Resulting choice of toric intraocular lens using three devices and online Barrett calculator

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Abstract

PURPOSE: To investigate interdevice agreement among toric power calculation difference based on corneal topography/ray-tracing aberrometry (iTrace), partial coherence interferometry (IOLMaster 500), and Scheimpflug imaging (Pentacam) for the measurement of anterior corneal astigmatism.

METHODS: The analysis included 101 eyes with regular astigmatism of 101 subjects. The main outcome measures were corneal cylinder power, axis of astigmatism, keratometry values. The toric power and intraocular lens (IOL) power was calculated using online Barrett toric calculator. Interdevice measurement and calculation agreement was assessed using paired sample t-test, and nonparametric test.

RESULTS: Significant interdevice difference existed for astigmatism magnitude, flat keratometry, steep keratometry and mean keratometry between iTrace and IOLMaster (all $P < 0.01$). Significant interdevice difference existed for flat keratometry, steep keratometry and mean keratometry (all $P < 0.001$) but not astigmatism magnitude ($P = 0.325$) between iTrace and Pentacam. Significant interdevice difference existed for astigmatism magnitude, steep keratometry and mean keratometry (all $P < 0.01$) but not flat keratometry ($P = 0.310$) between IOLMaster and Pentacam. For toric IOL power calculation, iTrace calculation was statistically higher than IOLMaster (0.49±0.36, $P <0.001$) and Pentacam (0.39±0.42, $P <0.001$). Moreover, Pentacam IOL power calculation was statistically lower than IOLMaster (-0.10±0.39, $P =0.009$). Toricity calculation difference was also existed among the three groups ($P = 0.004$).

CONCLUSIONS: The toric IOL power and toricity calculation difference based on iTrace, IOLMaster 500, and Pentacam anterior keratometry data should be noticed in clinic practice.

Introduction

Due to cataract patients’ postoperative visual quality affected by both surgical induced astigmatism (SIA) and preoperative corneal astigmatism measurement, so better clear corneal incision size and location, precise preoperative corneal astigmatism measurement should both be considered for correction during cataract surgery to gain better postoperative visual quality[1–3]. Rational surgical planning (toric intraocular lens (IOL), clear corneal incision at the steepest axis, peripheral corneal relaxing incisions etc) plays an important role in the whole process. Currently, there is no standard device for corneal astigmatism measurement and toric IOL calculation in clinic. Different types of keratometers (ray-tracing aberrometry, partial coherence interferometry, Scheimpflug imaging system) may provide different corneal astigmatism values for the same eye, which might provide different toricity choices for toric IOLs, even with use of the same formula.

iTrace ray-tracing aberrometry (Tracey™ Technologies, Texas, USA), based on corneal topography, can provide simulated keratometry (SimK) and astigmatism data with a diameter of 3.0 mm centered on the anterior corneal apex[4]. IOLMaster 500 (Carl Zeiss Meditec, Germany), based on partial coherence interferometry, measures anterior corneal astigmatism and curvature by analyzing the real position of each pair of reflection spots (six spots of light arranged in a hexagonal pattern) from the anterior surface of the cornea with a diameter ring of around 2.3 to 2.5 mm[5]. The Pentacam Scheimpflug imaging system (OCULUS, Wetzlar, Germany) can capture 25 to 50 images by rotating 360 degrees in one examination. It also can image and perform automated measurement of the anterior and posterior corneal surfaces. Anterior corneal astigmatism data, as a computerized value focused on the anterior 3.0 mm of the cornea, can be centered on the corneal apex or pupil[6]. Considering the other two devices corneal curvature measurement using data centered on apex, the Pentacam anterior axial keratometry data of 3 mm on the ring centered on corneal apex were used in this study.

Many toric IOL calculation methods have been provided, but researches demonstrated that Barrett toric calculator showed better performance than the other calculators[7]. Moreover, a recent research also demonstrated that astigmatism prediction errors with and without posterior corneal curvature measured and calculated using the updated Barrett toric calculator showed similar results[8].

Considering iTrace, IOLMaster and Pentacam were commonly used keratometry devices and Barrett toric calculator was a relatively good toricity calculator in clinic. We want to compare the toricity difference based above-mentioned three devices and the Barrett toric calculator in this study.

Methods

Subjects

This study was performed at the Shanxi Eye Hospital (Taiyuan, Shanxi, China). The research protocol was approved by the institutional review board of Shanxi Eye Hospital and carried out according to the tenets of the Declaration of Helsinki. Written informed consent was obtained from each subject after explaining the nature of this study.

Consecutive patients were enrolled between April 2017 and January 2019. The inclusion criteria were as follows: corneal regular astigmatism, no systemic disease, no pathological alteration of the anterior segment (such as dry eye[9], keratoconus, zonular dialysis, pseudoexfoliation syndrome, or corneal opacity), no retinal diseases impairing visual function, and no previous anterior or posterior segment surgery. Due to unstable fixation during each examination, patients failed to cooperate with any data acquisition process will be excluded from this study[10].

Data Acquisition

Corneal keratometry data was measured using the same sequence of iTrace, IOLMaster 500, and Pentacam HR for each eye. Measurements with good quality were used in the final analysis. The software used was version 6.1.0 for iTrace, version 7.5 for IOLMaster 500, version 1.20r36 for Pentacam HR. All measurements were performed in a semi-dark room. The subjects were asked to place their chin on the chin rest and press the forehead against the forehead strap. The eye was then aligned to the visual axis by using a central fixation light or target. The subjects were instructed to perform a complete blink before each measurement. A single trained operator (YQZ) performed all of the examinations using the three devices.

IOL power and toricity calculation

IOL power and toricity were calculated using the online Barrett toric calculator v2.0 (website: https://www.apacrs.org/disclaimer.asp?info=3). Axial length (AL), optical anterior chamber depth (ACD) of IOLMaster 500 was used as biometry data for calculation. The 3 mm simulated keratometry data of iTrace and axial keratometry data of 3 mm ring centered on anterior corneal apex of Pentacam HR were used for calculation. Moreover, target refraction was set as plano, incision SIA and incision location were set as 0.5 D and 120 degree for each calculation. Alcon SN6ATx IOL model with lens factor of 2.02 and A constant 119.26 were used for each calculation.

Double-angle plots of astigmatism

We use the double-angle plots method, which mentioned by Abulafia et al., to plot the astigmatism data of each device[11]. Different from the single-angle plot, it can display the magnitude and axis of the mean astigmatism and the confidence ellipse, which is helpful for the qualitative assessment.

Statistics

Statistical analyses were performed using commercial software (SPSS for Windows, Version 13.0; SPSS Inc., Illinois, USA). The Kolmogorov-Smirnov test was used to assess data normality. The statistical significance of the intradevice difference data (astigmatism magnitude, keratometry, IOL power) was investigated using the paired two-tailed t-test. Using Bonferroni correction for multiple comparisons, all tests had a significance level of 2.5%. Nonparametric (Friedman test) was utilized to compare the astigmatism axis, toricity, toric IOL axis among the three devices. All tests had a significant level of 5%.

Results

One hundred and one eyes of 101 subjects were included in the final study. Demographics of the study population are summarized in Table 1.

Table 1
Patient demographics.

Characteristic	No.
Eyes (% right eyes)	55(54.5%)
Age, y (mean ± SD)	66 ± 10
Sex (% male)	56 (55.4%)
Axial length, mm (mean ± SD)	23.37 ± 0.91
Anterior chamber depth, mm (mean ± SD)	3.10 ± 0.37
SD = standard deviation	

The mean simulated corneal keratometry measurements and mean difference of each parameter obtained using iTrace, IOLMaster 500,and Pentacam HR are listed in Table 2,3 and Fig. 1. No significant difference was found among the three devices for corneal astigmatism axis measurements (P = 0.967).

Table 2
Mean anterior corneal keratometry measurements obtained using iTrace, IOLMaster and Pentacam.

	iTrace at 3 mm (n = 101)	IOLMaster at 2.3 mm (n = 101)	Pentacam at 3 mm (centered on corneal apex) (n = 101)
Astigmatism magnitude (D)	1.86 ± 0.77 (range: 0.61–4.23)	1.95 ± 0.87 (range:0.34–4.50)	1.83 ± 0.79 (range:0.40–3.80)
Astigmatism axis (degree)	97 ± 68 (range:0-179)	99 ± 64 (range:1-179)	94 ± 47 (range:0-179)
Flat keratometry (D)	43.69 ± 1.58 (range:39.58–47.74)	44.04 ± 1.61 (range:39.57–47.74)	44.01 ± 1.58 (range:39.40–47.60)
Steep keratometry (D)	45.55 ± 1.62 (range:41.02–48.77)	45.99 ± 1.57 (range:42.13–49.41)	45.84 ± 1.60 (range:41.10–49.10)
Mean keratometry (D)	44.62 ± 1.55 (range:40.30-48.26)	45.02 ± 1.53 (range:40.85–48.51)	44.92 ± 1.54 (range:40.25–48.25)
D = diopters			

Table 3
Mean difference between every two devices for anterior corneal keratometry measurement.

	iTrace-IOLMaster	iTrace-Pentacam	IOLMaster-Pentacam
Astigmatism magnitude (D)	-0.10 ± 0.33 **(P = 0.005)**	0.03 ± 0.27 (P = 0.325)	0.12 ± 0.38 **(P = 0.002)**
Flat keratometry (D)	-0.35 ± 0.27 **(P < 0.001)**	-0.31 ± 0.33 **(P < 0.001)**	0.04 ± 0.36 (P = 0.310)
Steep keratometry (D)	-0.45 ± 0.26 **(P < 0.001)**	-0.29 ± 0.30 **(P < 0.001)**	0.16 ± 0.24 **(P < 0.001)**
Mean keratometry (D)	-0.40 ± 0.20 **(P < 0.001)**	-0.30 ± 0.29 **(P < 0.001)**	0.10 ± 0.24 **(P < 0.001)**
D = diopters			

As Table 3 demonstrated, significant interdevice difference existed for astigmatism magnitude, flat keratometry, steep keratometry and mean keratometry between iTrace and IOLMaster (all $P < 0.01$). Significant interdevice difference existed for flat keratometry, steep keratometry and mean keratometry (all $P < 0.001$) but not astigmatism magnitude ($P = 0.325$) between iTrace and Pentacam. Significant interdevice difference existed for astigmatism magnitude, steep keratometry and mean keratometry (all $P < 0.01$) but not flat keratometry ($P = 0.310$) between IOLMaster and Pentacam.

As Table 4 demonstrated, for IOL power calculation, iTrace calculation was statistically higher than IOLMaster (0.49 ± 0.36, $P < 0.001$) and Pentacam (0.39 ± 0.42, $P < 0.001$). Moreover, Pentacam IOL power calculation was statistically lower than IOLMaster (-0.10 ± 0.39, $P = 0.009$). For all participants IOL power comparison, there still 23 cases (22.8%) demonstrated IOL power difference ≥ 1.0D between iTrace and IOLMaster; the corresponding data between iTrace and Pentacam, IOLMaster and Pentacam was 18 cases (17.8%) and 6 cases (5.9%), respectively (Fig. 2).

Table 4
Intraocular lens power and Toric toricity calculated using online Barrett Toric Calculator for each device.

	iTrace (n = 101)	IOLMaster (n = 101)	Pentacam (n = 101)
IOL power (D)	20.8 ± 2.8 (range:12.5–27.0)	20.3 ± 2.9 (range:12.5–27.0)	20.4 ± 2.8 (range:12.5–27.0)
Toricity (T)	5 ± 2 (range:2–9)	5 ± 2 (range:2–9)	5 ± 2 (range:2–9)
Axis (degree)	62 ± 66 (range:1-180)	59 ± 64 (range:0-179)	64 ± 65 (range:1-179)
D = diopters			

Friedman test showed that toricity calculation difference was also existed among the three groups (P = 0.004). However, no significant difference was found for the toric axis among the three groups (P = 0.318). For toricity comparison, there were 46 cases (45.5%) demonstrated 1 scale toricity difference and 3 cases (3.0%) demonstrated 2 scale toricity difference between iTrace and IOLMaster; The corresponding data between iTrace and Pentacam, IOLMaster and Pentacam was 41 cases (40.6%) and 1 case (1.0%), 49 cases (48.5%) and 5 case (5.0%), respectively (Fig. 3).

Discussion

As previous researches has demonstrated, we also found the significant difference of mean keratometry, astigmatism magnitude and steep keratometry data between IOLMaster and Pentacam[12, 13]. Moreover, IOLMaster also demonstrated higher corneal keratometry values than iTrace. The main reason for the corneal keratometry measurement difference among the three devices can be attributed to the different measurement corneal diameter and different measuring technologies [9]. Moreover, The IOLMaster 500 device provides higher steep keratometry values than the other two devices, this may because it has the smallest measuring diameter than the other two devices[14].

The Barrett toric calculator takes into account the posterior cornea curvature (predicted, not measure), lens position, the thickness and the shape of the lens[8]. Moreover, this calculator also combined with the Universal II formula, which predicts the IOL power to work out the IOL position and use that to calculate the effect of IOL cylinder power at the corneal plane. Based on previous study, it performs better than other calculators[7]. Therefore, we use this free online calculator to test the influence and compatibility of different corneal keratometry measurement devices in this study.

Using Barrett toric calculator, we found the significant difference of IOL power between every two devices. However, based on most interval of IOL was 0.5D, the difference of iTrace-IOLMaster and iTrace-Pentacam should be noticed clinically. Moreover, around 20% of cases demonstrated IOL power difference ≥ 1.0D for iTrace-IOLMaster and iTrace-Pentacam. The IOL power difference between IOLMaster and Pentacam was the smallest and 94.1% cases were within the range of ± 0.5D. The toricity of toric IOL interval is from 0.5D to 0.75D (T2-T9) for each scale. For toricity result, 49 cases (48.5%) showed more than 1 scale difference between iTrace and IOLMaster. The corresponding data was 42cases (41.6%) and 54 cases (53.5%) for iTrace-Pentacam, IOLMaster-Pentacam, respectively. Moreover, there were 39 cases (38.6%) met the conditions of both IOL power within ± 0.5D and the same toricity between iTrace and IOLMaster. The corresponding result for iTrace and Pentacam, IOLMaster and Pentacam was 49 cases (48.5%) and 45 cases (44.6%), respectively. Based on our findings, there were still a big proportion of cases (more than a half) demonstrated inconsistent result. This finding also emphasize that ophthalmologists should be careful for the toric surgery plan, especially when the measured data and calculation result were inconsistent among different devices. The better thing is that no significant difference was found for the toricity axis among the three groups. Therefore, the overcorrection and undercorrection of astigmatism are the main problem during the surgical plan.

A limitation of this study was that we included no subgroups showing with-the-rule or against-the-rule corneal astigmatism calculation result difference. If the eyes are grouped into different subgroups, the results may differ. Moreover, no postoperative data to demonstrate which device measured value is more precise in clinic. This should be investigated in further study. However, the difference that we found in this study is helpful for ophthalmologist to consider when doing the surgery plan for astigmatism patients.

Conclusions

In conclusion, the present study evaluated the comparability of toric IOL power and toricity based on three different measurement devices and the online Barrett toric calculator. The IOL power and toricity difference based on iTrace, IOLMaster, and Pentacam keratometry data should be noticed in clinic practice.

Abbreviations

ACD = anterior chamber depth; AL = axial length; D = diopter; IOL = intraocular lens; SIA = surgical induced astigmatism; SimK = simulated keratometry;

Declarations

Acknowledgement

Not applicable.

Ethics approval and consent to participate

The research protocols were approved by the ethics committee of Shanxi Eye Hospital and were conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all individual participants included in this study.

Consent for publication

Not applicable.

Availability of data and materials

The raw datasets supporting the conclusions of this article are available from the corresponding author Dr. Xiaogang Wang with the email: movie6521@163.com.

Competing interests

The authors declare that they have no competing interest.

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Contributors

XGW: conception, design, data acquisition, analysis, drafting, critical revision. JD: conception design, data acquisition, drafting, critical revision. YQZ: conception, data acquisition, analysis, critical revision. All authors: final approval of the manuscript.

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Figures

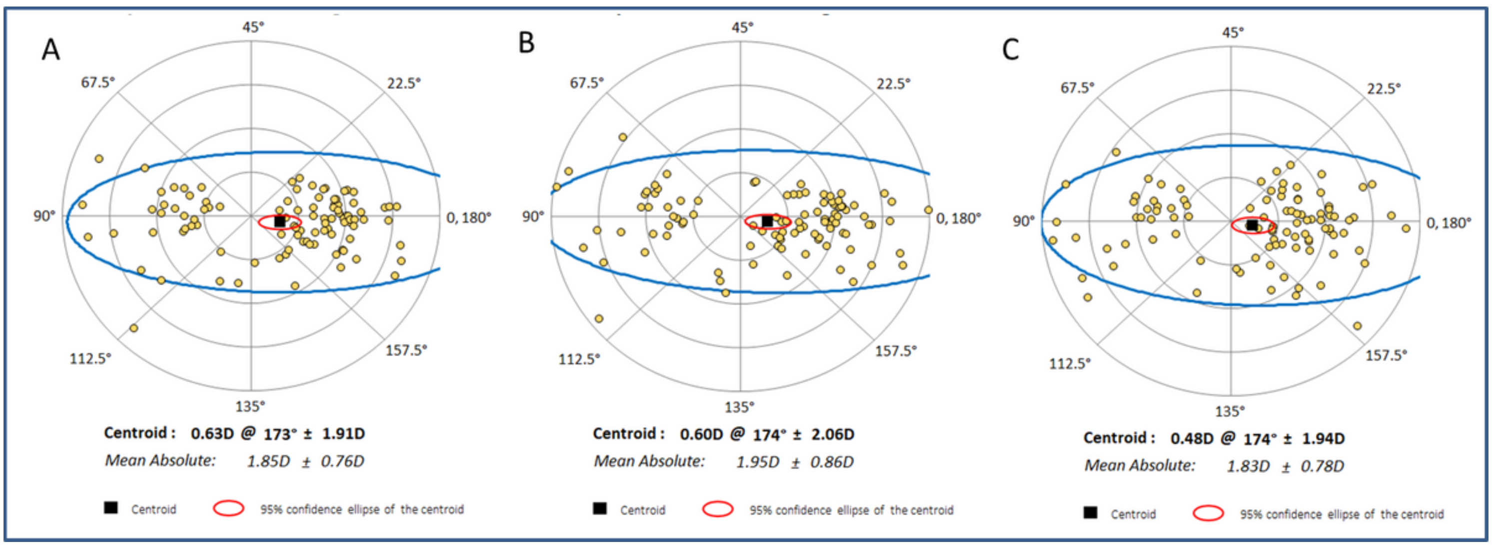

Figure 1

Double-angle plots of anterior corneal astigmatism differences among iTrace (panel A), IOLMaster 500 (Panel B), and Pentacam (Panel C) device. Note: centroid (solid square); 95% confidence of ellipse of the centroid (red color); 95% confidence ellipse of the dataset (blue color); each ring = 1.0 D.

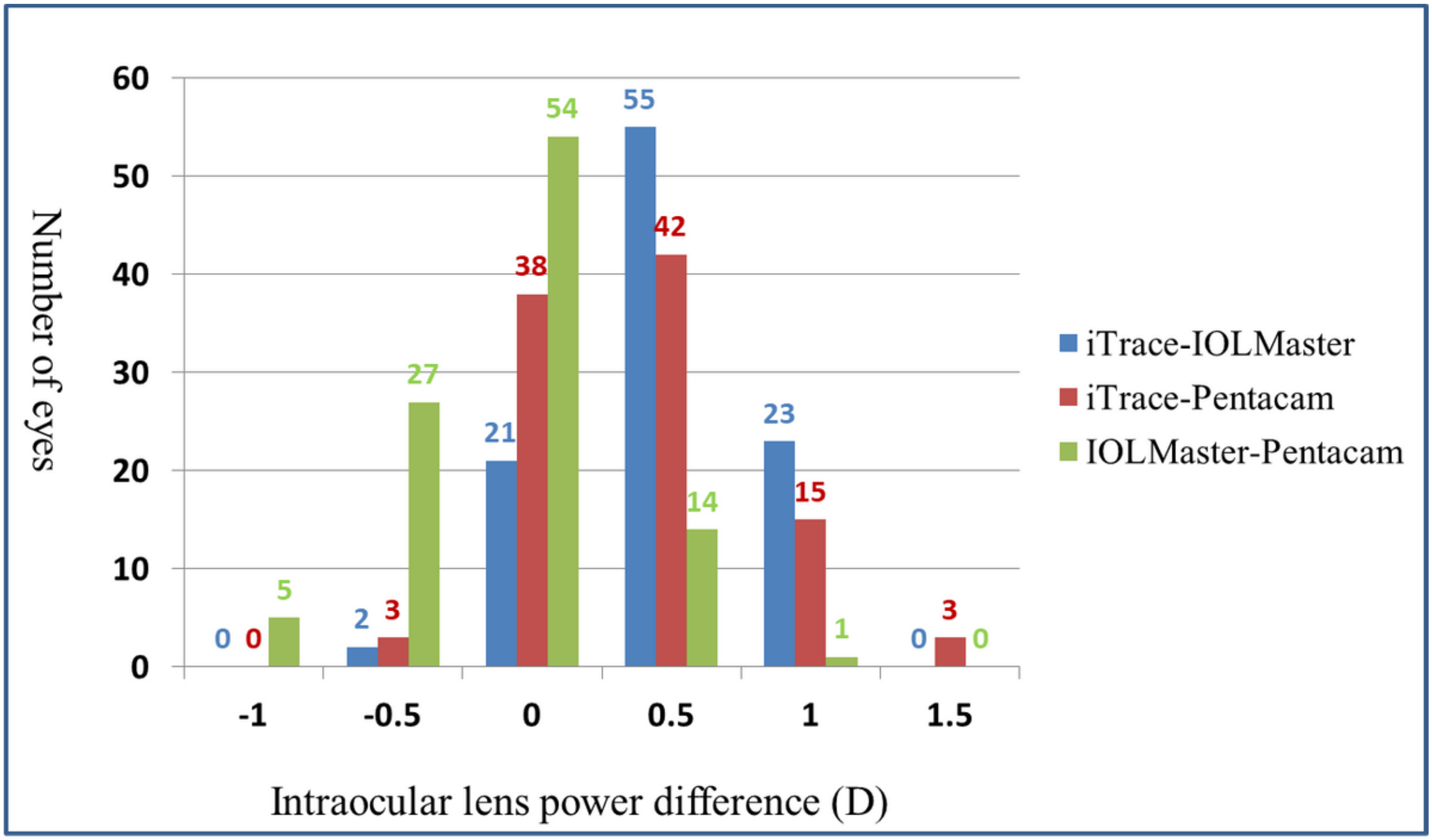

Figure 2

Case of participants whose intraocular lens power difference changed from -1.0 to 1.5 diopters, as calculated using iTrace, IOLMaster and Pentacam data.

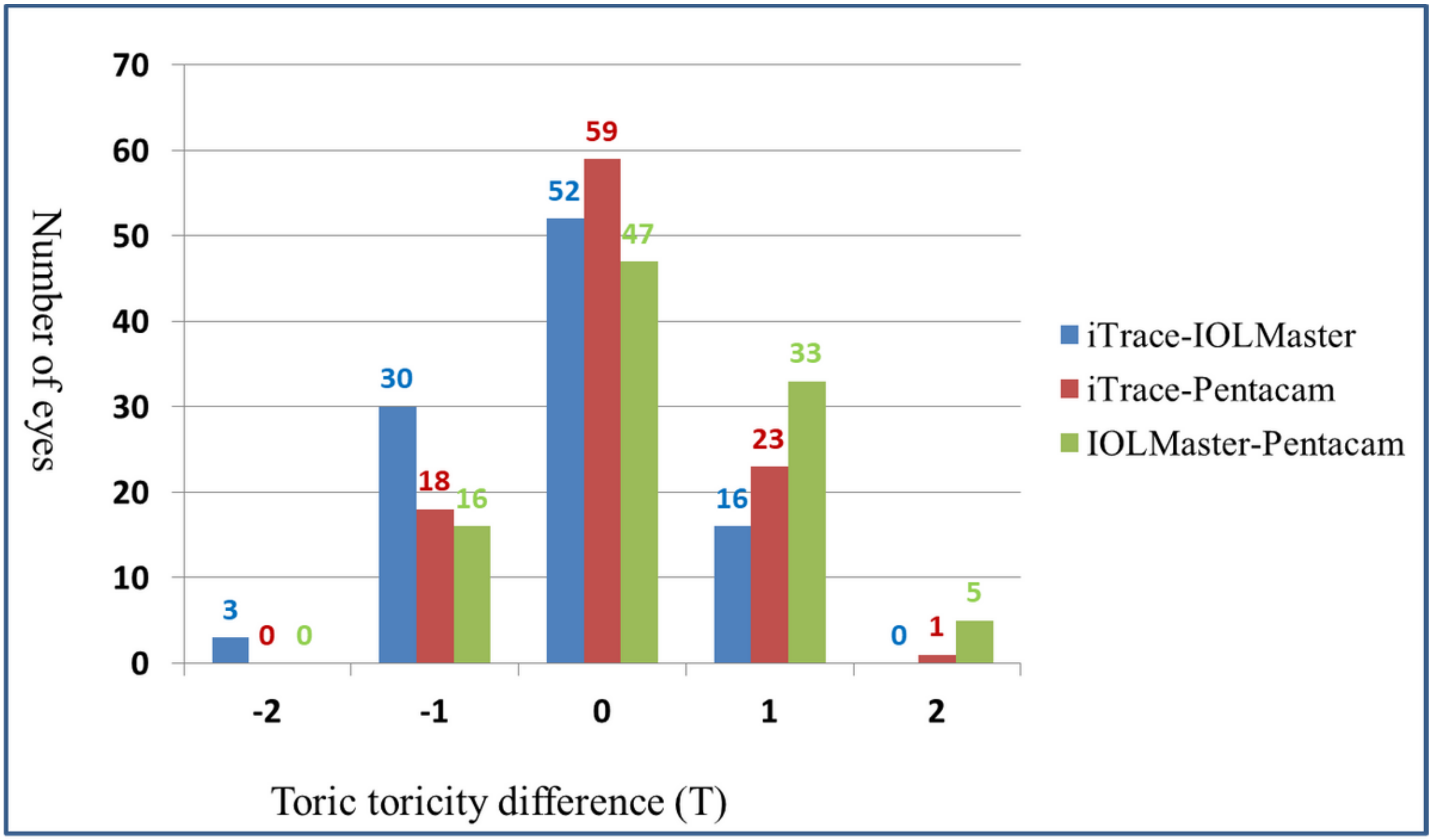

Figure 3

Case of participants whose toricity difference changed ≤ 2, as calculated using iTrace, IOLMaster and Pentacam astigmatism data.