Refractive state in patients with phacoemulsification of cataract in uncommon situations

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Abstract

Background: We undertook this study to determine the refractive state in patients who underwent non-complicated phacoemulsification under unusual situations.

Methods: This was a clinical, open, transversal, prospective and comparative study. Patients had the following conditions: congenital cataracts, hyperopia, myopia, and emetropia with previous corneal transplantation or vitreous cavity filled with silicone oil.

Results: Thirty six eyes were included in our study vs. control group (52 emetropic eyes). There was no statistical significance in spherical equivalent 6 weeks postoperatively, with 59% of patients within +1.00 D, 73% +2.00 D and 28% >+2.00 D.

Conclusions: Refractive state was favorable with an average of 0.96 D ± 6.27.

Key words: congenital cataract, phacoemulsification, intraocular lens calculation, myopic, hypermetropia.

Introduction

Primary ocular care comprises prevention of ocular diseases that may potentially cause blindness, including identification, treatment or transfer of the patients.1

Despite efforts in developing countries, the number of blind or incapacitated persons is growing due to the global increase and aging. The most recent estimate (1997) of world blindness is ~45 million persons, with cataracts constituting 47% of the total as a cause and an additional 135 million persons with poor vision. Eighty percent of blindness is preventable or reversible, and 9/10 blind persons live in developing countries such as Mexico.2

During the last two decades, intraocular lens (IOL) power calculations have significantly improved for replacement of the crystalline in cataract removal surgery. In 1977, in order to achieve emetropia with an IOL of the posterior chamber, +18.00 diopters (D) were added to the pre-cataract refraction. Ten years ago a good result was considered to be +1.00 D of the desired refraction. With the current technology, results <0.50 D are expected.3

However, it is not simple to achieve the desired refraction under special clinical situations such as retinal detachment treated with instillation of silicone oil in the vitreous cavity, eyes with extreme axial length, congenital cataracts and corneas with refractive power different from the original or previously subjected to refractive surgery or penetrating keratoplasty.3

Sweep A biometry has been used since 1970 to calculate axial length, using contact technique or immersion. The latter is used with ultrasound waves suspended in a small fluid bath that covers the cornea and thereby avoids indentation.3

Another measurement method is biometry of optic coherence with IOL (Carl Zeiss Meditec, Jena, Germany), which is five times more precise. However, it is necessary to look at a visual
object and it is not possible to use it in a medium with considerable opacity or in congenital cataracts, as frequently happens in our environment.\textsuperscript{3,4}

In elevated axial myopia the IOL calculation is not simple, and the presence of staphyloma may yield a biometric error due to scleral convexity in the posterior pole. Incidence of staphyloma increases in direct proportion with axial length. If suspected, a B sweep is recommended to identify this problem and assist in axial lengthening.\textsuperscript{3,5}

Another special situation is axial hypermetropia, as opposed to myopia, where the postoperative refractive error increases as axial length increases. Therefore, its measurement with immersion is recommended because small errors are significant in the postoperative refractive state.\textsuperscript{3}

One of the most difficult situations in IOL calculations is an eye with silicone in the vitreous cavity because the velocity of the ultrasound is different from the vitreous humor. Some examples are surgery for retinal detachment, severe myopia, proliferating vitreous retinopathy, proliferating diabetic retinopathy, and acquired immunodeficiency syndrome, giant retinal tear or history of ocular trauma. Measurement of both eyes is recommended.\textsuperscript{3}

Refractive surgery revolutionized the ophthalmologic world in the 1990s.\textsuperscript{3} As the number and type of keratorefractive procedures increase, the average population age moves towards the "age of cataracts." Therefore, the number of patients who will require cataract surgery after a refractive surgery increases each year.\textsuperscript{5,6} Keratorefractive procedures such as radial keratotomy (RK), photorefractive keratotomy (PRK) or LASIK, among others, are popular for ophthalmologists and patients. In the U.S. there are 1,300,000 keratorefractive surgeries calculated for the 21st century.\textsuperscript{5-9}

If subjecting a postkeratorefractive patient to surgery is not more complicated than operating on a virgin eye, its calculation of target IOL power poses a challenge and many complications. This could give as a result "refraction surprises" in patients subjected to cataract removal.\textsuperscript{5-9}

Average corneal keratometric power (KP) is 43.0 D. Use of a central average after RK, PRK, LASIK or penetration keratoplasty (PKP) for the common calculation of IOL has a predictive value with a tendency to under correction and leaves the patient with a hypermetropic or anisometropic correction.\textsuperscript{6,5}

Failures in the IOL calculation exist such as in the technique used for optical correction, applied mathematical formula or method of measurement of average keratometries, among others.\textsuperscript{8}

Keratometric error can be attributed to three principal factors:

1. Inadequate measurement of the anterior corneal curvature
2. Inadequate calculation of corneal refractive power
3. Incorrect estimate of the effective position of the lens

When performing keratometry it is assumed that the refractive index is represented jointly by the dioptric power of the anterior and posterior surfaces of the cornea. With the eyes subjected to keratorefractive surgery or PKP, this assumption is not valid. Irregular astigmatism of the paracentral cornea and the change in the relationship between its surfaces may cause invalidity of keratometric readings.\textsuperscript{6}

To evaluate the keratometric power, the “clinical history” method is used on performing a subtraction of the spherical equivalent corrected to the preoperative keratometric readings, but this only applies when we have prior information at our disposal. Another method is that of "rigid contact lens", on subtracting to the postrefractive keratometry the difference of the spherical equivalent between the use of contact lens and without use of it.\textsuperscript{8} Perez-Silguero et al. proposed to estimate the dioptic power of the IOL on implantation transoperatively, incorporating the patient and performing skioscopy, autorefractometry and subjective graduation.\textsuperscript{9}

Finally, IOL implant in a young eye that continually grows causes problems in this group of patients\textsuperscript{10,11} despite the Gordon tables of estimation of the ocular globe growth, according to age and formula for calculation of IOL searching for emetropia. A pseudophakic eye grows slower than an aphakic and the latter grows less than a phakic eye.\textsuperscript{10}

For this reason it is preferred to allow mild postoperative hypermetropia in children to reach adulthood to achieve emetropia or mild myopia.\textsuperscript{12} Pediatric cataract will always be a challenge and the options remain open.\textsuperscript{15}

Advances in cataract removal techniques and new IOL implants have converted it into a refractive method, achieving better visual capacity and increasing expectations.\textsuperscript{3,6,14}

Two large groups of formulas exist for calculation of IOL: regression and theoretical. In the SRK (Sanders, Retzlaff and Kraff) prototype of the first formula, IOL power is obtained by a constant “A” of the lens according to its material and angle of haptics, as well as its longitudinal axis (AP) (anterior face of the cornea to the anterior face of the retina) and average keratometric reading using the following formula:

\[ P = A - 0.9 \times K - 2.5 \times AP \]

However, there were postoperative refractive errors in non-emetropic patients and this formula was adapted, adding or subtracting arbitrarily to the constant of A if AP was less than or greater than 23 mm, respectively, as shown below:

\[
\begin{align*}
A &= A + 3 & (AP <21 \text{ mm}) \\
A &= A + 2 & (20 \text{ mm}_AP <21 \text{ mm}) \\
A &= A + 1 & (21 \text{ mm}_AP <22 \text{ mm}) \\
A &= A & (22 \text{ mm}_AP <24.5 \text{ mm}) \\
A &= A - 0.5 & (24.5 \text{ mm}_AP)
\end{align*}
\]

Thus, it is named SRK-II.\textsuperscript{14}

More recently, the theoretical optical formulas such as those of Hoffler, Haigis, and Holladay have been designed to calculate the IOL power in the most exact manner possible in eyes with AP axis different from 23 mm. They are all based on a simplified
principle that consists of a refractive surface (cornea) and a thin lens (IOL), according to a basic formula:

\[ P = \frac{n}{d} \times \left( AL - d \right) - \left( n + \frac{K + TR}{d} \right) \]

where “d” is the effective position of the lens and “TR” the corneal refraction power with feedback ability.

Currently, there is a new question: What is the refractive state in special situations of cataract removal by means of phaco-emulsification?

**Materials and Methods**

We evaluated the refractive state in patients who were subjected to cataract phacoemulsification under special situations in the period between May 1, 2006 and December 1, 2006. We conducted a clinical, open, prospective study with sequential and transversal selection.

Patients included those with cataracts and length of the ocular globe AP >24 mm, <21.9 mm or >22 mm but <23.9 mm and with some of the following special situations: prior keratorefractive surgery or corneal transplant, congenital cataract and/or vitreous cavity filled with silicon. Cataract removal was done by phaco-emulsification without complications, with IOL in capsular bag. Age of patients or patients’ gender was not considered in patient selection.

Exclusion criteria were patients with poor technique of measurement of the AP axis, poor technique of keratometric reading, rupture of the posterior capsule of the crystalline, placement of the IOL in the anterior chamber, placement of IOL in “sulcus”, herniation of the iris or conversion to extracapsular extraction technique (ECE).

Patients who did not have outpatient follow-up had luxation of the IOL to anterior chamber, non-centering of the IOL and endo-ophthalmitis.

Manual keratometric reading in two perpendicular planes was performed, using as the baseline the flattest corneal curvature by means of keratometer (Bausch & Lomb) with calibration =1.3375, all done by the same person who was expertly trained in the procedure.

Measurement of the AP axis of the ocular globe was performed with the patient in the dorsal decubitus position (erect on patients with silicone) and under topical ocular anesthesia (5% tetracaine) placing the immersion camera filled with a 0.9% saline solution and applying a 10-MHz ultrasound (US) probe inside the chamber to measure axial longitude. This was done with an US (model “Ultra scan”, Alcon) with velocity of 1532 msec for the aqueous humor and vitreous (980 msec in vitreous cavity filled with silicone) and 1641 for the crystalline, automatic mode, with an average of 10 measurements and a margin between them of <.05 mm.

In all cases it was complemented with an “A-B” mode to rule out aggregate pathology. In cases of elevated axial myopia or in the presence of subsequent staphylomas, the longitude was corroborated in this manner, in infants as well. All studies were performed by the same person expertly trained in the procedure.

The power of the IOL to be implanted was calculated entering average keratometry and axial longitude in US applying formulas according to the AP longitude. SRK-II formula was used for measurements between >22.0 mm and <23.9, SRK-T in >24.0 mm and Holladay 2 with AP longitude AP <21.9 mm by means of software loaded automatically. IOL power was given to achieve emetropia.

Cataract phacoemulsification was performed by the same surgeon, with principal port of 3 mm and accessory port of 0.8 mm, both in clear cornea with continuous circular capsulorrhexis, hydrodissection of the crystalline, fragmentation and aspiration by US. Placement of the IOL was in the hydrophilic acrylic type, one-piece with IV filter (AKREOS, Bausch & Lomb). Closure of the principal wound was done with 10-0 nylon sutures and edematization of the borders.

Postoperative retinoscopy was performed 4 to 6 weeks after scotopic conditions, with erect patients and visual fixation at 6 m. These were all performed by the same person expertly trained in the procedure. Results were expressed in spherical equivalents.

Statistical calculations were done using the SPSS 10.0 for Windows program to a significance of 0.05. Non-parametric Mann-Whitney U tests were performed because distribution of the variables did not meet the criteria of normality.

**Results**

There were 147 surgeries for cataract removal performed, of which 48 were not included because they were ECE, combined procedures of vitreous and retina, as well as transsurgical complications. An additional 10 patients were eliminated because of lack of follow-up or incomplete medical records.

There were 88 eyes included, 36 were classified with having some special situation and cataract. For the study, eyes were divided into the following groups: congenital cataract, hypermetropes, myopes, vitreous cavity filled with silicon and prior PKP. Fifty two additional eyes (emetropes) were used for the control group.

The control group was comprised of 52 eyes, 26 right and 26 left, 40% males and 60% females. Average age was 67 ± 14 years (CI 95% 3.8) and PK with range from 41.0 to 47.0 D (average 43.88 ± 1.37; CI 95% 0.37, 43.50-44.26) (Figure 1). AP axis was 22.09-23.84 mm (average 22.89 ± 0.43; CI 95% 0.11, 22.77-23.01) (Figure 2). Refractive state was -4.00 to +2.50 D (average -0.69 ± 0.95; CI 95% 0.26, -0.95 to -0.42). Thirty eight were within +1.00 D, 48 within +2.00 D and 4 >+2.00 D.

There were four males with an average age of 1-4 years included in the congenital cataract group, a total of 7 eyes, 3 right eyes and 4 left eyes. PK was 43.71 D ± 0.48 (CI 95% 0.36, 43.26-44.17),...
without statistical significance vs. the control group \((p = 0.750)\). AP axis had a range of 19.44 to 24.51 mm (average 22.45 ± 2.27; CI 95% 1.68, 20.35-24.55) with significant statistical difference vs. the control group \((p = 0.654)\). Refractive state was -4.00 to +3.50 D (average -0.71 ± 3.05; CI 95% 2.26, -3.53 to -2.10) with one patient within +1.00 D, three patients within +2.00 D and four patients >+2.00 D, without statistical significance between congenital cataract and control group \((p = 0.654)\) (Figure 3).

Ten patients were analyzed in the group of hypermetropes, nine females and one male (11 eyes, 5 right eyes and 6 left eyes). Ages ranged from 60 to 84 years (average 71 ± 7 years; CI 95% 0.89).
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finding statistically significant evidence to comment that PK is different between this group and the control group \((p < 0.05)\). AP axis was 0.19 to 21.94 mm (average 21.08 ± 0.72; CI 95% 0.42), also with statistically significant evidence between the hypermetrope and control group \((p < 0.05)\). Refractive state was -0.50 to -3.00 D (average -1.36 ± 0.90; CI 95% 0.53, -1.97 to -0.75), with seven within +1.00 D, 8 within +2.00 D and 3 >+2.00 D. There was no statistically significant difference found in the spherical equivalent between the control group and hypermetropes \((=0.053)\) (Figure 4).

Sixteen eyes were included in the myopic group, eight right eyes and eight left eyes, with three males and 11 females. Ages ranged from 44 to 83 years (average 56 ± 11 years; CI 95% 5.4). PK was 41.00 to 46.00 D (average 42.91 ± 1.35 D; CI 95% 0.66, 42.19-43.64) with significant statistical evidence to mention that PK is different between this group and the control \((p = 0.016)\). With AP axis it was from 24.25 to 31.49 mm (average 24.51 ± 1.35 D; CI 95% 0.91, 25.42-27.4), finding a statistically significant difference between the myopic group of patients and the control group \((p <0.05)\). The refractive state was -0.50 to +1.00 D (average -0.82 ± 1.04; CI 95% 0.51, -1.38--0.27); 12 within +1.00 D, 14 within +2.00 D and 2 >+2.00 D. There was no significant statistical difference between this group and the control group \((p = 0.544)\) (Figure 5).

There was one 25-year-old patient with vitreous cavity filled with silicone and PK 44.00 D, axial axis 24.5 mm and refractive defect -2.50 D. There was another patient with prior PKP secondary to keratoconus and right eye cataract with PK 46.62, axial axis 25.9 and refractive state +1.00 D.

Finally, a refractive state of the control group was achieved with 74% within +1.00 D, 93% within +2.00 D and 7% >+2.00 D. There was no significant statistical difference between this group and the control group \((p = 0.191)\) (Figure 6).

Discussion

During the 8 months of the study, 88 eyes were included and divided into two different groups. Gender distribution favored females (~60%).
The age group, with the exception of congenital cataracts, was within the first six decades of life, as reported by other studies.2

Our group of emetrope patients was comprised of 52 eyes with an average PK 43.88 ± 1.37 D (CI 95% 0.37, 43.50-44.26) similar to that of Elder et al. who reported 43.29 D (average 22.89 ± 0.43 mm; CI 95% 0.11, 22.77-23.01) vs. 23.39 mm; and refractive state of a period of 4-6 weeks of evolution after cataract extraction by means of phacoemulsification in previous emetrope patients reached a spherical equivalent with 1.00 D of 74%, 93% within 2.00 D and an isolated patient of +3.50 D vs. 80%, 99% and 1%, respectively.17

Of the group of myopic patients with average PK of 42.91 ± 1.35 D vs. the results by Colette et al.18 of 43.70 D, our results show lower keratometric values than the report from China, although our sample is larger (88 myopic patients but with different cataract removal techniques, some by phacoemulsification and others by ECE). Our average AP axis of 26.41 ± 1.86 is slightly less compared to 28.32 mm of Colette. We had 75% of eyes within 1.00 D in the refractive stage, 12.5% within 2.00 D and 12.5% >2.00 D vs. 54%, 35% and 11%, respectively.18 In Mexico, Kaiser-Lomparte et al. reported a refractive state within 1.00 D in ~50-85% depending on the formula used and the magnitude of the myopia, suggesting statistical significance of SRK-T (used in our study) in myopia magna compared to SRK-II, but not in those ocular globes with AP length <29.9 mm.19

In the group of congenital cataracts our age range was 1-4 years vs. Hug whose retrospective study included patients between 1 and 16 years20 or the study by López-Moreno with age range of 3-15 years21 and Acevedo-González et al. whose patients were from 10 months to 16 years.22 Our average age of 2.84 ± 0.92 years and PK of 43.71 ± 0.48 D were arbitrarily assigned due to the difficulty in its measurement, similar to Hug who reports values of 43.00.20 However, Tromans et al.12 report a corneal curvature of 6.58 to 8.43 mm (average 7.57 ± 0.41 SD). We used the formula for IOL calculation in relation to AP axis, with ranges from 19.44 to 24.51 mm and an average of 22.45 ± 2.27 vs. 17.9 to 26.36 mm and 21.3 ± 1.72, respectively, of Tromans et al.12 Inatomi suggests that the superiority of SRK-T over the empirical for the calculation in eyes <19 mm of axial longitude.11 Although our spherical equivalent is -0.71 ± 3.05, only 15% of the patients were within 1.00 D, 43% within 2.00 D and 57% >2.00 D vs. 46%, 26% and 28%, respectively, reported by López-Moreno.21 The former is justified due to the arbitrary value assigned to our keratometries, keeping in mind that the measurement of the AP longitude is performed transpalpebral and in B mode. Hug calculated IOL by means of transsurgical aphakia method, obtaining an average refractive state of 2.34 D for those >6 years of age and 2.50 D for those <6 years of age; however, their ranges are from -12.00 to +6.00.20

Better knowledge of the “in crescendo” refractive range in pseudophakic pediatric patients will help in the future to have more precise refractions. Also, rehabilitation of a unilateral pseudophakic patient is really a challenge, without having other complications such as posterior capsular opacity. Of course, average myopia of 5.49 D after 1 year of surgery in an infant is not a good result.19 Tromans et al. report an average prediction error of 1.4 D ± 1.6 SD; this error was significantly greater in eyes <20 mm (p = .04) and/or 36 months of age (p = .03).12

Eleven hypertropic eyes were intervened with PK 46.70 ± 1.51 and axis AP of 21.08 mm ± 0.72 vs. 20.44 mm ± 0.54 in a study by Eleftheriadis et al. performed on 15 eyes. Our spherical equivalent was -1.36 D ± 0.90 vs. -0.12 D ± 1.40 with 64% of the patients within +1.00 D, 73% within the +2.00 D and 27% >+2.00 D vs. 40%, 93% and 7%, respectively.23

Although we reported only one patient with vitreous cavity filled with silicone, and a spherical equivalent of -2.50 D, Ghoraba et al. reported 29 patients with cataract and its extraction by means of phacoemulsification or lensectomy, with a refractive state of 51.9% within the 1.00 D, 73.9% within 2.00 D and 15% 3.00 D.
or more. 25 We are aware of the difficulty in calculating the longitudinal axis in these patients. Habibabadi et al. reported on 13 patients with measurement of the AP axis by means of laser interferometry and refractive state at 12 weeks of $-0.30 \pm 0.90$ D with an average of 69.23% of the patients within $1.00$ D. 25 Takei et al. suggested measurement of the AP longitude by means of computerized tomography in cases with vitreous cavities partially filled with silicone, taking as the anterior pole the anterior face of the cornea and the posterior temporal pole to 4.5 mm with respect to the II nerve, achieving an average refractive state of $-0.27 \pm 1.59$ D, with 50% of the patients within $1.00$ D, 75% within $2.00$ D and 25% $>2.00$ D. 26

Only one patient with history of prior PPK was subjected to cataract phacoemulsification with a spherical equivalent of $+1.00$ D. Andrean et al. report on a PKP case and prior keratorefractive surgery, remaining with refractive state of $-0.50$ D. 27 Other studies such as that by Urrutia-Breton et al. report on a refractive state within $1.00$ D in 13% of patients subjected to prior keratorefractive surgery. However, his sample was relatively small ($n = 13$). 28 Argento et al. report on seven patients with the same characteristics and average refractive state of $0.19 \pm 1.01$ D. 29

It should be stressed that a statistically significant difference does not exist between the emetropo et group of patients when compared against each one of the others, such as the myopes, congenital cataracts and hypermetropes, with the refractive state always being $<1.00$ D on average, with the exception of the last group.

In conclusion, the refractive state reported in our patients is favorable; however, the percentage was $>2.00$ D in the special groups (mainly due to congenital cataracts) compared to the group of emetropes. In future surgeries we will correct these deficiencies because of the learning curve from the present study.

References