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Older age as risk factor for deviation from emmetropia in pseudophakia

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PURPOSE. *To find risk factors for deviation from emmetropia after cataract surgery in clinical practice.*

METHODS. *We evaluated the refractive outcome in 106 patients who had underone phacoemulsification and in-the-bag IOL placement 115 ± 10 days after surgery. Postoperative optical correction and refractive error (diopters of spherical equivalent - ED) were related to age and sex, pre-operative axial length and keratometric diopter power, and operative incision technique.*

RESULTS. *Emmetropia was achieved in 15% of cases; 65% of eyes needed a myopic correction, averaging =0.46±0.91 ED. The refractive error was 0.74 ± 0.61 ED (≤1 ED in 77% of cases, ≤ 2 ED in 97%). Both optical correction and refractive error were correlated to older age at the time of surgery (p=0.002 and p=0.001, respectively). Astigmatism appeared greater in clear-cornea incision than in limbar incision cases (p=0.05).*

CONCLUSIONS. *The higher refractive error in patients aged over 73 years suggests that age may be a risk factor for deviation from emmetropia after cataract surgery. (Eur J Ophthalmol 2001; 11: 133-8)*

KEY WORDS. *Phacoemulsification, IOL calculation, Refractive error, Emmetropia, Risk factors, Older age*

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INTRODUCTION

Intraocular lens (IOL) power calculation and phacoemulsification techniques have improved the refractive results in cataract surgery. Modern IOL calculation formulas aim to obtain a post-operative refraction as predictable as possible (1-4). Post-operative astigmatism may be reduced by the phacoemulsification technique, with a small incision and small overall diameter IOL (5). This allows cataract surgeons to obtain an increasing number of eyes with good uncorrected visual acuity.

We assessed the deviation from emmetropia after cataract surgery by phacoemulsificaion and in-the-bag IOL placement in routine surgical practice at Parma University hospital.

PATIENTS

This study included patients who underwent cataract surgery by phacoemulsification without intraoperative and postoperative complications in the period October 1998 – February 1999. Enrolment was based on retrospective data, while post-operative refraction was measured prospectively. We examined the records of 391 patients two weeks after surgery for the following exclusion criteria:

- age <40 years and >85 years;
- chronic weakening diseases such as liver or kidney pathologies, or tumors;
- psychiatric pathology (inability to cooperate);
- previous ocular pathology (severe chronic glaucoma, acute glaucoma attacks, corneal or vitreous opac-

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ities, keratoconus, maculopathy or chorioretinal degeneration, hypertensive and/or diabetic retinopathy, strabismus, serious ocular trauma or inflammation);
- previous ocular surgery (glaucoma, strabismus, retinal detachment surgery);
- mature and/or intumescent cataract, pseudoexfoliation syndrome;
- severe ametropias, such as myopia >10 diopters (D) and hyperopia >5 D, in which we needed a postoperative slight ametorpia;
- implantation, at the surgeon's choice, of a IOL-power differing from the predicted one;
- postoperative visual acuity (VA) <5/10.

We also excluded eyes with pre-operative corneal astigmatism >2.5 D because the implant calculation is less accurate in these cases (2, 6, 7) and eyes with post-operative astigmatism >2.5 D (either early or during the follow-up) to reduce the influence of the corneal curvature on the post-operative refraction as far as possible (7). Astigmatism was computed on the basis of keratometry, done 1-15 days before and 3 days and 10-15 days after surgery.

Patients not fulfilling any of these exclusion criteria were called for a visit including ocular refraction and natural or best-corrected VA measurement, anterior segment and fundus oculi examination. Considering the time needed for post-operative astigmatism to stabilize, these visits were scheduled within 90-140 days after surgery.

METHODS

In all cases the IOL power calculation aimed at postoperative emmetropia, defined as the condition in which the eye has the best distant VA without optical correction. A Haag-Streit Tekno K optical keratometer was used, and the values were recorded in diopters. The pre-operative keratometric diopter power (K) was calculated as the mean of the diopter values of the two main meridians.

Eyeball axial length (AL) was measured using a Nidek US-2000 applanation ultrasonic biometer (NIDEK Co., Ltd., 34-14 Maemama-Hiroishi-Cho Gamagori Aichi, Japan), set to a mean velocity of 1550 m/s. The IOL power was calculated by the biometer computerized unit, using both SRK II (8) and SRK/T formulas (9). We commonly use the SRK II formula, but in short or long eyes we prefer the SRK/T formula (3). Manufacturers A constants referring to the IOL type to be implanted, not personalised, are usually used because at the pre-operative examination it is not possible to plan which surgeon will operate which patient. The biometer also provides the predicted theoretical refractive error after IOL implantation, since lens powers are spaced at 0.5 D, and the calculated power is then approximated.

Cataract surgery was done by five different surgeons. The surgical technique consisted of limbar or clear-cornea incision, anterior capsulorhexis by needle or forceps with or without viscoelastic material, hydrodissection and phacoemulsification of the nucleus, infusion and aspiration of residual cortex, 5.2 mm incision, in-the-bag implantation of a Cilco M740BD IOL, X-shaped suture with 10.0 running nylon monofilament.

The post-operative refraction was measured by a Nidek AR-800 computerized autorefractometer. VA was measured using a decimal Armaignac optotype with serial letters. Since the optotype had 69 letters, the VA was given both in decimal lines (max. 10/10, considering it necessary to correctly identify all the letters except one in each line) and as the number of correctly identified letters (max. 69/69). Patients get the maximal VA by identifying at least 60/69 letters, corresponding to the sum of all the letters except one for each line of the optotype.

The actual post-operative refraction was identified with the optical correction (in diopters of spherical equivalent – ED, positive and negative values) used to get the best VA. The dioptric powers (D) of the spherical and cylindrical lens (the latter indicative of the post-operative astigmatism) were then evaluated separately. The expected postoperative refraction for each IOL actually implanted was then calculated and compared to the real post-operative refraction in order to obtain the refractive error (ED, absolute values). Mean post-operative refraction, spherical lens, post-operative astigamtism, absolute refractive error, and distribution of the deviation were calculated and related to patients' age and sex, pre-operative best corrected VA, AL and K, and the incision technique Student's t-test (two-tailed p), linear regression and the McNemar-test were used for statistical analysis.

RESULTS

Of the 133 patients called for the control visit, 128 attended. The follow-up was 115 ± 10 days (mean ± SD); 22 patients were excluded for the following reasons: development of post-operative astigmatism >2.5 D during the follow-up period, 14 cases; lack of co-operation, six cases; onset of central retinal vein thrombosis two months after surgery, one case; occipital cerebral hematoma one case.

The study group thus comprised 106 eyes of 106 patients, 65 (61.3%) males and 41 (38.7%) females. Mean age was 71.32 ± 8.93 years (range 41-85, median 73 years). The pre-operative AL was 23.3 ± 0.88 mm (range 21.8-26, median 23.16 mm). Pre-operative K was 42.98 ± 1.33 D (range 39.5-46.47, median 42.87 D). Pre-operative VA was 2.3 ± 1.6 decimal lines (range 0.1-5, median 2). In all cases IOL power was calculated by the SRK-II formula. A limbar incision was used in 57 cases (53.8%), a clear-cornea incision in 49 eyes (46.2%).

Maximal VA (10/10) was reached in 69 (65.1%) cases and 79 (74.5%) patients were able to correctly identify at least 60/69 letters of the optotype. Emmetropia was achieved in 16 patients (15%, 9 males and 7 females); 69 patients (65%, 44 males and 25 females) needed a myopic correction, and 21 (20%, 12 males and 9 females) a hyperopic correction.

Post-operative optical correction was –0.47 ± 0.91 ED (mean ± SD, range –3.35 to 1.87); values ranged from –1 to +1 ED in 76% of the cases, from –2 to +2 ED in 96%. The spherical lens was –0.22 ± 0.68 D (range –2.5 to +1.5), and post-operative astigmatism was –0.49 ± 1.16 D (range –2.5 to 2). Linear regression showed an increase of the post-operative myopic correction (F=5.41, significance = 0.02, Fig. 1) and post-operative myopic astigmatism (F=4.44, significance = 0.04, Fig. 2) with age, but no correlation with AL and pre-operative astigmatism. Linear regression found no correlation between spherical lens values and age, AL and pre-operative astigmatism.

In the whole sample, considering the absolute values for the optical correction, mean post-operative refraction was 0.78 ± 0.66 ED, the spherical lens was 0.45 ± 0.56 D and post-operative astigmatism was 1.01 ± 0.75 D. The refractive error was 0.74 ± 0.61 ED (range 0-2.95) with values ≤ 1 ED in 77% of cases and ≤ 2 ED in 96%. We related these values to pa-

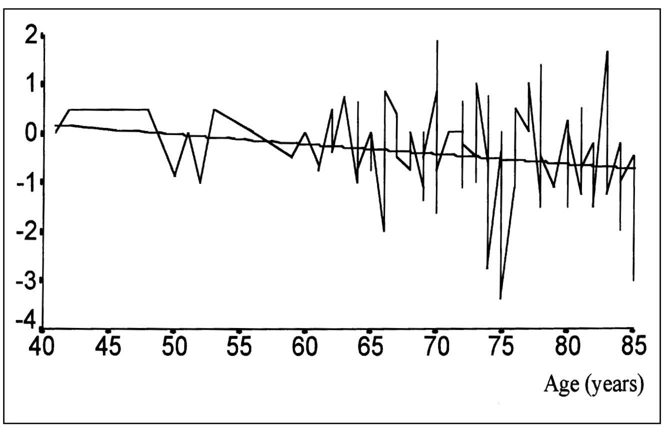

Fig. 1 - *Post-operative optical correction and patients' age (linear regression: significance = 0.02).*

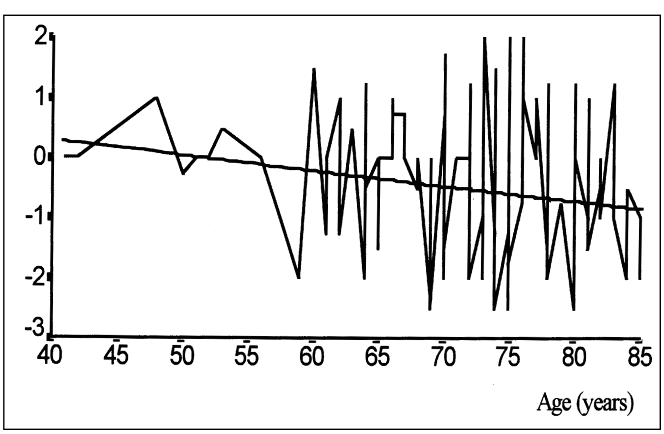

Fig. 2 - *Post-operative astigmatism and patients' age (linear regression: significance = 0.04).*

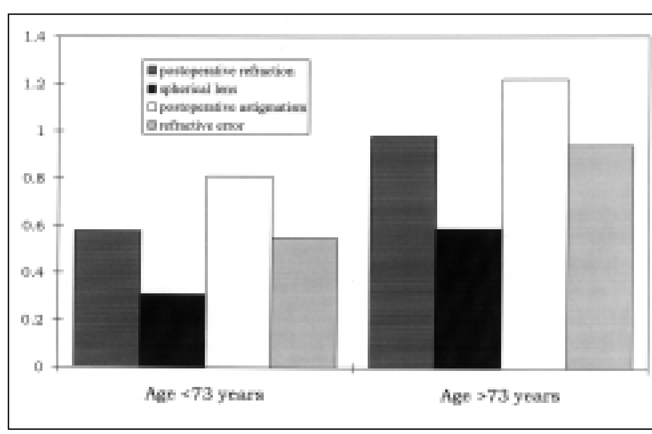

Fig. 3 - *Post-operative refractive parameters in age groups (mean absolute values, astigmatism and spherical lens in D, refraction and refractive error in ED).*

tients' age and sex, pre-operative VA, AL and K, and incision technique, dividing the study group on the basis of the median age, VA, AL and K. The results of Student's t-test are reported in Table I. All the post-operative refractive parameters appeared to be significantly higher in patients older than 73 years (Fig. 3). Post-operative astigmatism was also greater with a clear-cornea incision than with a limbar incision. However, the incision technique was equally distributed in the subgroups on the basis of age (McNemar test: $\chi^2 = 0.0185$, significance = 0.89). Pre-operative AL was 23.16 ± 0.82 mm in patients aged over 73 years and 23.35 ± 1.13 mm in patients aged ≤ 73 years. The difference did not appear related to age (Student's t-test: two-tailed p = 0.33).

DISCUSSION

Cataract surgery success rates improved steeply when IOL implantation became routine, remarkably improving the patients' vision. With more accurate and safer micro-surgery techniques and better design and material of the IOL, it became necessary to adapt the patient's vision to his requirements by bringing him to a condition of emmetropia. IOL power calculations, however, despite excellent accuracy rates still contain refractive errors. It is difficult to compare literature series because IOL calculation formulas, surgical techniques and data analysis all tend to differ.

In pseudophakia with posterior chamber IOL, post-operative refraction of 0.36 ± 0.96 D (2), -0.22 ± 1.27

TABLE I - POST-OPERATIVE REFRACTIVE PARAMETERS (MEAN ± SD) ABSOLUTE VALUES RESULTS OF STUDENT'S T-TEST (TWO-TAILED p)

	Number of cases	Post-operative Refraction	Spherical Lens	Post-operative Astigmatism	Refractive Error
Age ≤73 years	55	0.58 ± 0.49 ED	0.31 ± 0.43 D	0.81 ± 0.77 D	0.55 ± 0.46 ED
>73 years	51	0.98 ± 0.77 ED	0.59 ± 0.65 D	1.22 ± 0.68 D	0.94 ± 0.7 ED
Two-tailed p		0.002*	0.011*	0.007*	0.001*
Males	65	0.76 ± 0.70 ED	0.41 ± 0.54 D	1.04 ± 0.76 D	0.74 ± 0.62 ED
Females	41	0.80 ± 0.61 ED	0.50 ± 0.59 D	0.96 ± 0.74 D	0.73 ± 0.61 ED
Two-tailed p		0.76	0.45	0.66	0.89
AL ≤23.16 mm.	54	0.78 ± 0.64 ED	0.44 ± 0.59 D	1.02 ± 0.77 D	0.75 ± 0.67 ED
> 23.16 mm.	52	0.78 ± 0.62 ED	0.45 ± 0.53 D	0.99 ± 0.74 D	0.72 ± 0.56 ED
Two-tailed p		0.99	0.91	0.84	0.82
K ≤ 42.87 D	51	0.78 ± 0.70 ED	0.41 ± 0.53 D	0.95 ± 0.70 D	0.76 ± 0.65 ED
>42.87 D	55	0.78 ± 0.62 ED	0.48 ± 0.59 D	1.07 ± 0.8 D	0.72 ± 0.58 ED
Two-tailed p		0.99	0.59	0.42	0.74
Clear-cornea inc.	49	0.75 ± 0.72 ED	0.51 ± 0.56 D	1.17 ± 0.83 D	0.73 ± 0.68 ED
Limbar incision	57	0.79 ± 0.62 ED	0.37 ± 0.56 D	0.88 ± 0.66 D	0.75 ± 0.54 ED
Two-tailed p		0.73	0.27	0.05*	0.87
Pre-op VA ≤2	60	0.74 ± 0.71 ED	0.44 ± 0.57 D	0.93 ± 0.73 D	0.68 ± 0.63 ED
>2	46	0.84 ± 0.59 ED	0.48 ± 0.55 D	1.13 ± 0.80 D	0.84 ± 0.59 ED
Two-tailed p		0.45	0.74	0.22	0.22

D: diopters
ED: diopters of spherical equivalent
AL: eyeball axial length (pre-operative echobiometric measurement (23.16 mm = median)
K: mean pre-operative keratometric diopter power (42.87 D = median)
Pre-op AV: preoperative visual acuity in decimal lines (2 = median)
73 years: median age

D (4), -0.17 ± 1.71 D (5) and within ± 1 D in 68% of cases and ±2 D in 91% of cases (10) are reported. Emmetropia was reached in 7% of cases in a series including anterior chamber IOL (6). The refractive error was 0.17 ± 0.69 D (5), 0.75 ± 0.6 D (6), within 2 D in 95.5-99% and within 1 D in 77-94% of normal AL eyes (22-24.5 mm) (3, 11).

A rate between 43% and 67% of big refractive errors (>2 diopters) is not due to intrinsic errors in the mathematical formula, but is the result of inaccurate pre-operative measurements, as regards the biometric values, or of technical errors (12, 13). Independently of the formula chosen, the accuracy of IOL power calculation is related to many factors contributing to the eye's total refractive power. An 0.1 mm error in the measurement of the mean corneal radius means an error of 0.25 D in the intraocular lens power (14), while for a 1-D error in the corneal power a 1-D error may be present in the post-operative refraction (1). The accuracy of AL echobiometric measurement is ± 0.1 mm accounting for a calculation error not more than 0.25 D (15).

In eyes with a thick cataract in may be difficult to achieve optimum peak elevation of the retina and in thick cataracts the velocity of ultrasound propagation is higher (14, 15). Measuring a smaller eyeball in case of a thick cataractous lens may lead to post-surgical myopia (6, 11, 13) if the IOL has too great a power. All pre-operative predictions of the refractive result are in any case based on the assumption that surgery does not alter the eye structure. Some studies confirm that the AL is not modified much after cataract extraction and IOL implantation (8).

The refractive error also seems related to post-operative astigmatism (6, 13). Surgery can cause remarkable changes to the corneal curvature and immediately after the operation this induces or accentuates astigmatism that tends, however, to decrease as time passes. The entity of these changes differs according to the surgical technique, to the site of incision and to the suture. In order to introduce adequate corrections in the formulas using post-operative data, and therefore to obtain more precise results, the refractive outcomes need to be evaluated after stabilization of the astigmatism (3-6 months with a nylon suture: 8).

The choice of IOL may be another small source of error. The computerized calculation usually gives a dioptric power approximated to diopter hundredths, which it is hardly ever possible to implant because IOLs have a power approximated to 5 tenths of a diopter (1). Another possible technical source of error in predicting post-operative refraction is that not all IOL really present the power indicated on the package. The manufacturers themselves assure an accuracy of ± 0.25 D; nevertheless, measurements of the implantation power may differ between the various manufacturers from the methodological point of view.

In this study, our selection criteria excluded eyes with severe ametropias. For this reason, all cases had the IOL power calculated by the SRK-II formula, with AL values in the range in which this formula works better than newer generation theoretical formulas (3). The mean post-operative optical correction (-0.47 ± 0.91 ED, within ± 1 D in 76% of cases and within ± 2 D in 96% of cases) and the refractive error (0.74 ± 0.61 ED, within 1 D in 77% of cases and within 2 D in 96% of cases) were similar to those reported in the literature. Emmetropia was reached in 15% of cases, while 65% of eyes needed a myopic correction. The deviation from emmetropia and the refractive error appeared to be age-related, as was the degree of myopization. We found a shorter AL in patients aged over 73 years than in patients aged 73 years or less, but the difference was not significant. In the same way, there was no significant correlation between AL and degree of post-operative myopization. Thus, we cannot directly ascribe the myopization to the underestimated AL. The deviation from emmetropia comes both from the degree of post-operative astigmatism and from the post-operative spherical lens, which was significantly higher in older patients. The astigmatism was also greater with a clear-cornea incision, but this surgical technique appeared to be similarly distributed in the two age subgroups. The refractive error appeared unrelated to pre-operative VA, suggesting that when a good echobiometric retinal peak is obtained, a patient's fixation defect does not influence AL measurement and IOL power calculation.

Despite the accuracy of echobiometric and keratometric measurements and the use of more and more precise IOL power calculation formulas, emmetropia is still not reached in most pseudophakic patients. This limit of modern cataract surgery was confirmed by our study. The method used to recruit patients allowed us to evaluate the refractive outcome in the ordinary surgical practice of our department. However, to exclude any possible source of error (great pre-operative ametropia, high post-operative astigmatism, IOL power different from the predicted one), we considered a carefully selected sample of cases. The emmetropia rate in our study group would probably have been lower if we had included the entire population of patients who underwent cataract surgery. Our results, also suggested that age might be a risk factor for increased refractive error after cataract surgery and should be taken into consideration when collecting the patient's pre-operative information.

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REFERENCES

1. Hoffer KJ. Pre-operative cataract evaluation: intraocular lens power calculation. Int Ophthalmol Clin 1982; 22: 37-75.
2. Olsen T, Kirsten T, Corydon L. Theoretical versus SRK I and SRK II calculation of intraocular lens power. J Cataract Refract Surg 1990; 16: 217-25.
3. Sanders DR, Retzlaff J, Kraff M, Gimbel H, Raanan M. Comparison of the SRK/T formula and other theoretical and regression formulas. J Cataract Refract Surg 1990; 16: 341-6.
4. Hovding G, Natvik C, Sletteberg O. The refractive error after implantation of a posterior chamber intraocular lens. Acta Ophthalmol 1994; 72: 612-6.
5. Dam-Johansen M, Olsen T. Refractive results after phacoemulsification and ECCE. A comparative study. Acta Ophthalmol 1993; 71: 382-7.
6. Kalogeropoulos C, Aspiotis M, Stefaniotou M, Psilas K. Factors influencing the accuracy of the SRK formula in the intraocular lens power calculation. Doc Ophthalmol 1984; 85: 223-42.
7. Modorati G, Pierro L, Brancato R. Pre-operative astigmatism influence on the predictability of intraocular lens power calculation. J Cataract Refract Surg 1990; 16: 591-3.
8. Retzlaff J, Sanders DR, Kraff M. Lens implant power calculation. A manual for Ophthalmologists and Biometrists. Thorofare, New Jersey: Slack Inc Ed. 1990; 38: 165.
9. Retzlaff J, Sanders DR, Kraff M. Development of the SRK/T introacular lens implant power calculation formula. J Cataract Refract Surg 1990; 16: 333-40.
10. Gregory PTS, Esbester RM, Boase DL. Accuracy of routine intraocular lens power calculation in a district general hopsital. Br J Ophthalmol 1989; 73: 57-60.
11. Olsen T, Uggeroj Andersen C, Plesner HJ. Computerised intraocular lens calculation: clinical results and predictability. Br J Ophthalmol 1989; 73: 220-4.
12. Holladay JT, Prager TC, Lewis JW, Ruiz RS. Improving the predictability of intraocular lens power calculation. Arch Ophthalmol 1986; 104: 539-41.
13. Richards SC, Olson RJ, Richards WL. Factors associated with poor predictability by intraocular lens calculation formulas. Arch Ophthalmol 1985; 103: 515-8.
14. McEwan JR, Massengill RK, Friedel SD. Effects of keratometer and axial length measurement error on primary implant power calculation. J Cataract Refract Surg 1990; 16-1: 61-70.
15. Ossoinig KC. Standardized echography: basic principles, clinical application and results. Int Ophthalmol Clin 1979; 19-4: 127-210.