The effect of significant changes in corneal power after refractive surgery on the parameters of optical coherence tomography (OCT) has not been sufficiently studied. **Purpose** — to study effects of corneal refractive surgery on optical coherence tomography (OCT) measurements in patients with moderate and high myopia. **Material and methods.** OCT was performed in 62 patients (62 eyes) with myopia over 4 D before and one month after LASIK. The changes in 14 parameters of the thickness of the retina, ganglion cell-inner plexiform layer (GCIPL) and peripapillary retinal nerve fiber layer (pRNFL) were analyzed. **Results.** The mean refractive effect was 7.07±2.02 D (4.0 to 11.75 D). Postoperative changes in the parameters analyzed were insignificant, averaging not more than 1.3% of the baseline value with the exception of pRNFL thickness in the temporal quadrant (2.2%). Only six of the 14 parameters were statistically significant — retinal thickness in the central subfield and the inner nasal quadrant, average and minimum thickness of GCIPL, and pRNFL thickness (mean and in the temporal quadrant). Individual changes of the parameters in most patients did not exceed the error of method. **Conclusion.** In patients with moderate to high myopia, LASIK operation has only a slight effect on the OCT parameters of the retina and pRNFL. Only in patients with very high myopia, the decrease over 10 D in corneal refractive power creates an optical effect of increasing the average thickness of pRNFL and GCIPL by 2—3 µm. This should be taken into account when examining such patients for glaucoma.

**Keywords:** optical coherence tomography, myopia, LASIK, optical effect.

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Keratorefractive surgeries are widely used in current ophthalmological practice. They are most commonly performed in patients with myopia, even of very high degree. Such patients often have concomitant eye fundus pathology, which requires high-tech diagnostic methods, specifically the optical coherence tomography (OCT). A question has arisen whether significant changes in corneal refraction after a keratorefractive surgery can affect the results of OCT measurements.

Parameters of the ocular optical system, primarily eye’s axial length, are well known to change the quantitative measurements of OCT significantly, especially in people with refractive anomalies of higher degrees [1–6]; the influence of other characteristics has not been studied that closely. Some studies looked at the influence of keratorefractive surgeries on OCT measurements — thickness of peripapillary retinal nerve fiber layer (pRNFL) [7–10], less often — other eye fundus structures [10]. However, the main purpose of the majority of those works was to evaluate the possible damage the short-term increase in intraocular pressure (IOP) during LASIK could cause, particularly in terms of the method of forming a corneal flap (using a microkeratome or a femtolaser). Additionally, changes in pRNFL were analyzed using scanning laser polarimetry [9, 11–14].

Some authors simulated the effect of a keratorefractive surgery by using soft contact lenses and measuring pRNFL thickness [15–17], but had diverging results.

In view of the above, the purpose of the present study was to evaluate the effects of keratorefractive surgery on measurements obtained by optical coherence tomography (OCT) in patients with moderate and high myopia.

**Material and methods**

The study included 62 patients (62 eyes) who sought to undergo a keratorefractive surgery to correct moderate or high myopia at either S. Fyodorov Eye Microsurgery Federal State Institution (Moscow) or Medical Centre “Svetoch” (Pushkino). Each patient had one eye examined: in anisometropic patients — the one with higher degree of myopia, in patients with equal refraction — an eye chosen randomly. Inclusion criteria were myopia of more than 4 Dioptre (sphere equivalent), astigmatism of no more than 3.0 Dioptre, visual acuity with correction not lower than 0.8, patient age 18 or older. The study excluded patients with unstable visual fixation, optical media opacity, and serious concomitant diseases of the eye or of somatic origin. Patients were chosen using continuous selection method limiting the percentage of moderate myopia to 25%.

Preoperative examination included measurement of the eye’s axial length with AL-3000 biometer (Tomey, Japan). Additionally, before and 1 month after the surgery patients underwent standard spectral OCT without mydriasis on Cirrus HD-OCT (Carl Zeiss Meditec, U.S.A.; software version 10.0.0.14618). The macular area was scanned according to the “Macular Cube 512×128” protocol with following “Macular Thickness Analysis” and “Ganglion Cell Analysis”; the device measures the retinal ganglion cell and inner plexiform layers (RGC IPL)
together. Retinal thickness was analyzed in the central (fovea) area 1 mm in diameter and in the inner circle of ETDRS scheme divided into 4 quadrants — temporal, upper, nasal, and lower; peripheral parts of the macula were not included in the analysis due to large amount of artifacts seen in those areas in patients with high myopia. Examination of the optic disc area was performed according to the “Optic Disc Cube 200×200” protocol with data analysis on the “ONH and RNFL OU Analysis” software. At least two measurements of each type were done during each session. The scan data with the strongest signal and absence or minimal influence of artifacts caused by eye movements were considered final. Scans with signal strength of less than 6 (out of possible 10) were excluded. All measurements were carried out by the same specialist.

In 53 patients (85%), LASIK surgery (including personalized) was performed using WaveLight EX500 system (Alcon, U.S.A.), and corneal flap formation by femtosecond laser Femto LDV 6 (Ziemer, Switzerland); in 9 other patients (15%) — on excimer laser Nider EC-5000 (Nidek, Japan) with corneal flap formed by mechanical microkeratorete Zyoptix XP (Baish&Lomb, U.S.A.).

Statistical analysis was done on a personal computer using Excel (Microsoft) and STATISTICA 6 (StatSoft) software. Outlying values were excluded when differing from arithmetical average by more than 3 standard deviations — $M \pm 3\sigma$. Kolmogorov-Smirnov test was used to evaluate normalcy of distribution. The values distributed normally were put in $M \pm \sigma$ format; they were compared before and after the surgery using paired Student t-test. When distribution varied from normal, the data was shown as a median with indication of interquartile range — $Me (IQR)$. These values was compared using Wilcoxon test. Correlation of the parameters was assessed using linear regression method and Pearson correlation analysis. P values less than 0.05 were considered statistically significant.

Results

Fifteen patients (24%) had moderate myopia, 47 (76%) — high myopia. Mean age of the patients was $27.9 \pm 6.5$ (18 to 47 years old), among them 39 (63%) were female and 23 (37%) were male. Axial eye length was between 25.21 and 28.04 mm (in average 26.42±0.54 mm).

Preoperative period went without any complications. Baseline refraction values and its changes after surgeries can be seen in Table 1.

In most cases, the intended effect was achieved successfully. Only one patient with high myopia (-13.0 Diopters in spherical equivalent) and astigmatism of 2.5 Diopters had remaining myopia of (-)3.38 Diopters (in spherical equivalent) due to insufficient initial thickness of the retina (555 μm).

The quality of macular scans was high: only in 7 scans performed before and 5 scans performed after the surgery the signal strength was less than 8. The quality was somewhat lower in optic disc scans: only in half of cases the signal strength was 8 or higher, in other eyes it was 6—7. Analysis of RGC IPL was performed in 54 patients — 8 were excluded due to program errors with segmentation (12 protocols). Furthermore, analysis of macular retinal volume and mean retinal thickness was performed in 55 patients: 7 were excluded due to incorrect measurements (9 protocols). Particularly high number of inaccuracies was seen in optic disc measurements; in a third of all cases (21 patient) significant discrepancies were observed with automatic assessment of optic disc borders before and after the surgery. In this respect, analysis of optic discs was excluded from the study.

Main parameters of the retina before and after LASIK can be seen in Table 2.

The changes before and after LASIK were essentially insignificant and in most cases did not exceed 1% from the baseline values, with only RGC IPL having an increase of 1.1 to 1.3%. Moreover, changes in 5 out of 9 parameters were not statistically reliable.

Thickness of pRNFL before and after the surgery can be seen in Table 3.

Changes in pRNFL thickness after refractive surgery were also insignificant. They were between 0.4 and 1.2% of the baseline value in all the sectors except the temporal quadrant with 2.2% change in thickness. Only the changes in this parameter and mean pRNFL thickness were reliable.

Correlation analysis and linear regression were used to assess the dependency of changes in each parameter on the amount of refractive effect. In all cases, correlation was weak and statistically unreliable: correlation coefficient was lower than 0.27 and for pRNFL parameters — lower than 0.11.

However, the patients with higher refractive effect showed unreliable tendency for slightly more prominent changes. For example, increase of mean pRNFL thickness in patients with better than average refractive effect

<table>
<thead>
<tr>
<th>Table 1. Refraction before and one month after LASIK (n=62)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refraction</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Spherical equivalent, $M \pm \sigma$ (Min; Max)</td>
</tr>
<tr>
<td>Astigmatism, $Me (IQR)$</td>
</tr>
</tbody>
</table>

Note. $^*$ — $p<0.001$; $^{**}$ — $p<0.01$.
(>7.0 Diopters) was 1.44±2.72 μm (1.78±3.37%) as compared with 0.69±2.07 μm (0.80±2.56%) in patients with lower effect. Actual changes even in best refractive effect (11.75 Diopters) were 3 μm, while calculated value was 1.8 μm. In this specific case, for instance, mean GCIPL only increased by 1 μm (calculated value 1.75 μm), and retinal thickness in the foveal area did not change (was calculated to decrease by 2.5 μm).

**Discussion**

The changes of the parameters measured with OCT, primarily pRNFL and GCIPL, are considered important criteria in early detection and assessment of primary open-angle glaucoma progression [18–22]. The patients with high myopia, however, can prove challenging in terms of diagnosing glaucoma with OCT due to pathological changes in those patients and the way optical system of a myopic eye can influence OCT results [3, 4, 6, 23, 24]. The only question in this regard that has been relatively well studied is influence of axial eye length on the parameters measured with OCT in patients with refractive anomalies [1–6]. The impact of optic changes after keratorefractive surgeries on OCT measurements has not been studied sufficiently yet.

Another matter requiring evaluation is a theoretical possibility of increased IOP during eye fundus surgeries causing injury, primarily to pRNFL. To assess the possibility, some authors employed scanning laser polarimetry performed on GDx VCC (Carl Zeiss Meditec, U.S.A.) de-

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n</th>
<th>Before surgery</th>
<th>After surgery</th>
<th>Change</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retinal thickness, μm, M±σ (Min; Max)</td>
<td></td>
<td></td>
<td></td>
<td>-2.5±2.4</td>
<td>-1.0±1.0</td>
</tr>
<tr>
<td>Central area</td>
<td>59</td>
<td>258.6±21.1 (200; 311)</td>
<td>258.1±21.2 (198; 311)</td>
<td>(-3; 2)</td>
<td>1.3</td>
</tr>
<tr>
<td>Inner temporal quadrant</td>
<td>61</td>
<td>302.2±14.1 (269; 331)</td>
<td>302.2±13.9 (268; 334)</td>
<td>(-7; 7)</td>
<td>(-2; 2)</td>
</tr>
<tr>
<td>Inner upper quadrant</td>
<td>60</td>
<td>313.7±12.7 (280; 341)</td>
<td>313.5±11.9 (277; 335)</td>
<td>(-8; 8)</td>
<td>(-2.3; 2.7)</td>
</tr>
<tr>
<td>Inner nasal quadrant</td>
<td>61</td>
<td>316.8±14.6 (273; 362)</td>
<td>315.5±14.0 (271; 354)</td>
<td>(-8; 4)</td>
<td>(-2.2; 1.4)</td>
</tr>
<tr>
<td>Inner lower quadrant</td>
<td>59</td>
<td>309.5±13.2 (278; 344)</td>
<td>309.6±12.9 (278; 342)</td>
<td>(-6; 6)</td>
<td>(-1.8; 2.0)</td>
</tr>
<tr>
<td>Mean</td>
<td>51</td>
<td>269.6±10.5 (247; 293)</td>
<td>270.0±10.3 (247; 293)</td>
<td>0.3±1.9</td>
<td>0.1±0.7</td>
</tr>
<tr>
<td>Retinal macular volume, mm³, Me (IQR)</td>
<td>52</td>
<td>9.7 (9.5; 9.93)</td>
<td>9.7 (9.5; 9.9)</td>
<td>0</td>
<td>(-0.1; 0.1)</td>
</tr>
<tr>
<td>Mean, Me (IQR)</td>
<td>52</td>
<td>75 (73; 78)</td>
<td>76 (74; 79)</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Minimal, M±σ (Min; Max)</td>
<td>52</td>
<td>75.7±4.7 (66; 85)</td>
<td>76.4±4.3 (66; 85)</td>
<td>0.8±1.4</td>
<td>1.1±1.9</td>
</tr>
</tbody>
</table>

**Table 2. Parameters of the cornea measured by OCT before and one months after LASIK**

**Table 3. Parameters of pRNFL thickness measured by OCT before and one month after LASIK, M±σ (Min; Max)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n</th>
<th>Before surgery</th>
<th>After surgery</th>
<th>Change</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>62</td>
<td>84.2±5.5 (69; 102)</td>
<td>85.2±5.8 (72; 103)</td>
<td>1.0±2.3</td>
<td>1.2±2.9</td>
</tr>
<tr>
<td>Temporal quadrant</td>
<td>59</td>
<td>73.1±15.4 (40; 119)</td>
<td>74.6±15.8 (40; 125)</td>
<td>1.5±3.3</td>
<td>2.2±4.7</td>
</tr>
<tr>
<td>Upper quadrant</td>
<td>59</td>
<td>103.5±13.4 (75; 155)</td>
<td>103.8±13.7 (76; 158)</td>
<td>0.3±3.9</td>
<td>0.4±3.8</td>
</tr>
<tr>
<td>Nasal quadrant</td>
<td>58</td>
<td>58.1±8.6 (46; 90)</td>
<td>58.4±9.4 (43; 96)</td>
<td>0.3±3.1</td>
<td>0.4±5.5</td>
</tr>
<tr>
<td>Lower quadrant</td>
<td>62</td>
<td>103.5±12.6 (78; 136)</td>
<td>103.9±12.8 (78; 133)</td>
<td>0.4±5.6</td>
<td>0.5±5.5</td>
</tr>
</tbody>
</table>

Note. * – p<0.001; patients with incorrectly taken measurements and outlying values were excluded.
pRNFL after LASIK are low in most patients, and do not refraction weakened by 1 Diopter. Obviously, changes in was observed in the present study when patient’s ocular iliard effect, but of lower magnitude (about 0.11 μm/dptr) pRNFL thickness when adjusted for signal strength. Sim- for 1 Diopter, which amounted to 0.25 μm increase of or 0.4 μm in average while contact lens power decreased spectral OCT showed pRNFL thickening for 0.5 μm [16] (-)10.0 Diopters (0.25 μm/dptr). Studies that utilized irrelavant thickening of pRNFL by 2.5 μm with a lens of sic” OCT [17]. It’s worth noting that there was statistically absent in the results of only one study that utilized “clas-

The mentioned studies allowed ruling out the dam-
ing effect of the IOP increase that happens during the surgery. Degree of myopia did not play any role in this be-
cause it does not affect the magnitude of intraoperative IOP increase.

Another concern about possible effect of corneal re-

fraction change on pRNFL parameters could not be solved to a sufficient degree due to patients having mean myopia of (−)3 to (−)5 Diopters, with only two studies having pa-

Ents with myopia reaching (−)5.46 to (−)6.43 Diopters [10, 13]. Relatively low refraction change seem to have almost no effect on OCT measurements. In the present study, mean myopia was significantly higher — (−)7.5 Dio-

The present study only included patients with mod-

erate or high myopia, but looking at the results of individ-

uals with hypermetropia could also prove interesting. Taking into account the data on simulations with contact lenses, the effect of refractive surgeries on OCT measure-

ments in patients with high hypermetropia can be as in-

significant as in patients with myopia, although it needs further research.

Conclusion

In patients with moderate or high myopia, the effect of LASIK on retinal OCT measurements and pRNFL is insignificant (no more than 1.3% from baseline in average, with an exception of pRNFL thickness in the tempo-

ral quadrant). In patients with very high myopia, weaken-
ing of corneal refraction for more than 10 Diopters produces an optical effect of 2–3 μm increased mean thickness of pRNFL and GCIPL, which should be consid-

ered when evaluating such patients for glaucoma.

Author contributions:

Study conception and design: A.Sh., S.K., I.M., M.K. Acquisition and processing of data: S.K., I.M., M.K. Statistical analysis: A.Sh., M.K. Drafting of manuscript: A.Sh., M.K. Critical revision: A.Sh., S.K., I.M.

The authors declare that there are no conflicts of interest.
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