Difference in profile of peripheral defocus after orthokeratology and eximer laser correction of myopia

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*A variety of factors that change the topography of the cornea may also induce changes in peripheral refraction. **Purpose.** The paper is aimed at assessing the peripheral refraction and retinal contour of myopic eyes after FS-LASIK and orthokeratological (Ortho-k) correction. **Material and methods.** We examined a total of 30 patients (60 eyes) aging from 28.86 ± 2.83 years which included 12 patients (24 eyes) with myopia of -5.11 ± 05 D and with an axial length (AL) of 25.04 ± 0.33 mm before and 1 month after FS-LASIK surgery, and also included 18 patients (36 eyes) with myopia of -5.4 ± 0.24 D and AL of 25.78 ± 0.2 mm who wore ESA-DL Ortho-k lenses. The peripheral refraction of all the patients was measured using the Grand Seiko Open-field binocular autoref/keratometer and the peripheral eye length was measured using the IOL Master 500 (Carl Zeiss) at 15° and 30° nasally (N) and temporally (T), respectively, from the center of fovea. **Results.** The peripheral eye length measured before and after FS-LASIK as well as after Ortho-k correction was less in all peripheral zones than in the center, which corresponds to characteristics observed in hyperopic peripheral defocus. Refraction measured after FS-LASIK showed the formation of myopic defocus with a maximum at 30° from the following results: -2.49 D at T15°, -2.5 D at N15°, -6.73 D at T30°, and -7.8 D at N30°. The maximal myopic defocus after Ortho-k correction was detected in the middle periphery from these following results: -4.89 D at T15°, -5.51 D at N15°, -2.92 D at T30° and -2.4 D at N30°. **Conclusions.** Both procedures induced a significant peripheral myopic defocus. In the first case, the maximum values of defocus were detected in the peripheral zone (30° from the center of the fovea); in the second case, the maximal affects on the middle periphery were identified 15° from the center. Such patterns of peripheral refraction fully coincided with the specific changes in corneal topography after the two procedures. The retinal contour within 30° from the center retained the relative hyperopic defocus characteristic of intact myopic eyes.*

Ключевые слова: myopia, peripheral refraction, defocus, peripheral eye length, orthokeratology.

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Through visual feedback mechanisms, plus and minus defocus participate in the process of emmetropization in humans and other animal species [1—3]. The work of E. Smith et al. performed on humanoid monkeys showed that visual signals in the fovea are not the most important for the normal refraction process [4]. On the contrary, inducing hyperopic defocus onto the peripheral retina did result in an accelerated and even an uneven eye growth in the respective segments (local growth in the axial length of the eye) [5].

Based on the fundamental results of experiments from the last decade, attention was brought to the hypothesis that a hyperopic defocus induced onto the peripheral retina might be a risk factor to the development of myopia as a stimulus triggering compensatory eye growth. On the other hand, myopic defocus targeted onto the peripheral retina might also slow down or stop axial length growth, and consequentially, the development or progression of myopia. The possibilities of various relationships between the development of myopia and peripheral defocus have resulted in the increased interest towards the inventions or development of new methods for myopia correction that include the peripheral retina [6, 7]. In many clinical practices, myopic peripheral defocus is induced with the help of night gas permeable Ortho-k contact lenses that take into account any changes in profile of the corneal epithelium, resulting in the flattening of its central area and an exaggerated (and an increased refraction in) paracentral area. In many controlled experiments performed by various researchers, it is shown that school-aged children using Ortho-k lenses as their myopic treatment display a slowed down progression of nearsightedness as their axial length growth rate decreases [8–10]. More importantly, this deceleration can be tied back to a regularly significant induction of peripheral myopic defocus [11].

Various keratorefractive factors can also change the curvature, topography, and refractive error of the retina. In the last 10 years several experiments were performed overseas devoted to the peripheral refraction after Lasik surgery and the contradictory results. L. Ma et al. [12] discovered a significant formation of myopic defocus on the peripheral retina 20o from the center after Lasik; however, they did not compare this to the results after Ortho-k-correction. A. Queirós et al. [13] revealed an increase in peripheral myopia after Ortho-k-correction, however, their data showed that Lasik surgery decreased peripheral myopia along the entire horizontal meridian until 35o from the point of focus. Other documentation of parallel experimentation on the peripheral refraction and retinal contours after Lasik and Ortho-k lens correction have not been found.

The **PURPOSE** of this work is to compare the measurements of peripheral refraction and the retinal contours in myopic eyes after eximer laser and orthokeratology correction.

MATERIALS AND METHODS

30 patients (60 eyes) with moderate myopia were investigated in this study. The first group consisted of 12 patients (24 eyes) with moderate myopia from 21–39 years of age (in average 28.86 ± 2.83 years), who were assessed before and 1 month after the eximer laser myopia correction method FS-LASIK. Eximer laser correction was performed with an eximer laser Nidek EC 5000 and the following parameters: zone of ablation = 6.5 mm; transition zone = 7.0 mm; average depth of ablation = 92.5 ± 9.65 µm. The corneal flap was formed with a femtosecond laser, Femto LDV (Ziemer); the claimed thickness of the flap was 100 µm, and the diameter was 9.31 ± 0.09 mm. The initial refractive error measurements consisted of an average -5.11 ± 0.5 D and the anterior posterior axial length was 25.04 ± 0.33 mm. The second group consisted of 19 patients (36 eyes) who were users of night Ortho-k lenses, ESA-DL. The initial refractive error measurements consisted of an average —5.4 ± 0.24 D and the anterior posterior axial length was 25.78 ± 0.2 mm.

In addition to a standard ophthalmological checkup, all patients underwent an examination of their peripheral refraction and their eye length based on consistent retinal zones [14]: along the visual axis, 15° and 30° nasally (N15°, N30°), and 15° and 30° temporally (T15°, T30°) from the center of the fovea along the horizontal meridian (fig. 1). Peripheral refraction was determined with a binocular autoref/keratometer "open field" Grand Seiko WR — 5100K. An instrument was constructed with 4 markers for fixating the gaze at 15° and 30° nasally and temporally from the center. In each position the spherical equivalent of refraction was measured. For calculating peripheral defocus from the entire spherical equivalent the central (axial) refraction measurement was subtracted taking into account its sign (basically, the algebraic difference was taken, for example: (-4.0) — (-5.0) = + 1.0 D – hyperopic defocus).

The length of the eye using the same retinal zones was determined with partially-coherent interferometry on the apparatus IOL Master (Carl Zeiss, Germany) in the following way. Markers were attached to the screen of the apparatus, providing measured angles for focused gaze at 15° and 30° nasally and temporally. In case of cycloplegia, the measurements were taken when looking straight ahead and during fixation at every marker. For calculating defocus and understanding the eye's form, the difference between each peripheral and central measurement was taken. A relatively decreased eye length measured at the periphery compared to measurements from the center is suggestive of a decreased refractive error, or hyperopic defocus (indicated with a "+" sign); whereas, a relative increase suggests an increased refractive error, or myopic peripheral defocus (indicated with a "-" sign).

RESULTS AND DISCUSSION

As shown in tables 1 and 2, the peripheral length of the eye before and after eximer laser and during Ortho-k correction in all peripheral retinal zones was less than in the center, which is in agreement with the hyperopic peripheral defocus, inherent to moderately myopic eyes, and verifies a stretched ellipsoid form at the back of the eye in bounds of the experimental 30° zone.

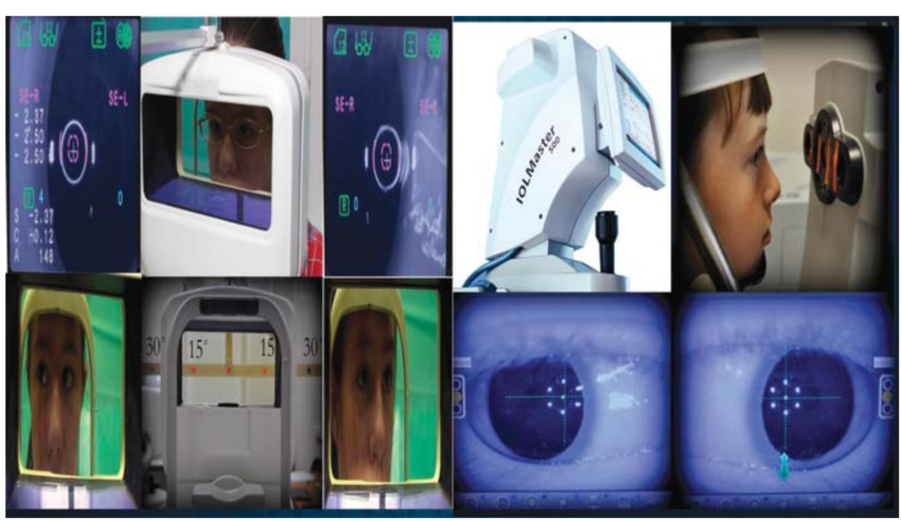

Fig. 1. The measurement of peripheral refraction (on the left) and peripheral eye length (on the right).

Table 1. Axial and peripheral eye length (mm) and the correlated peripheral defocus (mm) before and after FS-Lasik and after Ortho-k correction

Indicators	Angle of focused gaze from the optical axes				
	T30	T15	0	N15	N30
Peripheral eye length before FS-Lasik	24.27±0.28	24.91±0.28	25.04±0.33	24.95±0.39	24.72±0.41
Correlated peripheral defocus before FS-Lasik	0.77±0.1	0.13±0.07	–	0.09±0.09	0.32±0.09
Peripheral eye length after FS-Lasik	24.3±0.32	24.85±0.3	24.93±0.31	24.89±0.35	24.7±0.45
Correlated peripheral defocus after FS-Lasik	0.63±0.11	0.08±0.07	–	0.04±0.09	0.23±0.09
Peripheral eye length after Ortho-k correction	24.9±0.21	25.55±0.15	25.78±0.2	25.69±0.19	25.25±0.23
Correlated peripheral defocus after Ortho-k correction	0.88±0.08	0.23±0.04	–	0.09±0.08	0.53±0.15

Table 2. Results from the axial and peripheral refractometry (D) and associated peripheral defocus (D) before and after FS-Lasik and after Ortho-k correction

Indicators	Angle of focus gaze from the optical axes				
	T30	T15	0	N15	N30
Peripheral refraction before FS-Lasik	-3.3±0.65	-4.79±0.52	-5.11±0.5	-4.91±0.51	-3.37±0.6
Related peripheral defocus before FS-Lasik	1.81±0.54	0.32±0.19	–	0.2±0.15	1.74±0.52
Peripheral refraction after FS-Lasik	-6.24±0.68	-2.0±0.38	0.49±0.12	-2.01±0.39	-7.31±0.74
Related peripheral defocus after FS-Lasik	-6.73±0.67*	-2.49±0.37*	–	-2.5±0.38*	-7.8±0.73*
Peripheral refraction after Ortho-k correction	-4.35±0.65	-6.32±0.46	-1.43±0.17	-6.94±0.72	-3.83±0.83
Related peripheral defocus after Ortho-k correction	-2.92±0.67**	-4.89±0.47**	–	-5.51±0.7**	-2.4±0.82**

Note: * — the difference of the related peripheral defocus before and after FS-Lasik was significant, $p < 0.001$; ** — the difference of the related peripheral defocus before and after FS-Lasik and after Ortho-k correction was significant, $p < 0.001$.

The anterior-posterior axis which was measured from the front of the corneal surface to the pigment epithelium decreased by 0.11 mm after FS-Lasik, easily correlated to the depth of ablation. As work by E. Tay et al. has shown, the increase in depth of ablation by 1 μm led to a decrease in axial length by 0.00018±0.00005 mm [15].

A false trend was detected when eye length decreased (by 0.06 mm compared to the initial measurements) in the 15° paracentral zone, which should also be tied to the decreased corneal thickness following eximer laser ablation. In the nasal and temporal 30° zones, indicators of eye length did not change from the initial measurements.

Peripheral refraction data before and after FS-Lasik and after Ortho-k-correction is shown in table 2. As seen in the table, before Lasik refraction, as we moved from the center, refraction weakened and defocus in all peripheral zones was hyperopic which was in total agreement with the biometric data in table 1. In addition to the sign, the magnitude of defocus was in total agreement with each other: the minimum value of hyperopic defocus and the minimum value of eye length were identified in the zones at 15° nasally, and the maximum values — at 30° temporally from the center of the fovea.

After FS-Lasik surgery, the changed profile of the cornea, at all peripheral points a significant myopic defocus was identified: -2.49 D and -2.5 D at the central periphery, -6.73 D and -7.8 D temporally and nasally, respectively. It was interesting to compare peripheral defocus after eximer laser and Ortho-k correction. Initially, the defocus increases with time and reaches a maximum value at the peripheral center, in the 30 degree zone: -6.73 D at T30 and -7.8 D at N30. After Ortho-k correction, the opposite occurred as the maximum value in the peripheral center: -4.89 D at T15 and -5.51 D at N15; whereas, in the center, at the 30 degree zone, defocus decreased (-2.92 D at T30 and -2.4 D at N30) (table 2).

The data fully coincides with the changing corneal topography as a result of the studied correction methods (fig. 2). Eximer laser correction allowed an even and steady flattening of the front corneal surface within the boundaries of the ablation zones, so the maximum achieved curvature and refractive error or power was at the periphery of the related zone — the boundaries of the treated and intact cornea.

Ortho-k contact lenses formed another profile of the front corneal surface. Along with the flattening of the central area, the maximum increased curvature and refractive defocus (in the “zone of accumulation”) occurred, moving to the periphery — into the “leveling out zone”. In this way, peripheral refraction reflects changed in the corneal topography.

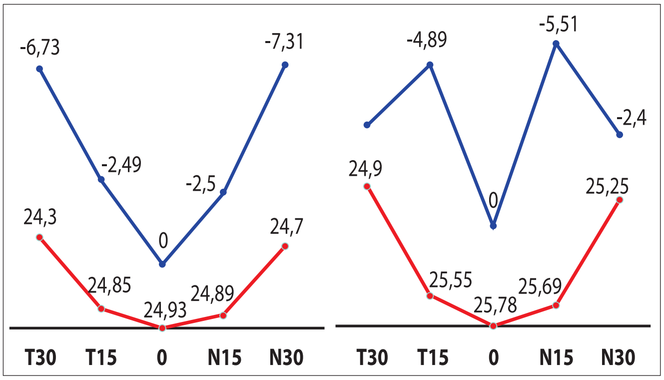

Fig. 2. Induced peripheral defocus (D) and the shape of the eye (mm) after FS-Lasik (on the left) and after Ortho-k correction of myopia (on the right).

CONCLUSION

Both methods — FS-Lasik and Ortho-k correction induced significant peripheral myopic defocus. After eximer laser correction, the maximum myopic defocus value was indicated in the most peripheral zone (30 degree nasally and temporally from the center of the fovea), and after Ortho-k-correction of myopia, the maximum myopic defocus value was indicated in the middle peripheral zone (at 15 degrees nasally and temporally from the center). In intact myopic eyes the results of the peripheral refractometry and partially coherent interferometry coincided and equally allows to judge the retina contours at the back of the eye. After eximer laser and Ortho-k correction of myopia the results of the peripheral refractometry and partially coherent interferometry did not coincide. The first results indicated signs of peripheral myopic defocus by the change in the topography of the cornea, whereas, the second results of hyperopic defocus were inherent to intact myopic eyes. The change in the corneal topography demonstrated an effect as a result of the peripheral refractometry (Grand Seiko WR-5100K) and not as a result of the optical biometer (IOL Master 500).

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