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Modified technique of hybrid phacoemulsification

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Aim — to develop a modification to femtosecond laser-assisted (hybrid) phacoemulsification (PE). **Material and methods**. Modified hybrid PE was performed in 225 patients (267 eyes) with grade II-IV lens nuclei in terms of their density. Conventional PE was performed in 237 patients (278 eyes). **Results**. By utilizing the suggested technique of PE, one can avoid certain problems of conventional surgery and optimize nucleus fragmentation and emulsification steps. **Conclusions**. The suggested modification to hybrid PE enables effective removal of grade II-IV cataract lenses at minimum ultrasonic load.

***Keywords**: cataract, phacoemulsification, lens nucleus, nucleus fragmentation, femtosecond laser.*

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Seeking to improve phacoemulsification (PE) technology, effective methods of minimally invasive nucleus fragmentation and emulsification have been developed, enabling less ultrasound exposure and, thus, less negative effects on intraocular structures. Modern surgical techniques ensure minimal surgical trauma, regardless lens density and the presence of ocular comorbidity [1—5].

The major advances in cataract lens removal include recent introduction of femtosecond (FS) laser. It is used to perform three key steps of the procedure: corneal tunnel incision, round capsulorhexis, and prefragmentation of the nucleus [6—8]. As we have already suggested in our previous publications, this improvement direction for cataract treatment can well be called hybrid phacoemulsification — by analogy from cardiovascular surgery. In cardiovascular surgery, the hybrid approach is promising and progressive. It combines advantages of conventional and minimal invasive endovascular surgery, considerably reducing intraoperative trauma during open-heart procedures. In cataract surgery, the use of FS laser in combination with classical ultrasonic phacoemulsification allows to perform some complication-prone technical steps on a "closed" eyeball.

The expediency of utilizing a FS laser to make a corneal tunnel incision is being currently debated. Many cataract surgeons do not regard such a measure as advantageous, particularly due to an associated increase in surgery duration. At the same time, the overwhelming majority agrees that FS laser-assisted capsulorhexis is more precise, i.e. perfectly round well-centered and strictly predetermined in diameter (with an accuracy within 0.1 mm) ensuring proper positioning of the intraocular lens (IOL) and even distribution of tension in the capsular bag, which is unobtainable with manual techniques. All this is especially important in premium-class IOL implantation, which is more demanding in accuracy of the refractive result [6, 7, 9].

Femtosecond laser enables treatment of all nuclear layers with the aim of its prefragmentation. The software allows for both radial and circular cuts (of a given diameter) as well as their combination at the request of the surgeon, hence, providing a significant reduction in ultrasonic power level and exposure time as compared to conventional PE. As reported by most of the researchers, incorporation of FS laser technology decreases the effective phacoemulsification time by several times [7, 10-12].

As shown by our experience with more than a 1,000 hybrid surgeries, there is still room to improve the intraoperative use of FS laser. It is also possible to solve some specific problems associated with this technology, such as pupil constriction due to laser-induced intensive release of prostaglandins from the iris [13,14]. Modifications to the technique of capsulorhexis aimed at prevention of partial coagulation of the anterior cortex would be also in demand. The mentioned coagulation takes place during anterior capsulotomy and greatly complicates further removal of nuclear masses and increases the duration of irrigation/aspiration as well as the required volume of irrigation solution.

Aim — to develop a modification to femtosecond laser-assisted hybrid phacoemulsification.

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Material and methods

Surgical treatment was performed in 462 patients (545 eyes). The follow-up period was up to 6 months. Group 1 (main group) consisted of 225 patients (267 eyes) aged from 56 to 77 years (63.9±2.2 years on average) who underwent ultrasonic phacoemulsification with FS laser-assisted capsulorhexis and prefragmentation of the lens nucleus according to a self-developed technique. These include 69 (25.8%) cases of grade II nuclei in terms of their density (Buratto's classification), 135 (50.6%) grade III and 63 (23.6%) grade IV cases. Group 2 (controls) included 237 patients (278 eyes) aged from 55 to 77 years (63.3±2.2 years on average), of them 74 (26.6%) grade II nuclei cases, 138 (49.7%) grade III cases, and 66 (23.7%) grade IV cases. These patients also received FS laser-assisted PE but this time according to conventional technique of capsulorhexis and nucleus prefragmentation, which is widely described in specialized literature.

Ophthalmic examination was performed before the surgery and then at days 1 and 3, months 1, 3, and 6. Patients with hypermature or complicated cataracts, narrow rigid pupils (preoperative mydriasis of less than 5.5 mm), lens subluxation, concomitant severe diabetes mellitus and those after previous surgical intervention on the eyeball were excluded from this study.

Besides general ophthalmic examination, the percentage of 'completely transparent corneas', which implies smooth and shiny ones with no folds in Descemet's membrane, was determined on postoperative day 1. Moreover, central corneal thickness and cellular density of posterior corneal epithelium (corneal endothelium) were assessed by means of SP-3000P non-contact microscope (Topcon, Japan) before and 3 months after the surgery.

In all cases a VICTUS femtosecond laser (Technolas Perfect Vision, Germany) was used to perform anterior capsulorhexis and prefragmentation of the lens nucleus.

Nuclear fragments created with the FS laser were further emulsified with Stellaris phaco system (Baush & Lomb, USA). Viscoelastics used were the same in all cases. For intraocular correction of aphakia, hydrophobic acryl IOLs with intracapsular fixation were implanted in all patients.

For standardization of the results, the effective phacoemulsification time was calculated by multiplying the ultrasound power level by active time of the phacoemulsification system in each case. The number of cases, in which anterior cortical layers were coagulated in the course of capsulorhexis, was evaluated in both groups during emulsification and irrigation/aspiration steps. The volume of irrigation solution spent for emulsification of nuclear fragments and irrigation/aspiration of cortical masses was also assessed.

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In order to prevent intraoperative pupil constriction, which is due to prostaglandins release from the iris as the result of FS laser treatment, the patients were prescribed instillations of prostaglandin synthesis inhibitors into the eye scheduled for surgery (3 times daily for 3 days before and 3 times in the morning of surgery). The second most important factor that determines the likelihood of pupil constriction is the time interval between FS laser step and emulsification. In both our groups, the said interval did not exceed 15 min (ranged from 5 to 14 min). Moreover, for maximum preoperative mydriasis, drugs were chosen that affect both pupillary sphincter and pupillary dilator.

Before surgery, as patient's details were being entered into the VICTUS, operating parameters were chosen depending largely on pupil diameter and nucleus density of the particular patient. In all cases, the capsulorhexis diameter was 5.2 mm, which ensures the most stable fixation of the IOL implanted in the capsular bag. In order to prevent laser coagulation of anterior cortical layers in the area of capsulorhexis and avoid associated difficulty in removing them afterwards, we reduced FS laser power level from 7,000 nJ (control group) to 6,700 nJ (main group) without having a negative impact on the quality of the opening. There were just a few cases of incomplete capsular cuts in the main group that did not, however, affect the shape of the opening after the flap was removed with forceps.

To minimize subsequent ultrasound exposure, we have proposed several modifications to femtosecond laser-assisted prefragmentation that allow for different density of the nuclei. Grade II nuclei from the control group received 4 laser-assisted radial cuts according to standard technique, while same-grade nuclei from the main group — 8, which, of course, slightly increased the total energy load, but enabled minimum or even zero ultrasound exposure during fragment removal. The power level of laser impulses was reduced from 7,000 nJ in the control group to 6,700 nJ in the main group.

In grade III nuclei patients from the control group we also performed 4 radial cuts but at 7,300 nJ. In the main group 8 radial cuts were combined with a 3 mm diameter central circular dissection at laser power level reduced to 7,000 nJ. This technique helped us to minimize ultrasound power level and exposure time during subsequent high-vacuum (up to 600 mmHg) emulsification of nuclear fragments.

As for grade IV nuclei, they received 8 laser-assisted cuts in both groups at different power levels (8,000-8,300 and 7,700 nJ respectively), but yet with no loss of fragmentation quality, even in deep nuclear layers. Moreover, in the main group the radial cuts were combined with a 3 mm diameter central circular dissection and the distance between the laser impact zone and posterior lens capsule was decreased from 700 to 500 microns. Reducing the thickness of nuclear matter left intact significantly simplified and accelerated the process of lens fragmentation. In the second step, we performed emulsification of the nucleus starting from the 3 mm diameter central zone that had been treated most intensively with the laser. First of all, a deep recess was formed (80—90% of the nucleus thick-

ness), which allowed other fragments to move freely (often without assistance) to the center of the capsular bag, from where they could be faster emulsified with much lower ultrasound power level and irrigation solution volume.

Removal of nuclear fragments was followed by irrigation/aspiration of remaining cortical masses. In 33 controls (11.9%) anterior cortical layers in the area adjacent to capsulotomy appeared coagulated, which greatly complicated their removal and resulted in approximately a threefold increase in the length of irrigation/aspiration as well as the volume of irrigation solution spent. In the main group, in which the laser power level during capsulotomy had been decreased, such a situation occurred just in 2 cases (0.8%), at that could well be conditioned by some distinctive features of these patients, especially, a significantly thinner anterior lens capsule.

A hydrophobic acrylic IOL was implanted into the capsular bag in all cases. Leftover viscoelastics were then removed from the anterior chamber using irrigation and aspiration. Corneal tunnel incisions were inspected for leakage.

Results and discussion

By utilizing the developed modifications to hybrid PE good results have been achieved in patients with various grades of nuclear density. The proposed algorithm of preparing the patient and minimum possible intervals between the first and second steps of the surgery allow to avoid intraoperative pupil constriction, which is rather common in femtosecond laser-assisted PE.

With laser power levels reduced by 300 nJ the problem of anterior cortical layers getting coagulated and stuck to the anterior capsule has been almost completely solved. The said problem if occurs greatly complicates lens removal, increases the volume of spent irrigation solution and, therefore, overall surgical trauma. The proposed surgical technique has reduced the incidence of this adverse event from 11.9% in the control group to 0.8% in the main group. It should be noted that a less significant change in laser power level (i.e. by 100—200 nJ or down to 6,800—6,900 nJ) does not provide the desired result, whereas a greater reduction is likely to disable capsulotomy and, thus, its expediency requires further investigation.

The proposed technical variants of FS laser-assisted nucleus prefragmentation enabled a significant decrease in energy load on ocular tissues during the second step of the surgery. In grade II nuclei patients our suggestions allowed high-vacuum emulsification of nuclear fragments with minimum ultrasound exposure. As for the effective phacoemulsification time, it changed from 0.83±0.17 sec in the control group, which was treated standarly, to 0.56±0.11 sec in the main group ($p<0.05$), which underwent the modified hybrid PE, i.e. decreased by the average of 32.5%.

In grade III nuclei patients the effective phaco time decreased by the average of 31.3% (from 2.97±0.53 sec in the controls down to 2.04±0.37 sec in the main group ($p<0.05$)).

In grade IV nuclei patients the said parameter decreased by the average of 22.7% (from 5.11±1.03 sec in the controls down to 3.95±0.81 sec in the main group ($p<0.05$)). Fragments emulsification started from the deep recess created in the central nucleus (80-90% of its thickness) allowed reduction in not only the total energy load on ocular tissues, but also the length of this surgical step.

There were no intraoperative complications in either group. After introducing instillations of prostaglandin synthesis inhibitors into preoperative preparation algorithm, the laser-induced pupil constriction for more than 2 mm (a typical problem of hybrid PE) occurred just in 7.7% of cases, which is much less often as compared with the data from other studies.

The results of the presented study confirm that the effective phaco time in hybrid PE is many times shorter than that in conventional PE indicating decreased surgical trauma. In particular, for grade II nuclei the said parameter went down from 2.78±0.51 sec in the controls (conventional PE) to 0.56±0.11 sec in the main group (modified hybrid PE), for grade III nuclei — from 4.59±0.91 sec to 2.04±0.37 sec, and for grade IV — from 8.37±1.73 sec to 3.95±0.81 sec.

Thus, the proposed modified technique of hybrid phacoemulsification is associated with significantly less ultrasonic load due to decreased duration of nuclear fragments emulsification as well as the volume of irrigation solution, which in turn has a positive effect on postoperative ocular status and the length of rehabilitation period. Postoperative follow up of these patients will be the objective of our future publications.

Conclusion

1. The proposed modification to hybrid PE enables effective removal of grade II-IV cataract lenses at minimum ultrasonic load.

2. By applying the developed algorithm of patient preoperative preparation, adhering to the minimum possible intervals between surgical steps, and reducing laser power levels during capsulotomy certain problems typical of hybrid technology can be almost completely avoided.

3. The suggested optimization of femtosecond laser-assisted fragmentation that allows for various densities of lens nuclei ensures less ultrasonic load on ocular tissues and faster fragments emulsification.

The author declares no conflict of interests.

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