의학석사 학위논문

Agreement between postoperative ideal axis and preoperative axis measured by PCI based, SS-OCT based ocular biometry or Scheimpflug based topography for toric IOL implantation

난시교정 인공수정체 삽입술 시 수술 후 이상적인 축과 수술 전 부분결합간섭, 파장가변 빛간섭단층촬영 기반 안구 생체계측, 샤임플러그 기반 각막지형도로 측정한 축 사이의 일치도 비교

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Abstract

Agreement between postoperative ideal axis and preoperative axis measured by PCI based, SS-OCT based ocular biometry or Scheimpflug based topography for toric IOL implantation

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Purpose

Comparison of ocular biometry and corneal topography in determining the axis of toric intraocular lens (IOL) implantation has not been reported in previous studies. Therefore, we compared the difference between postoperative ideal axis and preoperatively measured axis between PCI based ocular biometry (IOL Master 500), SS-OCT based ocular biometry (IOL Master 700) and Scheimpflug based topography (Galilei G4) for toric IOL implantation.

Methods

A total 64 eyes of 44 patients who received cataract surgery with toric IOL were retrospectively reviewed. The preoperative corneal astigmatism was measured using IOL Master (500 or 700) and Galilei G4. The ideal axis of toric IOL was calculated 1 month after the cataract surgery using an online toric IOL back-calculator. The

axis difference (AD) and the absolute axis difference (AAD) between the ideal axis and the preoperatively measured axis were compared in between IOL Master 500 standard keratometry (K), 700 K, total keratometry (TK) and Galilei G4 K, TK.

Results

IOL Master 500 showed 1.94 ± 10.78° of AD (K) and 7.74 ± 7.63° of AAD (K) and Galilei G4 showed −0.29 ± 11.88° of AD (K), −0.74 ± 12.40° of AD (TK), 8.94 ± 7.67 of AAD (K) and 9.39 ± 7.95 of AAD (TK) in IOL Master 500 group. In IOL Master 700 group, AD (K), AD (TK), AAD (K), and AAD (TK) were as follows; −1.45 ± 10.72, −1.33 ± 10.14, 6.00 ± 7.30, and 6.36 ± 6.72 in IOL Master 700 and −1.27 ± 11.36, −1.58 ± 12.21, 7.09 ± 7.38, and 8.24 ± 7.71 in Galilei G4. AD and AAD of IOL Master showed no significant difference compared with those of Galilei G4.

Conclusion

This study suggests that the agreement between postoperative ideal axis and preoperatively measured axis of Galilei G4 may be comparable to that of IOL Master.

Keywords : toric IOL, axis, PCI, SS−OCT, Scheimpflug based topography

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Contents

List of Tables and Figures

Chapter 1. Introduction

Since toric intraocular lens (IOL) was first introduced in 1992, toric IOL implantation has become widely used procedure in cataract patients with high corneal astigmatism.[1,2] When the plus cylinder axis of the toric IOL is properly aligned with the corneal steep axis, corneal astigmatism is corrected. Toric IOLs have been proven to be a stable, effective and predictable method in correcting corneal astigmatism in many studies.[3-6] Also, according to the previous study, correcting residual astigmatism significantly improved visual acuity at all contrast levels at both distance and near.[7]

Previous study showed that the more the toric IOL deviates from the intended axis, the less effective the astigmatism correction is.[8] However, the measured steep axis of the corneal astigmatism can be different between devices, and it is difficult to determine which value to use. Measurement errors may occur in various situations, such as head tilting or poor cooperation during the examination. Also, posterior corneal astigmatism can change the astigmatism axis of total keratometry (TK) from that of standard keratometry (K), and steep axis of K may not be concomitant to that of TK [9,10]. During the toric IOL axis calculation, measurement errors and the discrepancy of axis between K and TK can lead to the errors in the expected astigmatism correction.

Various devices can be used to determine the axis of toric IOL, such as auto keratometer, ocular biometer, and corneal topography. Among them, IOL Master 500 (Carl Zeiss Meditec AG, Jena, Germany) and IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany) are widely used ocular biometers and based on partial coherence interferometry (PCI) and swept-source optical

coherence tomography (SS-OCT) respectively. Galilei-G4 (Ziemer, Port, Switzerland) is a dual Scheimpflug corneal topography which is commonly used to evaluate the corneal astigmatism.

However, comparison between IOL Master and corneal topography in determining toric IOL axis has not been reported in previous studies. In this study, we evaluated the agreement between postoperative ideal axis calculated by an online toric IOL back-calculator and preoperatively measured axis by ocular biometry (IOL Master 700, IOL Master 500) and corneal topography (Galilei-G4).

Chapter 2. Methods

This study was approved by the Institutional Review Board of the Seoul National University Bundang Hospital (IRB No. B-2206-761-110). The study also adhered to the tenets of the Declaration of Helsinki. This study was conducted by reviewing the medical records of patients who underwent phacoemulsification and posterior chamber toric IOL (Zeiss AT TORBI 709M®, Carl Zeiss Meditec AG, Jena, Germany) implantation at the Seoul National University Bundang Hospital between July 2017 and January 2022. A total of 44 patients, 64 eyes were included in this study; 31 eyes of 19 patients underwent ocular biometry by IOL Master 500 in between July 2017 and February 2019 and 33 eyes of 25 patients were measured by IOL Master 700 in between March 2019 and January 2022. Corneal topography was measured by Galilei G4 in all patients. Exclusion criteria were as follows; corneal abnormalities including corneal opacity, degeneration or dystrophy, previous refractive surgery history, postoperative corrected distance visual acuity (CDVA) under 20/30, and age under 20 years.

Preoperative IOL Axis calculation

IOL cylinder power and axis of Zeiss AT TORBI 709M® was calculated using Z CALC online IOL calculator (https://zcalc.meditec.zeiss.com). The ocular parameters (axial length, anterior chamber depth, keratometry (flat K, steep K, and their meridians) by IOL Master 500 or IOL Master 700, 0.25 D of surgically induced astigmatism (SIA), and temporal incision orientation (0° or 180° according to the laterality of the eye) were entered in the calculator.

Toric IOL Axis marking

The patient was advised to maintain sitting and upright head position, and preoperative reference markings of 0° and 180° on the cornea was done using toric reference marker (AE-2793S, ASICO, IL, USA) right before the surgery.

Surgical technique

The surgery was performed by one experienced surgeon (JYH). Under topical anesthesia, temporal 2.2 mm incision was made, continuous curvilinear capsulorhexis and phaco-chop technique phacoemulsification, and toric IOL implantation were done and toric IOL was rotated to align the axis to steep corneal axis.

Ideal toric IOL axis calculation

The axis of the implanted toric IOL was measured using internal OPD map of wavefront aberrometer (Nidek OPD-SCAN III) at 1 month after the surgery. (Figure 1) Refractive outcome was measured by autorefraction. Given the data of refraction, and cylinder power and implanted axis of toric IOL, an online toric IOL back-calculator (astigmatismfix.com, Ocular Surgical Data LLC, Sioux Falls, SD, USA) was used to calculate the ideal axis of the IOL.[11,12] (Figure 2)

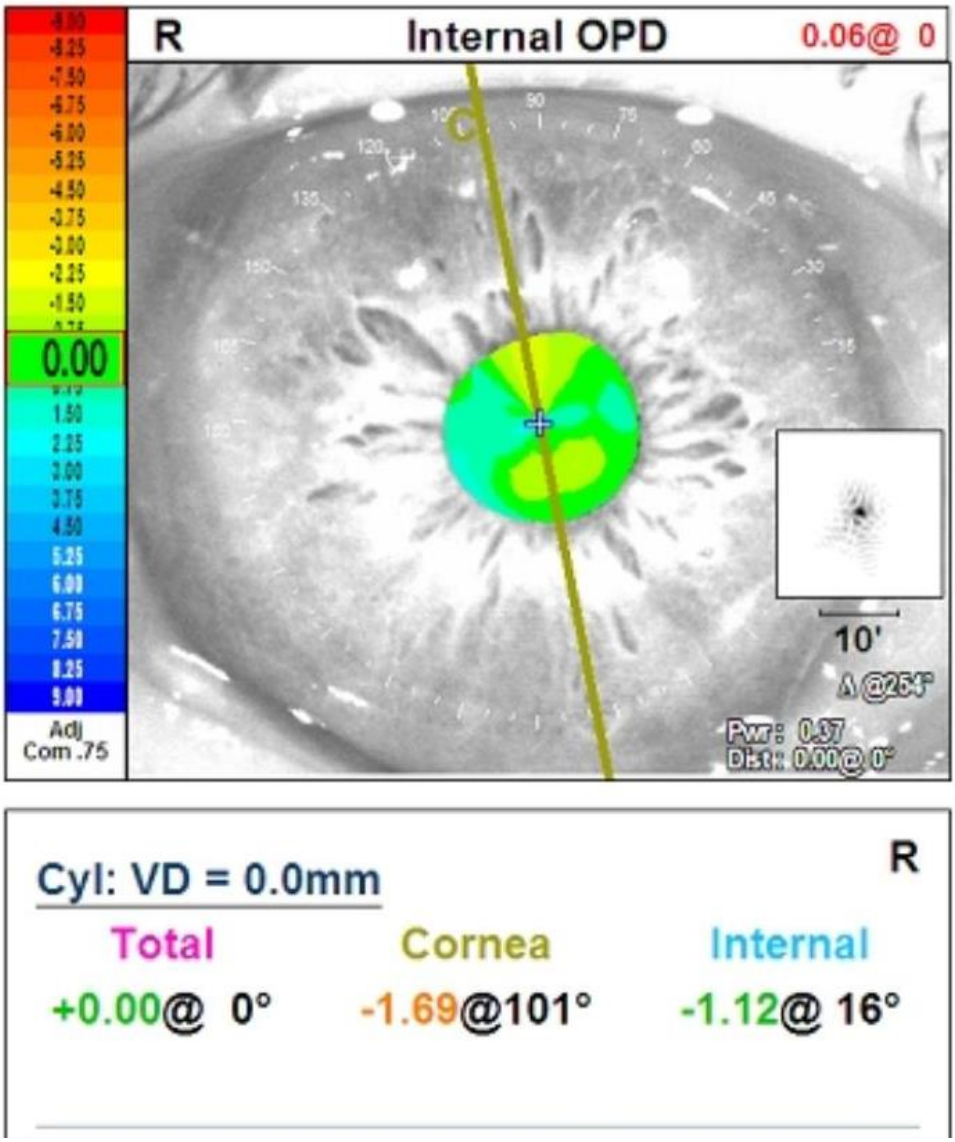

Figure 1. An example of internal OPD map of wavefront aberrometer

Internal OPD map shows the degree and axis of internal astigmatism, and the axis of the implanted toric IOL can be measured. The IOL axis of this example is measured as 16° .

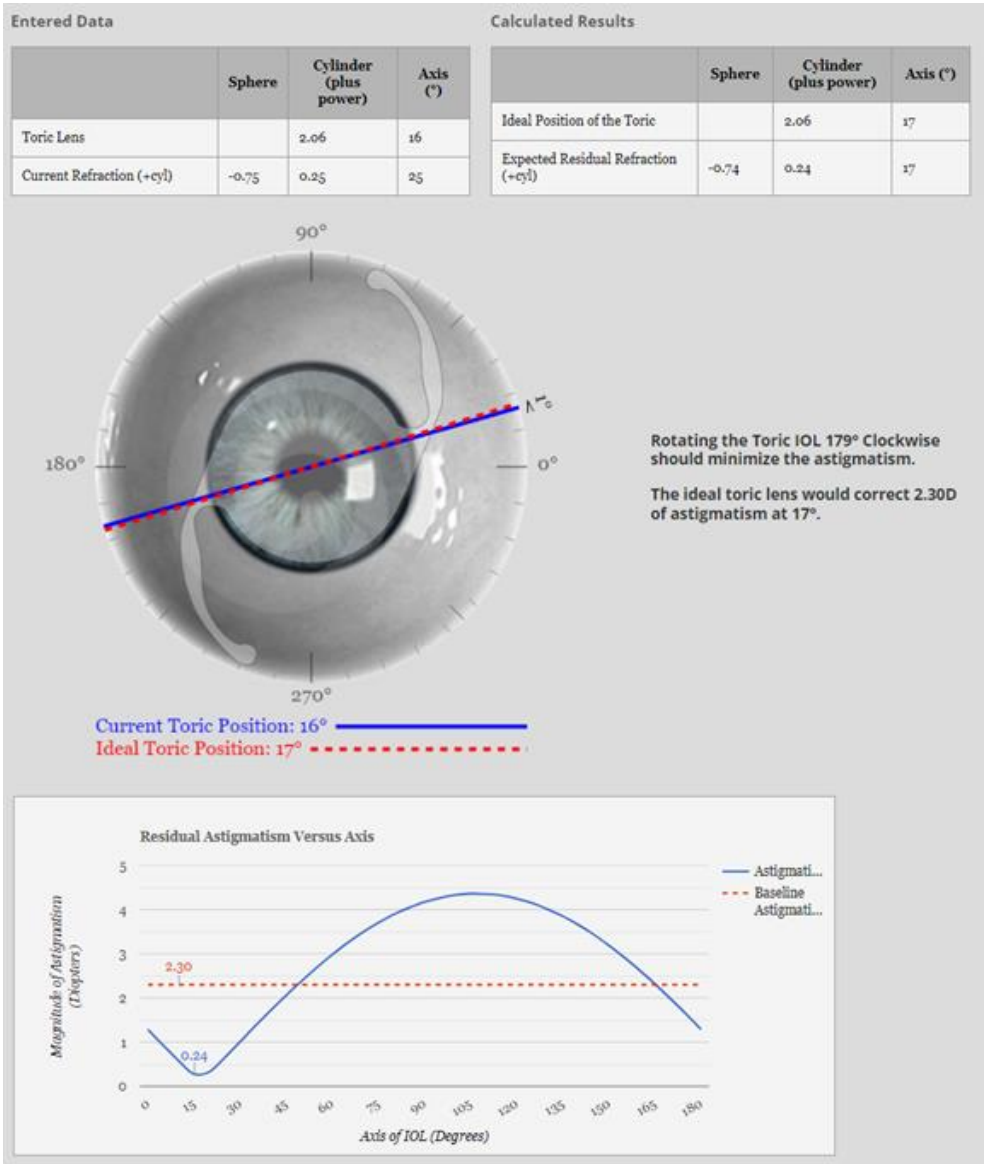

Figure 2. An example of an online toric IOL back-calculator

An online toric IOL back-calculator provides the ideal axis of toric IOL by entering postoperative refraction, cylinder power and current axis of toric IOL. The ideal axis of the toric IOL in this example is 17° .

Postoperative outcome measures

The IOL Master and Galilei G4 was compared using the axis difference (AD) between the ideal axis and the measured axis. The AD was defined as ideal axis − calculated axis, and the absolute axis difference (AAD) was defined as the absolute value of AD.

Subgroup analysis were also performed in patients with steep axis difference over 10° between IOL Master (500 or 700) and Galilei G4. AAD was compared between IOL Master and Galilei G4.

Statistical Analysis

Statistical analysis was performed using SPSS software version 25.0 (SPSS, Inc, Chicago, IL, USA) and Prism 9 software (GraphPad Software, Inc., San Diego, CA). Paired t−test was used to compare the keratometric value and the magnitude of astigmatism between IOL Master (500 or 700) and Galilei G4. The AD and AAD were compared between IOL Master (500 or 700) and Galilei G4 using the repeated measures analysis of variance (ANOVA) and F−test. In subgroup analysis, Friedman test was used to compare the AAD in between IOL Master and Galilei G4. The data are presented with mean value ± mean standard deviation (SD), and statistical significance was verified if $p < 0.05$.

Chapter 3. Results

Baseline demographic data are shown in table 1. The average age was 59.4 years in IOL Master 500 group and 65.9 years in IOL Master 700 group. IOL Master 500 group consisted of 12 men and 19 women. Nineteen men and 14 women were included in IOL Master 700 group. Seventeen eyes were right and 14 eyes were left in IOL Master 500 group and 16 right eyes and 17 left eyes were included in IOL Master 700 group. The spherical equivalent and cylinder power of the implanted IOLs were 18.57 ± 3.12 D and 3.12 ± 1.36 D in IOL Master 500 group and 16.63 ± 5.75 D and 2.79 ± 0.81 D, respectively.

Table 1. Baseline demographic data and ocular biometric values in IOL Master 500 group and IOL Master 700 group

Parameter	IOL Master 500 group	IOL Master 700 group
Age (years)	59.4 ± 15.9	65.9 ± 10.9
Sex (M / F)	12 (38.7 %) / 19 (61.3 %)	19 (57.6 %) / 14 (42.4 %)
Laterality (R / L)	17 (54.8 %) / 14 (45.2 %)	16 (48.5 %) / 17 (51.5 %)
AL (mm)	23.82 ± 1.24	25.30 ± 3.24
ACD (mm)	3.24 ± 0.52	3.24 ± 0.43
LT (mm)		4.42 ± 0.42
WTW (mm)		11.15 ± 2.54

Values are presented as mean ± SD or number unless otherwise indicated.
AL, axial length; ACD, anterior chamber depth; LT, lens thickness; WTW, white to white diameter

Keratometric values and corneal astigmatism are shown in table 2 and table 3. Preoperatively measured astigmatism was 2.89 ± 1.43 diopters (D) by K of IOL Master 500, and 2.66 ± 1.07 D and 2.66 ± 1.39 D by K and TK of Galilei G4 in IOL Master 500 group. IOL Master 700 showed astigmatism of 2.37 ± 0.79 D (K) and 2.45 ± 0.78 D (TK) and Galilei G4 showed 2.27 ± 0.84 D (K) and 2.33 ± 0.72 D (TK) in IOL Master 700 group. Flat K, steep K, and KA (standard keratometric astigmatism) showed no significant difference between IOL Master (500 or 700) and Galilei G4. Flat TK and steep TK showed significant difference between IOL Master 700 and Galilei G4 in group 2 ($p < 0.001$ and $p < 0.001$, respectively), but TKA (total keratometric astigmatism) showed no statistical difference between the two devices. The average standard keratometric astigmatism axes were 84.67° by IOL Master 500 and 88.09° by Galilei G4 in IOL Master 500 group and 171.21° by IOL Master 700 and 175.9° by Galilei G4 in IOL Master 700 group. (Figure 3)

Table 2. Preoperative keratometric values in IOL Master 500 group

	IOL Master 500	Galilei G4	P value[a]
Flat K (D)	43.46 ± 1.95	43.51 ± 1.82	0.531
Steep K (D)	46.35 ± 2.21	46.17 ± 1.87	0.262
KA (D)	2.89 ± 1.43	2.66 ± 1.07	0.126

Values are presented as mean ± SD or number unless otherwise indicated. K, standard keratometry; KA, standard keratometric astigmatism; D, Diopter.

[a]Paired t-test

Table 3. Preoperative keratometric values in IOL Master 700 group

	IOL Master 700	Galilei G4	P value[a]
Flat K (D)	42.55 ± 2.07	42.61 ± 2.07	0.363
Steep K (D)	44.92 ± 1.96	44.88 ± 1.94	0.599
KA (D)	2.37 ± 0.79	2.27 ± 0.84	0.189
Flat TK (D)	42.52 ± 2.09	40.67 ± 1.96	<0.001
Steep TK (D)	44.97 ± 1.97	43.00 ± 1.95	<0.001
TKA (D)	2.45 ± 0.78	2.33 ± 0.72	0.142

Values are presented as mean ± SD or number unless otherwise indicated.
K, standard keratometry; KA, standard keratometric astigmatism; TK, total keratometry; TKA, total keratometric astigmatism; D, Diopter.
[a]Paired t-test

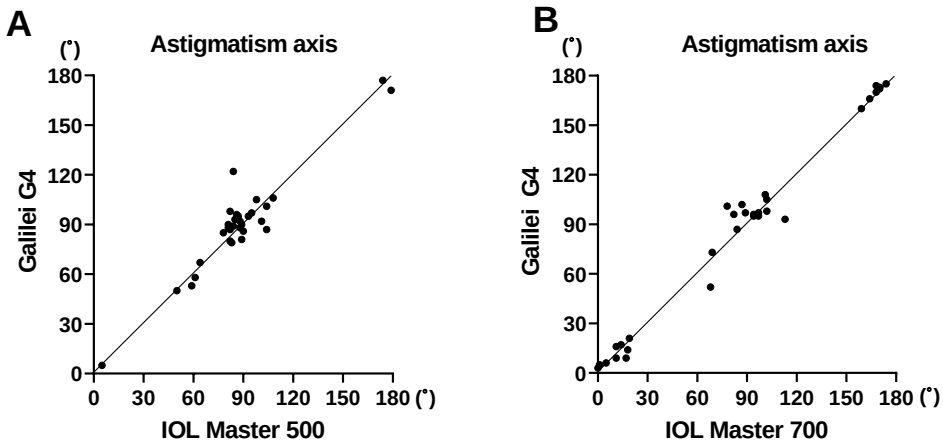

Figure 3. Astigmatism axis of standard keratometry by IOL Master 500 and Galilei G4 in IOL Master 500 group (A) and IOL Master 700 and Galilei G4 in IOL Master 700 group (B).

The standard keratometric astigmatism axes of all patients by IOL Master (500 or 700) and Galilei G4 are presented as dots on the graphs. The average astigmatism axes were 84.67° with IOL Master 500 and 88.09° with Galilei G4 in IOL Master 500 group and 171.21° with IOL Master 700 and 175.9° with Galilei G4 in IOL Master 700 group by double angle plots.

In IOL Master 500 group, the AD was 1.94° in K of IOL Master 500, and −0.29° and −0.74° in K and TK of Galilei G4. The AAD was 7.74° (K) by IOL Master 500, and 8.94° (K), 9.39° (TK) by Galilei G4. The AD and AAD were compared between IOL Master 500 and Galilei G4, and no statistical difference was found. (Figure 4)

In IOL Master 700 group, the AD was −1.45° (K) and −1.33° (TK) by IOL Master 700 and −1.27° (K) and −1.58° (TK) by Galilei G4. The AAD was 6.00 (K) and 6.36 (TK) in IOL Master 700, and 7.09 (K) and 8.24 (TK) in Galilei G4. The AD and AAD showed no statistical significance between K and TK of IOL Master 700 and those of Galilei G4. (Figure 5)

F−test was also conducted to compare the variance among the variables, but there was no significant difference between IOL Master and Galilei.

Subgroup analyses were also performed in IOL Master 500 group and IOL Master 700 group. AAD in patients with astigmatism axis difference between K (IOL Master 500 or 700) and K (Galilei G4) over 10° were analyzed. (Figure 6) No statistical difference in AAD between IOL Master and Galilei G4 was found in both groups.

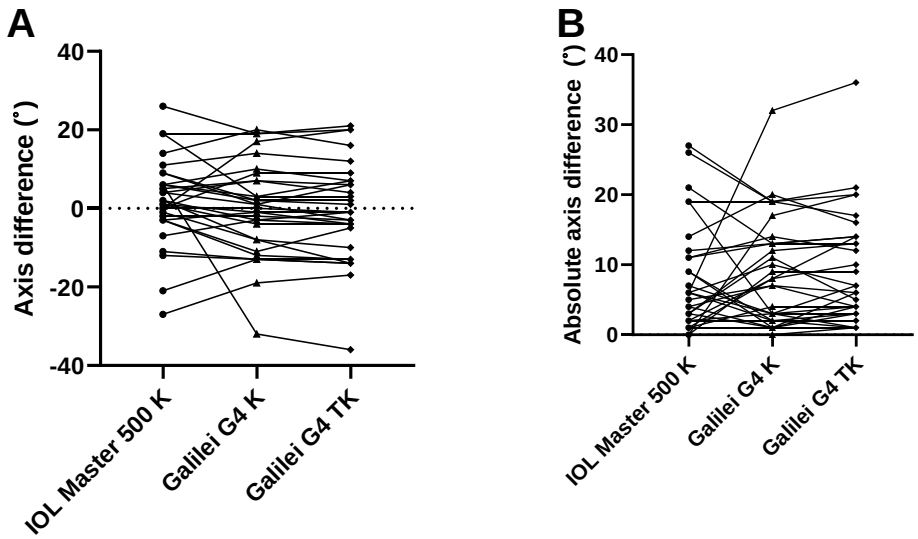

Figure 4. The AD and AAD of IOL Master 500 (K) and Galilei G4 (K, TK) in IOL Master 500 group.

(A) The AD of K (IOL Master 500), K (Galilei G4), and TK (Galilei G4) were compared and no significant difference was found between the variables.

(IOL Master 500 K vs. Galilei G4 K: p = 0.4011, IOL Master 500 K vs. Galilei G4 TK: p = 0.3258, Galilei G4 K vs. Galilei G4 TK: p = 0.6264)

(B) The AAD of K (IOL Master 500), K (Galilei G4), and TK (Galilei G4) did not show any significant difference.

(IOL Master 500 K vs. Galilei G4 K: p = 0.6873, IOL Master 500 K vs. Galilei G4 TK: p = 0.5365, Galilei G4 K vs. Galilei G4 TK: p = 0.6100)

**AD, axis difference; AAD, absolute axis difference

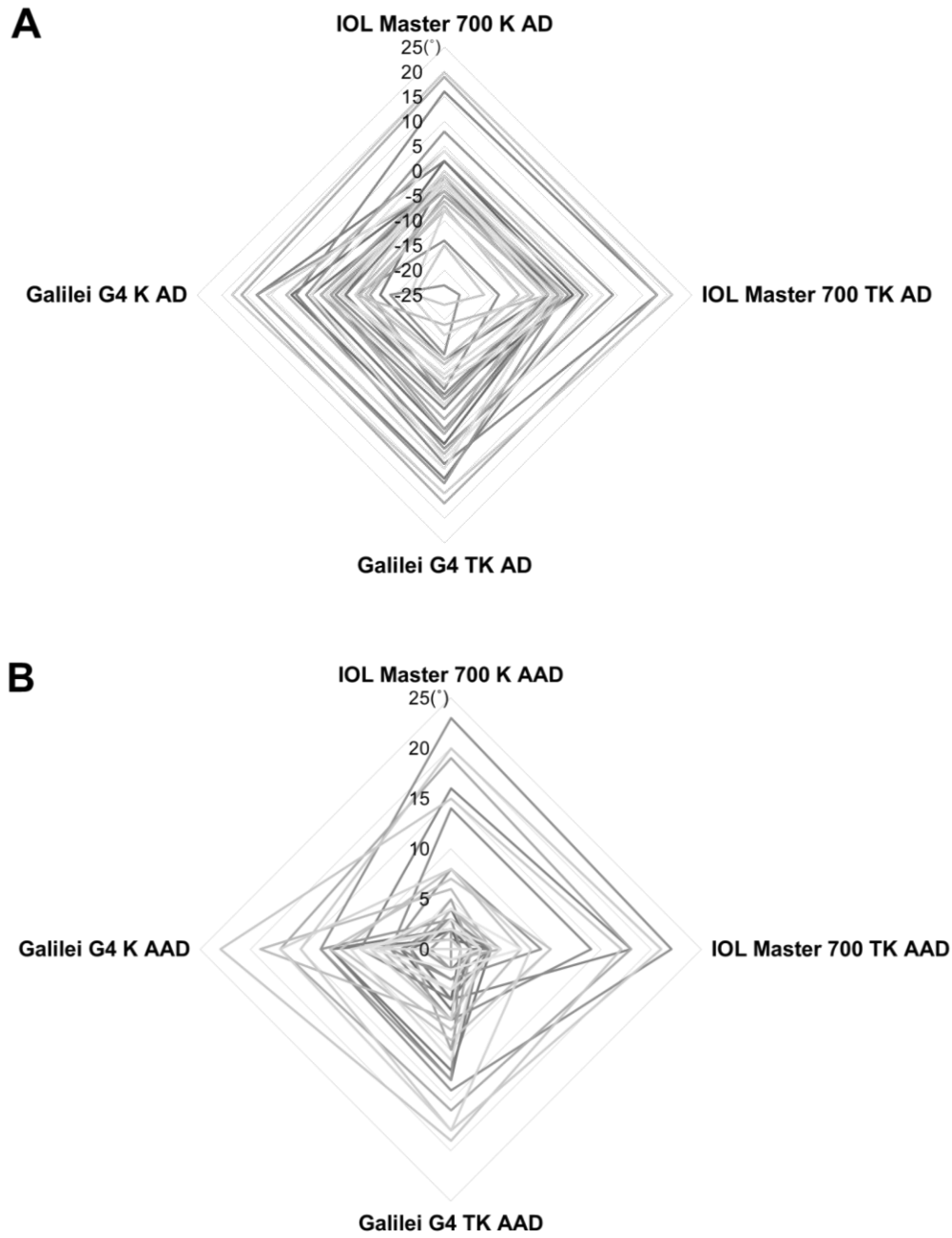

Figure 5. AD and AAD of IOL Master 700 (K, TK) and Galilei G4 (K, TK) in IOL Master 700 group.

(A) The AD of K (IOL Master 700), TK (IOL Master 700), K (Galilei G4), and TK (Galilei G4) were compared, and no significant difference was found between the variables.

(IOL Master 700 K vs. IOL Master 700 TK: p = 0.9745, IOL Master 700 K vs. Galilei G4 K: p = 0.9985, IOL Master 700 K vs. Galilei G4 TK: p = 0.9996, IOL Master 700 TK vs. Galilei G4 K: p > 0.9999, IOL Master 700 TK vs. Galilei G4 TK: p = 0.9969, Galilei G4 K vs. Galilei G4 TK: p = 0.9558)

(B) The AAD of K (IOL Master 700), TK (IOL Master 700), K (Galilei G4), and TK (Galilei G4) did not show any significant difference.

(IOL Master 700 K vs. IOL Master 700 TK: p = 0.5745, IOL Master 700 K vs. Galilei G4 K: p = 0.6584, IOL Master 700 K vs. Galilei G4 TK: p = 0.1204, IOL Master 700 TK vs. Galilei G4 K: p = 0.8797, IOL Master 700 TK vs. Galilei G4 TK: p = 0.2332, Galilei G4 K vs. Galilei G4 TK: p = 0.1586)

**AD, axis difference; AAD, absolute axis difference

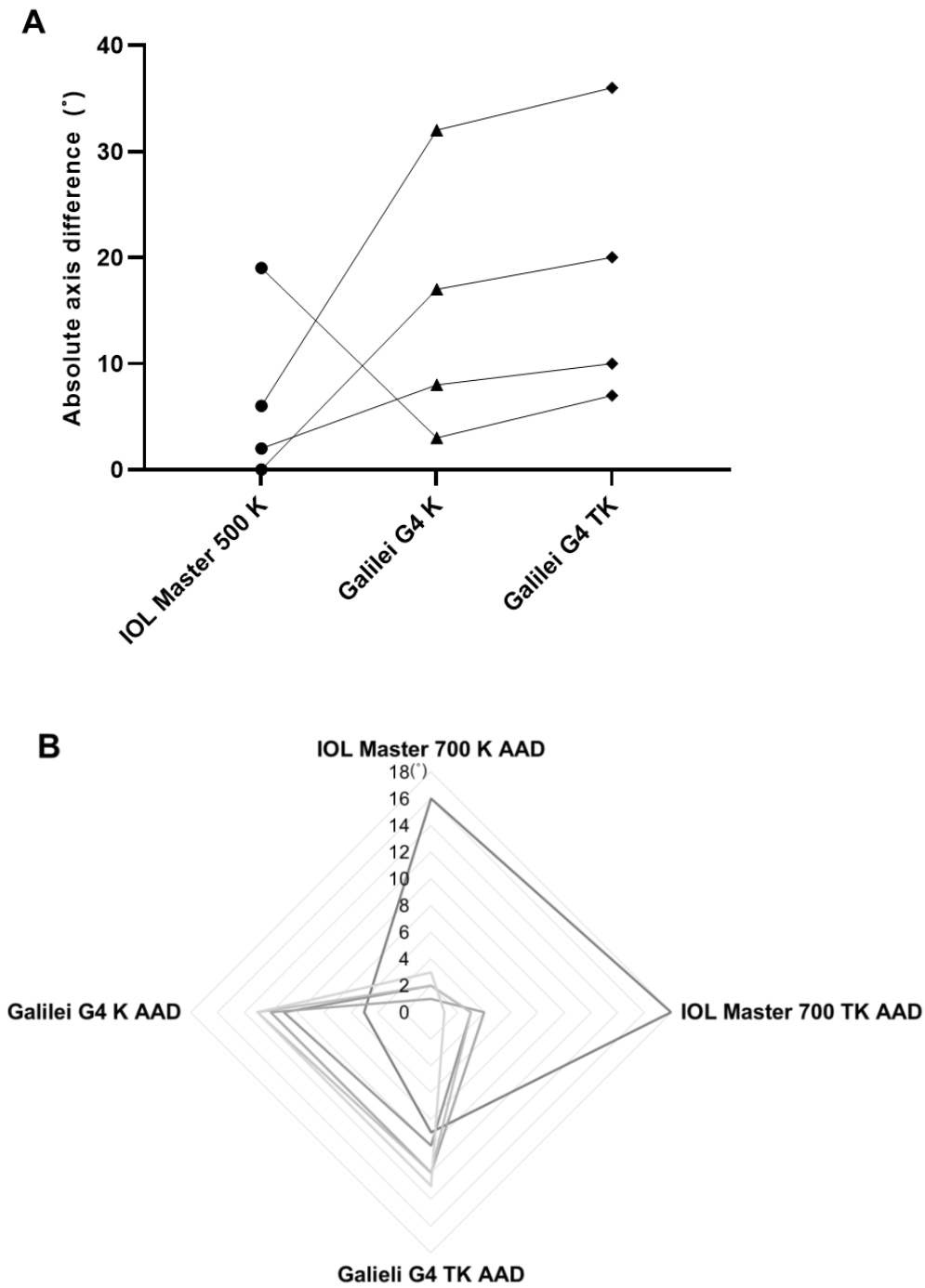

Figure 6. The AAD of IOL Master (500 or 700) and Galilei G4 in patients with steep axis difference over 10° between the devices.

(A) The AAD of K (IOL Master 500), K (Galilei G4), and TK (Galilei G4) were compared and no significant difference was found

between the variables.

(IOL Master 500 K vs. Galilei G4 K: $p > 0.9999$, IOL Master 500 K vs. Galilei G4 TK: $p = 0.2313$, Galilei G4 K vs. Galilei G4 TK: $p = 0.4719$)

(B) The AAD of K (IOL Master 700), TK (IOL Master 700), K (Galilei G4) and TK (Galilei G4) did not show any significant difference.

(IOL Master 700 K vs. IOL Master 700 TK: $p > 0.9999$, IOL Master 700 K vs. Galilei G4 K: $p = 0.3003$, IOL Master 700 K vs. Galilei G4 TK: $p = 0.5185$, IOL Master 700 TK vs. Galilei G4 K: $p > 0.9999$, IOL Master 700 TK vs. Galilei G4 TK: $p > 0.9999$, Galilei G4 K vs. Galilei G4 TK: $p > 0.9999$)

**AAD, absolute axis difference

Chapter 4. Discussion

This is the first study to compare the preoperatively measured axis of ocular biometry and Scheimpflug based topography in toric IOL implantation. In this study, we calculated the ideal axis of toric IOL after the cataract surgery and compared with the preoperative axis of IOL Master and Galilei G4. AD and AAD of IOL Master and Galilei G4 did not show any significant difference.

The axis determination of toric IOL is critical for maximizing the corrective effect of astigmatism. Toric IOL misalignment of 10 degrees and 20 degrees reduce the effect of correcting astigmatism to 2/3, 1/3 of total correction effect.[13] A 30−degree misalignment of toric IOL produces astigmatism of the same magnitude in different axis and is ineffective in astigmatism correction.[1,13,14]

There are various types of ophthalmologic equipment to measure corneal astigmatism, and of those, IOL Master and Galilei G4 are widely used. In some cases, there is discrepancy in the values between the devices and sometimes it is difficult to determine which value to use. No previous study has been reported about the comparison of postoperative ideal axis and preoperatively measured axis between ocular biometer and Scheimpflug based topography. However, present study did not show any significant difference between the devices.

Unlike IOL Master 500, posterior keratometry (PK) and TK can be measured by IOL Master 700 and Galilei G4. The axis of TK of IOL Master 700 and Galilei G4 were also compared, but there was no significant difference between IOL Master 700 and Galilei G4.

IOL Master 500 is based on partial coherence interferometry (PCI) biometer and uses 6 points in one zone (2.4 mm).[15,16] On the

other hand, IOL Master 700 obtains keratometric data with 18 spots in hexagonal patterns at three zones of the cornea (1.5 mm, 2.5 mm, and 3.5 mm).[17] Galilei G4 is a hybrid device that combines dual rotating Scheimpflug cameras and a Placido disc.[18,19] Dong et al[20] suggested that the difference of corneal power measurement between IOL master and corneal Scheimpflug topography may be due to the difference in analytic zone size. Different analyzing area can make the difference of the corneal astigmatism axis in ocular biometry and corneal topography.

An online toric IOL back-calculator can provide information on residual astigmatism changes with rotation of toric IOL, and has been used in previous studies to estimate the magnitude of IOL rotation after toric IOL implantation or the degree of residual cylinder reduction in toric IOL reorientation.[21-24] In this study, we used an online toric IOL back-calculator to evaluate the ideal axis of implanted toric IOL and compared it with the measured axis of preoperative ocular biometer or Scheimpflug based corneal topography.

AD and AAD were evaluated to compare IOL Master with Galilei in measuring corneal astigmatism in both devices. AD is a value considering the directionality of the measurement error in a clockwise or counterclockwise direction, and AAD is a value without directionality. There was no significant difference in AD and AAD between IOL Master and Galilei G4.

According to the preoperative corneal astigmatism axes, there were more with-the-rule (WTR) astigmatism patients in the IOL Master 500 group, and more against-the-rule (ATR) astigmatism patients were included in the IOL Master 700 group. Previous studies showed that corneal astigmatism changes from WTR to ATR

with age. [25-27] Mean age was higher in IOL Master 700 group and there was a possibility that more patients with ATR astigmatism were included in IOL Master 700 group.

The mean absolute difference between the intended axis by preoperative Z CALC toric IOL calculator and the actual axis measured by OPD scan was 8.29° . Several causes could make the difference. Early postoperative toric IOL rotation of 4-5° has been reported in several studies.[28,29] Also, manual toric reference marking might result in errors in 0° and 180° reference on the cornea. Slight head tilt of the patient during the reference marking or during the examination could also make the errors in the axis evaluation.

There are some limitations in this study. The anterior segment photography with dilation of pupil was not done in this study. Using both anterior segment photo images and internal OPD map of OPD scan III, the evaluation of implanted toric IOL axis could be more accurate. Also, image guided digital marking system such as Verion Digital Marker (Alcon Laboratories, Inc., TX, USA) showed better results in toric IOL alignment comparing with manual marking procedure.[30,31] Also, it is possible that no statistical significance was found due to the low baseline astigmatism axis difference between IOL Master and Galilei G4. We performed subgroup analysis with the patients of astigmatism axis difference between IOL Master and Galilei G4 over 10° but could not find any significant difference between the devices. In subgroup analysis, there were only 4 patients in IOL Master 500 group and 5 patients in IOL Master 700 group. Further investigation with a larger number of studies in patients with large discrepancy between IOL Master and Galilei G4 is needed to increase statistical reliability. Also, using digital

marking system and postoperative evaluation by both OPD scan III and anterior segment photography could make the result more reliable.

In conclusion, this study suggests that the agreement between postoperative ideal axis and preoperatively measured axis of Galilei G4 may be comparable to that of IOL Master.

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초록

난시교정 인공수정체 삽입술 시 수술 후 이상적인 축과 수술 전 부분결합간섭, 파장가변 빛간섭단층촬영 기반 안구 생체계측, 샤임플러그 기반 각막지형도로 측정한 축 사이의 일치도 비교

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김성환

목적

백내장 수술 시 난시교정 인공수정체의 축을 결정할 때 안구 생체계측과 각막지형도의 비교는 이전 연구에서 보고된 바가 없다. 이에 본 연구에서는 부분결합간섭 기반 안구 생체계측(IOL Master 500), 파장가변 빛간섭단층촬영 기반 안구 생체계측(IOL Master 700)과 샤임플러그 기반 각막지형도(Galilei G4) 사이의 축 정확도를 비교해보고자 하였다.

방법

백내장 수술 시 난시교정 인공수정체를 삽입한 44명의 환자, 66안에 대해 후향적으로 분석하였다. 수술 전 각막 난시는 IOL Master (500 혹은 700)와 Galilei G4 를 이용해서 측정하였다. 백내장 수술 한 달 후 온라인 토릭 역계산기를 이용해 난시교정 인공수정체의 이상적인 축을 계산하였다. 이상적인 축과 수술 전 측정된 축의 차이값(AD)과 축 차이값의 절대값(AAD)을 IOL Master와 Galilei G4에서 각각 비교하였다.

결과

수술 전 IOL Master 500으로 안구 생체계측을 시행한 군에서 IOL

Master 500은 K AD 1.94 ± 10.78°, K AAD 7.74 ± 7.63° 의 수치를 보였고, Galilei G4는 K AD −0.29 ± 11.88°, TK AD −0.74 ± 12.40°, K AAD 8.94 ± 7.67, TK AAD 9.39 ± 7.95 의 값을 보였다. IOL Master 700을 시행한 군에서는 IOL Master 700은 K AD −1.45 ± 10.72, TK AD −1.33 ± 10.14, K AAD 6.00 ± 7.30, TK AAD 6.36 ± 6.72 의 값을 보였고, Galilei G4 K AD −1.27 ± 11.36, TK AD −1.58 ± 12.21, K AAD 7.09 ± 7.38, TK AAD 8.24 ± 7.71 의 수치를 보였다. IOL Master에서의 AD, AAD 값은 Galilei G4의 AD, AAD 값과 비교할 때 통계적으로 유의한 차이는 보이지 않았다.

결론

난시교정 인공수정체의 이상적인 축과의 일치도를 평가할 때 Galilei G4는 IOL Master와 견주어 비교할 만한 결과를 보여주는 것으로 사료된다.

주요어 : 난시교정 인공수정체, 난시축, 부분결합간섭계, 파장가변 빛간섭단층촬영, 샤임플러그 기반 각막지형도

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