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Article

Axial Length Shortening After Cataract Surgery: New Approach to Solve the Question

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Purpose: To check if optical biometry can detect eventual corneal power (Km) and axial length (AL) cataract surgery-related changes that could influence the refractive outcome.

Methods: Patients scheduled for sequential bilateral cataract surgery between January and September 2017 were included in the present study. One hundred ninety-six eyes of 98 patients (48 males) were selected. Before surgery of the first eye, patients underwent a complete ophthalmic examination, including IOLMaster biometry; the same evaluations were repeated in both eyes the day before the fellow eye cataract surgery, performed at least 2 months after the first one. The differences in Km and AL in the first operated eyes were evaluated, and the fellow eyes were used as controls.

Results: Km differences in the operated eyes ranged from −1.97 to +0.98 diopter (D) (mean = −0.02 ± 0.36 D) (P = 0.89); in the nonoperated eyes they ranged from −0.6 to +0.7 D (mean = 0 ± 0.20 D) (P = 0.91). The AL differences (pseudophakic option) in the operated eyes ranged from −0.35 to +0.15 mm (mean = −0.10 ± 0.08 mm) (P < 0.001); with the aphakic option they ranged from −0.24 to + 0.26 mm (mean = 0.01 ± 0.08 mm) (P= 0.38). In the nonoperated eyes, the AL differences ranged from −0.04 to +0.06 mm (mean= 0 ± 0.02 mm) (P = 0.02).

Conclusions: The modern phaco-technique seems not to induce changes in Km and AL, supporting the hypothesis that the differences in AL are due to an incorrect estimation in pseudophakic eyes.

Translational Relevance: The results of our study may improve the AL measurements in pseudophakic eyes.

Introduction

The leading cause of blindness worldwide is due to cataract, and its extraction is one of the most commonly performed surgeries in the world.[1]

Today, cataract surgery, due to the phacoemulsification techniques, to the improvements in intraocular lens (IOL) calculations, and to the IOL manufacturing, is considered one of the most successful procedures in ophthalmology.

The IOL power calculation is mainly based on the preoperative measurement of the mean corneal power (Km), the axial length (AL), and the estimation of the effective lens position.[2–4] In some cases, these measurements could be not reliable, such as in eyes that underwent corneal refractive surgery[5–10] or eyes in which there were corneal irregularities.[11,12]

As these measurements are performed before surgery, normally they do not take into account eventual changes that could be due to the surgical procedure, such as changes in the corneal power. It is well known that the surgical cut can induce modifications in corneal astigmatism,[13,14] but we were not able to find studies that focused their attention on eventual changes in the Km.

Regarding the AL changes after cataract surgery, several studies, mainly based on ultrasound measurement, discussed a possible AL reduction or increase after cataract surgery, concluding that these changes were not present if different sound velocities were utilized in pseudophakic eyes.[15–17] In most recent

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Table 1. Corneal Power Evaluation

	Before		After		
	Range	Mean ± SD	Range	Mean ± SD	*P*
Operated eye	40.82–49.03	43.79 ± 1.61	40.96–48.88	43.80 ± 1.56	0.89
Fellow eye	40.89–48.36	43.84 ± 1.56	40.84–49.03	43.83 ± 1.61	0.91

Km values in diopters in terms of mean ± standard deviation (SD) and range of the operated and fellow eyes, before and after the cataract surgery.

years, after the introduction of the optical biometers, other papers dealing with this issue were published. These authors agree with the previously published studies that could not prove a true AL reduction following cataract surgery, but they suggest that the mean AL shortening is related to the group refractive index incorporated in the calculation.[18–20] Thus, they propose to apply a correcting factor to measure the real AL after cataract surgery.

The purpose of this study was to determine if, by applying this correcting factor to an optical biometer, namely the IOLMaster (Carl Zeiss Meditec AG, Jena, Germany), we could detect eventual changes, or if further modifications are needed to improve these measurements, or, as suggested by another study, the changes are related to a wrong assessment of the preoperative sound speed in the cataractous lens.[21]

Methods

Patients scheduled for bilateral cataract surgery at the Eye Department of the University of Salerno between January 2017 and September 2017 were included in the present study. Patients that underwent previously refractive surgery were excluded from the study. The study was consistent with the tenets of the Declaration of Helsinki, and institutional ethics committee approval and written informed patient consent were obtained from all individual participants included in the study. The time interval for the surgery of the fellow eye was at least 2 months after the previous surgery. Before the first cataract surgery, both eyes of the patients underwent a complete ophthalmic examination, including an evaluation with an IOLMaster (5.4.4.0006; Carl Zeiss Meditec AG). The AL evaluation was the mean of at least three measurements, with the highest signal-to-noise ratio at least above 2. Based on these criteria, 196 eyes of 98 patients (48 males) were identified.

The same evaluations were repeated in both eyes the day before the fellow eye surgery.

The first operated eyes were evaluated, and the fellow eyes were used as control. Only eyes without previous ocular surgery; with ocular media that allowed the IOLMaster evaluation; without glaucoma, corneal scars, or other ocular or systemic diseases that could alter the results of the study; and eyes that underwent uneventful surgery were included in the present study.

One surgeon (N.R.) performed all surgeries using the same surgical procedure. The clear corneal stab incision was made using a 3.0-mm stainless knife at 12.00. A continuous curvilinear capsulorhexis of approximately 5.0 mm in diameter was performed

Table 2. AL Evaluation

	Before		After		
	Range	Mean ± SD	Range	Mean ± SD	*P*
Operated eye	21.58–29.51	23.69 ± 1.31	21.50–29.31[a]	23.58 ± 1.31[a]	<0.001[a]
			21.61–29.42[b]	23.69 ± 1.31[b]	0.388[b]
Fellow eye	21.53–28.97	23.59 ± 1.23	21.55–28.94	23.60 ± 1.22	0.022

[a] AL in the operated eyes was calculated with pseudophakic option.
[b] AL in the operated eyes was calculated with aphakic option.
Axial values in millimeters in terms of mean ± SD and range of the operated and fellow eyes before and after the cataract surgery.

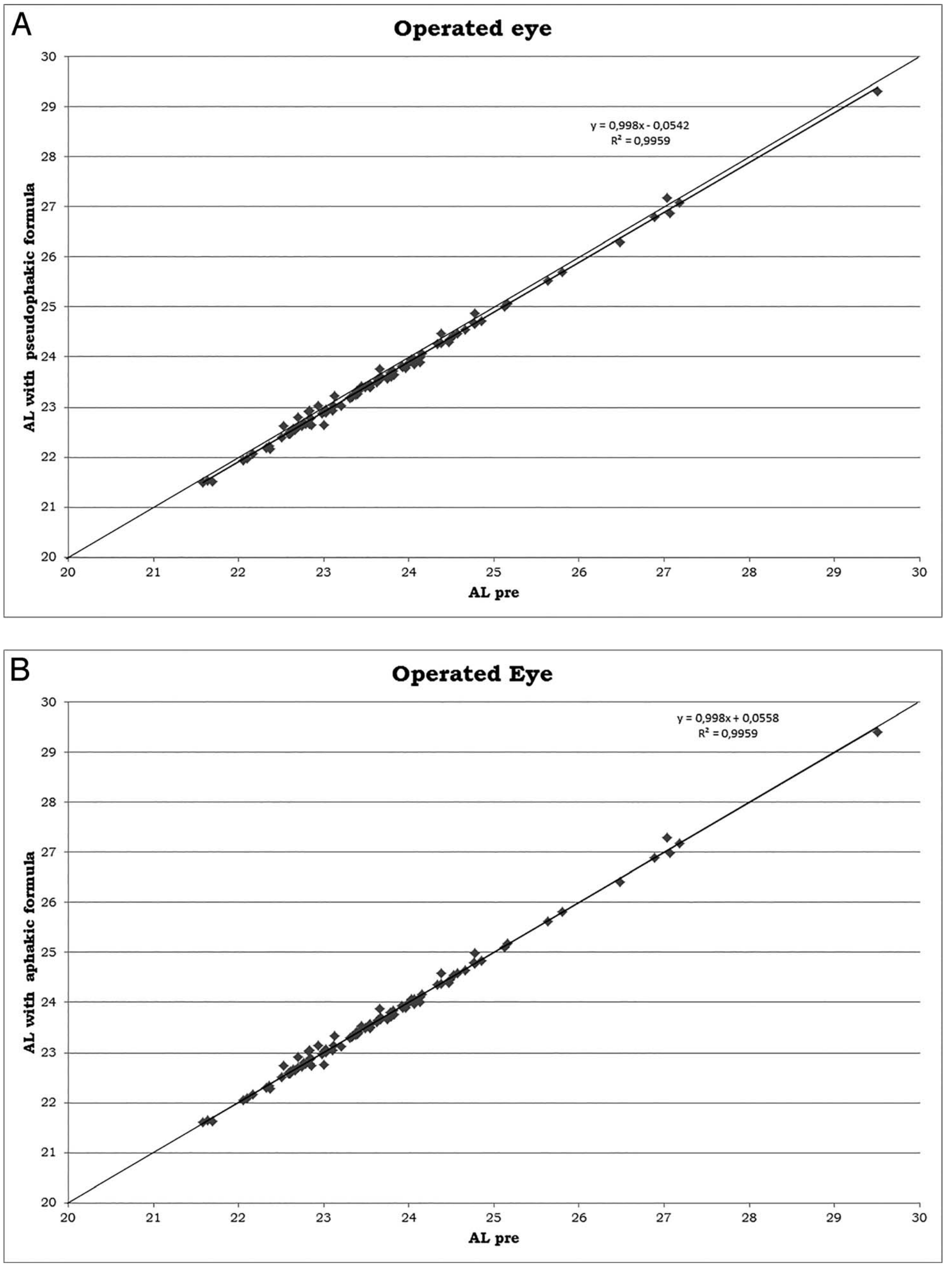

Figure 1. (A) Plot between the AL measurements before cataract operation on the horizontal axis and AL measurement after cataract operation on the vertical axis, calculated using the pseudophakic option (in millimeters). (B) Plot between the AL measurement before cataract operation on the horizontal axis and AL measurement after cataract operation on the vertical axis, calculated using the aphakic option (in millimeters).

using a 25-gauge bent needle and a capsulorhexis forceps. After hydrodissection, endocapsular phacoemulsification of the nucleus and aspiration, an IOL (PCB00; Abbot Medical Optics, Santa Ana, CA, USA) was implanted. Hydration of the wounds, without corneal suture, was performed, and the eye was patched. None of the eyes received astigmatism keratotomy, limbar relaxing incision, or any other corneal incision beside the superior corneal stab incision and the paracenteses.

The Km and AL measurements obtained in the operated eyes before and 2 months after surgery were compared to the measurements obtained in the fellow eyes at the same time interval. A statistical evaluation was performed utilizing a paired *t*-test, a Bland-Altman evaluation, and R^2 analysis.

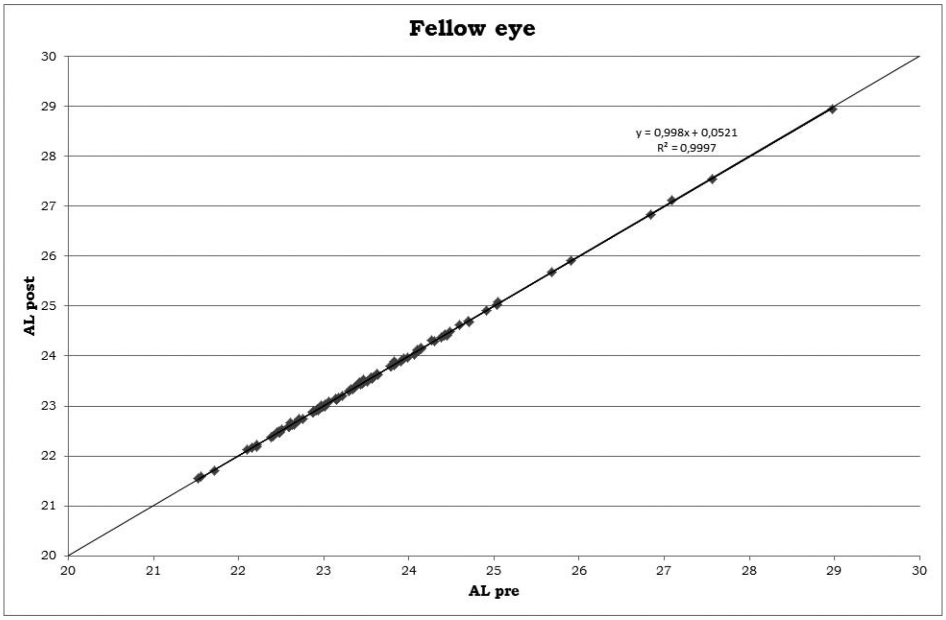

Figure 2. Fellow eye: Plot between the first and the second (2 months later) AL measurements calculated using the phakic option (in millimeters).

For the measurements of the AL after cataract surgery in the operated eye, the IOLMaster pseudophakic and aphakic options were utilized.

Results

The measurements of the first operated eyes and the fellow eyes before and at least 2 months after surgery are reported in Tables 1 and 2 and in Figures 1 to 4.

According to these findings, in the operated eyes there was a nonsignificant decrease in the Km with a difference ranging from −1.97 to +0.98 D (mean = −0.02 ± 0.36 D) ($P = 0.89$); in the nonoperated eyes there was a nonsignificant increase in the Km, with a difference ranging from −0.6 to + 0.7 D (mean = 0 ± 0.20) ($P = 0.91$).

In the operated eyes, with the pseudophakic option, the differences in AL between pre- and postsurgery measurements ranged from −0.35 to +0.15 mm (mean = −0.10 ± 0.08 mm), with a statistically significant difference ($P < 0.001$).

Utilizing the aphakic option after surgery, the differences in AL between pre- and postsurgery ranged from −0.24 to +0.26 mm (mean = 0.01 ± 0.08 mm), with a nonstatistically significant difference ($P = 0.38$). In the nonoperated eyes, the differences in AL between pre- and postsurgery ranged from −0.04 to +0.06 mm (mean= 0 ± 0.02 mm), with a nonstatistically significant difference ($P = 0.02$).

Discussion

To measure the IOL power to be inserted in the eye in the case of cataract extraction, we preoperatively measure the Km readings and the AL of the eye.

It is well known that the corneal astigmatism could be influenced by the cut we make into the cornea to enter into the eye. For this reason several authors concentrated their attention on how to minimize astigmatism onset after surgery, focusing their attention to the astigmatism present before[22–24] and after surgery.[25–29] To make such an evaluation, it is mandatory to perform a vectorial analysis.[30] However, we decided not to check this in our patients because this topic has been widely studied in the international literature,[25–29,31] and we could have added no new information.

Theoretically, the cut that we make in the cornea could alter not only the astigmatism, but also the corneal curvature and thus the AL. If this is true, this variation should be taken into account when we calculate the IOL power to be implanted and could therefore explain some unexpected differences. After an extensive review of the international literature, we were not able to find papers focusing on the changes in the total corneal power that could be present after

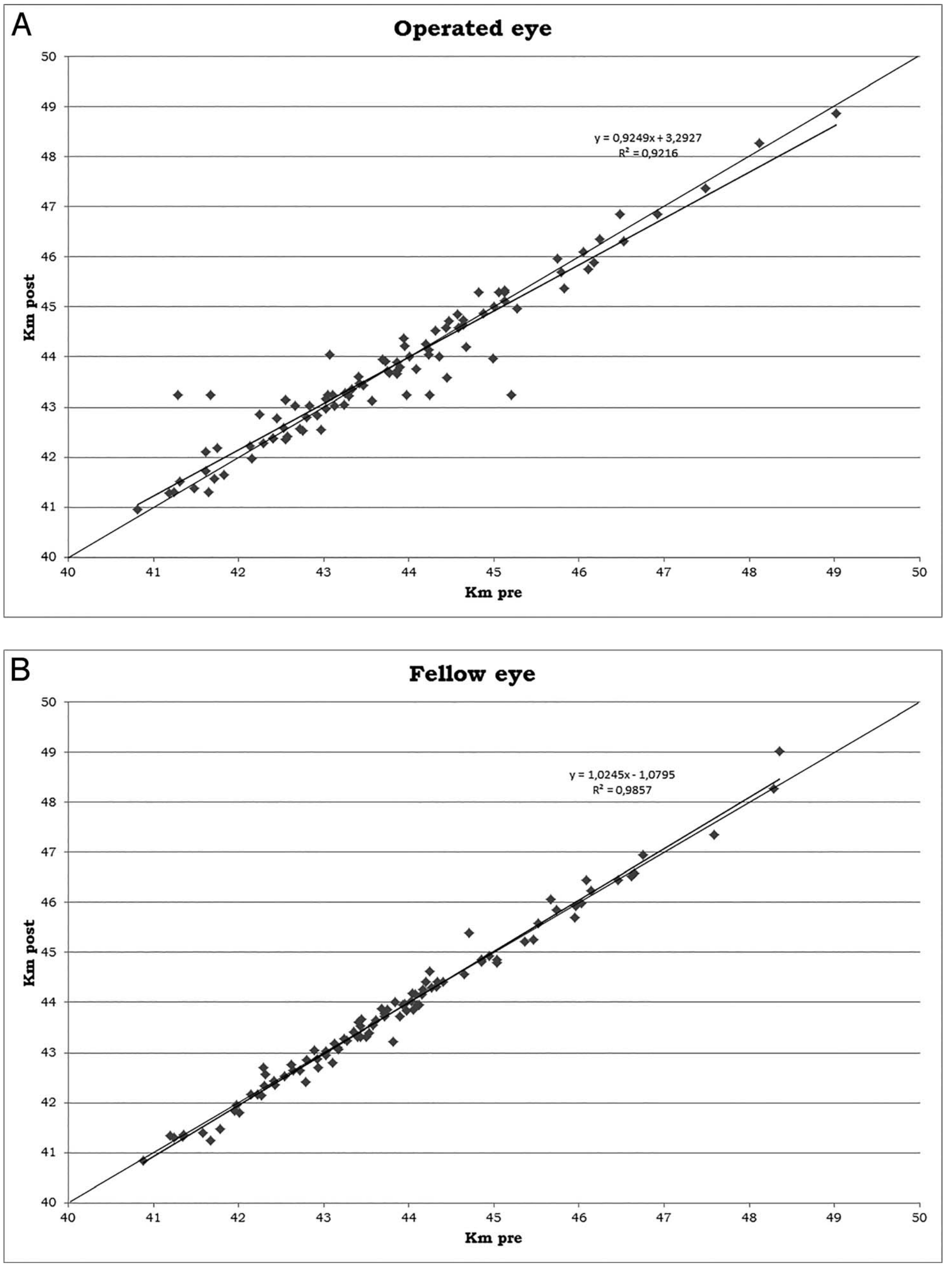

Figure 3. (A) Plot between the Km measurements (in diopters) before cataract operation on the horizontal axis and 2 months after on the vertical axis. (B) Fellow eye: Plot between the first and the second (2 months later) Km measurements.

surgery. Our findings of nonsignificant changes in Km both in operated (Fig. 3A) and fellow eyes (Fig. 3B), could be related to the minimally invasive techniques currently utilized in the modern phacosurgery.

Up until a few years ago, ultrasound was considered to be the gold standard in AL measurement, but today the introduction of the interferometric devices into the market has made these instruments the new gold standard.[18]

Utilizing these new devices, it has been shown that some procedures such as photorefractive keratectomy could change the AL.[9] Thus, we wondered if this could happen in cataract surgery: according to the results we obtained in this study, there is a slight but significant reduction in the AL measurement after cataract surgery (Fig. 1A, Fig. 4A).

There are four hypotheses to explain these differences in AL: one could be that the reduction in Km after the surgery could flatten the anterior

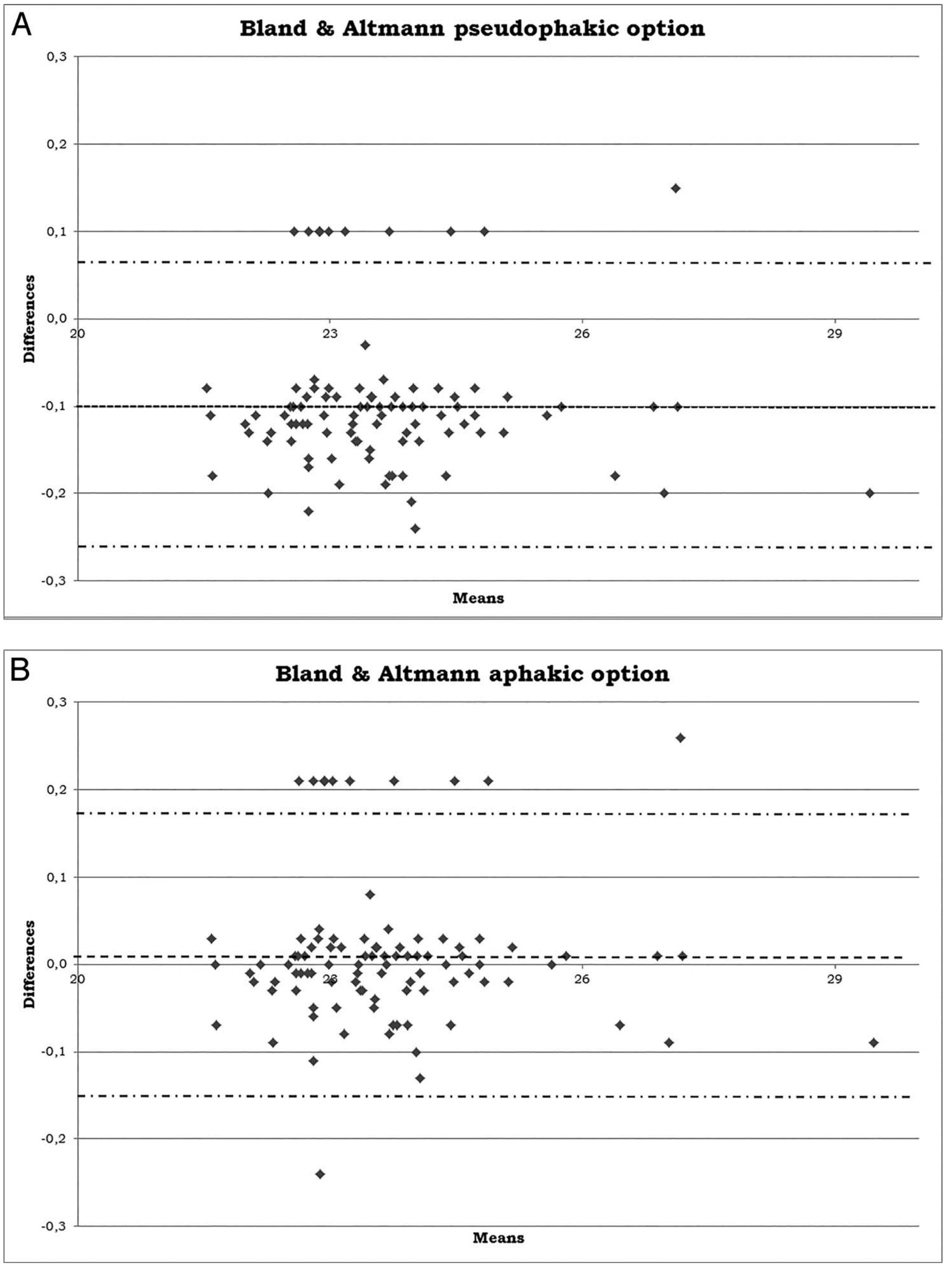

Figure 4. (A) AL measured before and after cataract operation utilizing the pseudophakic option (in millimeters). Bland-Altman diagram with median difference and agreement limits (including 95% of all difference values). (B) AL measured before and after cataract operation utilizing the aphakic option (in millimeters). Bland-Altman diagram with median difference and agreement limits (including 95% of all difference values).

chamber and consequently reduce the AL. We did not find any significant change in the Km (Fig. 3A), thus this hypothesis could not explain the decrease in the AL. The second hypothesis is that the extraction of the lens causes a decrease in the volume of the eye, with subsequent decrease in the AL. The third hypothesis is that no changes are present, but rather the differences are due to an incorrect estimation in pseudophakic eyes, despite the change in AL measurement modality from phakic to pseudophakic (Fig. 1A, 4A), that could not be sufficient to correct the AL measurement.

A fourth hypothesis could be that the incorrect measurement is the preoperative one because we know the real refractive index of the implanted lens, whereas the refractive index of the human lens could vary due to the cataract grade. Drexler et al.[21] found that changing the preoperative refractive index of the lens would compensate for the difference in pre- and postoperative axial length. Our results, instead, show that the preoperative AL well correlates with the postoperative one, both with the pseudophakic (Fig. 1A, 4A) and the aphakic (Fig. 1B, 4B) formulas. This seems to contradict the Drexler findings because different ranges of refractive index in the preoperative eyes should have given not only an homogeneous decrease but also a wider spread of the measurements, with a poor correlation not present in our patients. The reason could be that in our patients the range of refractive indices was not so wide. However, it is well known that these biometers do not work if the opacities are too strong. For this reason, in our opinion, the efficiency of AL measurements does not depend on the changes of the refractive index of the lens, but other factors could be involved.

Theoretically another reason could be a lack of repeatability of the IOLMaster measurements, but this is not true in our case because there was no significant difference in the measurements of the fellow nonoperated eyes (Fig. 2).

The presence of changes in the AL induced by cataract extraction is not new: Binkhorst[32] took into account the decrease in the AL after cataract surgery when in 1975 he developed his formula for IOL power calculation. A few years later, other studies found that there was no significant shortening of the eye after cataract surgery[15] and suggested[16] that to accurately measure the AL after IOL implantation, different propagation speed must be considered for calculation. This principle was utilized also when partial coherence interferometry was introduced in the IOL power calculation,[18] suggesting utilization of a 0.12-mm corrective factor for the acrylic and 0.08 mm for the polymethylmethacrylate lenses to have equivalent pre- and postoperative measurements.[19] This factor has been taken into account by the IOLMaster, which adds 0.1 mm in case of pseudophakic measurement. Our study proves that even with this correcting factor we still found a decrease in the AL (Fig. 1A, 4A). The reason for this could be either a real decrease in the AL measurement or an inaccuracy in the suggested correcting factors previously described.[19]

In fact, in that paper the IOLMaster was compared with contact A scan, assumed to be a gold standard. Unfortunately, it is now considered to be unreliable, and it is not really clear if the authors used a mean velocity or different velocities according the ocular media, as should be done.

Conclusion

We cannot prove that the third hypothesis of no changes in the AL after cataract surgery is correct, but if it is, based on our results, the use of the aphakic option instead of pseudophakic one could be a way to solve the problem in AL measurement.

In our opinion, the reason for decrease in AL measurement after cataract surgery is still an open question. Even if the calculations and the differences between pseudophakic and aphakic options seem to make the third hypothesis more likely, as in utilizing the aphakic option, the differences are not statistically significant.

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