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Examination and optical correction of the vision system following the procedure of cataract removal

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The main goal of this thesis was a comprehensive assessment of the condition of the vision system following cataract surgery and implantation of posterior chamber artificial lens and assessment of the postoperative astigmatism, considering the dynamics of reduction of the postoperative astigmatism in the early postoperative period (3 months after the surgery). Also, the assessment of binocular vision of the operated patients was carried out. The results obtained were related to the currently used procedure methods, *i.e.*, phacoemulsification and extracapsular cataract removal. The thesis is realized in cooperation with the Ophthalmic Department of the Province Hospital in Poznań (Szpital Wojewódzki w Poznaniu), Poland.

Keywords: physiological optics, optometry, binocular vision, stereopsy, cataract.

1. Introduction

The thesis involves examination and optical correction of the vision systems in patients who underwent cataract surgery. This is the first attempt at taking up advanced research on patients who underwent such surgery. The condition of the vision system following the procedure is and certainly will be the subject of interest of many ophthalmologists, both those who conduct the cataract surgery, and those who examine the sight acuity and choose appropriate correction for patients in their everyday practice. The extent of postoperative astigmatism depends on the length of the surgical wound, its location and the selected manner of closing the eyeball. The value of postoperative astigmatism is the greater, the longer the surgical wound and the more central its location in the cornea. Placing the suture and its tension also affect the level of postoperative astigmatism. The rate at which the postoperative astigmatism is reduced also depends

on the length and location of the surgical wound and the manner of its closing. Thus, there is a need to examine the postoperative astigmatism, with appropriate statistical follow-up, with reference to the surgical methods currently used. Patients who uderwent cataract surgery require proper optical correction. Optical correction should include the correlation of refraction of the pseudoaphasic eye and the time elapsed since the surgery. Moreover, following the cataract surgery there is a change in the correlation between accommodation and convergence of the vision system, which significantly influences its functioning. Bearing the above in mind, as well as the fact that methods of cataract surgery undergo changes and modifications, there is us doubt that continuous research should be conducted in this area. The research provides significant practical implications for ophthalmologists and optometrists.

2. Material and methodology

The results presented encompass two research areas. The first one is related to the assessment of postoperative astigmatism in patients who underwent cataract surgery, the second one is related to the assessment of binocular vision and stereopsy in patients who underwent cataract surgery and implantation of intraocular artificial lens. The subjects were operated by the same team of experienced surgeons.

In order to assess the postoperative astigmatism and the dynamics of reduction of the postoperative astigmatism, 140 patients (89 females and 51 males) were subjected to examination, who had undergone cataract surgery in the Ophthalmic Department of the Province Hospital in Poznań. The patients whose surgery was conducted without intraoperational complications, who had not been diagnosed for complications within three months of the procedure were qualified for examination. All the patients had posterior chamber artificial lenses implanted. The patients were classified into 4 groups, depending on the manner of opening and closing the eyeball.

Group I (16 eyes): patients who underwent phacoemulsification from a 5 mm incision in the corner of cornea and the incision closed with a single criss-cross suture.

Group II (22 eyes): patients who underwent phacoemulsification procedure from a 5 mm cornea incision with a single loop suture.

Group III (62 eyes): patients who underwent phacoemulsification procedure from a 3.5 or 5.0 mm tunnel incision without a suture.

Group IV (40 eyes): patients who underwent phacoemulsification from a 12 mm incision in the corner of cornea and the incision closed with a continuous criss-cross suture.

The thesis relates to the patients for whom it was possible to carry out examinations of astigmatism in the 2^{nd}, 7^{th}, 30^{th} and 90^{th} day after the surgery. Objective test of refraction and central keratometry was performed using a Zeiss Humprey System Acuitus 5010 automatic refractometer. The subjective refraction was performed applying a cylindrical method with fogging using a phoropter.

The post-surgery astigmatism was also approximated using exponential curve. The constant of astigmatism reduction a and the half-value period of post-operative astigmatism T were determined for the particular groups, which correlate as follows:

$$aT = \ln 2 \quad \text{or} \quad aT = 0.693$$

The 186 patients were examined in order to assess the binocular vision. A control group consisted of 100 subjects. The group under examination consisted of 86 subjects who underwent cataract surgery using phacoemulsification and extracapsular methods, in the Ophthalmic Department of the Province Hospital in Poznań. The patients whose surgery was conducted without intraoperational complications, who had not been diagnosed for complications within three months of the procedure were qualified for examination. All the operated patients had posterior chamber artificial lenses implanted. The subjects were classified into three groups. Group I: Patients who underwent unilateral cataract surgery (31 subjects), whose acuteness of sight in the other eye was $V \geq 0.7$ after correction. Group II: patients who underwent bilateral cataract surgery (55 patients). Group III: patients who did not undergo cataract surgery (100 patients) – control group.

Use was made of a broad range of research methods for assessing spacial vision and stereopsy. The tests were as exact as possibile, they consisted in determining: horizontal phoria, ranges of vergence for far distance using a phoropter, and far distance stereopsy tests. Theoretical determination of fusional convergence, AC/A ratio was also performed. The results obtained were assessed using Sheard's,

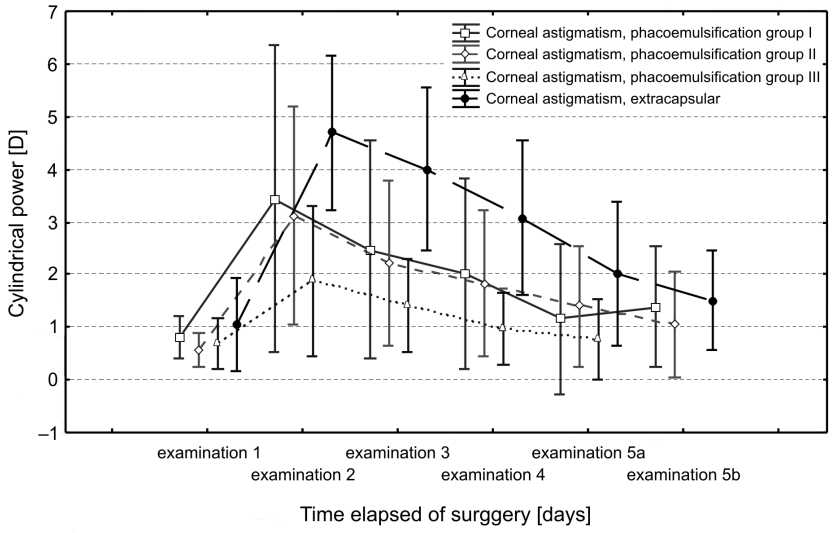

Fig. 1. Corneal post–operative astigmatism surgical methods.

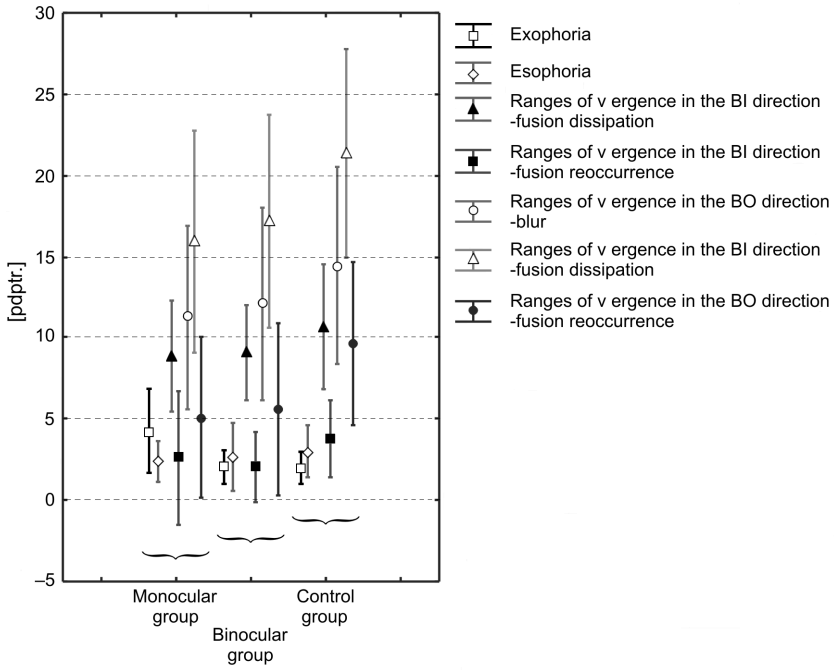

Fig. 2. Horizontal phoria and range of vergence in BI and BO directions for far distance.

Percival's and Saladin's criteria and with reference to a standard established by Morgan for the ophthalmologically healthy persons.

3. Results

Changes in corneal astigmatism after cataract surgery using phacoemulsification and extracapsular methods are presented in Fig. 1. The results of tests of horizontal phoria and ranges of vergence for far distance are presented in Fig. 2. Figure 3 presents quantitative incidence of basic disturbances of convergence and accommodation system. Figure 4 presents the stereoscopic acuteness of sight for far distance.

4. Description

The value of early post-operative astigmatism following cataract surgery depends primarily on the length of the incision. After extracapsular cataract removal, with average incision length of approx. 12 mm led in the corner of cornea, the astigmatism after 48 hours in our tests amounted to 4.69 D on average. Similar values were presented by CAVALLINI *et al.* [1], LESIEWSKA-JUNK *et al.* [8], SMYK *et al.* [13]. Shortening the operative incision owing to the application of phacoemulsification method results in at least twofold decrease of post-operative astigmatism. It then

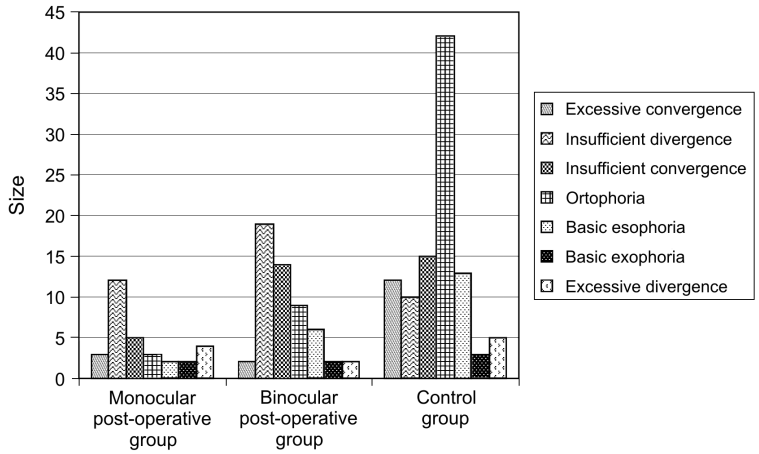

Fig. 3. Convergence disturbance.

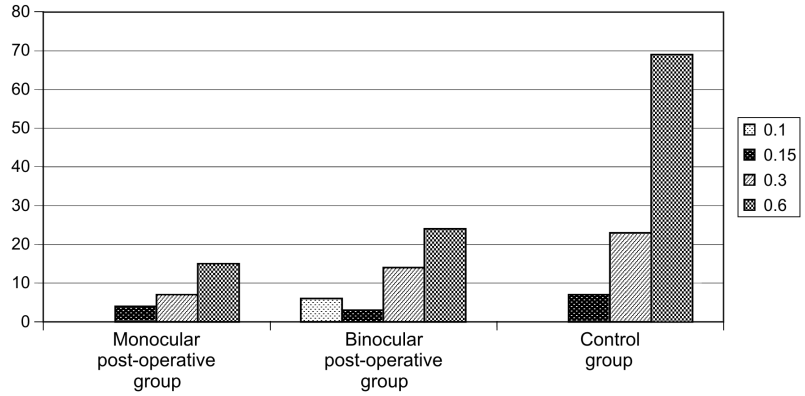

Fig. 4. Stereopsy for far distance.

depends on the manner of closing the incision. For the tunnel corneal-incision without suture our tests showed on average 1.36 D, with a single loop suture 1.98 D, and in the case of a single criss-cross suture 2.98 D. A significant reduction in post -operative astigmatism due to phacoemulsification is reported by CAVALLINI *et al.* [1], GRYMIN *et al.* [4], KAŁUŻNY *et al.* [7], LESIEWSKA-JUNK *et al.* [8] and SMYK *et al.* [13]. The reduction of post-operative astigmatism within the first three months of cataract surgery is faster. In order to assess the dynamics of astigmatism reduction we suggest introducing a half-value period of astigmatism reduction T for the constant of astigmatism reduction a, which are correlated as follows: $aT = 0.693$. The average half-value period of astigmatism reduction in our research was the shortest after phacoemulsification without suture (21 days), and slightly longer following

phacoemulsification with suture (single criss-cross suture – 31 days, single loop suture – 32 days). After extracapsular cataract removal the average half-value period of astigmatism reduction proved to be the longest (47 days). As emphasized by KAŁUŻNY *et al.* [7], LESIEWSKA-JUNK *et al.* [8], MULLER-JENSEN *et al.* [10], SMYK *et al.* [13], as well as others, in the later post-operative period, *i.e.*, 2 years after the surgery, post-operative astigmatism did not differ from the condition before the surgery in any of the group of patients.

5. Conclusions

The results of measurements made led to the following conclusions:

– the value of early post-operative astigmatism following the cataract removal surgery by way of facoemulsification depends on the manner of opening the anterior chamber and the manner of closing the surgical wound,

– the lowest average values of post-operative astigmatism relate to patients who underwent facoemulsification from scleral/corneal tunnel incision without suture,

– closing the wound with a strut causes an increase of early post-operative astigmatism, with a single loop suture causing lower post-operative astigmatism than a single criss-cross suture,

– average value of post-operative astigmatism following the extra-capsular cataract surgery is at least twice as high as that obtained after facoemulsification,

– the astigmatism reduction constant a and the half-value period T are parameters that well describe the dynamics of reduction of post-operative astigmatism,

– usually, three months after the surgery post-operative astigmatism decreases to such levels that correction possibly made at that time is relatively stable.

– as regards to the control group and Morgan's standard, the patients, after cataract surgery indicate decreased scopes of fusional convergence at both far and near distance in the BI and BO directions,

– average values of horizontal and vertical phoria at far and near distance in the groups of patients who underwent unilateral and bilateral cataract surgery are higher as compared to Morgan's standard and the values set in the control group,

– performing cataract surgery including implantation of artificial lens allows stereopsy to be maintained,

– patients who underwent cataract surgery require not only exact examination and correction of refraction, but also examination, and if need arises, correction of binocular vision disorders.

The results presented provide a comprehensive assessment of the condition of the vision system following cataract surgery with reference to the procedures currently used. The research conducted should contribute to increasing the knowledge of assessment of binocular and spacial vision following cataract removal. This seems particularly important, especially considering the fact that cataract surgery is the most frequent, complex ophthalmological surgery. It is estimated that in Poland only, there are 30 000 such operations a year, including implantation of intraocular artificial lens.

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