25. World Health Organization. Nutritional anaemias: tools for effective prevention and control [electronic resource]. Geneva: World Health Organization; 2017. Available at: https://www.who.int/publications/i/item/9789241513067

26. Zheng J, Liu J, Yang W. Association of Iron-Deficiency Anemia and Non-Iron-Deficiency Anemia with Neurobehavioral Development in Children Aged 6-24 Months. *Nutrients*. 2021;13(10):3423. Published 2021 Sep 28. doi:10.3390/nu13103423

DIAGNOSTIC AND TREATMENT METHODS

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RESULTS OF CLINICAL APPLICATION OF DYNAMIC PNEUMOAPPLANATION METHODS OF THE CORNEA IN MYOPIA

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The introduction into clinical practice of research methods based on dynamic corneal pneumoapplanation significantly expanded the possibilities of clinical (in vivo) assessment of the "biomechanics" of eye structures in myopia. This review summarizes the results of using pneumoapplanation methods to assess biomechanical indices in initial myopia and after its laser correction.

Keywords: cornea, biomechanical properties, pneumoapplanation methods, myopia.

The size and shape of the fibrous (corneoscleral) envelope of the eye are the main components of refractive disorders formation. Myopic defocus can be associated primarily with an increase in the anteroposterior axis (APA) as well as an increase in corneal refraction. According to the three-factor theory of myopia pathogenesis by E.S. Avetisov, APA instability with a tendency to increase due to impaired mechanical properties of the sclera is an anatomical cause of progressive myopia [1]. On this basis, the main focus of biomechanical studies of the ocular fibrous membrane in myopia is related to the evaluation of various sclera parameters. On the basis of a set of studies (in vitro mechanical tests, measurement of eyeball stiffness, determination of the deformation coefficient and acoustic density of the sclera, ophthalmomechanography), it was established "that the range of elastic deformations of the sclera decreases and the contribution of the viscous component ..... increases with progressing myopia, resulting in irreversible stretching of the sclera and in an increase in the OPC" [2]. In high myopia, the sclera is characterized by a decrease in strength and elastic modulus predominantly in the equatorial and posterior regions, with these changes occurring first in the equatorial zone, followed by changes in the posterior part of the sclera.

The introduction into clinical practice of research methods based on dynamic corneal pneumoapplanation significantly expanded the possibilities of clinical (in vivo) assessment of the "biomechanics" of eye structures in myopia. This review summarizes the results of pneumoapplanation techniques application for biomechanical evaluation in initial myopia and after its laser correction.

Modern techniques of bidirectional pneumoapplanation of the cornea. The first device to use the effect of an air jet for dynamic corneal deformation was the ORA (Oclual Response Analyzer, USA). Biomechanical parameters generated by standard ORA software are corneal hysteresis (CH) and corneal resistance factor (CRF). CH is a conventional value reflecting visco-elastic properties of the cornea, while CRF characterizes the resistance of corneal tissue itself which would exist at zero ophthalmotonus [6, 39, 45-46].

Corvis ST technology (Oculus, Germany) belongs to an alternative method of biomechanical characteristics measurement using corneal pneumoapplanation. This device uses high-speed Scheimpflug camera to fix transverse section of cornea (4330 frames per second) during deformation in real time followed by program analysis to obtain different biomechanical indices, the most used ones according to literature data are as follows [2, 4, 17, 22-23, 35, 40, 42]:

- Applanation-1 Time (A1T), ms - time of the first applanation;
- Applanation-2 Time (A2T), ms - time of the second applanation;
- Applanation-1 Lenght (A1L), mm - diameter of the "flattened" corneal area during the first applanation;
- Applanation-2 Length (A2L), mm - diameter of the "flattened" cornea during the second applanation;
- Applanation-1 Velocity (A1V), m/s - inner corneal velocity during the first applanation (it indirectly reflects corneal viscosity);
- Applanation-2 Velocity (A2V), m/s - speed of corneal outward movement to the initial position at the second applanation (the higher the value, the higher the degree of corneal elasticity);
- Highest Concavity Peak Distance (HCPD), mm - diameter of maximum concavity, i.e. the distance between the two highest points of the cornea at its greatest concavity (it indirectly reflects corneal stiffness);
- Highest Concavity Radius (HCR), mm - radius of curvature of the concavity of the cornea at the greatest deformation;
- Deformation amplitude (DA), mm - amplitude of deformation, the value of displacement of the corneal apex at its maximum "indentation" relative to the original shape (MDA - maximum amplitude of deformation);
- Central corneal thickness (CCT), μm - thickness of the cornea in the central zone;
- Deformation Amplitude Ratio (DA Ratio) - ratio between the deformation amplitude at the corneal apex and the

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deformation amplitude in the paraoptical zone with a radius of 2 mm.

According to theoretical studies, the following changes in the indicated indices may indicate a decrease in corneal stiffness [27, 51]:

- decrease in the time (A1T) and length of the first applanation (A1L);
- increase in the first applanation velocity (A1V) and deformation amplitude (DA) during the first applanation;
- increase in amplitude of deformation (DA) and maximum amplitude of deformation (MDA);
- short peak distance (HCPD) and increased concavity radius (HCR);
- increased second applanation time (A2T), decreased second applanation diameter (A2L) and second applanation velocity (A2V);
- decrease in the amplitude of deformation (DA) during the second applanation.

It has been noted that the radius of greatest concavity (HCR), the rate of second aplanta (A2V) and its diameter (A2L) have large differences in terms of coefficient of variation, while the maximum amplitude of deformation (MDA) is a stable index [5, 49].

It should be noted that in addition to biomechanical parameters, both of the above devices allow determining a number of indices reflecting the level of intraocular pressure.

Results of dynamic corneal pneumoapplanation in baseline myopia. In a series of studies using ORA, a clear correlation between a significant decrease in CH and CRF and an increase in ROP (i.e., degree of myopia) was shown [6-7, 10-11, 28, 36]. At the same time, the difference in CH correlated with the interocular difference in the POC value between the two eyes of each patient [13]. On this basis, it was suggested that eyes with a lower CH value and more easily deformable fibrous membrane are at greater risk of ROP elongation. Most authors explain the decrease in CH value by the fact that the development of myopia is associated with a decrease in sclera and extracellular matrix thickness, an increase in the enzyme matrix metalloproteinase that destroys collagen. In addition, a decrease in collagen fibril diameter and proteoglycansynthesis content was found in the development of myopia, which leads to an additional decrease in sclera thickness and scleral tissue stretching. Similar changes can occur in the cornea during the development of myopia, with the corneal "biomechanics" reflecting its viscoelastic properties and mechanical strength of stromal collagen fibrils interacting with the extracellular proteoglycan matrix [36, 52].

At the same time, other studies did not reveal the above correlation, which may be related to the characteristics of the clinical material (age range, degree of myopia, ethnicity). Thus, with an average myopia of 2.35±2.49 D, no dependence of CH on refractive index was detected. The mean CH and CRF were 11.78 ± 1.55 (range, 6.93-16.53) and 11.81 ± 1.71 (range, 7.83-16.83) mmHg, respectively. These values did not differ significantly by age, gender, or race (the study included individuals from India, Singapore, and China) [24]. In another study with myopia ranging from (-) 9.00 to (-) 19.00 dpts, no correlation was found between biomechanical indices of bidirectional corneal pneumoapplanation and the degree of myopia. The mean values differed between women and men: CRF, 10.326 and 9.810 mmHg (P=0.0266); CH, 10.421 and 9.727 mmHg (P=0.0031), respectively. In addition, there was a negative correlation between biomechanical indices and age and a positive correlation with corneal thickness in the central zone [39].

In a comparative study using the Corvis ST device, 94 patients with myopia between (-) 0.5 and (-) 17.5 dptr aged 29 to 74 years and 25 "emmetropes" aged 19 to 75 years were examined [6]. In high degree myopia, there was an increase in outward applanation velocity (A2V) and peak distance (PD) (-0.398 ± 0.014 m/s and 2.48 ± 0.04 mm) compared to those in moderate degree myopia (-0.352 ± 0.009 m/s and 2.37 ± 0.03 mm) and emmetropia (-0.347 ± 0.012 m/s and 2.36 ± 0.06 mm). In addition, a positive correlation was found between the amplitude of deformation (DA) and the magnitude of APA and a negative corneal greatest concavity (HCR) index with the mean keratometry and APA data.

When comparing the results obtained using Corvis ST and ORA in 172 patients with different degrees of myopia, the dependence of the decrease in the index of the greatest corneal concavity (HCR) on the degree of myopia was revealed. Corneal hysteresis (CH) also tended to decrease with increasing degree of myopia [21].

In a study of 266 Indians with myopia between 19 and 36 years of age, 23 of 32 Corvis ST values were independent of the degree of myopia and only 9 were significantly different in high degree myopia [43]. In another study, the time required for the second applanation (A2T) and the amplitude of deformation (DA) were significantly lower for the second applanation, while the amplitude of deformation (DA) for the first applanation and the radius of deformation (DA Ratio) were higher for high degree myopia [38]. It should be noted that the deformation amplitude index (DA) is an indicator of corneal biomechanical properties and a decrease in corneal thickness is accompanied by an increase in its deformation potential.

In high myopia, we observed a decrease in the radius of greatest concavity (HCR), an increase in the maximum amplitude of deformation (MDA), a higher rate of second aplasia (A2V) and a decrease in its diameter (A2L), which, according to the study authors, indicates that the cornea is more deformable when the anteroposterior axis is increased [19]. Similar results were obtained in other comparative studies [6, 50].

Results of dynamic corneal pneumoapplanation after laser correction of myopia. Modern laser technologies of keratorefractive surgery used for myopia involve a change in corneal curvature (flattening) as a result of a varying degree of corneal thickness reduction due to the so-called ablation. In the currently most used methods of laser correction this is technologically realized on the basis of surface laser influence on the cornea without flap formation (PRK), preliminary flap formation (LASIK) and intrastromal removal of so called lenticule through a small incision (SMILE) [9, 44, 47-48, 50]. The necessity of clinical researches including methods of corneal pneumoapplanation is dictated by potential changes of initial "biomechanics" of a cornea due to its thickness reduction. Considering the known variability of pneumoapplanation technique indices, this review presents only studies in which postoperative changes in corneal "biomechanics" were compared with the initial data.

After LASIK, a decrease in preoperative CH and CRF values (from 11.52 +/- 1.28 to 9.48 +/- 1.24 and from 11.68 +/- 1.40 to 8.47 +/- 1.53 mmHg, respectively) and correlation of the degree of decrease with refractive effect was noted [18]. In other studies, after LASIK, CH and CRF decreased from 10.44 to 9.3 mmHg and from 10.07 to 8.13 mmHg. [26] and from 9.5 +/- 1.9 to 6.7+/-1.7 and from 9.7 +/- 1.8 to 8.0 +/- 1.6 mmHg, respectively [15]. In one study, the Delta score was used to characterize the reduction of CH and CRF after LASIK. The correlation with ablation depth was stronger for DeltaCRF (r=0.457) than for DeltaCH (r=0.271) [14]. When analyzing results after LASIK and its modification (LASEK), with a mean baseline CH of 10.8 +/- 1.5 mmHg, the mean postoperative ones decreased statistically significantly to 9.0 ± 1.3 and 8.6 ± 2.1 mmHg, respectively.

In a series of studies, a comparative assessment of changes in biomechanical parameters after different laser correction techniques was performed. The retrospective study presented changes in ORA and Corvis ST values after LASIK and SMILE (mean baseline myopia 5.16±1.42 and 5.43±1.17 Dpts, respectively). ORA data one month after the interventions showed a greater decrease in CH and CRF after LASIK (8.46±1.76 and 7.45±2.39; 9.99±1.76 and 9.43±1.55 mmHg after LASIK and SMILE, respectively) [16]. At the same time, a more pronounced decrease in the first aplasia time (A1T), greatest concavity (HC Time) and second aplasia time (A2T) was noted after SMILE, which, according to the authors, may reflect the preservation of greater corneal stiffness after the "flapless" procedure. At the same time, the increase in flattened corneal diameter at the second applanation (A2L), concave corneal radius of curvature (HCR) and maximum concavity diameter (HCPD) after LASIK, suggesting stronger corneal deformation to the inside during the air pulse.

More pronounced changes in CH and CRF after LASIK were also noted in other studies in high myopia correction, which presumably, in addition to an increase in ablation volume, could be due to the necessity of corneal flap formation during this intervention [29, 41]. The authors of other studies are of the same opinion [18, 25, 30, 34]. The results of comparative assessment of changes in biomechanical indices of ORA after LASIK and PRK (which does not imply formation of a superficial corneal flap) are indirectly in favor of this assumption [31]. The decrease of CH and CRF was more pronounced after LASIK (by 0.6 and 0.7 mmHg on average, respectively, compared to those after PRK). Moreover, irrespective of the correction technique, there was a high correlation between the initial myopia value and postoperative changes in biomechanical indices.

The effect of flap formation on corneal "biomechanics" after LASIK may be related to corneal delamination exactly in the surface layers of stroma. It has been revealed experimentally that anterior part of corneal stroma (from 100 to 120 microns) is the most rigid due to tightly interwoven anterior collagen plates. This physiological corneal property was confirmed in a study in which lower CH and CRF values after LASIK were found only in a subgroup of patients with high myopia, i.e. with increased ablation affecting these stromal layers [32].

The potential effect of stratification on corneal "biomechanics" is indirectly confirmed by the data of analysis of PRK and SMILE results, in which this technical element is absent. The average decrease of CH (by 1.9 and 2.5 mmHg) and CRF (by 3.4 and 3.2 mmHg), respectively, was found to be close in values [33].

From the position of excluding the possible influence of initial corneal biomechanical properties on postoperative results of pneumoapplanation it is worth mentioning an original study from the methodological point of view in which the so-called "paired-eyed" design was used: in a group of 30 patients with medium degree myopia LASIK was performed in one eye and SMILE in the other eye [29]. The results obtained are in a certain contradiction with the above studies: 6 months after LASIK and SMILE the CH and CRF values were 9.02±1.27 and 8.07±1.26; 8.95±1.47 and 7.77±1.37 mm Hg respectively, i.e. there was no tendency for a more pronounced decrease of biomechanical indices after LASIK. It may have been due to limitations in the degree of initial myopia.

In conclusion of this section, the main conclusion of two foreign literature reviews concerning the results of pneumoapplanation after various techniques of laser myopia correction is that SMILE "flapless" ("non-flap") technology, involving preservation of corneal surface layers, has less effect on changes in biomechanical indices [37,53].

Conclusion. The research results presented in the review indicate that in myopia the clinical application of corneal pneumoapplanation techniques to determine biomechanical indices may address two main objectives:

1. evaluation of biomechanical changes of the fibrous membrane with increasing anteroposterior axis value and, as a consequence, myopia;

2. to analyze the dependence of corneal "biomechanics" changes due to corneal thickness reduction on technological peculiarities of laser refractive interventions.

In general, the results obtained while solving the above-mentioned tasks are of expected character. Both a significant increase in PPO axis in high myopia and a decrease in corneal thickness as a result of laser surgery are accompanied by a certain decrease in various biomechanical indices determined by bi-directional corneal pneumoapplanation. According to the majority of sources, flap formation and increased ablation volume make a "decisive contribution" to the change of biomechanical indices during laser correction.

In spite of the zone of application of mechanical influence of pnevoapplanation methods (cornea!), it is necessary to consider that anatomic integrity of sclera and cornea as components of fibrous membrane to some extent complicates selective evaluation of their biomechanical properties, because the applanation "response" under influence on cornea most likely depends on fibrous membrane condition in general. Nevertheless, considering the "causality" of biomechanical changes, we can conventionally consider that at initial myopia they can be connected with sclera structure disturbances, and after laser refractive surgery - with cornea.

In perspective, from a practical point of view, the solution of the first problem can contribute to improving the monitoring algorithm for progressive myopia and the second one - to assess reliably the intraocular pressure level after laser myopia correction using aplanar tonometry techniques.

It should be emphasized once again that at initial myopia and analysis of pneumoapplanometry data one should consider the potential influence of not only corneal condition but also the known biomechanical changes in the sclera as a component of the fibrous membrane increased in size to various degrees on the findings. Biomechanical "response" to targeted pneumoapplanation of only cornea does not exclude "participation" in its formation of the sclera as well. Proceeding from it, researches in this direction can be focused on experimental biomechanical tests which algorithm will demand the decision of questions connected with reception of isolated samples of a cornea and a choice of testing technique.

Reference

1. Avetisov E.S. Blizorukost' [Myopia]. Meditsina [Medicine. 2nd ed., 1999; 288 (In Russ.).]

2. Antonyuk V.D., Kuznetsova T.S. Issledovanie biomekhanicheskikh svoistv rogovitsy na pribore CORVIS ST (Oculus, Germaniya) u patsientov s miopiei i miopicheskim astigmatizmom [Study of corneal biomechanical properties on CORVIS ST device (Oculus, Germany) in patients with myopia and myopic astigmatism]. Oftal'mokhirurgiya [Ophthalmosurgery. 2020; 4:20-28 (In Russ.).]

3. Iomdina E.N., Bauer S.M., Kotliar K.E. Biomekhanika glaza: teoreticheskie aspekty i klinicheskie prilozheniya [Eye biomechanics: theoretical aspects and clinical applications]. Real'noe Vremya [Real Time. Moscow, 2015 (In Russ.).]

4. Solodkova E.G., Balalin S.V., Fokin V.P. Otsenka zavisimosti biomekhanicheskikh svoistv

rogovitsy ot topometricheskogo i biometricheskogo pokazatelya [Evaluation of corneal biomechanical properties dependence on topometric and biometric index] Sovremennye problemy nauki i obrazovaniya [Modern problems of science and education. Moscow: 2021; 3: 0.17513/spno.30895 (In Russ.).]

5. Ali N.Q., Patel D.V., McGhee C.N. Biomechanical Responses of Healthy and Keratoconic Corneas Measured Using a Noncontact Scheimpflug-based Tonometer Invest Ophthalmol Vis Sci. 2014; 55: 3651–3659. doi: 10.1167/iovs.13-13715

6. Lee R., Chang R.T., Wong I.Y. [et al.] Assessment of corneal biomechanical parameters in myopes and emmetropes using the Corvis ST. Clin Exp Optom. 2016; 99(2): 157-162. doi:10.1111/cxo.12341.

7. Jiang Z., Shen M., Mao G. [et al.] Association between corneal biomechanical properties and myopia in Chinese subjects. Eye (Lond). 2011; 25(8): 1083-1089. doi:10.1038/eye.2011.104.

8. Bailey MD, Zadnik K. Outcomes of LASIK for myopia with FDA-approved lasers. Cornea. 2007; 26: 246–254. doi.org/10.1097/ICO.0b013e318033dbf0.

9. Bailey MD, Zadnik K. Outcomes of LASIK for myopia with FDA-approved lasers. Cornea. 2007; 26: 246–254. doi:10.1097/ICO.0b013e318033dbf0.

10. Altan C., Demirel B., Azman E. [et al.] Biomechanical properties of axially myopic cornea. Eur J Ophthalmol. 2012; 22(7): 24-28. doi:10.5301/ejo.5000010

11. M. Shen, F. Fan, A. Xue [et al.] Biomechanical properties of the cornea in high myopia. Vision Res. 2008; 48(21): 2167-2171. doi:10.1016/j.visres.2008.06.020.

12. Galletti J.G., Pförtner T., Bonthoux F.F. Improved keratoconus detection by ocular response analyzer testing after consideration of corneal thickness as a confounding factor. J Refract Surg. 2012; 28(3): 202-208. doi:10.3928/1081597X-20120103-03.

13. Chang P., Chang S., Wang J. Assessment of corneal biomechanical properties and intraocular pressure with the Ocular Response Analyzer in childhood myopia. Br J Ophthalmol. 2010; 94(7): 877-881. doi:10.1136/bjo.2009.158568.

14. Chen S., Chen D., Wang J. Changes in Ocular Response Analyzer parameters after LASIK. J Refract Surg. 2010; 26(4): 279–288 doi: 10.3928/1081597X-20100218-04

15. Pepose J.S., Feigenbaum S.K., Qazi M.A. Changes in corneal biomechanics and intraocular pressure following LASIK using static, dynamic, and noncontact tonometry. Am J Ophthalmol. 2007; 143(1): 39-47. doi:10.1016/j.ajo.2006.09.036

16. Osman I.M., Helaly H.A., Abdalla M. [et al.] Corneal biomechanical changes in eyes with small incision lenticule extraction and laser assisted in situ keratomileusis. BMC Ophthalmol. 2016; 16: 123. doi:10.1186/s12886-016-0304-3

17. Nemeth G., Szalai E., Hassan Z. [et al.] Corneal biomechanical data and biometric parameters measured with Scheimpflug-based devices on normal corneas. Int J Ophthalmol. 2017; 10(2): 217–222. doi:10.18240/ijo.2017.02.06.

18. Pedersen I.B., Bak-Nielsen S., Vestergaard A.H. [et al.] Corneal biomechanical properties after LASIK, ReLEx flex, and ReLEx smile by Scheimpflug-based dynamic tonometry. Graefes Arch Clin Exp Ophthalmol. 2014; 252(8): 1329-1335. doi:10.1007/s00417-014-2667-6

19. He M., Wang W., Ding H. [et al.] Corneal Biomechanical Properties in High Myopia Measured by Dynamic Scheimpflug Imaging Technology. Optom Vis Sci. 2017; 94(12): 1074-1080. doi:10.1097/OPX.0000000000001152.

20. Wang J., Li Y Y., Jin Y. [et al.] Corneal Biomechanical Properties in Myopic Eyes Measured by a Dynamic Scheimpflug Analyzer. J Ophthalmol. 2015; 10.1155/2015/161869.

21. Sedaghat M.R., Momeni-Moghaddam H., Azimi A. [et al.] Corneal Biomechanical Properties in Varying Severities of Myopia. Front Bioeng Biotechnol. 2021; 21(8):10.3389/fbioe.2020.595330.

22. Wang W., He M., He H. [et al.] Corneal biomechanical metrics of healthy Chinese adults using Corvis ST. Cont Lens Anterior Eye. 2017; 40(2): 97–103. doi:10.1016/j.clae.2016.12.003

23. Huseynova T., Waring G.O., Roberts C. [et al.] Corneal biomechanics as a function of intraocular pressure and pachymetry by dynamic infrared and Scheimpflug imaging analysis in normal eyes. Am J. Ophthalmol. 2014; 157(4): 885-893. doi:10.1016/j.ajo.2013.12.024

24. Lim L., Gazzard G., Chan Y.H. [et al.] Cornea biomechanical characteristics and their correlates with refractive error in Singaporean children. Invest Ophthalmol Vis Sci. 2008; 49(9): 3852-3857. doi:10.1167/iovs.07-1670.

25. Wu D., Wang Y., Zhang L. [et al.] Corneal biomechanical effects: small-incision lenticule extraction versus femtosecond laser-assisted laser in situ keratomileusis. J Cataract Refract Surg. 2014; 40: 954–962. Doi:10.1016/j.jcrs.2013.07.056

26. Ortiz D, Piñero D, Shabayek MH, Arnalich-Montiel F, Alió JL. Corneal biomechanical properties in normal, post-laser in situ keratomileusis, and keratoconic eyes. J Cataract Refract Surg. 2007; 33(8): 1371-1375. doi:10.1016/j.jcrs.2007.04.021.

27. M.L. Salvetat, M. Zeppieri, C. Tosoni [et al.] Corneal Deformation Parameters Provided by the Corvis-ST Pachytonometer in Healthy Subjects and Glaucoma Patients. J Glaucoma. 2015; 24: 568–574. doi:10.1097/IJG.0000000000000133

28. Song Y., Congdon N., Li L. [et al.] Corneal hysteresis and axial length among Chinese secondary school children: the Xichang Pediatric Refractive Error Study (X-PRES) report 4. Am J Ophthalmol. 2008;145(5): 819-826. doi:10.1016/j.ajo.2007.12.034

29. Agca A., Ozgurhan E.B., Demirok A. [et al.] Comparison of corneal hysteresis and corneal resistance factor after small incision lenticule extraction and femtosecond laser-assisted LASIK: A prospective fellow eye study. Cont Lens Anterior Eye. 2014; 37(2): 77-80. doi:10.1016/j.clae.2013.05.003

30. Xia L., Zhang J., Wu J. [et al.] Comparison of Corneal Biological Healing After Femtosecond LASIK and Small Incision Lenticule Extraction Procedure. Curr Eye Res. 2016; 41(9): 1202-1208. doi:10.3109/02713683.2015.1107590.

31. Kamiya K., Shimizu K., Ohmoto F. Comparison of the changes in corneal biomechanical properties after photorefractive keratectomy and laser in situ keratomileusis. Cornea. 2009; 28: 765–769. doi:10.1097/ICO.0b013e3181967082

32. Wang B, Zhang Z, Naidu RK [et al.] Comparison of the change in posterior corneal elevation and corneal biomechanical parameters after small incision lenticule extraction and femtosecond laser-assisted LASIK for high myopia correction. Cont Lens Anterior Eye. 2016; 39(3): 191-196 doi:10.1016/j.clae.2016.01.007.

33. Yıldırım Y., Ölçücü O., Başcı A. [et al.] Comparison of Changes in Corneal Biomechanical Properties after Photorefractive Keratectomy and Small Incision Lenticule Extraction. Turk J Ophthalmol. 2016; 46(2): 47-51. doi: 10.4274/tjo.49260.

34. Wang D., Liu M., Chen Y. [et al.] Differences in the corneal biomechanical changes after SMILE and LASIK. J Refract Surg. 2014; 30: 702–707. doi:10.3928/1081597X-20140903-09.

35. Ambrosio R. Jr., Ramos I., Luz A. [et al.] Dynamic ultra-high speed scheimpflug imaging for assessing corneal biomechanical properties. Rev Bras Oftalmol. 2013; 72: 99–102

36. Öner V., Taş M., Özkaya E., Oruç Y. Effect of pathological myopia on biomechanical properties: a study by ocular response analyzer. Int J Ophthalmol. 2015; 18(2): 365-368. doi:10.3980/J.ISSN.2222-3959.2015.02.27.

37. Guo H., Hosseini-Moghaddam S.M., Hodge W. Corneal biomechanical properties after SMILE versus FLEX, LASIK, LASEK, or PRK: a systematic review and meta-analysis. BMC Ophthalmol. 2019; 1(1): 167. doi:10.1186/s12886-019-1165-3.

38. Hon Y., Lam A.K. Corneal deformation measurement using Scheimpflug noncontact tonometry. Optom Vis Sci. 2013; 90(1): 1-8. doi:10.1097/OPX.0b013e318279eb87.

39. Terai N., Raiskup F., Haustein M. [et al.] Identification of biomechanical properties of the cornea: the ocular response analyzer. Curr Eye Res. 2012; 37(7): 553–562. doi: 10.3109/02713683.2012.669007

40. Vinciguerra R., Elsheikh A., Roberts C.J. [et al.] Influence of pachymetry and intraocular pressure on dynamic response parameters in healthy patients. J. Refract Surg. 2016; 32: 550-561. doi:10.3928/1081597X-20160524-01

41. Li H., Wang Y., Dou R. [et al.]. Intraocular pressure changes and relationship with corneal biomechanics after SMILE and FS-LASIK. Invest Ophthalmol Vis Sci. 2016; 57: 4180-4186. Doi:10.1167/iovs.16-19615.

42. Roberts C.J., Mahmoud A.M., Bons J.P. [et al.] Introduction of Two Stiffness Parameters at Interpretation of Air Puff Induced Biomechanical Deformation Response Parameters with a Dinamic Scheimpflug Analyser. Journal of Refract Surgery. 2017; 33(4): 266-273. doi:10.3928/1081597X-20161221-03

43. Kenia V.P., Kenia R.V., Pirdankar O.H. Association between corneal biomechanical parameters and myopic refractive errors in young Indian individuals. Taiwan J Ophthalmol. 2020;10(1): 45-53. doi:10.4103/tjo.tjo_15_19.

44. Lawless M, Hodge C. LASIK. Int Ophthalmol Clin. 2013; 53: 111-128. doi. org/10.1097/IIO.0b013e318271346e.

45. Luce D.A. Determining in vivo biomechanical properties of the cornea with an ocular response analyzer. / D.A. Luce // J Cataract Refract Surg. - 2005. №.31(1). – P.156–162. doi:10.1016/j.jcrs.2004.10.044.

46. Luce D. Methodology for corneal compensated IOP and corneal resistance factor for an ocular response analyzer. Invest Ophthalmol Vis Sci. 2006; 47. E-Abstract 2266

47. Woreta F.A., Gupta A., Hochstetler B. [et al.] Management of post-photorefractive keratectomy pain. Surv Ophthalmol. 2013; 58(6):529-535. doi:10.1016/j.survophthal.2012.11.004.

48. Mysore N., Krueger R. Advances in Refractive Surgery: May 2013 to June 2014. Asia Pac J Ophthalmol (Phila). 2015; 4(2):112-120. doi:10.1097/APO.0000000000000117.

49. Asaoka R., Nakakura S., Tabuchi H. [et al.] The Relationship between Corvis ST Tonometry Measured Corneal Parameters and Intraocular Pressure, Corneal Thickness and Corneal Curvature. PLoS One. 2015;10: e140385. doi:10.1371/journal.pone.0140385

50. Tomás-Juan J., Murueta-Goyena Larrañaga A., Hanneken L. Corneal Regeneration After Photorefractive Keratectomy: A Review. J Optom. 2015; 8(3):149-169. doi:10.1016/j.optom.2014.09.001.

51. Wang W., Du S., Zhang X. Corneal Deformation Response in Patients with Primary Open-angle Glaucoma and in Healthy Subjects Analyzed by Corvis ST. Invest Ophthalmol Vis Sci. 2015; 56: 5557–5565. doi:10.1167/iovs.15-16926

52. Kotecha A. What biomechanical properties of the cornea are relevant for the clinician? Surv Ophthalmol. 2007; 52(2): 109-114. doi:10.1016/j.survophthal.2007.08.004

53. Yang E., Roberts C.J., Mehta J.S. A Review of Corneal Biomechanics after LASIK and SMILE and the Current Methods of Corneal Biomechanical Analysis. J Clin ExpOphthalmol. 2015; 6: 507. doi:10.4172/2155-9570.1000507

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THE ROLE OF RELAPAROSCOPY IN THE DIAGNOSIS AND TREATMENT OF POSTOPERATIVE BILE LEAKS

The effectiveness of relaparoscopy in the diagnosis and treatment of patients who developed bile leakage after surgery on the gallbladder and bile ducts was studied. It was revealed that the use of minimally invasive endoscopic technologies in the early diagnosis of postoperative bile leakage of the gallbladder and biliary tract makes it possible to determine the nature of this complication, the optimal method of elimination, justify the transition to conversion, and avoid inappropriate relapses.

Keywords: bile discharge, laparoscopic cholecystectomy, postoperative complications.

Introduction. Cholecystectomy (CE) is the most common operation, and the number of cholecystectomies performed annually exceeds 500 thousand [5, 8].

One of the leading places in the structure of early postoperative complications after cholecystectomy is the outflow of bile, which should be considered as an independent problem. Bile outflow after cholecystectomy is observed in about 0.5% of cases [3, 6, 7, 14].

This indicator increases to 1-1.2% when using laparoscopic techniques to remove the gallbladder, as well as in cases of conversion, when difficulties and complications arise during surgery [1, 2, 11, 12].

After open cholecystectomy, bile leakage is observed in 5-15% of cases, after mini-access cholecystectomy, in 3.6%, after laparoscopic cholecystectomy, in 2-5% of cases [3, 4, 9, 10, 13].

About 750,000 cholecystectomies are performed each year in the United States, most of which are performed laparoscopically. Complications after cholecystectomy are not uncommon and lead to an increase in morbidity and financial burden. Some of the most common complications of laparoscopic cholecystectomy include damage to the biliary tract (0.08%-0.5%), bile leakage (0.42%-1.1%), stones in the common bile ducts (0.8%-5.7%), postcholecystectomy syndrome (10%-15%) and diarrhea after cholecystectomy (5%-12%).). [10, 14] Endoscopy plays an important role in the diagnosis and treatment of biliary complications and in many cases can provide the final treatment. There is no consensus on the best therapeutic approach to biliary complications. [10]

Ultrasound (ultrasound) - diapeutics and laparoscopy, used in surgical pathologies of the abdominal cavity, open up wide opportunities for optimizing early diagnosis and treatment tactics of postoperative bile leakage.

The aim of the study was to evaluate the effectiveness of laparoscopy in the diagnosis and treatment of bile leaks that occur after cholecystectomy and operations on extrahepatic bile ducts.

Materials and methods of research. The research work was carried out during 2010-2021 at the clinical bases of two departments of general Surgery of the Azerbaijan State Institute of Advanced Medical Training named after A.Aliyev. Based on the results of diagnosis and treatment of patients who developed bile leaks in the postoperative period, operations were performed on the gallbladder and bile ducts.

The main group included patients (n=567) who, in surgical tactics and for the treatment of complications, were given preference to the active use of endovideosurgery in the development of complications after surgical interventions in the bile ducts.

The control group included patients (n=148) who used "traditional" methods of surgical correction of complications that arose after similar surgical interventions.

The criterion for inclusion in the study is the occurrence of intra–abdominal complications in the early period after surgical interventions on the bile ducts.

The criterion for exclusion from the study is the critical severity of the patients' condition.

Complications in the early postoperative period were clinically diagnosed in 160 out of 567 patients (28.2%) in the developed main group and in 41 out of 148 patients (27.7%) in the control group. In the main group, bile leaks was detected in 88 patients after laparoscopic cholecystectomy, in 16 patients after mini-laparotomic cholecystectomy and in 56 patients after traditional cholecystectomy.

In 15 clinical cases (9.4%), when performing minimally invasive interventions with damage to the extrahepatic bile ducts is clearly impractical, relaparotomy was performed according to the indications. Laparoscopy was performed in 145 (90.6%) patients of the main group according to indications that were confirmed on the basis of bile drainage, peritoneal signs and ultrasound signs of fluid in the abdominal cavity.

The control group included 41 patients with postoperative bile leaks, but without the use of minimally invasive technologies.

To assess postoperative bile leaks, we used a modified classification by Morgensten L. (2006) [15], in which not only the daily output of bile flowing from the abdominal drainage tube, but also the volume of a limited liquid derivative in the projection of the gallbladder bed, as well as ultrasound data mainly took into account the presence of free fluid in the abdominal cavity and its localization.

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