Title

The combined effect of tropicamide and phenylephrine on corneal astigmatism axis

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Abstract

Purpose. To analyze astigmatism axis changes after tropicamide and phenylephrine combined instillation.

Method. One hundred and thirty-one eyes from sixty-six patients enrolled this cross-sectional study. An extensive ocular examination was carried out prior to tropicamide and phenylephrine instillation. Power and axis value from flat, steep, and mean keratometry were calculated using an Auto Kerato-Refractometer (AKR). Later, topography and tomography maps were evaluated with Pentacam HR® (Oculus, Wetzlar, Germany). Subsequently, a single drop of tropicamide 1% and phenylephrine hydrochloride 10% were instilled twice, with a five-minute gap between each instillation. After thirty minutes, the AKR and Pentacam HR® tests were repeated.

Results. Incyclotorsion was found in 59 eyes (45.1 %) and mean absolute incyclotorsion change was 3.91 ± 3.62 degrees (0.10 to 14.20). Excyclotorsion was found in 72 eyes (54.9%) and mean excyclotorsion change was 4.99 ± 5.94 degrees (0.20 to 36.20). We observed that 74.6% and 68.1% of eyes experienced incyclotorsion and excyclotorsion within 0 to 5 degrees, respectively. Fewer patients experienced incyclotorsion and excyclotorsion changes within 5 to 10 degrees, precisely 11.8% and 19.4%, respectively. Eyes that experienced over 10 degrees of incyclotorsion and excyclotorsion were 13.6% and 12.5%, respectively.

Conclusion. Astigmatism axis could change after combined tropicamide and phenylephrine instillation. Reference axis marking in astigmatism correction surgery should be performed under the same circumstances as the astigmatism axis has been measured.

Keywords; tropicamide; phenylephrine; astigmatism; axis

Introduction

Accommodation mechanism is a consequence of events including ciliary muscle contraction, reduction of zonular tension on lens equator, lens thickness increase and refractive power increase for near vision.[1] Changes in astigmatism during accommodation are controversial.[2–4] Pseudo-accommodation occurs in pseudo-phakic patients, suggesting that accommodation mechanism is complex and might involve corneal changes.[3] The eye may decrease the amount of astigmatism by selective sector contraction of the ciliary muscle during accommodation.[2] This phenomenon is called 'astigmatic accommodation'[2] and may cause eye convergence movements and misalignments between the eye and the measurement instrument. [5,6] Astigmatism changes during accommodation have been recently discussed. [2,4] Bagheri et al.[2] suggested that the eye could decrease the amount of astigmatism power by selective sector contraction of the ciliary muscle during accommodation. This group also evaluated astigmatism changes after cycloplegia with cyclopentolate by three different methods and found subtle changes in the power of astigmatism. Moreover, they observed that the axis changed more than 5° in 26.8% (5° ± 10.5°), being more than 50° in some patients. This group demonstrated that corneal astigmatism changed after cycloplegia regardless of lenticular astigmatism.

Tropicamide is characterized by a quick mydriatic and cycloplegic effect appearing 20-30 minutes after instillation and a recovery after six hours.[7] Phenylephrine hydrochloride is generally used to strengthen the mydriatic effect of other drugs such as tropicamide.[8] The possible effect of phenylephrine hydrochloride on accommodation has been widely researched and has frequently led to disagreements.[8,9] Approximately 30% of patients with cataracts have more than 1.00 diopter of corneal astigmatism.[10] In addition, a single degree of rotation of a toric intraocular lens (IOL) from the ideal axis causes an error of 3.3%. Therefore, a 5 degree rotation may cause an error of 15%, and a 30 degree rotation a 100% error.[10] Thus, an adequate alignment of the IOL in its implantation axis is essential to achieve the efficiency of astigmatic correction. The majority follow a three-step procedure. Initially, the horizontal corneal axis (0 to 180 degrees) is marked preoperatively with the patient sitting up to avoid cyclotorsion bias. Later, in the operation room, the target axis for the toric IOL is marked using an axis gauge. Lastly, the toric IOL is implanted and rotated in order to match the alignment marks.[11] Roughly, a 5 degree mean error has been described following this 3-step procedure.[11]

The purpose of this research is to analyze astigmatism axis changes after tropicamide and phenylephrine combined instillation. To the best of our knowledge, this is the first study to measure astigmatism power (true net power and

total corneal refractive power) and axis changes after pharmacological mydriasis combining tropicamide and phenylephrine.

Patients and Methods

Design

One hundred and thirty-one eyes from sixty-six patients enrolled this cross-sectional study. Patients were recruited between August 2019 and November 2019. The study was conducted in the following facilities: (1) Regional University Hospital of Malaga (Spain), (2) Ophthalmology Clinic Dr. Nebro (Malaga, Spain) and (3) Ocular Surgery Institute (San José, Costa Rica).

Ethical aspects

All patients included in this study were adequately informed verbally and in writing of the benefits, characteristics, and risks of the process. All patients signed an informed consent prior to the measurements. This study was conducted in accordance with the tenets of the Helsinki Declaration and the Institutional Review Board of Andalucía approved the research.

Subjects

Sixty-six patients (34 women and 32 men) were recruited and voluntarily approached the clinic to undergo the tests. Patient's average age was 49.24 ± 19.17 years (range between 18 and 79 years). The inclusion criteria consisted in the following: (1) age between 20 and 80 years, (2) astigmatism between 1.00 D and 4.00 D, (3) cataracts, refractive lens exchange or corneal refractive surgery candidates. The exclusion criteria were: (5) eye disorders, such as glaucoma, diabetic retinopathy or retinal diseases, (6) progressive corneal diseases, such as keratoconus or presumed keratoconus, and pellucid marginal degeneration, (7) pregnant or breastfeeding patients, (8) patients applying topical ocular drops different from artificial tears, (9) patients in treatment with antidepressants, antihistamines, phenothiazines or lithium, that may affect accommodation, (10) patients suffering from eye muscle diseases, such as strabismus or nystagmus, or any other disease that affected ocular fixation and (11) blind patients or with amblyopia in the other eye within a visual acuity ≤ 20/200.

Procedure

An exhaustive ocular examination was carried out by an expert ophthalmologist prior to tropicamide and phenylephrine dilation, including corrected and uncorrected in distance and near visual acuity, manifest refraction and astigmatism evaluated by the Jackson cross cylinder method and Auto Kerato-Refractometer (AKR) (Topcon KR8800 Topcon Inc., Tokyo, Japan). Flat, steep, and mean keratometry power and axis were obtained by AKR. Later, topography and tomography maps were measured using Pentacam HR® (Oculus, Wetzlar, Germany). Subjects were tested between 16:00 p.m. and 20:00 p.m. under mesopic illumination condition (between 0.01 to 3.00 cd/m^2). The following parameters were calculated using the Pentacam HR® device; (1) flat keratometry power and axis (SimK1); (2) steep keratometry power and axis (SimK2); (3) mean keratometry power and axis (SimKm); (4) power and axis from true net power (TNP), measured in the steep axis, including the anterior and posterior corneal faces, and finally, (5) total corneal refractive power (TCRP) which included anterior and posterior corneal faces, central corneal thickness and spherical aberration, calculated according to Snell's law. These values were obtained from the power distribution map in the central 4 millimeters and centered in corneal apex. In addition, retinal optical coherence tomography was carried out using spectral domain optical coherence tomography (SD-OCT) (Optovue Inc., Fremont, CA). Subsequently, a single drop of tropicamide 1% and phenylephrine hydrochloride 10% were instilled twice, with a five-minute gap between each instillation. After thirty minutes, the AKR and Pentacam HR® tests were repeated. The AKR value was obtained by an average of three measurements. Regarding Pentacam HR®, two measurements were carried out and the one with the best quality was considered. When both measurements were adequate, the first one was chosen by default.

Statistical analysis

Statistical analysis was carried out using SPSS statistics 26.0 (IBM Corporation, Armonk, NY, USA). Right and left eyes were analyzed in separated groups. The direction of axis change was considered as incyclotorsion for right eyes and excyclotorsion for left eyes if the difference between the post-dilated axis and the pre-dilated axis was negative. Thus, it was considered excyclotorsion for right eyes and incyclotorsion for left eyes if the difference between post-dilated within pre-dilated was positive. Vector analysis in both numerical and graphical reports were implemented by the Alpins Method[12], created by The ASSORT® Group Analysis Calculator. The axis change was presented with the double angle graph method defined by Mermelstein-Flikier. T-test and paired t-test were performed for parametric dependent variables. Agreement significance study was determined between flat and

steep AKR measurement, and SimK Pentacam HR® measurements with Spearmen coefficient and Bland Altman plot[13]. A *p* value of less than 0.05 was considered statistically significant.

Results

Data was divided into incyclotorsion and excyclotorsion and by right and left eye changes. Table 1 showed diopter and axis changes before and after tropicamide and phenylephrine dilation measured by AKR. Keratometry diopters changes were statistically non-significant. Incyclotorsion changes were statistically significant in the right and left eyes meridians (P = 0.003 and 0.0001, respectively). Mean right and left incyclotorsion axis changes were 6.81 ± 10.99 and 4.32 ± 4.79 degrees, respectively. Excyclotorsion axis changes were also statistically significant in right and left eyes axis (P = 0.0001 and 0.001, respectively). Mean right and left excyclotorsion axis changes were 4.77 ± 4.65 and 12.38 ± 17.84 degrees, respectively. Considering both eyes, incyclotorsion and excyclotorsion groups, 9 eyes were extreme values and had a cyclotorsion greater than 20º.

Regarding keratometry, Table 1 also shows diopter and axis changes before and after tropicamide and phenylephrine dilation measured with Pentacam HR® using SimK. Keratometry diopter changes were statistically non-significant. Incyclotorsion axis changes were statistically significant in the right and left eye meridians (P = 0.0001, both). Mean right and left eyes incyclotorsion changes were 3.05 ± 2.97 and 4.46 ± 3.92 degrees, respectively. Excyclotorsion axis changes were also statistically significant in right and left eyes meridians (P = 0.0001, both). Mean right and left eyes excyclotorsion changes were 4.63 ± 5.27 and 5.51 ± 6.89 degrees, respectively. Considering both eyes, incyclotorsion and excyclotorsion groups, 2 eyes were extreme values and had a cyclotorsion greater than 20º. Incyclotorsion was found in 59 eyes (45.1 %) and mean absolute incyclotorsion change was 3.91 ± 3.62 degrees (0.10 to 14.20). Excyclotorsion was found in 72 eyes (54.9%) and mean excyclotorsion change was 4.99 ± 5.94 degrees (0.20 to 36.20). We observed that 74.6% and 68.1% of eyes experienced incyclotorsion and excyclotorsion within 0 to 5 degrees, respectively. Fewer patients experienced incyclotorsion and excyclotorsion changes within 5 to 10 degrees, precisely 11.8% and 19.4%, respectively. Eyes that experienced over 10 degrees of incyclotorsion and excyclotorsion were 13.6% and 12.5%, respectively. Mean Central corneal thickness achieved statistically significant differences between before dilation 534.47 ± 37.08 µm (480.00 to 644.00 µm) and after dilation (539.06 ± 37.46 µm), P = 0.0001. AKR and Pentacam double angle standard graphs for corneal analysis astigmatism, based on the Alpins Method,[12] were represented in Figure 1 and Figure 2, respectively. Correlation study between AKR and SimK-Pentacam measurements showed that previous

flat and steep keratometry achieved significant correlation of r = 0.217 (P = 0.03) and r = 0.436 (P = 0.001), respectively. In addition, post dilation flat and steep keratometry also showed significant relation among AKR and SimK with r = 0.296 (P = 0.003) and r = 0.389 (P = 0.0001), respectively. Similarly, Bland and Altman plot were presented in Figure 3 which also showed a good agreement between measurements. TNP and TCRP Pentacam HR® measurements were very similar and were represented in Table 1.

Discussion

Our results show a significant change in astigmatism axis after mydriasis using a combination of tropicamide and phenylephrine. We observed statistically significant changes in astigmatism axis according to right and left eyes incyclotorsion and right and left eyes excyclotorsion measurements. According to Helmholtz ,[14] accommodation by contraction of the ciliary muscle increases lens thickness and curvature leading to an increase in optical power.[14] However, corneal changes caused by accommodation are controversial.[2,4,15] Bagheri et al[2] suggested that the eye can decrease the amount of astigmatism by selective sectorial contraction of the ciliary muscle during accommodation. Ciliary muscle is anatomically near the limbus, suggesting that its contraction mostly affects the corneal periphery. [3,15] Alternatively, central corneal area may be flattened by an increase in intraocular pressure as a result of forward movement of the lens. [16] Some studies showed that mydriatic agents can change the central corneal thickness [17,18] , and our results agree with them since we achieved an increase of central corneal thickness of 4.58 ± 5.49 µm.

Other studies imply that corneal variations during accommodation are due to cyclotorsion caused by focus changes while undergoing corneal topography.[19,20] When rotation is corrected, corneal changes reduce and are statistically non-significant during accommodation.[15,19,20] On the other hand, Bayramlar et al[21] observed no corneal variations or corneal cyclotorsion during accommodation. He et al[16] observed an increase in mean corneal radius at the vertex and in the shape parameter when fixation was changed from far to near viewing condition. These changes were minor although statistically significant. We can only speculate the reason.
On one hand the origin of the cyclotorsion could be an accommodative factor, as the AKR target was an accommodative one, while the Pentacam target was a non-accommodative light. Therefore, accommodation could influence cyclotorsion. Buehren et al.[20] and Read et al. [19] reported a significant difference after an accommodation period in the astigmatism axis and cyclotorsion. Since tropicamide does not achieve a complete cycloplegia it might not cause a complete accommodation blockade. Therefore, this possible residual accommodative status could be one of the causes of the difference between the mentioned instruments.[7]
On the other hand, another plausible reason could be that both technologies use different ways to measure the keratometry. The Pentacam is a Scheimpflug camera that considers the two major meridians perpendicular to each other on the central 3.0 mm corneal ring. SimK1 and and SimK 2 represent the simulated keratometric reading in the flat and steep meridians.[22] The Topcon KR 8800 auto-kerato-refractometer measures curvature in the central 3.0 mm of the cornea. It determines the radius of curvature of the anterior cornea based on the reflection of infrared beams and changes in the divergent rays and can measure curvature radius in the five to 10 mm range.

Tropicamide is a short-acting cycloplegic drug that relaxes the ciliary muscle and blocks accommodation.[23] Chen at al. reported that corneal curvature flattened between 0.026 and 0.039 D after cycloplegia with tropicamide. However, corneal astigmatism suffered no significant variations. These results are in line with our outcomes. Many surgeons select combinations of tropicamide and phenylephrine for maximum mydriatic effect for cataract surgery. The effect of phenylephrine hydrochloride on accommodation is yet controversial after being widely researched.[8,9] Several studies concluded that there is a slight loss of accommodation after phenylephrine hydrochloride,[8,24,25] even if the reduction in accommodation is limited and does not have great clinical importance.[8] Saitoh et al[26] found that both the anterior and posterior corneal shape changed after mydriasis (using a combination of tropicamide and phenylephrine) increasing the value of the best fit sphere (BFS), resulting in pharmacological corneal flattening. In accordance, our results showed statistically non-significant changes in astigmatism power after mydriasis.

Similar to our findings, Millodot et al.[27] reported changes in astigmatism axis over 5 degrees after mydriasis with dark focus in several directions in half of their cases. Lee et al[28] reported that measurements of AKR, iTrace wavefront aberrometry, Orbscan topography and Pentacam HR® (Oculus, Wetzlar, Germany) were comparable and therefore could be used interchangeably.[28] A single degree error in the toric IOL placement can induce a 3% loss of visual acuity.[10] A 10 degree variation may cause a loss of one third of astigmatism, reducing the IOL power.[10] Misplacement of the toric IOL greater than 30 degrees induces additional astigmatism, which causes patients to experience symptoms such as blurred vision, headache and fatigue. We found a greater than 10-degree misalignment in approximately 10% of eyes. Preoperative initial corneal marking procedure is an important step for the alignment of toric IOL and corneal refractive surgery, and errors in this procedure are a cause of misplacement of the toric IOL.

Similar to the preoperative protocol of astigmatism axis marking of the horizontal meridian (0º-180º) while the patient is in upright sitting position and looking straight,[11] according to our findings, we suggest that we should include the pupillary condition in this protocol. This is, if we have calculated the power and axis of a toric IOL or a corneal astigmatism refractive correction under miosis, we should proceed with the preoperative corneal axis marking under miosis. Should we mark the axis under mydriasis, we could risk an incorrect axis marking. Similarly, if we calculate the prior measurements under mydriasis, the corneal axis marking should be performed under the same condition. Therefore, although we found that the change in the axis is relatively low, we should

not ignore the rare finding of patients with a change greater than 10º, as these cases may present in our daily practice affecting the postoperative refraction of the patient if the post mydriatic astigmatism axis change is not considered. We hypothesize that this change in astigmatism axis observed in the SimK, TNP and TCRP values under mydriasis using the combination of tropicamide and phenylephrine may be due to cyclotorsion and could be one of the causes of unexpected refractive residual defects, often incomprehensible, that we seldom experience in clinical practice. We propose that this challenge could be explained by not assessing axis change after pharmacologic mydriasis, like the error that we could experience if we would not consider cyclotorsion that occurs while lying down. This error would add to the average 5º error observed by Visser et al.[11] in the widely used 3-step ink-marker procedure.

The main limitation of the study is that retrospective data was used for analysis. Multiple examiners were involved in examining the patients in this study, so the lack of a standardized examination can cause some bias. In addition, pupil size diameter was not measured in this study. However, all patients were visually verified for pharmacological mydriasis after drug administration. Furthermore, the change in the astigmatism axis due to a cyclotorsion is a derived theory from different research [2,4,15] [27] that should be detailed in future studies. Unfortunately, we did not have the iris image map with the blood vessels in our Pentacam's version. Currently, it is possible in Pentacam AXL or Pentacam Wave. Therefore, we cannot confirm that the origin of this change is due to another cause such as the pachymetry change. However, the change in the axis and not in the magnitude is what guides us in this hypothesis. Another limitation is that we did not measure the repeatability neither reproducibility of the measurements, although we have observed that there was an agreement on these measurements using ARK and Pentacam. To the best of our knowledge, the sample size is one of the largest to date. Further longer follow-up is needed to evaluate incyclotorsion and excyclotorsion astigmatism axis changes. Also, it would be interesting to study the effect of other pharmacological mydriatics and their combinations.

In conclusion, astigmatism axis could change after mydriasis with the combination of tropicamide and phenylephrine. We suggest that eye marking prior to a toric IOL implantation or astigmatism corneal refractive surgery should be done under the same conditions in which astigmatism has been assessed.

Declarations

Conflicts of interest: All authors declare no competing interest.

Source of Funding: No funding support

Ethics approval: This study was conducted in accordance with the tenets of the Helsinki Declaration and obtained Institutional Review Board approval.

Consent to participate: All patients included in this work were adequately informed verbally and in writing of the benefits, characteristics, and risks of the surgeries. All patients signed an informed consent prior to the surgery and after the interview performed with the ophthalmologist.

Consent for publication: All authors consent publication of this article

Availability of data and material: Data available on demand

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Figure Legends

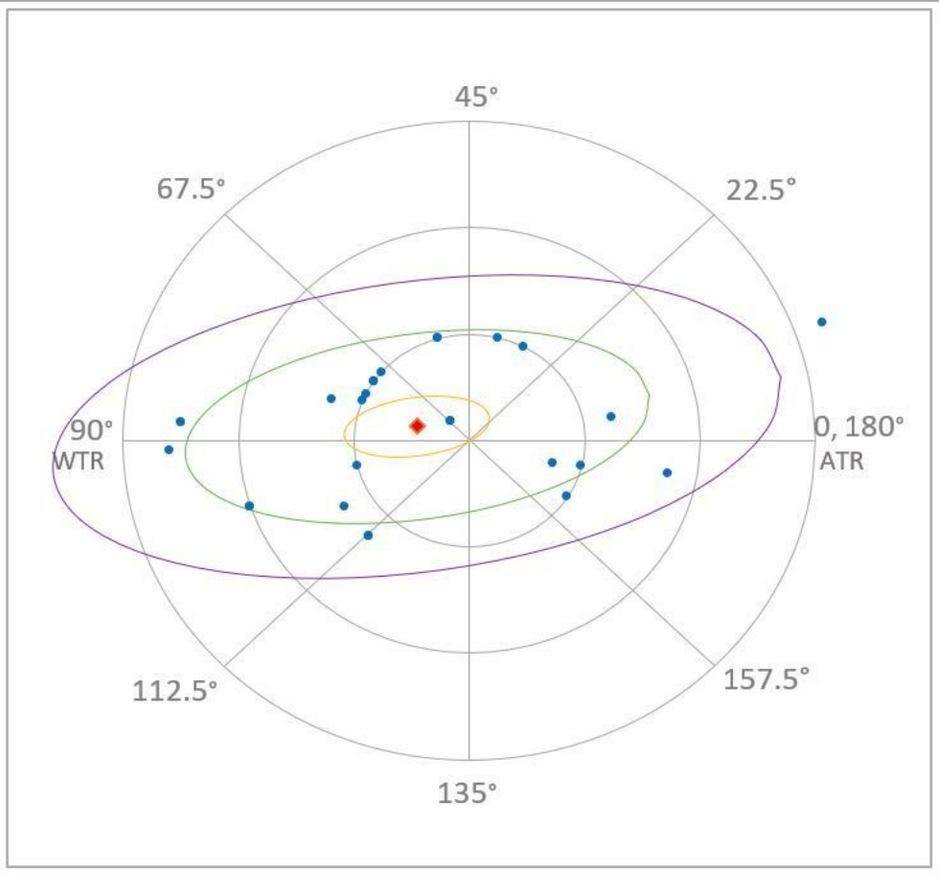
Figure 1 – Double angle diagram for Autorefractokeratomer represented by Mermelstein-Flikier plot. First row; left figure: previous dilation incyclotorsion right eye and right figure: posterior dilation incyclotorsion right eye. Second row; left figure: previous dilation excyclotorsion left eye and right figure: posterior dilation excyclotorsion left eye. Third row; left figure: previous dilation excyclotorsion right eye and right figure: posterior dilation excyclotorsion right eye. Fourth row; left figure: previous dilation incyclotorsion left eye and right figure: posterior dilation incyclotorsion left eye.

Figure 2 – Double angle diagram for Pentacam represented by Mermelstein-Flikier plot. First row; left figure: previous dilation incyclotorsion right eye and right figure: posterior dilation incyclotorsion right eye. Second row; left figure: previous dilation excyclotorsion left eye and right figure: posterior dilation excyclotorsion left eye. Third row; left figure: previous dilation excyclotorsion right eye and right figure: posterior dilation excyclotorsion right eye. Fourth row; left figure: previous dilation incyclotorsion left eye and right figure: posterior dilation incyclotorsion left eye.

Figure 3. Bland and Altman plot for differences and mean between auto-refractokeratometer and Pentacam. A – Previous flat meridian. B – Previous steep meridian. C – Posterior flat meridian. D – Posterior steep meridian.

Table 1. Cyclotorsion mean changes between right and left eyes

30Cyclotorsion RE: Right eye LE: Left eye	Mean Power Differences ± SD (Dioptres)	P value	Mean Cyclotorsion ± SD (Degrees)	P value	Cyclotorsion Magnitude (Degrees)	Cyclotorsion ≥ 2º (%)	Cyclotorsion ≥ 5º (%)	Cyclotorsion ≥ 10º (%)
Auto Keratometer (No cyclotorsion in 13 eyes, 9.9%)								
Incyclotorsion RE (n=27, 20.6%) LE (n=25, 19.0%)	 0.32 ± 1.00 0.27 ± 0.72	 0.10 0.06	 6.81 ± 10.99 4.32 ± 4.79	 0.003 0.0001	 2.46 to 11.16 2.34 to 6.28	 70.4 40.0	 44.5 32.0	 18.5 20.0
Excyclotorsion RE (n=35, 26.7%) LE (n=31, 23.6%)	 0.06 ± 0.45 0.08 ± 0.57	 0.40 0.39	 4.77 ± 4.65 12.38 ±17.84	 0.0001 0.001	 3.17 to 6.37 5.84 to 18.93	 65.7 80.6	 56.0 45.1	 8.6 38.7
Pentacam (All eyes with cyclotorsion)								
Incyclotorsion RE (n=23, 17.5%) LE (n=36, 27.5%)	 0.02 ± 0.15 0.02 ± 0.14	 0.43 0.26	 3.05 ± 2.97 4.46 ± 3.92	 0.0001 0.0001	 1.76 to 4.33 3.13 to 5.78	 56.6 72.2	 17.3 30.6	 4.3 19.4
Excyclotorsion RE (n=43, 32.8%) LE (n=29, 22.1%)	 0.05 ± 0.17 0.00 ± 0.17	 0.05 0.91	 4.63 ± 5.27 5.51 ± 6.89	 0.0001 0.0001	 3.01 to 6.26 2.89 to 8.13	 69.8 76.1	 30.2 34.3	 9.3 17.2
Total Net Power (All eyes with cyclotorsion)								
Incyclotorsion RE (n=17, 12.9%) LE (n=34, 25.9%)	 0.00 ± 0.14 0.05 ± 0.15	 0.87 0.07	 2.97 ± 2.02 6.82 ± 5.36	 0.0001 0.0001	 1.93 to 4.01 4.94 to 8.69	 76.5 85.3	 11.8 52.9	 0.0 26.5
Excyclotorsion RE (n=49, 37.4%) LE (n=31, 23.6%)	 0.03 ± 0.14 0.00 ± 0.16	 0.15 0.91	 5.46 ± 5.80 6.90 ± 6.18	 0.0001 0.0001	 3.79 to 7.12 4.63 to 9.17	 65.3 74.2	 40.8 45.2	 16.3 32.3
Total Real Corneal Power (No cyclotorsion in 2 eyes, 1.5%)								
Incyclotorsion RE (n=17, 12.9%) LE (n=36, 27.5%)	 0.03 ± 0.20 0.03 ± 0.13	 0.49 0.48	 2.91 ± 1.91 6.29 ± 5.27	 0.0001 0.0001	 1.93 to 3.90 4.50 to 8.07	 76.5 80.6	 11.8 50.0	 0.0 25.0
Excyclotorsion RE (n=47, 35.8%) LE (n=29, 22.1%)	 0.02 ± 0.15 0.27 ± 0.99	 0.34 0.14	 7.12 ± 9.02 6.10 ± 5.76	 0.0001 0.0001	 4.47 to 9.77 3.91 to 8.29	 66.0 75.9	 42.6 41.4	 21.3 27.3



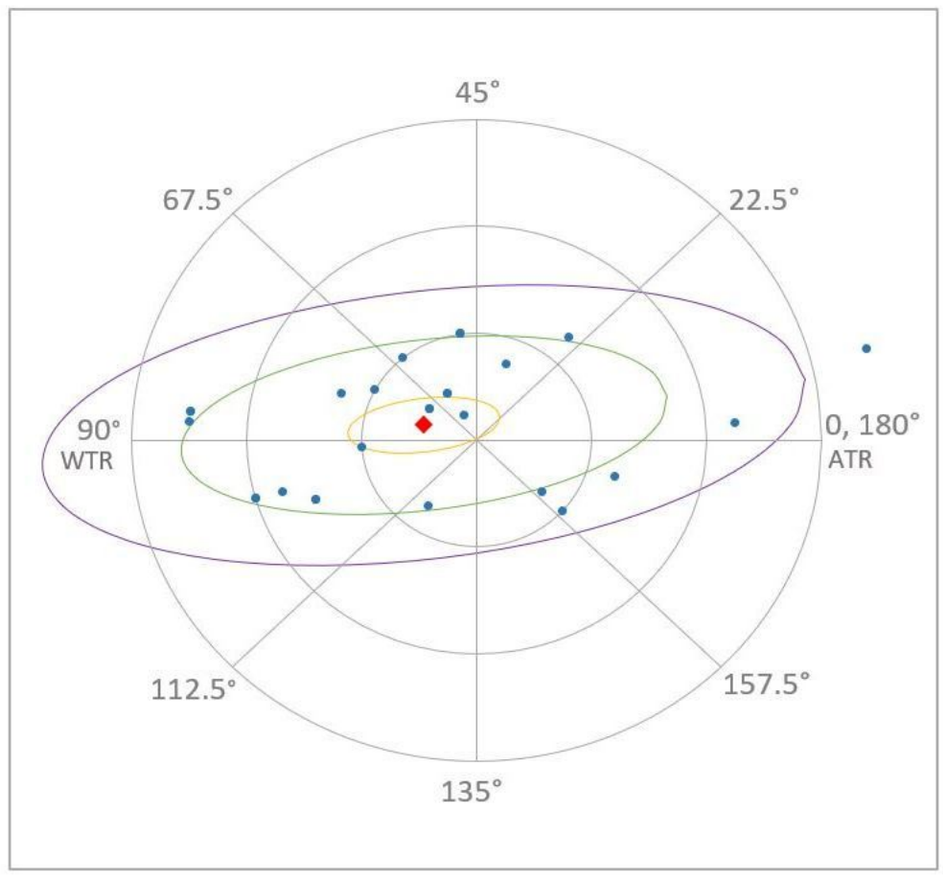
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 27

Centroid: 0,47 D @ 82° ± 1,46 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



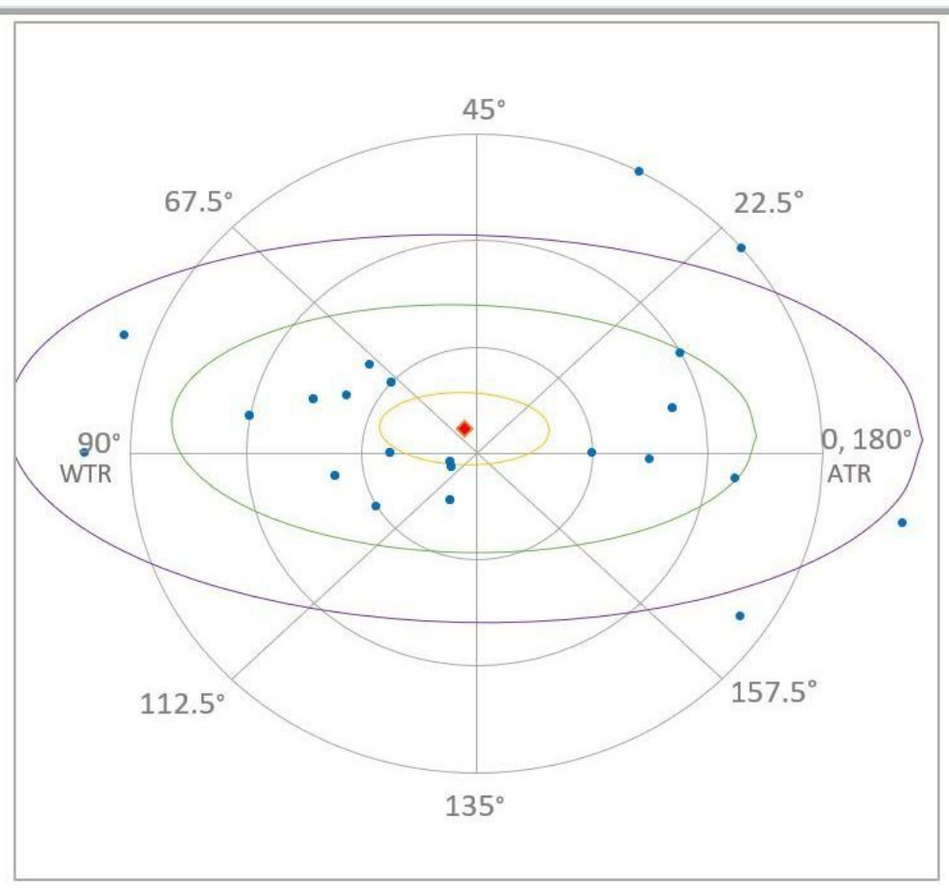
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 27

Centroid: 0,48 D @ 81° ± 1,50 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



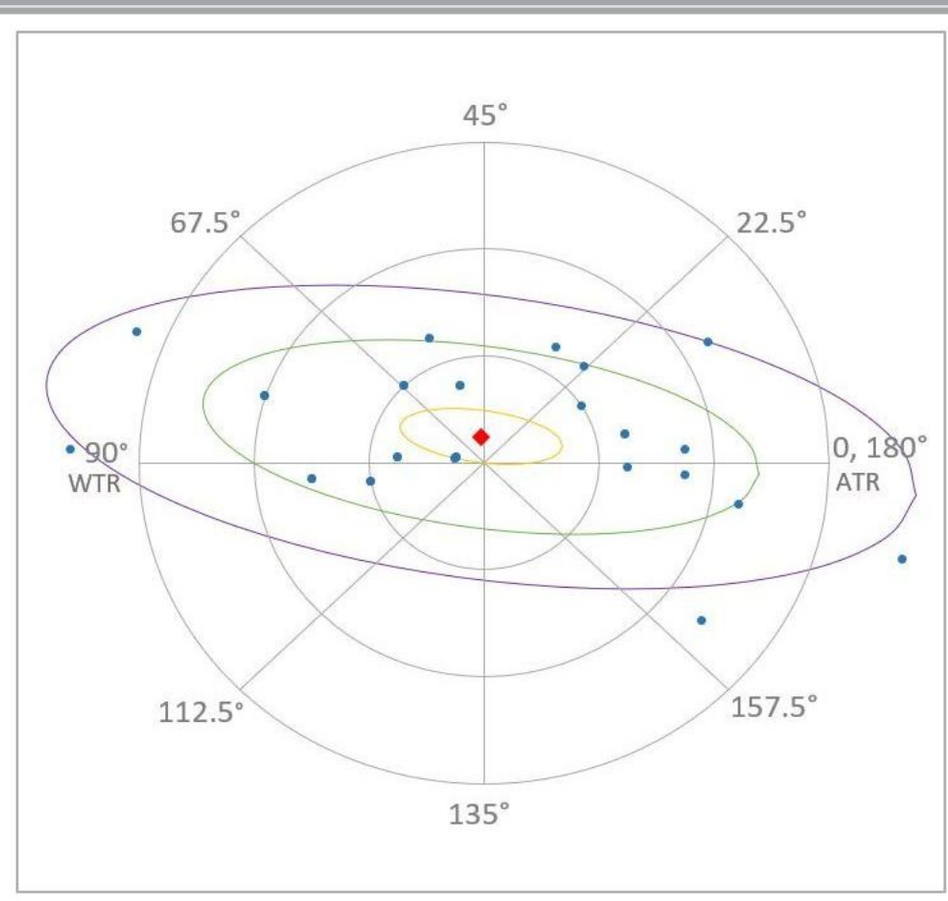
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 31

Centroid: 0,26 D @ 58° ± 1,84 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



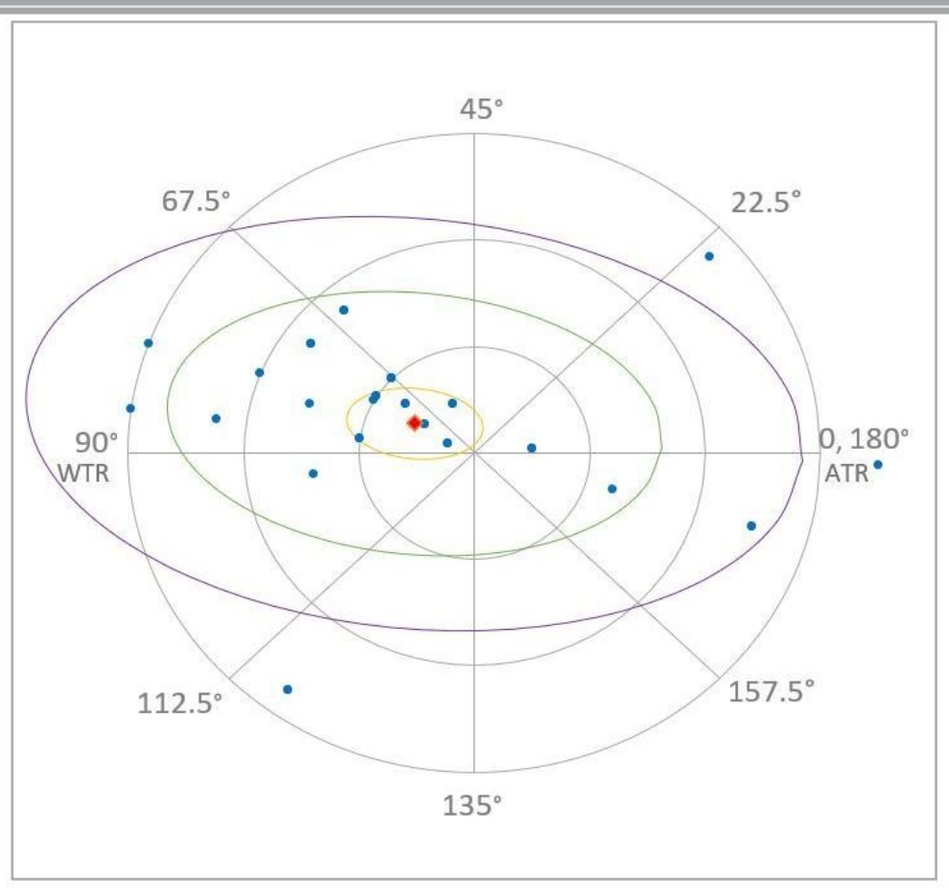
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 31

Centroid: 0,25 D @ 48° ± 1,70 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



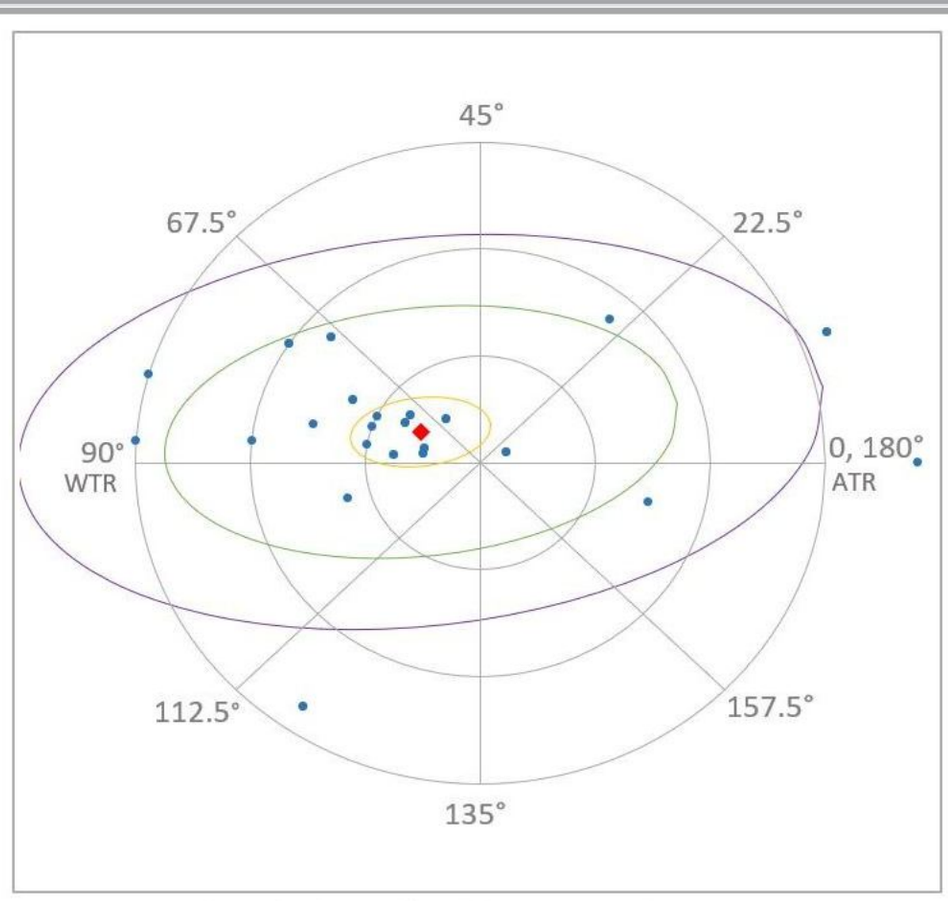
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 35

Centroid: 0,58 D @ 76° ± 1,64 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



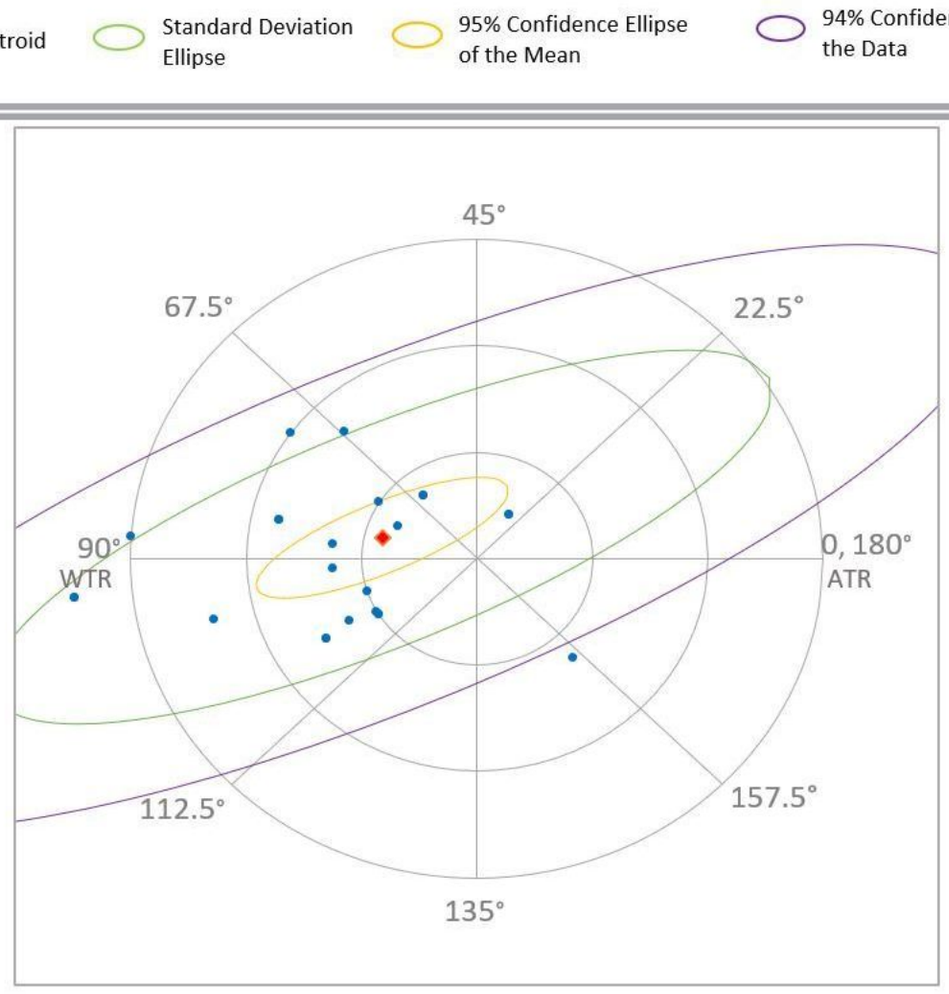
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 35

Centroid: 0,59 D @ 75° ± 1,67 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



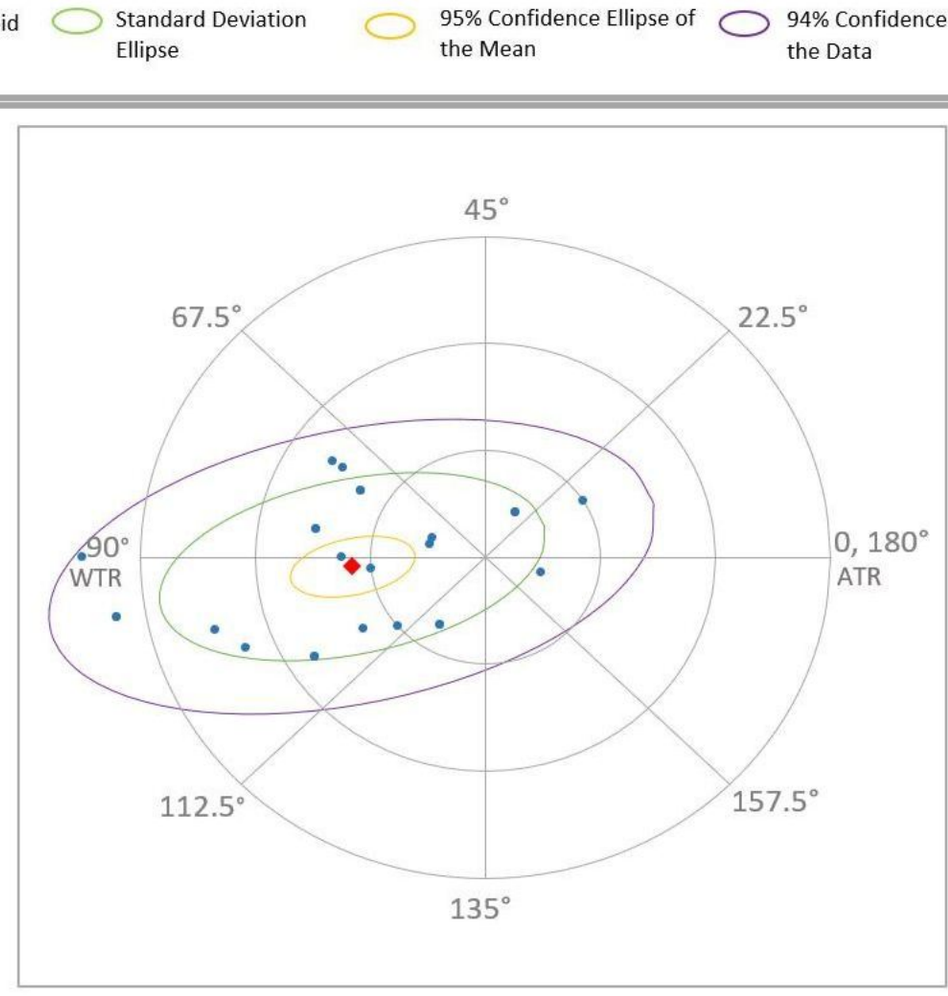
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 25

Centroid: 0,85 D @ 83° ± 2,52 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



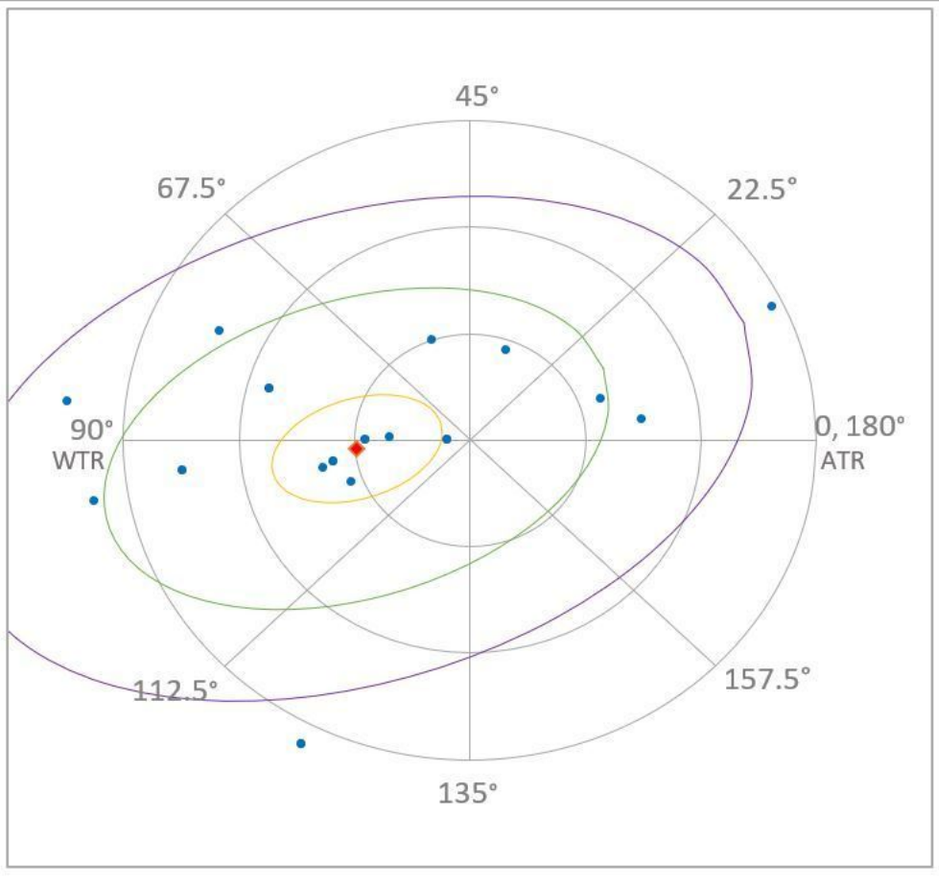
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 25

Centroid: 1,16 D @ 92° ± 1,25 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



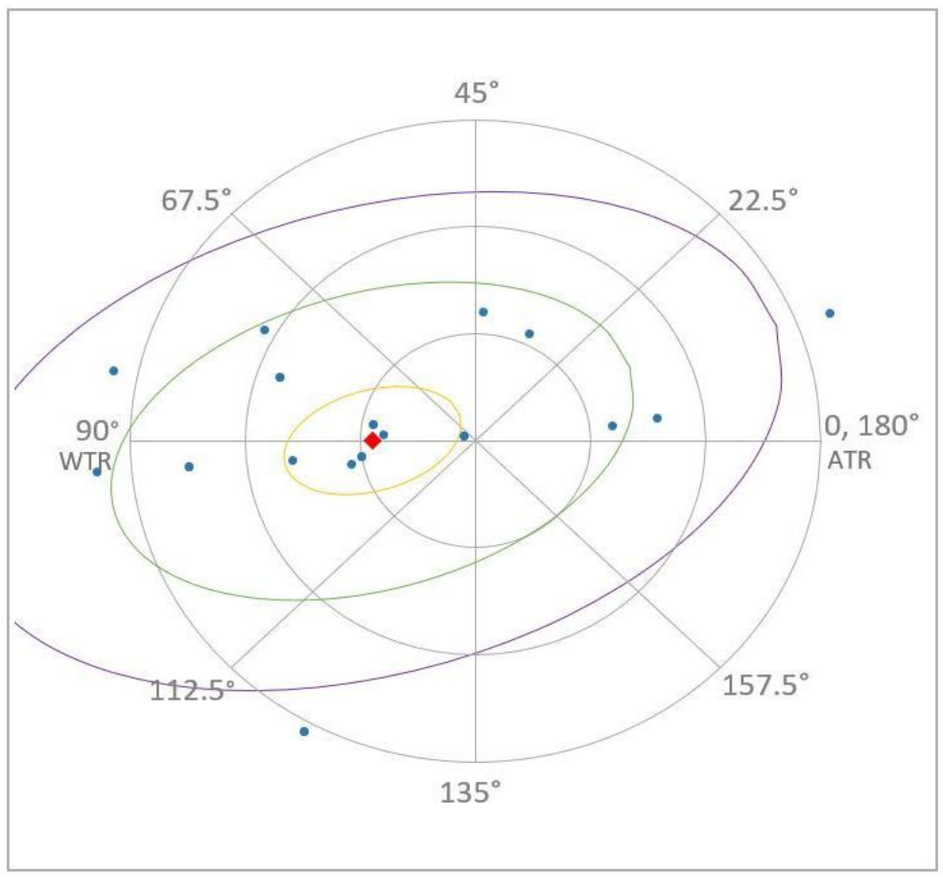
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 23

Centroid: 0,99 D @ 92° ± 1,76 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



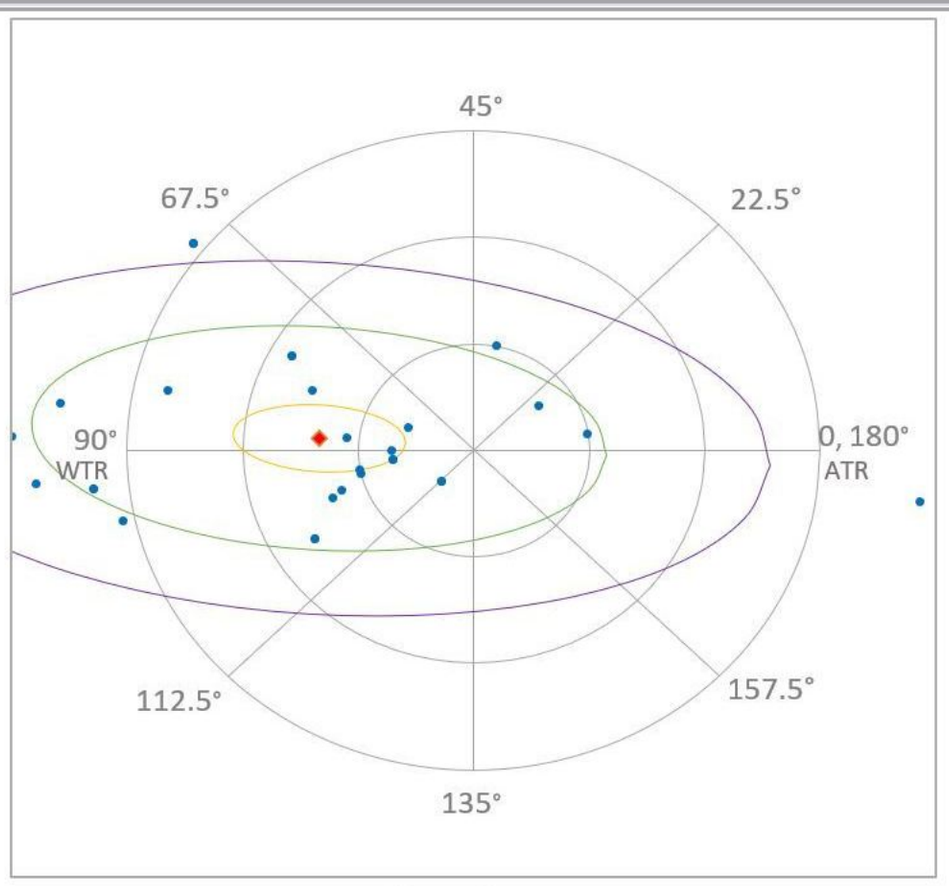
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 23

Centroid: 0,90 D @ 90° ± 1,80 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



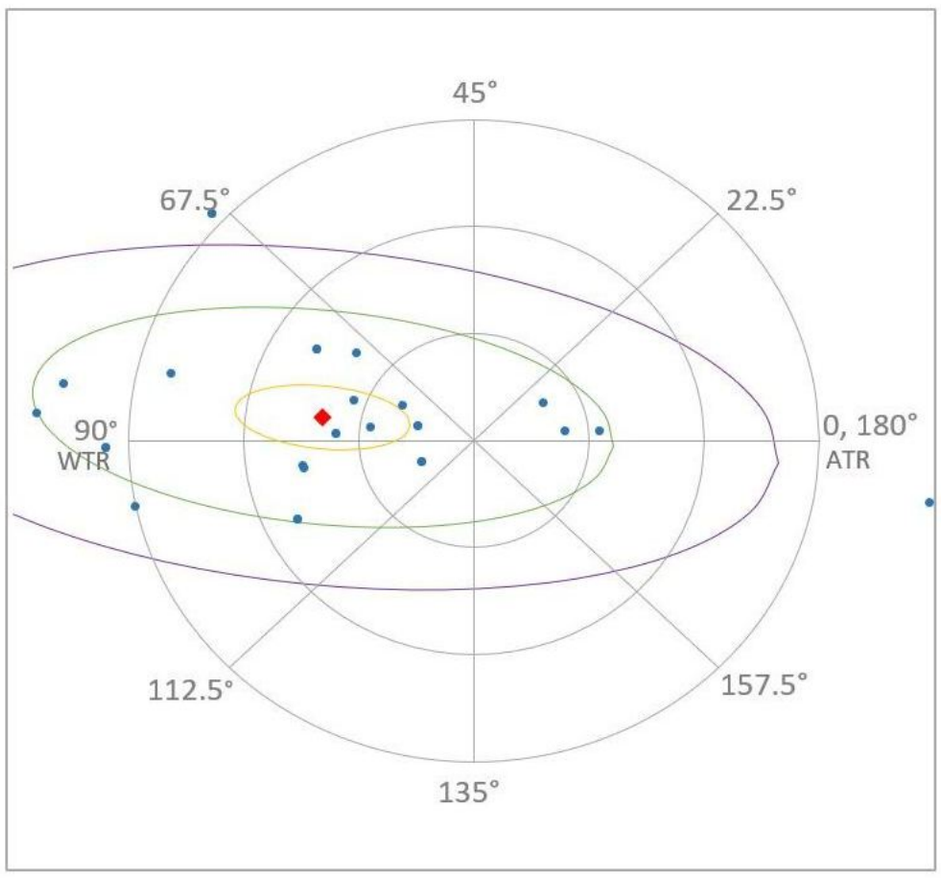
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 29

Centroid: 1,34 D @ 88° ± 1,79 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



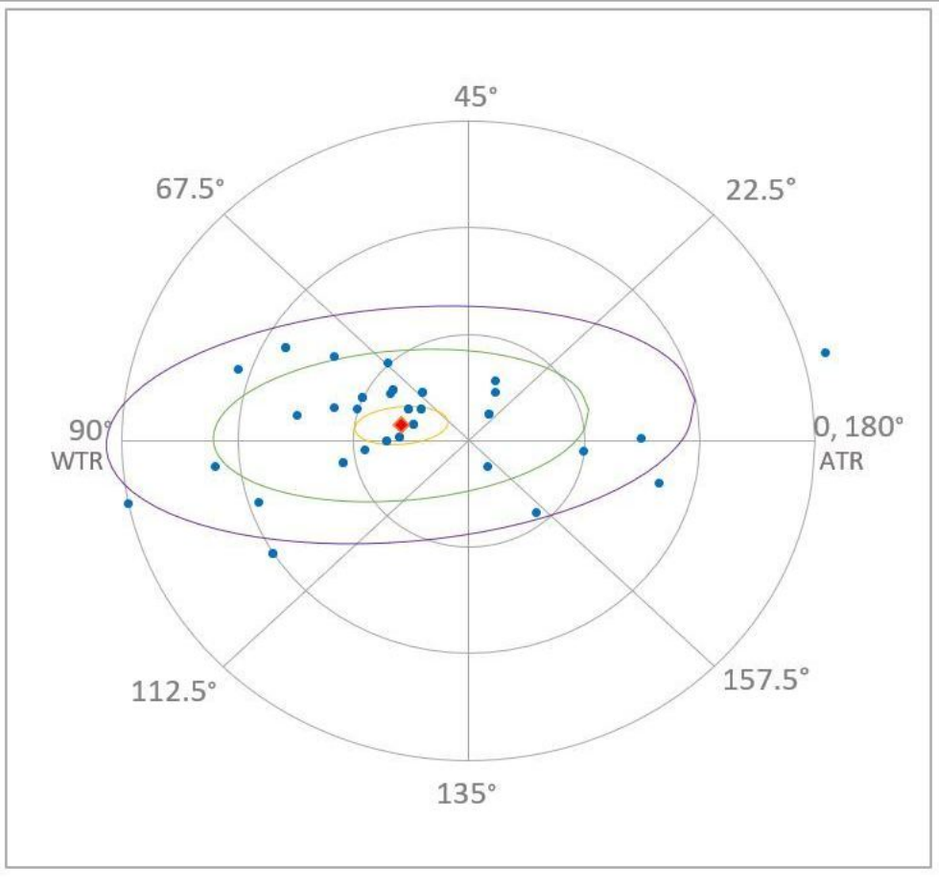
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 29

Centroid: 1,33 D @ 85° ± 1,80 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



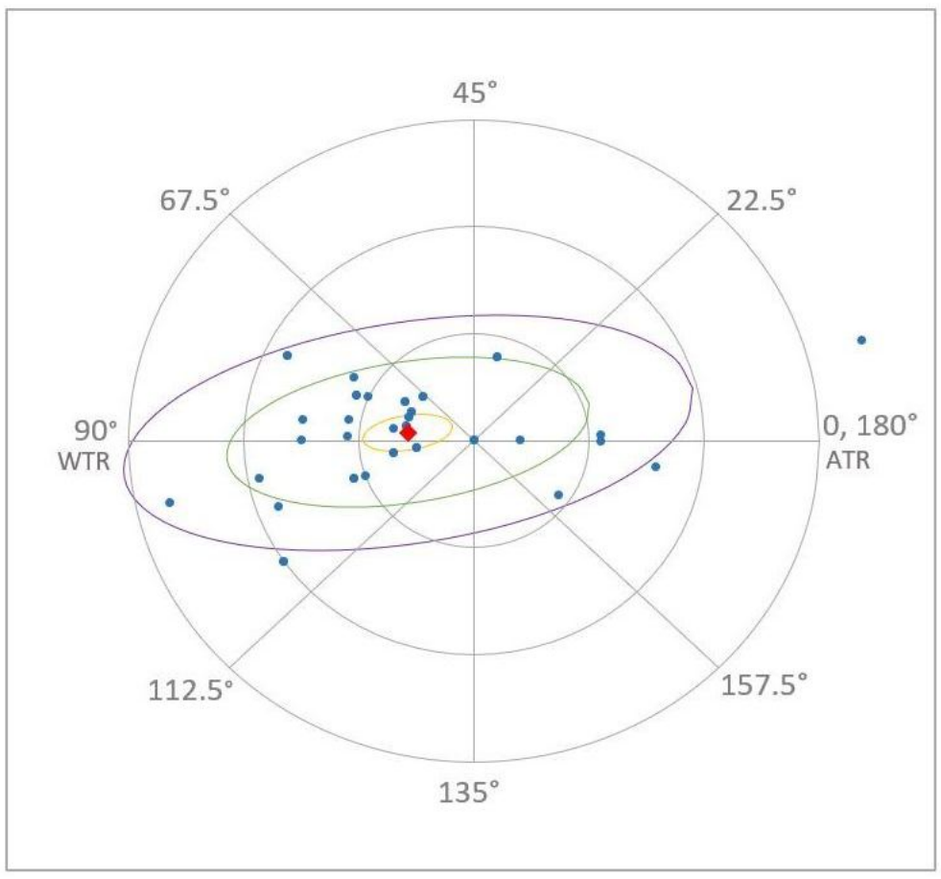
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 43

Centroid: 0,60 D @ 83° ± 1,17 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



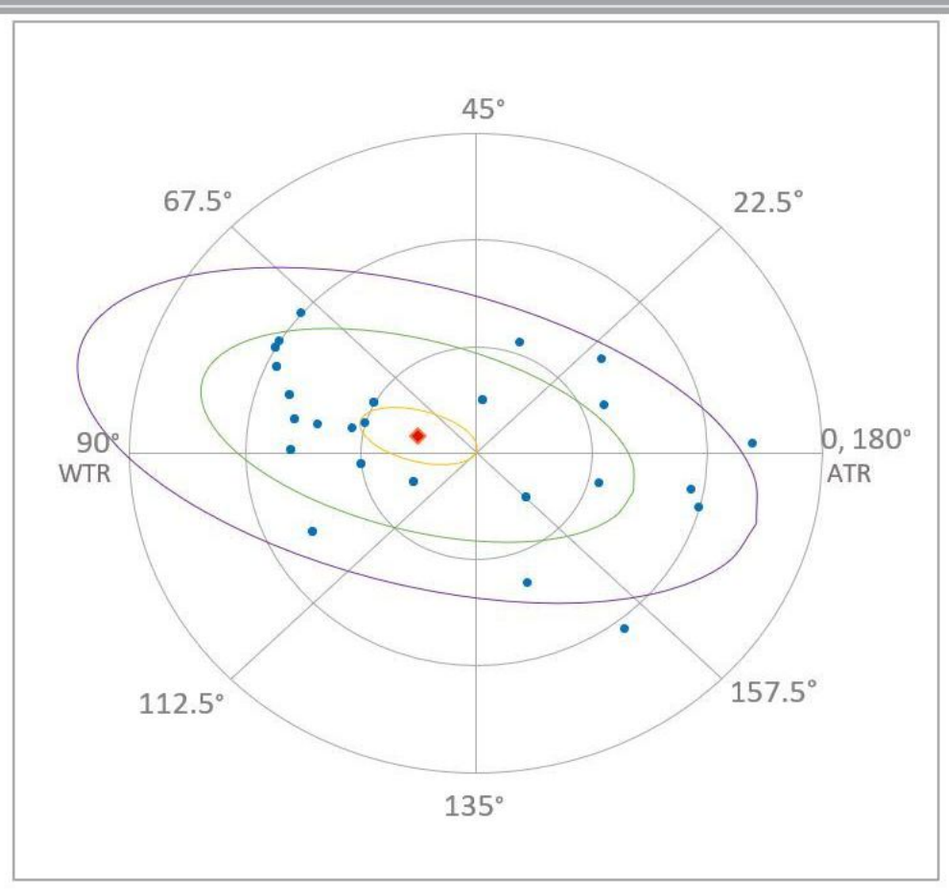
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 43

Centroid: 0,58 D @ 86° ± 1,14 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



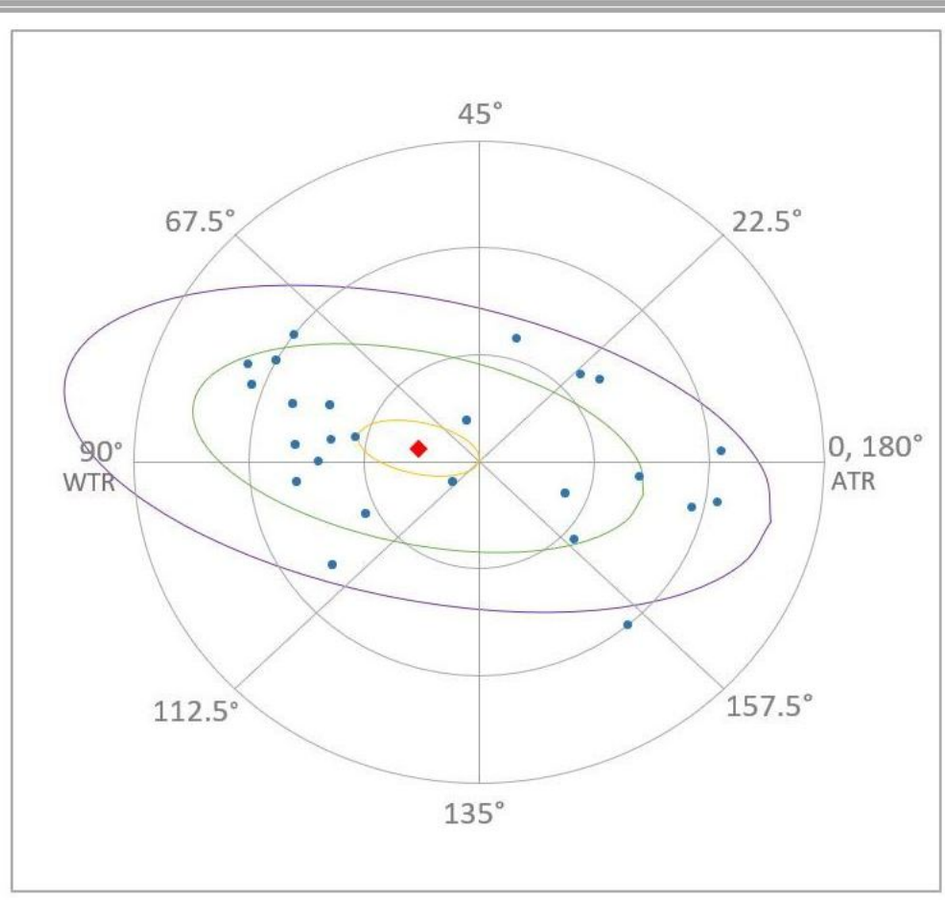
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 36

Centroid: 0,53 D @ 81° ± 1,41 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data



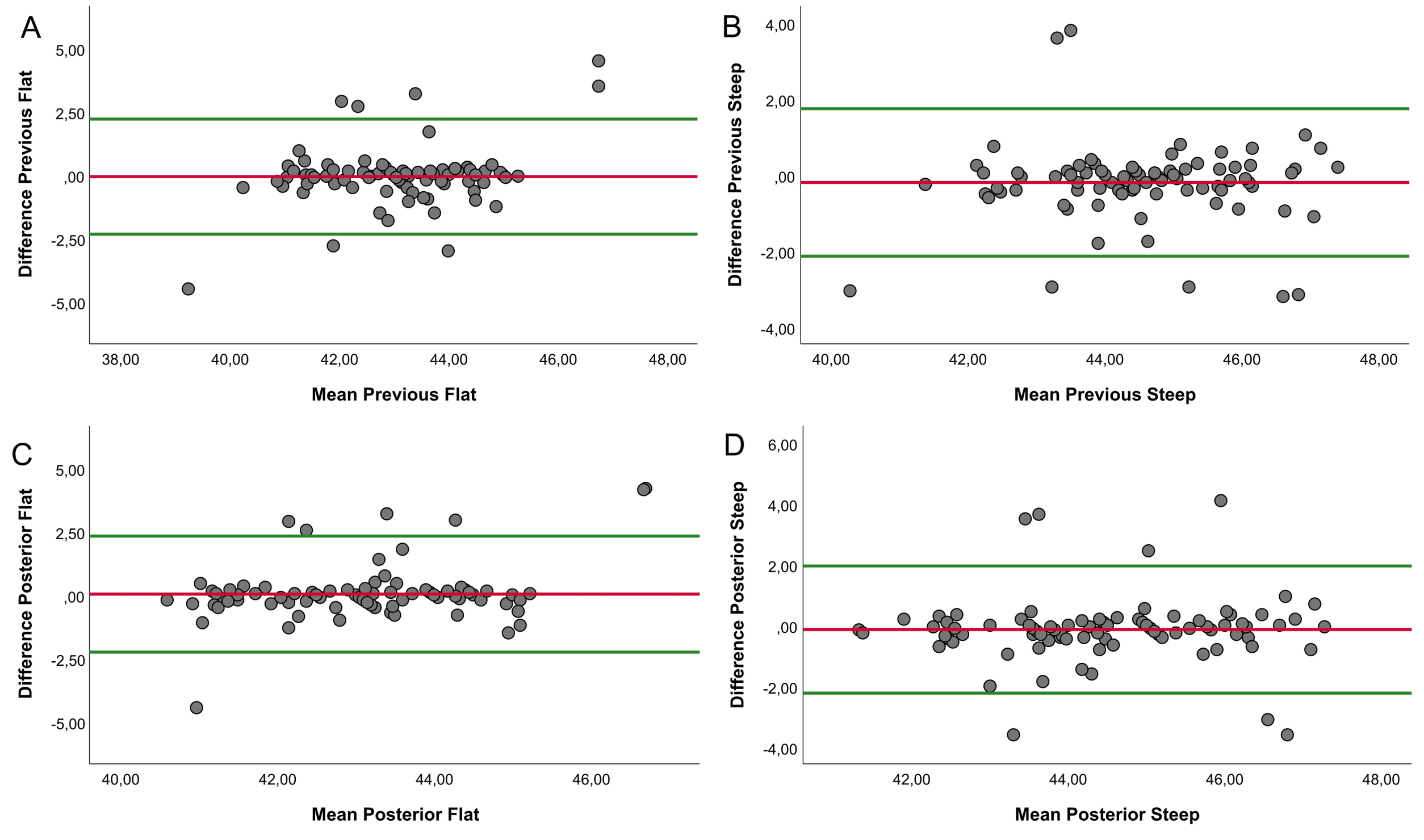
Mermelstein-Flikier Keratometry Plot Tool

Each Ring
1.00 D

Cases: 36

Centroid: 0,54 D @ 83° ± 1,45 D

Centroid | Standard Deviation Ellipse | 95% Confidence Ellipse of the Mean | 94% Confidence Ellipse of the Data


A
Difference Previous Flat
5,00
2,50
,00
-2,50
-5,00
38,00
40,00
42,00
44,00
46,00
48,00
Mean Previous Flat
B
Difference Previous Steep
4,00
2,00
,00
-2,00
-4,00
40,00
42,00
44,00
46,00
48,00
Mean Previous Steep
C
Difference Posterior Flat
5,00
2,50
,00
-2,50
-5,00
40,00
42,00
44,00
46,00
Mean Posterior Flat
D
Difference Posterior Steep
6,00
4,00
2,00
,00
-2,00
-4,00
42,00
44,00
46,00
48,00
Mean Posterior Steep