

The effect of pupillary dilatation on IOL power measurement by using the IOLMaster

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Abstract The aim of this study is to assess the agreement of IOL power and ocular biometry measurements before and after pupillary dilatation by using the IOLMaster. This was the prospective nonrandomized cohort study. Measurements were taken with the IOLMaster[®] (Carl Zeiss Meditec AG, Jena, Germany) from healthy volunteers at the Department of Ophthalmology, King Chulalongkorn Memorial Hospital. Axial length (AL), keratometry both flattest and steepest (K_1 , K_2), and anterior chamber depth (ACD) were measured before and after the dilatation of the pupil with 1 % tropicamide. The IOL power was

calculated using the Sanders–Retzlaff–Kraff/Theoretical (SRK/T) formula. The mean difference of each parameter was assessed by Bland–Altman plot analysis. 384 eyes from 195 healthy volunteers were measured. The mean age of the patients was 52.39 ± 1.02 years (range 21–79). Pupillary dilatation had no significant effect on AL ($p = 0.07$), keratometry [steepest K ($p = 0.95$) and flattest K ($p = 0.17$)], and IOL power (Alcon SN60WF) ($p = 0.40$) obtained from the IOLMaster. However, ACD was significantly increased post-dilatation ($p < 0.05$). The Bland–Altman plot indicated good concordance in nearly all parameters except ACD. For ACD measurements, the 95 % limit of agreement between pre-dilatation and post-dilatation was -0.47 to 0.23 mm; therefore, 92.2 % of the measurement differences were with a LoA of -0.47 to 0.23 mm. There were no eyes that could not be measured by the IOLMaster. The dilatation of the pupil had no significant effect on AL, keratometry measurements, and SRK/T calculated IOL power. However, the ACD significantly increased post-dilatation.

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Introduction

The increase in patient expectations in preoperative cataract surgery has led ophthalmologists to explore

new ways to best satisfy them. Alongside the best surgical techniques and type of IOL selection accurate measurements of ocular biometry and IOL power calculation are essential for achieving the target refraction after cataract surgery. Cataract surgery resulted in a large and comparable improvement in subjective quality of vision [1].

There are several kinds of biometry and IOL calculation formulae currently in use. Optical biometry is now accepted as standard worldwide. Each IOL calculation formula requires different important parameters such as axial length (AL), anterior chamber depth (ACD), and corneal curvature [2, 3].

Biometry with an undilated pupil makes it easier for the patient to fixate. In patients with dilated pupils, technical problems may arise in fixation.

Some studies on dilatation and IOL measurement have found that pupil dilatation does not affect the accuracy of the IOLmaster [4]. Nevertheless, some surgeons believe that dilatation of the pupil causes patients to have poor fixation [4]. As cataract surgery is our routine procedure, we would like to shorten the visit time of the cataract patients by providing a one-stop service rather than rescheduling them to be measured on another day. We set out to assess whether dilatation will affect IOL measurement by comparing relevant values pre- and post-dilatation by using the IOLmaster.

Patients and methods

This was a prospective cohort study to compare IOL power, AL, keratometric reading, and ACD between pre- and post-pupil dilatation by the IOLMaster device V.5 (Carl Zeiss Meditec AG, Jena, Germany). We had financial support from the Quality Improvement Fund, King Chulalongkorn Memorial Hospital.

This study was conducted under an institutional protocol at the outpatient clinic Department of Ophthalmology, King Chulalongkorn Memorial Hospital from February 2013 to July 2013.

384 eyes from 195 volunteers who came for eye examination (48 men and 147 women) with a mean of 52.4 years (range 21–79 years) were included in this prospective study. The inclusion criteria were an age of more than 20 years who visited the outpatient Department of Ophthalmology, King Chulalongkorn Memorial Hospital. The exclusion criteria were

previous ophthalmic surgery, active eye disease, angle closure suspect (examined under Sussman Four-mirror Gonioscope), lens opacity that limited the IOLmaster measurement, history of mydriatic drug allergy, history of contact lens wear, poor ocular fixation, and inability to remain in an upright position.

All research procedures followed the tenets of the Declaration of Helsinki. The protocol was reviewed and approved by the Research Affairs, Faculty of Medicine, Chulalongkorn University. This study was approved by IRB committee of Faculty of Medicine, Chulalongkorn University (IRB 43/55) and registered in the Thai Clinical Trials Registry (TCTR 20130313001).

The purpose of the study was explained to every participant, and informed consent was obtained. All the pre- and post-dilated pupil measurements were taken on the same day. All measurements were performed by the same experienced examiner. Ocular biometry measurements were made using the IOLmaster version 5 (Carl Zeiss Meditec AG, Jena, Germany).

The measurements of AL, ACD, corneal curvature (flattest meridian of corneal curvature [K1] and steepest meridian of corneal curvature [K2]) were taken by an examiner. Participants were asked to blink before measurements were taken to create an optically smooth tear film over the cornea. Cycloplegia was achieved using one drop of an eye solution containing 1 % tropicamide (Mydriacyl: Alcon Laboratories, Thailand) every 15 min or until full dilatation (≥ 8.00 mm). After cycloplegia had been achieved, the measurement procedures were repeated.

The Alcon SN60WF with a manufacturer-recommended A constant of 119 was used for the IOL power calculation. The refractive target was zero (emmetropia) or ± 0.25 D. The Sanders–Retzlaff–Kraff/Theoretical formular (SRK/T) was used to calculate the IOL power with the IOLMaster with and without mydriasis.

Statistical analysis

Statistical analysis was performed with Stata/SE 12.1. All the results are presented as the mean \pm SD. The measurements of IOL power, AL, keratometric reading (K), and ACD with and without pupillary dilatation performed by the IOLMaster were compared by a paired *t* test. The agreement and interchangeability

Table 1 Demographic data of patients

Sex	Male 48 (24.62 %)	Female 147 (75.38 %)
Measured eye	Right eye 193	Left eye 191

between pre-dilatation and post-dilatation were determined using the Bland–Altman analysis [5] (plots with 95 % limits of agreement) in IOL power (Alcon SN60WF), AL, keratometric reading (K), and ACD.

Results

One hundred ninety five patients (384 eyes) were included in the study. The mean age of the study population was 52.39 ± 1.02 years (range, of 21–79 years). The demographic data of patients are shown in Table 1.

The main outcomes were AL, keratometric reading (steepest K and flattest K), ACD, and IOL power pre-dilatation and post-dilatation, are presented in Table 2. There were no statistically significant differences between the AL and keratometric reading (steepest K and flattest K), and IOL power. However, the ACD was significantly increased post-dilatation (-0.12 mm; $p < 0.05$).

Discussion

This paper sets out to consider adjustments to the routine preoperative cataract surgery procedures of our department. We normally schedule patients for at least two visits before the day of the operation due to the uncertainty about whether the use of cycloplegic eye drops would affect the IOL calculation power. Proving the hypothesis that pupillary dilatation has no effect on IOL calculation power would mean not only

reducing the steps of the preoperative cataract surgery process, but also saving time and traveling expenses for the patients. It also allows the determination of the effect of pupillary dilatation on the SRK/T formula for IOL calculation.

Our study revealed that dilatation does not affect the SRK/T calculated IOL power (Alcon SN60WF). The Bland–Altman plot showed the 95 % limits of agreement between pre-dilatation and post-dilatation as ($-0.609, 0.583$).

For other relevant measurements, we found that AL and keratometric biometry ($K1, K2$) were not affected by dilatation (p value was 0.0715, 0.1677, 0.9495, respectively); however, the ACD was significantly increased post-dilatation, that may be because the lens and iris plane move backward on dilatation.

In contrast to other studies, there were no statistically or clinically significant differences in postoperative refractive errors between the two categories of patients by applanation biometry before and after pupil dilatation [6]. Heatley and co-workers showed a statistically significant change in $K2$ and average keratometry values but no significant change in AL or IOL power between undilated and dilated pupil biometry readings [4]. Drexler and co-workers [7] found that accommodation of four to five diopters could increase AL by 0.013 and 0.005 mm in emmetropic and myopic patients, respectively, using partial coherence interferometry. Sheng et al. [8] found that cycloplegia had no significant effect on IOL Master AL measurements but produce a significant increase in ACD as measured with the IOLMaster. Cheung [9] found that the effect of cycloplegia on AL measurement with IOLmaster was insignificant in children aged from seven to 15 years; meanwhile, ACD measurement was significantly affected by cycloplegia. Huang et al. [10] found that cycloplegia

Table 2 The main outcomes of the study

Measurements	Mean \pm SD Pre-dilatation	Mean \pm SD Post-dilatation	Mean difference	95 % CI	p value
Axial length (mm)	23.38 ± 1.13	23.38 ± 1.13	0.0033	$-0.0003, 0.0069$	0.0715
Flattest K (D) ($K1$)	44.05 ± 1.53	44.03 ± 1.54	0.0171	$-0.0072, 0.0413$	0.1677
Steepest K (D) ($K2$)	45.03 ± 1.6	45.03 ± 1.59	-0.0073	$-0.233, 0.2184$	0.9495
Anterior chamber depth (mm)	3.15 ± 0.37	3.27 ± 0.37	-0.1185	$-0.1362, -0.1007$	<0.05
IOL power in SN60WF (D)	20.68 ± 3.1	20.69 ± 3.1	-0.013	$-0.0435, 0.0175$	0.4021

Fig. 1 Bland–Altman analysis of differences of the axial length before and after pupillary dilatation and mean. The differences of the axial length before and after pupillary dilatation plotted against the mean differences. The *dotted line* represents the 95 % limits of agreement

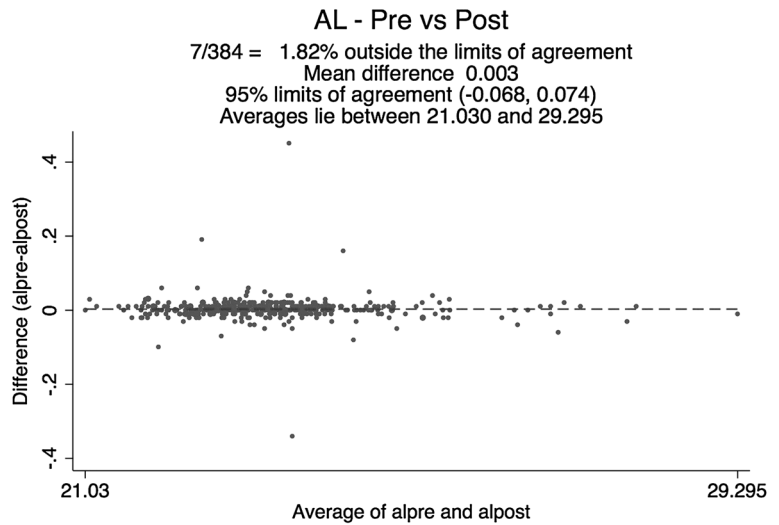
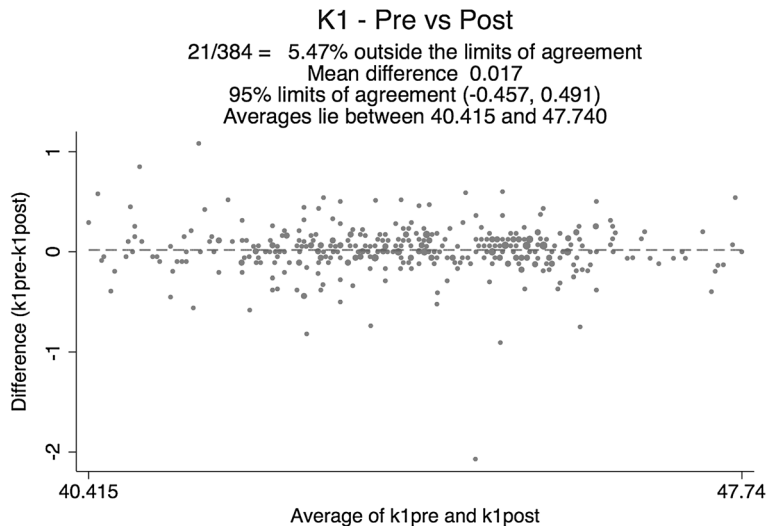


Fig. 2 Bland–Altman analysis of differences of the flattest K ($K1$) before and after pupillary dilatation and mean. The differences of the flattest K ($K1$) before and after pupillary dilatation plotted against the mean differences. The *dotted line* represents the 95 % limits of agreement



had no significant effect on AL or corneal curvature that measured from Lenstar (Haag-Streit AG). However, ACD and white to white (WTW) significantly increased postcycloplegia (Lenstar, 0.09 ± 0.06 and 0.10 ± 0.17 mm, respectively; IOLMaster, 0.06 ± 0.07 and 0.43 ± 0.35 mm, respectively; $p < 0.001$). The Lenstar is also a new optical low-coherence reflectometry (OLCR) ocular biometry device with noncontact measurement. It measures central corneal thickness (CCT), ACD, lens thickness, AL, retinal thickness, K values, WTW, pupillometry, and eccentricity of the visual axis relative to the optical axis. This device has also been found to provide repeatable,

reproducible measurements and can be used interchangeably with Sirius (Scheimpflug camera and Placido-disk topography device) for CCT, ACD, mean K , and WTW [11].

From the SRK/T formula (by Sanders, Retzlaff and Kraff), $P = A - (2.5 L) - 0.9 K$, in which P = lens implant power for emmetropia (diopters), L = axial length (mm.), K = average keratometric reading (diopters), and A = constant specific to the lens implant to be used, we found that the variable factor of IOL power changing is L (axial length) and K (average keratometric reading) [12].

Emmetropia IOL power, D (IOLemme): [13]

Fig. 3 Bland–Altman analysis of differences of the steepest K ($K2$) before and after pupillary dilatation and mean. The differences of the steepest K ($K2$) before and after pupillary dilatation plotted against the mean differences. The dotted line represents the 95 % limits of agreement

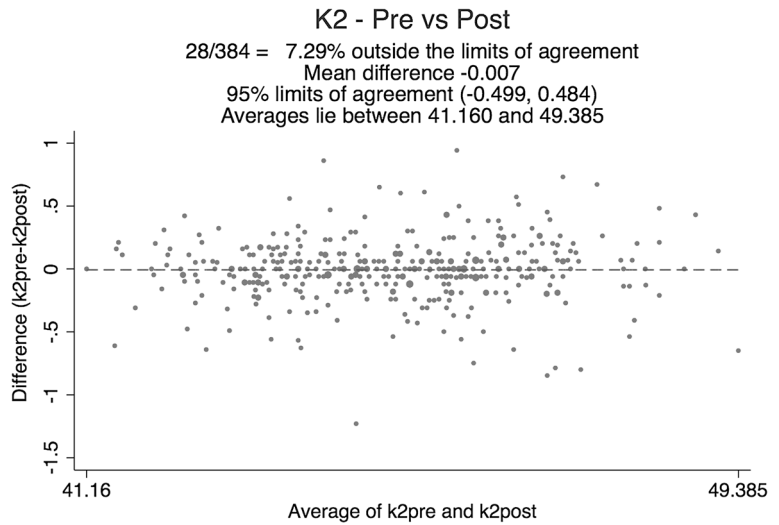
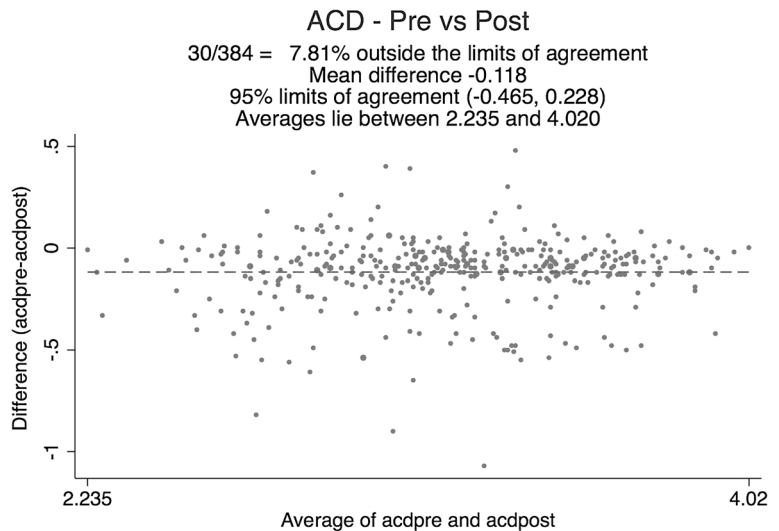


Fig. 4 Bland–Altman analysis of differences of the anterior chamber depth (ACD) before and after pupillary dilatation and mean. The differences of the anterior chamber depth (ACD) before and after pupillary dilatation plotted against the mean differences. The dotted line represents the 95 % limits of agreement



$$IOL_{emme} = \frac{1000 \times n_a \times (n_a \times r - n_c ml \times LOPT)}{(LOPT - ACD) \times (n_a \times r - n_c ml \times ACD)}$$

$n_a = 1.336, n_c = 1.333, n_{c,ml} = 0.333.$

The accuracy of IOL power measurement is not a concern, according to the findings of this study. However, some formulae such as Haigis [2] or Holladay [3], which require ACD, may not benefit from our study.

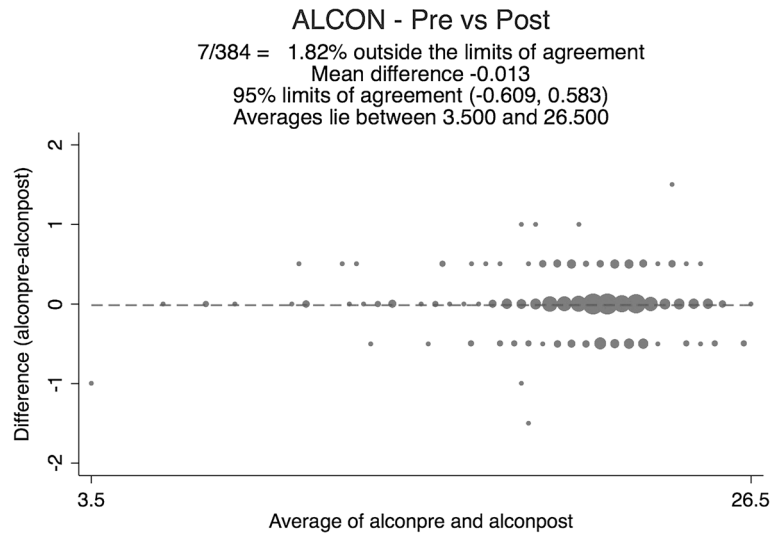
A limitation of this study is that the findings might be different using other measurement tools beside the

IOLMaster. Our data are specific to the common range of IOL power (see also Fig. 1); we do not have data for extreme IOL power values.

In recent formula, the effective lens position (ELP) has been taken into account. ELP is a virtual position that is assumed by preoperative data as corneal radii, AL, and ACD [14–19] (Figs. 2, 3).

Further research should be done in order to confirm our findings with other measurement tools and to explain why the anterior chamber is the only affected component, and by which mechanism. The newer generations of IOL formulae that use ACD to calculate

Fig. 5 Bland–Altman analysis of differences of the SRK/T calculated IOL power (ALCON SN60WF) before and after pupillary dilatation and mean. The differences of the SRK/T calculated IOL power (ALCON SN60WF) before and after pupillary dilatation plotted against the mean differences. The dotted line represents the 95 % limits of agreement



the IOL power should be observed to determine whether or not there is an effect of ACD on IOL power not only in monofocal IOL implantation but also in multifocal IOL implantation. As the good postoperative visual outcome, contrast sensitivity and high-quality of life after multifocal IOL implantation [20]. And the patients request multifocal IOL.

Dilatation does not affect the measurement of the AL and, keratometric readings, with the exception of ACD. This finding is beneficial for the SRK/T formula that does not use ACD, as it means that we can do ocular biometry measurement and use the SRK/T formula for IOL calculation within the same day, after we have dilated the patient's eye and examined it thoroughly. Thus, patients need not come back for another visit, which is a practical benefit to them. However, IOL Master produces unpredictable results in certain refractive conditions like high astigmatism, Myopia, or Hyperopia. In eyes with congenital anomalies, extremely short and long eye and in Post-corneal refractive surgery, the results are also compromised [21–25]. In our study the ACD was significantly increased post-dilatation, hence the formula to calculate IOL power which is use ACD measurement should also be reconsidered (Figs. 4, 5).

Conflict of interest No author has a financial or proprietary interest in any material or method mentioned.

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