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Ten years of experience in the use of solid-state laser technology in refractive surgery

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ESSAY

Goal. To evaluate the advantages of solid-state lasers and ultraviolet radiation with a wavelength of 213 nm as applied to laser refractive surgery. To evaluate the effectiveness and safety of solid-state technology based on ten years of experience in the operation of refractive solid-state laser system "OLIMP-2000/213".

Material and methods. In the Clinic of Laser Eye Microsurgery A. Tikhov (Yaroslavl) since 2010, refractive operations are performed using solid-state technology. For eight years on a solid-state laser system "OLIMP-2000/213" the clinic performed 4,700 operations using the LASIK and MAGEK methods.

Results and discussion. From the point of view of clinical application, the advantages of solid-state technology are due to the physical properties of UV radiation with a wavelength of 213 nm. It provides high radiation tolerance to the degree of hydration of the cornea and the presence of a layer of liquid on its surface, as well as to the microclimate in the operating room. The operational advantages of solid-state refractive system are determined by the design of the laser emitter: this technology does not require expensive preventive works, it frees the user from issues of acquisition, storage and operation of gas mixtures.

The conclusion. The results of a decade of experience in the operation of solid-state laser refractive system characterize solid-state technology as a safe, clinically effective and economically advantageous direction for the development of laser refractive surgery.

Relevance

Despite the rapid development of laser surgery of the cornea, the excimer laser remains the main instrument of most refractive surgeons for two decades already. "Quality and reliability, time-tested" - the principle relating to excimer lasers. And it's hard to argue with this. Nevertheless, at the end of the last century, studies began abroad on searching for alternative sources of ultraviolet (UV) radiation for the needs of refractive surgery. As a result, a solid-state laser unit LightBlade (Novatec Laser Systems Inc., USA) appeared, followed by solid-state refractory platforms LaserSoft (Katana Technologies, Germany) and Pulzar Z1 (CustomVis, Australia), generating UV radiation with a wavelength of 210 and 213 nm respectively [1, 9]. In studies, the safety of this type of radiation for all eye structures has been proven [1, 6, 10-12]. In addition, solid-state lasers and the radiation generated by them, by some parameters, were even more "convenient" than excimer lasers. In particular, this concerns their maintenance and operation, as well as the physical properties of the radiation itself, which provide greater stability of the system's energy indicators during the operational day and allow working in the so-called "wet ablation" mode.

Despite the fact that solid-state technology has long been used in lasers for photocoagulation and photodegradation of eye tissues, it has not been widely used in refractive surgery. And if abroad and in some countries of the former Soviet Union successfully using the LaserSoft and Pulzar Z1, in Russia, according to our data, there are no such platforms. Perhaps, therefore, solid refractive technology for refractive surgeons in our country is a sphere of heightened interest, on the one hand, criticism and discussion, on the other.

Material and methods

In 2007, at the Laser Eye Microsurgery Clinic A. Tikhov (Yaroslavl), work began on the development of a solid-state refractive scanning laser system. In 2009, her clinical trials began. In 2010, the OLIMP-2000/213 system was registered and certified, which allowed it to be used as a second platform for performing refractive operations [2, 3]. Until 2013, operations in the clinic were simultaneously performed on the excimer laser system "OLIMP-2000/193" and on the solid-state system "OLIMP-2000/213". In 2013, we completely switched to solid-state technology. Since 2011, the solid-state laser system «OLIMP-2000/213» has been successfully operating at the Republican Center for Eye Microsurgery in the city of Ukhta (the Republic of Komi), and since 2015 in the branch of our clinic (Cherepovets). During 8 years of operation on a solid-state system, the clinic team was able to compare the clinical results obtained on platforms generating radiation with a wavelength of 193 and 213 nm, the features of their functioning, operation and maintenance. The results obtained convinced us of the efficiency, stability, predictability and safety of the solid-state system [4, 5]. In addition, there was a decrease in labor costs for its maintenance and a reduction in the cost of operations. That is why the choice was made in favor of solid-state technology, and excimer system, effectively worked in the clinic and branches for more than 10 years, were disposed of.

For eight years on a solid-state laser system "OLIMP-2000/213" the clinic performed 4,700 operations using the LASIK and MAGEK methods. The duration and course of the early postoperative period, the timing of achieving maximum visual acuity are comparable with those after the operations performed on the excimer laser equipment.

Results and discussion

From the point of view of clinical application, the advantages of solid-state technology are due, first of all, to the physical properties of UV radiation with a wavelength (λ) of 213 nm. It was found that water, physiological saline, balanced saline solution have lower absorption coefficients and greater penetration depth for radiation with λ = 213 nm (in comparison with λ = 193 nm) [7, 8]. In addition, radiation with λ = 213 nm is closest to the maximum absorption of corneal collagen. The combination of the above factors ensures a high tolerance of this type of radiation to the degree of hydration of the cornea and the presence of a layer of liquid on its surface, as well as a lower sensitivity of radiation to the moisture and temperature in the operating room. All this makes it possible to ablate the stroma of the cornea in the most physiological state of the cornea, thus forming uniform and smooth surfaces. It should also be noted that the small spot size combined with high generation frequency and low pulse energy provide accurate ablation with less energy and thermal stress on the corneal stroma. The operational advantages of solid-state refractive system, in turn, are due to the actual design of the laser emitter. Laser radiation of the infrared spectrum (λ = 1064 nm) is formed by optical pumping of a neodymium-doped Aliumumitrite garnet (Nd: YAG) crystal. Working ultraviolet radiation with a wavelength of 213 nm is obtained by nonlinear conversion of the main radiation λ = 1064 nm into the second (λ = 532 nm), third (λ = 355 nm) and fifth (λ = 213 nm) harmonics. To increase the resource of key elements of nonlinear optics, modern protection technologies (heat stabilization, evacuation, special coatings) are used. This technology does not require expensive preventive works necessary for long-term, high-quality and uninterrupted functioning of the laser emitter.

In addition, the operation of solid-state system frees the user from issues related to the acquisition, storage, operation, replacement and disposal of gas mixtures containing aggressive for laser elements and toxic fluorine. And the only consumable element in the maintenance of the plant is distilled water in the cooling system.

The innovative design of the body of the solid-state refractive system of the third generation, as well as its small dimensions and weight, make it possible to state for the first time an absolutely new quality for refractive lasers - mobility. The installation can be easily moved both within the same building and within the framework of mobile medical programs. For convenience of transportation the unit is dismantled for 4 compact modules. The design of the laser provides resistance to misalignment. Assembly and setup of the installation in a new work place takes no more than two hours; exit to the operating mode - no more than 30 minutes. The dimensions of the installation allow working in small operating areas, and features of radiation with a wavelength of 213 nm allow paying less attention to strict monitoring of temperature and humidity in the operating room.

The system of automatic maintenance of energy in real time guarantees a high level of stability of ultraviolet radiation. With an operating energy of 0.5 mJ, Gaussian energy distribution in a spot 0.5 mm in diameter and a generation frequency of 300 Hz, the energy spread is less than 3%.

Switching to diode pumping of the active element allowed to reduce energy consumption several times and significantly increase the energy efficiency of system. A tracking system operating in the visible spectrum with a high resolution, in the non-inertial mode to capture the iris pattern, tracks all eye movements, including rotational ones. A highly detailed image on the monitor allows the surgeon to carry out the operation "on the monitor".

The software allows performing operations of personalized ablation and operations using a tissue-preserving algorithm. The additional option provides a wide range of customized tools for conducting separate stages of non-penetrating deep sclerectomy. In addition, the software automatically controls the work of the engineer, protecting against errors related to the human factor; and also maintains a full account of all the manipulations of the surgeon and engineer in the form of logging and audio registration.

Conclusion

Ten-year experience in the technical operation of solid-state laser refractive plants confirmed all the advantages of UV radiation with λ = 213 nm, described earlier in foreign sources. Own 8-year experience of using solid-state laser technology in clinical practice has confirmed its effectiveness and safety. Stability of operation and simplified algorithm of maintenance of the solid-state plant, as well as the absence of expensive expendable materials, allowed to reduce operating costs and cost of refractive operations.

The combination of the above factors characterizes solid-state technology as a clinically effective and economically advantageous direction for the development of laser refractive surgery.

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