Central and Peripheral Changes in Anterior Corneal Topography after Orthokeratology and Laser in situ Keratomileusis

Han-Yin Sun[1, 2, 3], Hsiu-Wan Yang[4], I-Tsung Wu[4], Jung-Kai Tseng[2, 3] and Shun-Fa Yang[1, 5*]

[1]Institute of Medicine, Chung Shan Medical University, Taichung, Taiwan, ROC
[2]Department of Optometry, Chung Shun Medical University, Taichung, Taiwan, ROC
[3]Department of Ophthalmology, Chung Shun Medical University Hospital, Taichung, Taiwan, ROC
[4] Department of Optometry, Central Taiwan University of Science and Technology, Taichung, Taiwan, ROC
[5]Department of Medical Research, Chung Shan Medical University Hospital, Taichung, Taiwan, ROC
Tel: +886-4-24730022 Fax: +886-4-23248131 *e-mail: ysf@csmu.edu.tw

Abstract: To compare the values of the data on the central and peripheral curvature of the cornea in order to determine the differences between the overall corneal curvature after custom laser in situ keratomileusis (LASIK) and orthokeratology procedures in correcting refractive error. We evaluated 12 patients undergoing orthokeratology for the correction of myopia spherical equivalent (OD, mean±SD = -3.67 ± 2.16D; OS, mean±SD = -4.02 ± 2.21D), 10 patients undergoing custom LASIK surgery (OD, mean±SD = -4.25 ± 2.43D; OS, mean±SD = -4.41 ± 3.01D). The values of the front corneal surfaces were derived using Medmont E300 corneal topographer Version 4.9.0.0 (Medmont, Camberwell, Victoria, Australia) prior to and at least 3 months after each treatment with samples taken from the center of the cornea and 4 points to each side of the horizontal meridian at intervals of 1 mm. Among the two clinical groups, no statistically significant differences on OD and OS were found for the spherical equivalent ($p = 0.756$ and $p = 0.423$). The refractive power of elevation became positive in the central nasal (4 mm) and temporal regions (4 mm). The changes in OD were statistically significant ($p<0.001$) in nasal 2 mm after orthokeratology compared to the value for the case of LASIK. The OS date of post- minus pre-orthokeratology compared with that of LASIK exhibited significant differences on the nasal region (2-3 mm) and temporal region (2-3 mm) ($p<0.001$). The differences in the changes in the front corneal curvature between LASIK and orthokeratology reveal a much different mechanism for alternating corneal power. The changes in the corneal surface refractive power are 2 to 3 times greater in LASIK procedures than in orthokeratology for both central and peripheral regions.

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1. Introduction

Myopia is a serious public health problem worldwide, specifically in Asian countries, where this disease is highly prevalent [1]. The areas of intervention that attempts to address this disease have focused on some measures and alternatives to the traditional use of enhanced eyeglasses to correct refractive errors. These measures include orthokeratology (OK) [2, 3] and laser assisted in situ keratomileusis (LASIK) [4]. Orthokeratology (OK) is a non-surgical procedure accomplished by wearing overnight retainer lenses that reshape the cornea. Such lenses are particularly designed with a rigid gas permeable contact lens that is used while sleeping. After modifying the shape of the corneal curvature, the light that enters the eye can focus precisely on the retina, without further need for other corrective measures. While this method allows people to see clearly during daytime, this effect is temporary. On the other hand, LASIK is an advanced procedure that reshapes the cornea to correct refractive errors, such as near-sightedness (myopia), far-sightedness (hyperopia), and distorted vision (astigmatism). Microkeratome is first used to create a hinged flap on the surface of the cornea. Subsequently, the flap is reflected back, the exposed cornea (stoma) is reshaped by the excimer laser, and the flap is finally replaced, without sutures.

The study of corneal topography in preoperative and postoperative evaluations of surgical and non-surgical procedures is important. Although numerous studies have focused on the changes in the central curvature, the goal of the present study is to compare the values of the central and peripheral curvature of cornea data to identify the differences between the overall corneal curvature after LASIK and orthokeratology procedures in correcting refractive error.

2. Materials and methods

Subjects and Inclusion Criteria

The present study draws on the clinical records of 22 patients, who were recruited to participate in this study as candidates after undergoing orthokeratology using corneal refractive therapy (CRT, n=12) and customized LASIK (CL, n=10). Patients with myopia of between -3.00D and -9.00D between and refractive astigmatism of less than 4.00D were included. All patients do not have any history of ocular disease or trauma, and have not undergone previous ocular surgery. A minimum of 3 months after treatment was required to ensure that the topography of cornea was stable.

The corneal locations included in the analysis are those within the central 6 mm of the cornea, given that this was the optical zone for all the patients. Thus, the present study focused on analyzing the central, 1, 2, 3, and 4 mm chord areas. The topography of cornea examined is shown in Figure 1, which indicates the area, central curvature, and measurements along the center to the peripheral 4 mm.

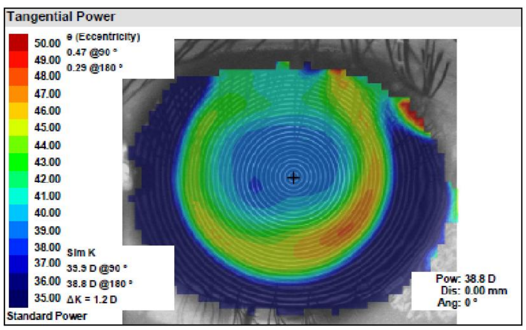

Figure 1: The topography of the cornea includes the central curvature, and the center to the periphery measures 4 mm.

Orthokeratology Lens Characteristics

The orthokeratology lenses used in the present study were manufactured by the Hiline Optical Company, Taipei, Taiwan using Boston XO materials (Rochester, NY, USA, ISO/Fatt Dk 100), with the following parameters: total diameter of 10.6 mm, BOZD of 6.0mm, and center thickness of 0.22 mm.

The lenses to be worn were initially selected based on the baseline corneal apical radius of the curvature and corneal eccentricity, which were derived using a corneal topographer (model E-300; Medmont Pty. Ltd., Brisbane, Queensland, Australia), a visible horizontal iris diameter, and the desired refractive change. The lens-fitting program subsequently selected the most appropriate trial lens to be worn for an initial overnight trial for lens-wearing. The lens design was modified based on the corneal topographic changes determined through the first night of the trial lens-wearing, and the appropriate final lenses were ordered.

Laser in Situ Keratomileusis Surgery

The surgical procedure for LASIK was based on international standards, and the commonly accepted criteria for refractive surgery procedures were followed; that is, the surgeon leaves one edge of the tissue attached to patient's eye, forming a flap. The flap measures 120 µm, 9.5 mm in diameter, with a standard and customized ablation profile that was produced using the STAR S4 IR™ Excimer Laser (Abbott Medical Optics Inc.) All the surgical procedures succeeded.

Outcomes

Corneal topography was measured using the Medmont E300 Corneal Topographer Version 4.9.0.0 (Medmont, Camberwell, Victoria, Australia). Three images were captured, and the data from the associated map displays were averaged on every measurement instance. Topographic data were collected from the center of corneal topography (C), 4 mm from the nasal corneal (N1, N2, N3, and N4), and 4 mm from the temporal corneal (T1, T2, T3, and T4). Topographic data were obtained for each region. The pretreatment best fit sphere (BFS) was automatically calculated for each cornea using the Medmont E300 Corneal Topographer. The same BFS was used again for each cornea after intervention to maintain the same reference surface for subsequent comparisons.

Statistical Analysis

For statistical analysis, the SPSS software package v.17 (SPSS Inc., Chicago, IL) was used. Regression analysis and paired-sample *t* test were performed to analyze the correlations between refractive and topographical changes and the statistical significance of topographic changes, respectively. For statistical purposes, a *P* value of less than 0.05 was considered statistically significant.

3. Results

The present study included 44 eyes from 22 patients, with a mean age of 24.4 ± 8.8 years (ranging from 14 to 39). Table 1 shows the pretreatment data for spherical equivalent and astigmatism. Mean values and stand deviation (SD) for the two groups of the selected patients are listed for each of the variables. The orthokeratology group comprises 12 patients, with mean age of 18.8 ± 4.46 years old. The equivalent sphere of OD is -3.67 ± 2.16 diopters, and OS is -4.02 ± 2.21 diopters. The *Jo* of OD is -0.16 ± 0.69 diopters, and *J45* is -0.28 ± 0.84 diopter. The *Jo* of OS is 0.39 ± 0.52 diopters, and *J45* is -0.06 ± 0.29 diopters. On the other hand with mean age of 33.88 ± 3.04 years old. The equivalent sphere of OD is -4.25 ± 2.43 diopters, and OS is -4.41 ± 3.01 diopters. The *Jo* of OD is 0.26 ± 0.38 diopters, and *J45* is -0.11 ± 0.13 diopter. The *Jo* of OS is 0.46 ± 0.58 diopters, and *J45* is -0.04 ± 0.07 diopters. No statistically significant differences were found for the spherical equivalence among the two clinical groups (p = 0.756 and p = 0.423, Kruskal-Wallis test).

Table 1 Descriptive Statistics for Population Data Collection

	Age	M (D)		*J*0 (D)		*J*45 (D)	
		OD	OS	OD	OS	OD	OS
Ortho-K	18.08±4.46	-3.67±2.16	-4.02±2.21	-0.16±0.69	0.39±0.52	-0.28±0.84	-0.06±0.29
LASIK	33.88±3.04	-4.25±2.43	-4.41±3.01	0.26±0.38	0.46±0.58	-0.11±0.13	-0.04±0.07
P	<0.00	0.756	0.423	0.259	0.785	0.112	0.03

M, J0, and J45 are refractive components.
Ortho-K, orthokeratology; LASIK, laser in situ keratomileusis.

In Table 2, the mean value, SD, and the value of statistical significance for corneal topography difference for OD among pretreatment, post-treatment, and post-treatment minus pre-treatment stages are presented separately for each technique. The change in refractive power for the post-procedure after Orthokeratology compared to LASIK on the front surface elevation at the central region, the nasal 1-3 mm and temporal 1-3 mm distance became negative, and exhibited a significant decrease in nasal 2 at 3 mm. The refractive power of elevation became positive in the central region, with nasal at 4 mm and temporal at 4 mm. The changes were statistically significant ($p<0.001$) in the nasal 2 mm region after orthokeratology, unlike with the LASIK case.

In Table 3, the value of the statistical significance for corneal topographical difference in OD for the pretreatment, post-treatment, and post-treatment minus pre-treatment stages are presented separately for each technique. For the front corneal surface, both surgical procedures decreased the refractive power on the front surface elevation significantly after treatment, with a nasal 1-2 mm and temporal 1-2 mm distance. The date of post- minus pre- Orthokeratology compared with LASIK procedures showed a significant difference in nasal 2-3 mm and temporal 2-3 mm ($p<0.001$).

4. Discussions

Videokeratoscopy is the most common method for peripheral curvature examination [5], particularly in surgical and non-surgical evaluations [6, 7]. The results of this study show the different alterations in the power of the anterior corneal surface from the center towards the peripheral cornea, after receiving different corneal refractive treatment options [8]. The previous study, which used similar data, showed a loss in corneal power within the analyzed area of up to 6 mm in corneal diameter [9]. The topographic change in the front corneal surface after LASIK and orthokeratology procedures may appear similar. Based on a hypothesis that proposed that the periphery of the cornea become steeped with orthokeratology [10] and LASIK, we assumed that the decrease in refractive is caused by tissue recombination from the center to the periphery, regardless of the treated zones that decreased the power between the central treated and peripheral non-treated zones [11]. As expected, the quantitative analysis of the change in refractive power between surgical and orthokeratology procedures presented remarkable differences.

The differences observed when analyzing the peripheral change results from LASIK and orthokeratology can be attributed to the biomechanical response after LASIK. The orthokeratology data shows that the front surface of cornea is less impacted in the peripheral zone. In contrast, orthokeratology causes dramatic changes in the corneal front surface that is an effective correction for low to moderate refractive errors [12, 13]. The previous study showed that orthokeratology slows down the progression of myopia by altering the refractive power of the corneal front surface (Tables 2 and 3). This observation shows that the changes in the peripheral refraction under orthokeratology were similar to that under LASIK surgery. In addition, these findings are similar to those found in previous studies [14, 15].

Nevertheless, the present study has not analyzed the back corneal surface. Another study that focused on the changes in corneal curvature that were obtained using Orbscan II; however, no differences were found using the Pentacam, which evaluated the posterior elevation after PRK [16]. This result shows the overestimation of the peripheral thickness of the cornea by Orbscan II compared with that using ultrasound pachometry [17]. Nevertheless, a plausible explanation for this phenomenon is that Orbscan II measures the front surface curvature of the cornea, and that slit imaging is employed to derive the back surface of corneal and thickness of cornea using pachometry.

To sum, the current study has shown that the decrease in power and curvature of the cornea indicate the different features of the geometrical nature of the cornea, particularly after LASIK procedures. The results of the current study, which uses a point-to-point analysis of the changes in corneal curvature instead of a simple study, will provide better understanding of the effects of the reshaping of the cornea on the central corneal curvature. The changes in corneal surface refractive power are 2 to 3 times greater in LASIK than in orthokeratology procedures in either the central or the peripheral region.

Table 2. Pre-treatment, post-treatment, and different (post-pre) value of OD.

		LASIK		Ortho-K	
OD		Mean ± SD	Post-pre *p*	Mean ± SD	Post-pre *p*
N1	Pre	43.45±0.79	-4.57±1.67	43.62±1.24	-3.11±2.28
	Post	38.32±1.35	0.125	40.58±2.47	0.125
N2	Pre	43.54±0.81	-4.65±2.05	43.83±1.10	-0.67±0.84
	Post	38.89±1.57	0.00	42.67±1.53	0.00
N3	Pre	43.80±0.92	-2.44±1.77	44.02±1.13	1.50±1.62
	Post	41.36±1.51	0.00	45.43±2.23	0.00
N4	Pre	43.51±1.07	0.15±1.88	43.78±1.24	0.57±0.91
	Post	43.66±1.58	0.274	44.48±1.75	0.274
C	Pre	44.24±1.10	-4.93±2.14	44.28±1.47	-3.61±2.27
	Post	38.89±1.26	0.211	40.98±2.48	0.211
T1	Pre	43.65±0.88	-4.41±1.75	43.83±1.22	-3.37±2.08
	Post	38.96±1.39	0.261	40.80±2.52	0.261
T2	Pre	44.09±0.88	-3.36±1.83	44.27±1.24	-1.89±1.60
	Post	40.08±1.25	0.074	42.93±2.21	0.074
T3	Pre	44.76±1.08	-1.06±2.50	44.98±1.25	0.27±1.91
	Post	42.30±1.27	0.195	45.89±2.19	0.195
T4	Pre	45.01±1.43	0.49±2.61	45.48±1.42	0.50±0.87
	Post	44.53±1.72	0.98	45.95±1.70	0.98

Table 3. Pre-treatment, post-treatment, and different (post-pre) value of OS.

		LASIK		Ortho-K	
OS		M3an±SD	Post-pre *p*	Mean±SD	Post-pre *p*
N1	Pre	43.51±0.88	-5.51±1.82	43.87±1.23	-3.03±2.12
	Post	38.94±1.25	0.035	40.75±2.49	0.035
N2	Pre	43.63±0.72	-4.65±2.06	44.03±1.22	-1.17±0.84
	Post	39.10±1.46	0.00	43.58±2.12	0.00
N3	Pre	43.85±0.81	-2.44±1.77	44.3±1.60	1.42±1.62
	Post	40.94±1.67	0.00	46.02±2.02	0.00
N4	Pre	43.63±1.17	0.15±1.88	44.04±1.26	0.70±0.91
	Post	43.33±1.44	0.391	44.5±1.73	0.391
C	Pre	43.86±1.31	-5.35±1.98	44.23±1.20	-3.31±2.37
	Post	38.93±1.42	0.059	40.81±2.52	0.059
T1	Pre	43.58±0.89	-4.68±1.91	44.02±1.21	-3.03±2.00
	Post	39.16±1.26	0.085	40.64±2.52	0.085
T2	Pre	43.86±0.90	-4.01±1.82	44.43±1.25	-1.33±1.69
	Post	40.50±1.43	0.003	42.53±1.86	0.003
T3	Pre	44.26±1.02	-2.56±1.97	45.09±1.28	0.90±1.86
	Post	43.18±2.31	0.001	45.36±2.17	0.001
T4	Pre	44.61±1.28	-0.48±2.22	45.62±1.44	0.4±0.77
	Post	45.1±2.72	0.185	46.13±1.79	0.185

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Corresponding Author:
Shun-Fa Yang, Ph.D.
Institute of Medicine, Chung Shan Medical University, Taichung, Taiwan, 402, Republic of China
Department of Medical Research, Chung Shan Medical University Hospital, Taichung, Taiwan 402, Republic of China
E-mail: ysf@csmu.edu.tw

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