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Original Article

Intra-correlations between cataract density based on Scheimpflug image, phacodynamics, surgery duration, and endothelial cell loss after phacoemulsification

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Abstract

Purpose: To assess intra-correlations between lens density based-on Scheimpflug Imaging System, power used during surgery, surgery duration, and endothelial cell loss in eyes with nuclear cataract.
Setting: Department of Ophthalmology, King Fahd Hospital of the University, Alkhobar, Saudi Arabia.
Design: Prospective cross-sectional observational study.
Methods and material: The objective lens density and endothelial cell density were measured using the Scheimpflug system and specular microscopy, respectively. Intra-operatively, all phacodynamic parameters and duration of the surgery were documented.
Results: This study of 62 patients (71 eyes) with a mean age of 58.56 ± 10.4 years. The mean Scheimpflug-measured lens density was 13.93 ± 3.27. The mean phacodynamic parameters, namely, power, ultrasound time, and elliptical motion were 13.63 ± 6.38, 1.27 ± 1.12, and 50.56 ± 50.06, respectively. There were a positive linear correlations between the Scheimpflug-measured lens density and phacodynamic parameters, power (AVG %), ultrasound time, and elliptical motion ($r = 0.501$, $r = 0.620$, and $r = 0.641$, respectively; all $P < .001$), amount of endothelial loss ($r = 0.445$, $P < .001$), and surgery duration ($r = 0.346$; $P < .01$). Phacodynamic parameters were positively correlated with degree of endothelial loss ($P < .01$). The length of the surgery failed to show any correlation with damage happened to the endothelium ($r = 0.210$, $P > .05$).
Conclusion: A positive correlations were observed between Scheimpflug-measured lens density with phacodynamic parameters, surgery duration, and endothelial loss. A strong correlation was observed between the degree of endothelial cell loss and phacodynamic parameters but not with the length of the procedure.

Keywords: Scheimpflug imaging system, Endothelial cell loss, Lens density, Surgery duration

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Introduction

As a significant factor in the development of blindness globally, cataract is of primary concern from a public health perspective.[1] Cataract surgery requires an objective approach to preoperative evaluation, principally with respect to the assessment of nuclear cataracts, to achieve the maximum optical quality.[2]

As the clinically most significant sub-category, nuclear cataracts in particular demand processes which are sufficiently

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objective to address challenges in grading,[3] along with estimating phacoemulsification energy requirements.

The classic grading process, the Lens Opacities Classification System III (LOCS III) under a slit lamp, is one of a number of clinical classifications routinely used in cataract grading.[4] Nonetheless, the requirement for a more objective method of grading nuclear cataracts was proposed in recent research by Maraini et al.[5]

An established disadvantage of methods using clinical parameters (such as slit-lamp assessment, age of patient, best-corrected visual acuity (BCVA), or lens imagery) is the subjective nature of the grading process and, as is the case for LOCS III and similar methods, discrepancies in routine performance. For example, slit-lamp settings[6] and the evaluator's expertise[7] can play a role.

Proposed in the early 20th century, the Scheimpflug principle forms the fundaments of Scheimpflug imaging, a well-established process for cataract evaluation which was first implemented in the 1970s.[8] When used in conjunction with the LOCS III system, visual function, and phacoemulsification energy, Scheimpflug imaging can be thought of an objective process for assessing lens nuclear density.[9–11]

Under the Scheimpflug principle, the plane of film aligns with the optical section through the lens, a convenience of the Scheimpflug system as it can thus ensure a uniformly-focused portrayal of a lens portion. This regularity in the plane of focus of the lens image as a whole may to some degree mitigate the artefacts observed in Scheimpflug photography and thus allow more discreet levels of progression to be identified.[12]

The correlation between Scheimpflug-measured lens nuclear density and phacoemulsification energy was evaluated in this research by the application of Pentacam Scheimpflug imaging in patients with age-related nuclear cataract. Additionally, the impact of surgery duration on endothelial cells density, as well as the correlation between phacoemulsification energy and degree of endothelial cells loss, was evaluated.

Subjects and methods

Patients with age-related nuclear cataracts but no previous history of ocular surgery, diagnosed between April 2015 and September 2015, were enrolled in this prospective, cross-sectional, observational trial at King Fahd University Hospital, Alkhobar, Saudi Arabia. A thorough assessment was performed on each patient prior to surgery, following the provision of written informed consent. The assessment included corrected and uncorrected distance visual acuity, slit-lamp assessment, Goldmann applanation tonometry, fundoscopy, intraocular lens calculation, Scheimpflug analysis, and specular microscopy.

Following pupil dilation with topical tropicamide 1.0% in combination with phenylephrine 2.5%, two measurements were collected per eye using the Scheimpflug system. This process was applied to evaluate lens density prior to surgery provided by the 3-D image of the anterior segment. The ''region of interest'' (ROI) was selected as the lens density along the nuclear region,[13,14] the average ROI was applied in the analysis and measured automatically. The automatic release mode was implemented to mitigate against operator-dependent variables, and the final analysis incorporated only those scans with a 95% quality factor.

Prior to surgery and one month after, specular microscopy (CEM-530, NIDEK CO., Ltd.) was performed three times. In both situations, the highest endothelial cells density has been chosen.

The same surgeon carried out the cataract surgery, using the same procedure, a 2.2 mm temporal clear corneal incision under local anesthesia with a stop and shop method to halve the nucleus. All the cases have been done using the endocapsular phaco technique, and the mechanical breakdown of the nucleus also done inside the bag whenever is needed. A WHITESTAR Signature phacoemulsification apparatus (Abbot Medical Optics) implementing the Elliptical cutting pattern was used for phacoemulsification in the capsular bag. Measurements of the intraoperative power (AVG %), elliptical motion (EFX), and ultrasound time (UST) were taken, with theatre staff documenting the duration of the surgical procedure; starting from creating the incisions till the end of the surgery. The study did not include any incidences of intraoperative complications that were shown to impact the endothelial cells.

The Scheimpflug-measured lens density was compared with the phacodynamic parameters, surgery time, and degree of endothelial cells loss following the procedure using a Pearson correlation analysis. Similarly, the phacodynamic parameters and surgery time were compared with the degree of endothelial cells loss. SPSS software (version 19.0, International Business Machines Corp.) was applied for the statistical analysis. A P value of less than 0.05 was considered statistically significant, and all data were expressed as the mean ± standard deviation.

Results

Of a study population of 62 patients, 41 were males (66.1%) and 21 were females (33.9%), with a mean age of 58.56 ± 10.4 years (range, 40–77 years). A total of 71 eyes (52.1% right eye and 47.9% left eye) were assessed in the

Table 1. Pre-operative and intra-operative parameters.

Parameter		Mean ± SD	Range
Age (years)		58.56 ± 10.4	40, 77
Lens nuclear density (based on Scheimpflug system)		13.93 ± 3.27	7.60, 22.60
Pre-operative endothelial cells density		2550.90 ± 336.88	1669, 3309
Phacodynamics	*Power (AVG%)*	13.63 ± 6.38	0.00, 29.00
	Ultrasound Time (minutes)	1.27 ± 1.12	0.00, 4.36
	Elliptical motion (EFX)	50.56 ± 50.06	0.00, 300
Surgery duration (minutes)		21.72 ± 7.34	10, 50

SD = Standard deviation.

Table 2. Comparing between endothelial cell density, hexagonality, and central corneal thickness values before and after surgery using a specular microscopy.

Parameter		Paired differences Mean ± SD	Skewness	Kurtosis	*P* value
Pair 1	Cell density pre-op Cell density post-op	442.70 ± 328.43	1.18	2.07	<.001*
Pair 2	Hexagonality pre- op Hexagonality post-op	2.54 ± 5.58	1.19	6.02	<.001*
Pair 3	CCT pre-op (micrometer) CCT post-op (micrometer)	−5.85 ± 12.85	−1.77	7.44	<.001*

SD = Standard deviation.
CCT = Central Corneal Thickness.
Pre-op = pre-operative, Post-op = post-operative.
* *P* value calculated using two-tailed paired sample test.

study. Table 1 shows pre-operative and intra-operative parameters.

The degree of endothelial cell density loss (pre-surgery $M = 2550.90$, $SD = 336.88$, and post-surgery $M = 2108.20$, $SD = 489.50$), decrease in endothelial cells hexagonality (pre-surgery $M = 67.18$, $SD = 5.27$, and post-surgery $M = 64.65$, $SD = 6.55$), and central corneal thickness increase (pre-surgery $M = 556.04$, $SD = 41.96$, and post-surgery $M = 561.89$, $SD = 40.87$) were evaluated using a two-tailed paired sample t test.

For the degree of variation between pre-surgery and post-surgery values of endothelial cell density loss, decrease in hexagonality, and increase in central corneal thickness, the skew and kurtosis levels were calculated at 1.18 and 2.07, 1.19 and 6.02, and -1.77 and 7.44 respectively, below the maximum permitted values for a t-test (i.e. skew <|2.0| and kurtosis <|9.0|. The acceptance of normal distribution of differences scores was thus achieved, as was statistical significance ($P < .001$) in comparing the pre-surgery values to post-surgery with respect to endothelial cell counts, hexagonality, and corneal thickness changes Table 2.

The phacodynamic parameters used during phacoemulsification, namely, power (AVG %), ultrasound time, and elliptical motion showed a strong positive linear correlation with Scheimpflug-measured lens nuclear density ($r = 0.501$, $r = 0.620$, and $r = 0.641$, respectively; all $P < .001$) (Fig. 1a–c). The length of surgery showed a moderate positive correlation with the Scheimpflug-measured lens nuclear density ($r = 0.346$; $P < .01$) (Fig. 1d). A strong positive correlation was also demonstrated between the degree of endothelial cell loss and the nuclear density of the lens ($r = 0.445$, $P < .001$) (Fig. 1e).

Both, ultrasound time and elliptical motion, revealed to have a strong positive correlation with the degree of endothelial cell loss post-surgery ($r = 0.458$ and $r = 0.440$, respectively; both $P < .001$). A moderate positive correlation was demonstrated between the average power (AVG %) used during the procedure and the degree of endothelial cell loss ($r = 0.377$, $P < .01$) (Fig. 2a–c). The Duration of surgery failed to show any significant correlation with the degree of endothelial cell loss ($r = 0.210$; $P > .05$).

Discussion

A positive correlation was demonstrated in our study between the Scheimpflug system assessment of nuclear lens density, and power required for phacoemulsification, surgery time, and degree of endothelial cell loss post-surgery. Although the correlation was moderate in respect to the duration of the surgery, a strong correlation was shown for the remaining parameters (average power used, ultrasound time, elliptical motion, and degree of endothelial cell loss).

Lim et al.[11] demonstrating a strong correlation between the power energy during phacoemulsification and Scheimpflug-measured lens density were emulated here.

In a study conducted to correlate the cataract density graded by the Scheimpflug imaging system with visual function and phacoemulsification energy. A positive correlation between the lens density and phacoemulsification time and energy was found.[15]

Demircan et al.[16] evaluated the relationship between the lens density based on Pentacam nucleus staging software and level of ultrasound energy during phacoemulsification. Significant linear correlations have been noticed between Pentacam nucleus densitometry and total ultrasound time and cumulated dissipated energy.

Strong positive correlations were observed in our study between the phacodynamic parameters and the degree of endothelial cells loss following the surgery. With the hardness of the nucleus, more phacoemulsification energy and time were mandated for hard nucleus removal in the phacodynamics context.

A similar correlation was detected in another study[17] comparing the effect of hydrodynamic and phacodynamic parameters on corneal endothelial cell loss. A strong relationship between ultrasound energy and endothelial cell loss was determined.

Since the length of the surgery had a positive correlation to the lens density but not to the amount of the endothelium loss and the lens density showed a strong positive correlation with the degree of endothelial cell loss. A potential method of addressing the nucleus hardness can be addressed. Instead of applying higher power to break down the nucleus (thus causing further damage), we propose increased attention to breaking down the nucleus by mechanical means. Although, we didn't measure the actual time of handling the nucleus fragmentation which will give us a better judgment in term of measuring its effect over the endothelium in compare to the amount of the power used.

Objective evaluation of cataracts, and estimates of cataract surgery success, is facilitated by the more objective assessments of cataract density (if additional ocular pathology is disregarded) by the Scheimpflug-measured lens density method.

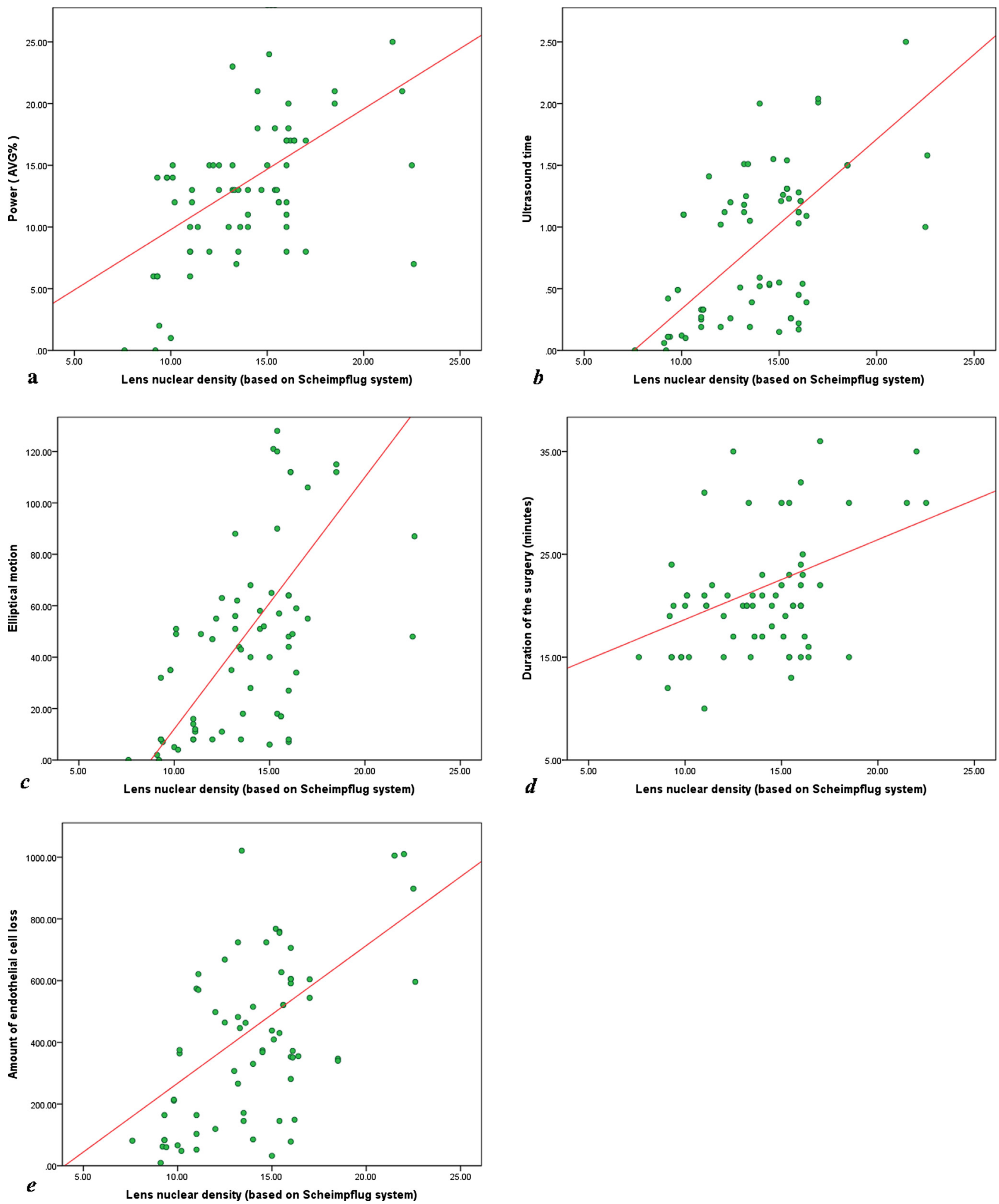

Fig. 1. The correlation between the lens nuclear density based on Scheimpflug system with the average power used during surgery ($r = 0.501$; $P < .001$; (a), ultrasound time ($r = 0.620$; $P < .001$; (b), elliptical motion ($r = 0.641$; $P < .001$; (c), duration of the surgery ($r = 0.346$; $P < .01$; (d), and amount of endothelial cells loss ($r = 0.445$; $P < .001$; (e).

In conclusion, he evaluation of nuclear cataract and estimation of phacoemulsification energy successfully employed a Scheimpflug system-based assessment of lens density, which corresponded to the power requirements of phacoemulsification. A strong correlation was observed between the degree of endothelial cell loss and the phacodynamic

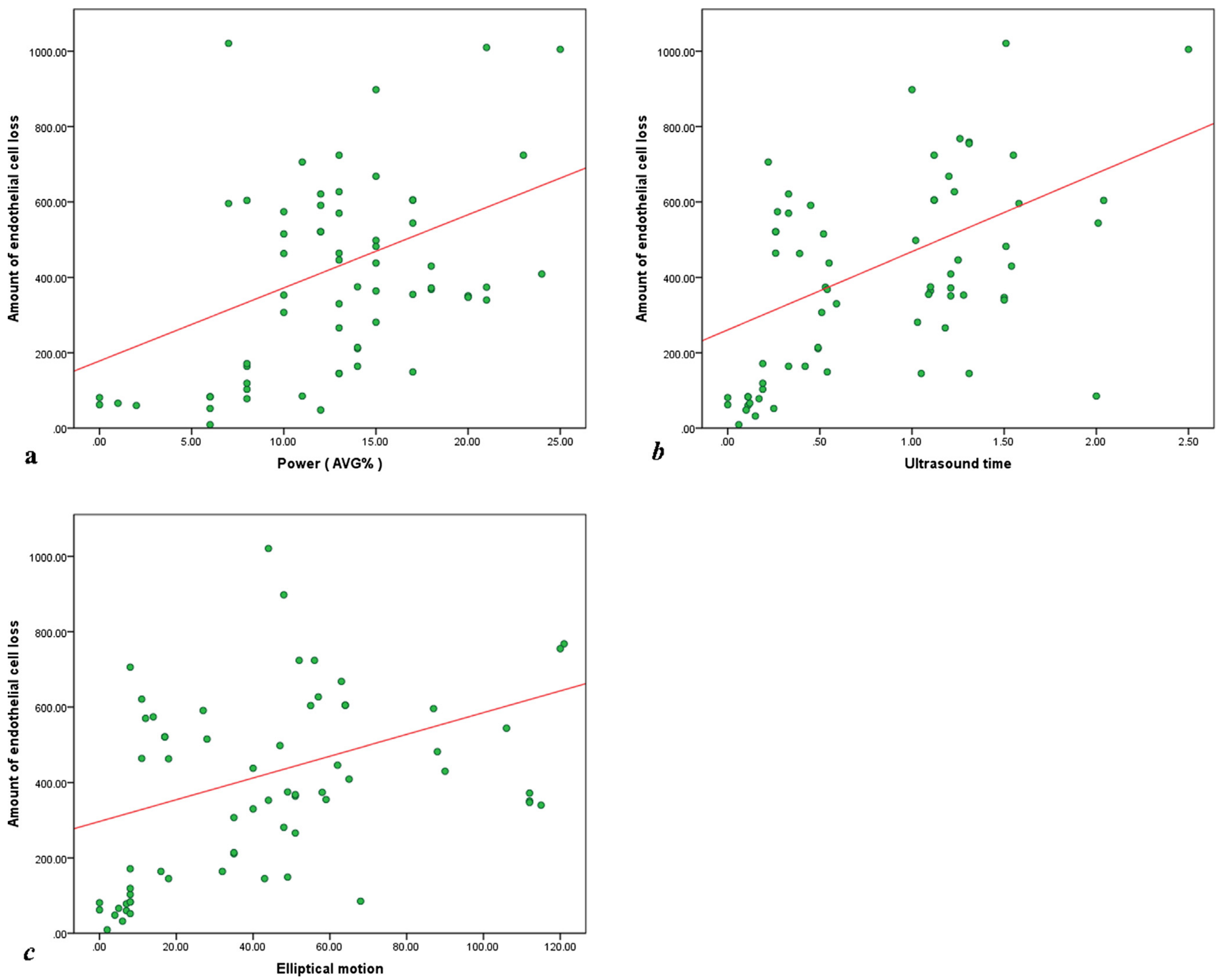

Fig. 2. The amount of endothelial cells loss correlated with phacodynamic parameters, namely, average power used during surgery ($r = 0.377$; $P < .01$; (a), ultrasound time ($r = 0.458$; $P < .001$; (b), elliptical motion ($r = 0.440$; $P < .001$; (c).

parameters of ultrasound time and elliptical motion, but not with the length of the procedure. In summary, for incidences of hard nucleus cataract, it was suggested that mechanical breakdown of the lens nucleus was a process worthy of more focusing than increasing the phacoemulsification power.

Conflict of interest

The authors declared that there is no conflict of interest.

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