STUDY OF ABLATED SURFACE SMOOTHNESS AND THERMAL PROCESSES IN RABBIT CORNEA TREATED WITH MICROSCAN-VISUM AND MICROSCAN-PIC EXCIMER LASER SYSTEMS

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In ophthalmology, excimer lasers are used for treating different refractive disorders. The performance of an excimer laser station can be assessed by a number of criteria, such as cornea surface smoothness after the ablation, differences between the diameter of the postoperative optical zone that received full correction and the diameter of the programmed optical zone, and cornea heating during the surgery. The article presents the results of the assessment of three Russian excimer laser systems: MicroScan-PIC 100 Hz, MicroScan-Visum 300 Hz and MicroScan-Visum 500 Hz (Optosystems Ltd.). The smoothness of the ablated surface was measured by New View — 5000 Zygo interferometer (Zygo Corporation, USA). Using PMMA plates, the ablated surface was formed tenfold with each laser as an imitation of the 3.0 D myopia surgical correction, with the optical zone diameter of 6 mm and the transition zone diameters of 2.3 mm for MicroScan-PIC 100 Hz and of 1.9 mm for MicroScan-Visum 300 Hz and MicroScan-Visum 500 Hz. Thermal processes in the cornea were studied in 15 grey chinchillas over 1 year old with a weight of 2–3 kg. With each of the laser systems, phototherapeutic keratectomy was performed on 5 eyes. The smoothest ablated surfaces were formed by MicroScan-Visum 500 Hz. Cornea temperature was the highest here (+ 3.95 °C by the end of treatment), but still within the range of values acceptable for modern scanning type lasers.

Keywords: excimer laser system, MicroScan-PIC 100 Hz, MicroScan-Visum 300 Hz, MicroScan-Visum 500 Hz, ablation, cornea, error of refraction

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According to the World Health Organization, the number of people with refractive errors has been steadily increasing in recent decades. Data obtained from various authors indicate that there is about 27 to 45 % prevalence of myopia and myopic astigmatism among people of working age in Russia, US and EU [1]. However, there has been an improvement both in the traditional (spectacle and contact lens correction) and in the surgical methods of correction of refractive errors.
Keratorefractive surgery with various lasers has improved rapidly [2–4].

In recent years, ophthalmologists from different countries have gained extensive clinical experience in the use of excimer laser for correction of refractive errors [3, 5–11]. In Russia, researchers are working to design excimer laser systems and introduce them into clinical practice. Since the late 1980s, Eye Microsurgery, an intersectional research & technology complex, has created excimer lasers and deployed them into clinical practice. This complex has been doing this in cooperation with laser manufacturer – Physics Instrumentation Center of the General Physics Institute, Russian Academy of Sciences and Optosystems. Excimer laser system MicroScan-PIC was presented in 2000. Along with operations based on LASIK (laser in situ Keratomieusis) and TransPRK (transepithelial photorefractive keratectomy) standard technologies, the laser allows to perform personalized operations based on corneal topography and aberrometry data. Analysis of clinical and functional results of such operations showed that they are of high predictability, stability and safety [12].

Several criteria are used for objective assessment of the quality of excimer laser systems. One of them is the smoothness of corneal surface formed by the excimer laser. A smoother corneal surface facilitates normal course of corneal epithelialization after surgery and minimizes the likelihood of fibroplasia [13]. Quantitative characteristics of smoothness allow to obtain a measurement with interferometric microscopes from Zygo Corporation (USA). A number of investigators have shown that surface smoothness is higher in flying spot scanning lasers than in full-aperture lasers and lasers that use scanning slit and stopped down ablation formation system [14,15].

Another important criterion is the association of the diameter of optical zone of full-aperture lasers created by the laser light spot diameter. This association is an important criterion in producing an optical zone of the required diameter. As a rule, that the diameter of the optical zone is 6 mm, the diameter of the laser light spot is about 3.0 mm. Each laser system allows to obtain differen the light spot diameters — 1.15 and 0.95 mm respectively. MicroScan-Visum 300 Hz and MicroScan-Visum 500 Hz (this was due to different excimer laser light spot diameters — 1.15 and 0.95 mm respectively). Ten lenses for each of the lasers was formed on the plates, after which all the lenses were measured using interference microscope New View — 5000 Zygo. The following indicators characterizing the quality of the formed lens surface were identified:

- RMS — root mean square deviation of the surface points relative to the average height across the study area;
- PV — distance between the highest and lowest points of the study area;
- Ra — average deviation of surface points from the middle surface.

Moreover, it was considered that the better the surface smoothness, the smaller the value of these indicators would be.

Thermographic analysis of corneal temperature changes was conducted in 15 gray chinchilla rabbits, more than one year old and with live weight of 2–3 kg. The experiment was approved by the Intercollegiate Ethics Committee (Minutes No 10–12 of 18 October 2012). Each of the three laser systems was used to operate on 5 eyes (one eye per animal). 15 min before the surgery, the rabbits were administered with 2 ml of ranolanium solution. The surgery was performed under local anesthesia (triple instillation of 1 % inokain solution). The estimated ablation depth during PTK was 52 microns.

Thermal imaging complex Thermo View Ti30 (Raytek, USA) was used to measure the corneal temperature. Imaging was carried out in a room with ambient temperature of 16.7 °C at a distance of 60–70 cm with frequency of 1 Hz and up to 0.1 °C accuracy. On the PC, thermal imager data were converted to thermographic map using a software tool supplied with the device, and the maximum and minimum corneal temperatures during the surgery were determined. Corneal emissivity was set at 0.93 (like water), i.e. it was considered that 0.93 of the total corneal radiation enters the device and the device adds 0.07 when calculating the temperature. For example, if the temperature is 37.3 °C for k = 0.93, then temperature will be equal to 36.1 °C for k = 1 for the same thermogram.

Data was statistically processed using software programs Statistica 6.0 (StatSoft, USA) and Excel 2003. Variation statistics methods were used. The results were presented as arithmetic mean (M) and standard deviation (σ). Student’s t-test for independent cases was used to compare the means and evaluate the significance of differences (p = 0.05).

RESULTS

The results of comparative analysis of the quality of ablation surface of lens are presented in table 1. Laser system MicroScan-Visum 500 Hz yielded the best smoothness.
Table 1. Indicators of the ablation surface quality of lens formed on polymethylmethacrylate plates using radiation from MicroScan-PIC 100 Hz, MicroScan-Visum 300 Hz and MicroScan-Visum 500 Hz systems, nm (M ± δ, p <0.05)

<table>
<thead>
<tr>
<th>Laser system</th>
<th>RMS</th>
<th>PV</th>
<th>Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroScan-PIC 100 Hz</td>
<td>392 ± 75</td>
<td>6454 ± 1752</td>
<td>311 ± 68</td>
</tr>
<tr>
<td>MicroScan-Visum 300 Hz</td>
<td>351 ± 35</td>
<td>2754 ± 298</td>
<td>282 ± 25</td>
</tr>
<tr>
<td>MicroScan-Visum 500 Hz</td>
<td>338 ± 25</td>
<td>2960 ± 51</td>
<td>268 ± 20</td>
</tr>
</tbody>
</table>

DISCUSSION

Laser system MicroScan-Visum 500 Hz yielded the smoothest ablative surfaces. Although corneal heating obtained with this laser was the highest (+3.95 °C by the end of surgery), the value was within acceptable range. For example, during LASIK surgery for treatment of high myopia Sph -9.25D using popular laser Schwind AMARIS 500 Hz (SCHWIND eye-tech-solutions, Germany), the corneal temperature increased by 3.73 °C [21].

CONCLUSIONS

All the three laser systems studied can create a high-quality ablation surface. However, the MicroScan-Visum 500 Hz system gave the best result. The laser yielded the highest corneal heating during phototherapeutic keratectomy in rabbits, but the value did not exceed the permissible values. After the study, MicroScan-Visum 500 Hz was recommended for clinical research.
Table 2. Dynamics of thermal processes in a rabbit cornea during phototherapeutic keratectomy using laser systems MicroScan-PIC 100 Hz, MicroScan-Visum 300 Hz and MicroScan-Visum 500 Hz, °C (M ± δ, p<0.05)

<table>
<thead>
<tr>
<th>Laser system</th>
<th>Initial corneal temp.</th>
<th>Maximum corneal temp. at the end of surgery</th>
<th>Increase in temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroScan-PIC 100 Hz</td>
<td>31.0 ± 0.03</td>
<td>32.2 ± 0.88</td>
<td>1.17 ± 0.05</td>
</tr>
<tr>
<td>MicroScan-Visum 300 Hz</td>
<td>31.8 ± 0.07</td>
<td>33.2 ± 1.21</td>
<td>1.42 ± 0.34</td>
</tr>
<tr>
<td>MicroScan-Visum 500 Hz</td>
<td>31.0 ± 0.47</td>
<td>34.9 ± 1.36</td>
<td>3.95 ± 0.89</td>
</tr>
</tbody>
</table>

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