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ORIGINAL PAPER

A model for predicting sulcus-to-sulcus diameter in posterior chamber phakic intraocular lens candidates: correlation between ocular biometric parameters

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Abstract

Purpose The aim of this study was to determine the correlation between ocular biometric parameters and sulcus-to-sulcus (STS) diameter.

Methods This was a cross-sectional study of preoperative ocular biometry data of patients who were candidates for phakic intraocular lens (IOL) surgery. Subjects underwent ocular biometry analysis, including refraction error evaluation using an autorefractor and Orbscan topography for white-to-white (WTW) corneal diameter and measurement. Pentacam was used to perform WTW corneal diameter and measurements of minimum and maximum keratometry (*K*). Measurements of STS and angle-to-angle (ATA) were obtained using a 50-MHz B-mode ultrasound device. Anterior optical coherence tomography was performed for anterior chamber depth measurement. Pearson's correlation test and stepwise linear regression analysis were used to find a model to predict STS.

Results Fifty-eight eyes of 58 patients were enrolled. Mean age ± standard deviation of sample was 28.95 ± 6.04 years. The Pearson's correlation coefficient between STS with WTW, ATA, mean *K* was 0.383, 0.492, and − 0.353, respectively, which was statistically significant (all $P < 0.001$). Using stepwise linear regression analysis, there is a statistically significant association between STS with WTW ($P = 0.011$) and mean *K* ($P = 0.025$). The standardized coefficient was 0.323 and − 0.284 for WTW and mean *K*, respectively. The stepwise linear regression analysis equation was: (STS = 9.549 + 0.518 WTW − 0.083 mean *K*).

Conclusion Based on our result, given the correlation of STS with WTW and mean *K* and potential of direct and essay measurement of WTW and mean *K*, it seems that current IOL sizing protocols could be estimating with WTW and mean *K*.

Keywords Sulcus-to-sulcus diameter · White-to-white corneal diameter · Phakic intraocular lens

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Introduction

A Phakic intraocular lens (pIOL) is a supplementary lens that is inserted into the eye to correct refractive errors, so it is an efficacious technique for correcting refractive errors in patients who would otherwise be poor candidates for corneal refractive surgery [1]. The designs of pIOLs have evolved over many years. Most early designs have been abandoned because of high rates of complications, usually, due to poor anatomic fit [2, 3].

Nowadays, the FDA-approved pIOLs have acceptable rates of complications and, despite the risks, remains an attractive method compared with alternative operative treatments [4].

A major concern in anterior chamber pIOL is safety that is usually associated with the lens sizes and correct implantation because they are associated with poor lens size. Commonly, the white-to-white (WTW) corneal diameter, obtained externally, is used to estimate the lens size [5, 6]. The WTW corneal diameter is the horizontal distance between the borders of the corneal limbus [5]. Studies have suggested using WTW corneal diameter to estimate angle diameter associated with error of more than 0.50 mm in the predicted refraction after IOL implantation [7].

Recently, some surgeons have used direct sulcus-to-sulcus diameter (STS) measurements for lens sizing [8, 9]. The sulcus diameter can be directly measured using very high frequency digital ultrasound [8, 9].

There is a controversy about the correlation of WTW and STS [9]. In contrast to a number of previous studies where no correlation was reported between WTW and STS [10, 11], some study demonstrated that STS measurements combined with the WTW measurements resulted in better control of the vault than traditional lens sizing using WTW [9].

Considering the importance of these ocular biometric variables and the ease of measuring of some of these variables, it will be important to explore any relationship that may exist between ocular biometric variables and STS. The aim of this study was to determine the association between ocular biometric parameter and STS measurements in the Iranian adult population.

Materials and methods

Study design and participant

This is a cross-sectional study of preoperative ocular biometry data of 58 eyes from participants aged 18–60 years old who were candidates for pIOL surgery. The research followed the tenets of the Declaration of Helsinki and was approved by the Isfahan University of Medical Sciences Research Ethics Committee, Isfahan, Iran (Research No. 395479). Cases were excluded if there was a history of contact lens use, history of ocular or systemic medication use, history of any ocular intervention, or if data were missing.

Retrospective chart review

Medical records of subjects who were candidates for pIOL surgery were reviewed. These records included age, gender, visual acuity, best-corrected visual acuity (BCVA), WTW distance, STS diameter, angle-to-angle (ATA) diameter, anterior chamber depth (ACD), crystalline lens rise (CLR), and refractive error.

Clinical ophthalmic and ocular biometry evaluation

Subjects underwent ocular biometry, including a refraction error evaluation using an autorefractor (KR-1 Auto Kerato-Refractometer, TOPCON, Japan), and measurements of WTW measurement and minimum and maximum keratometry (*K*) performed with a Pentacam HR System (Oculus Optickgerate GmbH, Wetzlar, Germany).

Measurements of STS and ATA were obtained using a 50-MHz B-mode ultrasound device (Compact Touch STS, Quantel Medical, France). ACD and CLR measurements were performed with an anterior optical coherence tomography (OCT) (Swept-source 1000 CASIA AS-OCT, Tomey, Nagoya, Japan).

A single optometrist performed all ocular biometric evaluations.

Statistical analysis

All statistical analyses were carried out with the SPSS package, version 20.0 (SPSS, Chicago, USA). Continuous data were expressed as mean ± standard

deviation (SD) and median (range). The Pearson's correlation test and stepwise linear regression analysis were used for correlation assessment. $P < 0.05$ was considered statistically significant.

Results

Population characteristics

A total number of 58 patients who were candidate for pIOL surgery with the mean ± SD age of 28.95 ± 6.04 years (ranged from 20 to 55 years old) were included in the final analysis. Thirty-four subjects (58.6%) were females. The mean ± SD of WTW distance and STS was 11.87 ± 0.36 and 11.87 ± 0.57, respectively. Demographic data and ocular biometric characteristics of participants are shown in Table 1.

Correlation between STS and ocular biometric parameter

The Pearson's correlation coefficient between STS with WTW (Fig. 1a), ATA (Fig. 1b), mean keratometry (*K*) (Fig. 1c), and ACD endo (Fig. 1d) was 0.383, 0.492, − 0.353, and 0.262, respectively, which was statistically significant ($P < 0.001$) (Table 2).

The correlation between STS and other ocular biometric parameter by Pearson's correlation analysis is shown in Table 2.

Stepwise linear regression analysis

Using stepwise linear regression analysis, among ocular biometric parameters as predictors of STS, a statistically significant association was found between STS with WTW ($P = 0.011$) and mean *K* ($P = 0.025$). The standardized coefficient was 0.323 and − 0.284 for WTW and mean *K*, respectively. The stepwise linear regression analysis equation was:

$$\text{STS} = 9.549 + 0.518\ \text{WTW} - 0.083\ \text{Mean}\,K$$

The results of the stepwise linear regression analysis are summarized in Table 3.

An increase in 1 mm of WTW was associated independently with an increase in 0.518 mm in STS, while an increase in 1 diopter (D) of mean *K* was associated independently with a decrease in 0.083 mm.

Table 1 Demographic and clinical characteristics of study participants

Age (years)	
Mean ± SD	28.95 ± 6.04
Median (range)	30 (20–55)
Gender	
Male (*n* %)	12 (41.4)
Female (*n* %)	17 (58.6)
STS	
Mean ± SD	11.87 ± 0.57
Median (range)	11.84 (10.56–13.07)
SE	
Mean ± SD	− 8.91 ± 7.34
Median (range)	− 9.43 (− 30.50 to + 19.30)
ATA	
Mean ± SD	12.10 ± 0.33
Median (range)	12.08 (11.35–12.89)
WTW	
Mean ± SD	11.87 ± 0.36
Median (range)	11.80 (11.00–12.60)
CLR	
Mean ± SD	− 12.12 ± 161.64
Median (range)	13.00 (− 389 to 339)
Mean *K*	
Mean ± SD	44.92 ± 1.97
Median (range)	44.55 (41.85–52.40)
ACD (epithelial)	
Mean ± SD	3.93 ± 0.21
Median (range)	3.93 (3.51–4.39)
ACD (endothelial)	
Mean ± SD	3.42 ± 0.22
Median (range)	3.41 (2.98–3.89)
CCT	
Mean ± SD	502.36 ± 41.05
Median (range)	496.50 (401–588)

STS sulcus-to-sulcus, *SE* spherical equivalent, *ATA* angle-to-angle, *WTW* white-to-white, *CLR* crystalline lens rise, *K* keratometry, *ACD* anterior chamber depth, *CCT* central corneal thickness

Discussion

The results of our study demonstrated the ability of the WTW diameter and mean *K*, which are directly

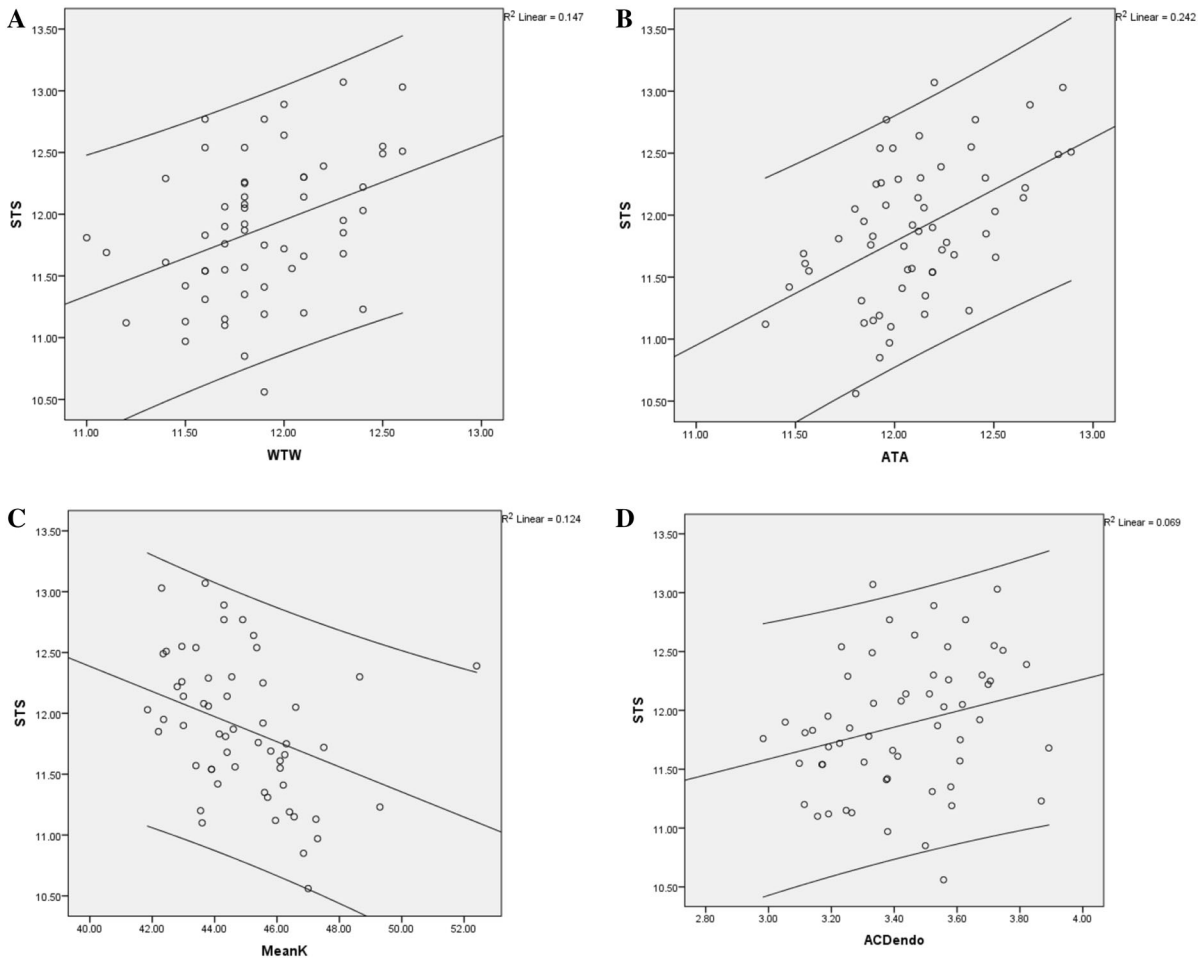

Fig. 1 Scatter diagram and linear regression line of the association between STS with WTW (**a**), ATA (**b**), mean *K* (**c**), and ACD endo (**d**)

Table 2 Correlation between STS and other ocular biometric parameter (Pearson's correlation analysis)

Variables	ATA	WTW	CLR	Mean *K*	ACD (epithelial)	ACD (endothelial)	CCT	SE
STS								
Correlation coefficient	0.492	0.383	− 0.237	− 0.353	0.229	0.262	− 0.199	− 0.210
P value	< 0.001	0.003	0.073	0.007	0.084	0.047	0.135	0.114

STS sulcus-to-sulcus, *ATA* angle-to-angle, *WTW* white-to-white, *CLR* crystalline lens rise, *K* keratometry, *ACD* anterior chamber depth, *CCT* central cornea thickness, *SE* spherical equivalent

measured by the rotating Scheimpflug camera system, to predict STS diameter in Iranian adult populations.

Since there is a statistically significant linear correlations between STS diameter with WTW diameter and mean *K*, measuring WTW diameter and mean *K* using Pentacam® could be consider as an alternative method of validating anterior segment dimensions currently.

Because exact sizing of pIOLs is critical due to limited space for implantation and the sensitive structures surrounding the implanted IOL, the use of

Table 3 Stepwise linear regression analysis for the association of STS with other parameters

Predictor variables	Regression coefficients (*B*)	Standard error	Standardized regression coefficient (Beta)	*t*	*P* value
Constant	9.459	3.113	–	3.113	.004
WTW	0.518	0.197	0.323	2.630	.011
Mean *K*	− 0.083	0.036	− 0.284	− 2.313	.025
SE	–	–	− 0.181	− 1.513	.136
CLR	–	–	− 0.176	− 1.444	.155
ACD	–	–	0.146	1.023	.311

WTW white-to-white, *K* keratometry, *SE* spherical equivalent, *CLR* crystalline lens rise, *ACD* anterior chamber depth

imaging or methods to improve the fit and safety of pIOLs is needed.

A lens that is too long, an oversized lens, presses on the iris root and can lead to sectoral iris atrophy and pupil ovalization [12, 13]. Whereas a lens that is too small, an undersized lens, can become mobile and result in endothelial cell loss and iritis [12, 14].

Measurement of the horizontal corneal diameter yields important clinical information for diagnostic purposes as well as for surgical procedures, such as implantation of anterior chamber IOLs in phakic eyes [15, 16].

There are several techniques for measurement of WTW diameter, which can be divided into two main groups: manual (calipers and scales in slit-lamp) and automated devices, including ultrasonic biomicroscopy, magnetic resonance imaging, Orbscan II, and OCT [15–18].

The understanding of optical components and ocular biometric parameters improves the selection of best lens size and position. For more sensitive prediction of lens size, measuring of the other ocular biometric parameters, including STS, ATA diameter, minimum and maximum *K* and ACD, could be necessary to predict an accurate lens implantation in anterior chamber phakic IOL [19].

In establishment of previous studies, this study also describes a statistically significant correlation between WTW and ATA diameter, which concurs with previously published reports [20]. This correlation was compatible with the results of Reinstein et al. that used VHF digital ultrasound [9]. It has also been shown that the WTW diameter is correlated with the lens diameter [21].

The current fitting strategy is based on WTW measurement. This may not correspond well with internal anterior chamber width. The average values of the dimensions of the optical components depend on race, age, and gender [22].

Oh et al. reported a significant correlation between ATA and STS [19] as was found in the present study and the study of Reinstein et al. [9].

In another study that evaluated the agreement and interchangeability between ACD and *K* in pIOL calculations, Sayed et al. demonstrated that there was a good agreement in ACD and *K*, making them interchangeable in biometry and phakic IOL power calculation. They also described that they are not interchangeable when regarding WTW line measurement [6].

There are some limitations in this study that need to be addressed. Unfortunately, we did not record axial length (AL) data in this study regarding the relationship between the AL and other ocular biometric parameters.

The data that were used to generate the regression models are based on our participants selected from our country, so the clinical predictability of the model as a reliable value for the evaluation of this correlation can be different in this population than with others.

Further investigations are required to investigate the relationship between the STS and other biometric parameter for the sizing and anatomic fit of pIOLs before surgery in different races and ethnicities.

Conclusion

Based on our result, given the correlation of STS with WTW and mean *K*, and potential of direct and essay measurement of WTW and mean *K*, it seems that

current IOL sizing protocols could be estimating with WTW and mean *K*.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval For this type of study formal consent is not required.

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