denervation of the rabbit cornea affects epithelial properties. *Exp Neurol*. 1980, 69(1): 196–201.

22. Sanaty M, Temel A. Corneal sensitivity changes in long-term wearing of hard polymethylmethacrylate contact lenses. *Ophthalmologica*. 1998, 212(5): 328–330.

23. Millodot M. Effect of long-term wear of hard contact lenses on corneal sensitivity. *Arch Ophthalmol*. 1978, 96(7): 1225–1227.