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Astigmatism prevalence and biometric analysis in normal population

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Abstract:	Introduction: Our aim was to analyze the magnitude, the orientation and the age-related changes of corneal astigmatism and its correlation with biometric parameters in healthy eyes. Patients and methods: Patients over 15 years were enrolled in our study. Exclusion criteria were previous ocular surgery, corneal disease or contact lens wearing. Axial length (AL), keratometric readings and anterior chamber depth (ACD) were assessed using IOLMaster. Results: In our study 1092 eyes were examined. The mean age was 69.64±15.25 years (range: 15-100 years). AL was 23.32±1.49 mm and ACD was 3.17±2.03 mm. Higher AL and ACD values were observed in male patients. The overall astigmatism was 0.89±0.72 D. The magnitude of astigmatism was ≥0.5 D in 73.53% of the cases, ≥1.0 D in 32.78%, ≥1.5 D in 13.55% and ≥2.0 D in 6.86%. In our population 582 eyes (53.3%) showed with-the-rule astigmatism, 309 (28.3%) against-the-rule, 201 (18.4%) oblique astigmatism regardless to gender. Significant against-the-rule astigmatic shift was verified with aging. Significant correlation was found between age and ACD (r=-0.39, p<0.001), age and AL (r=-0.15, p<0.001), AL and flat (r=-0.54, p<0.001) and steep keratometric readings (r=-0.49, p<0.001). Conclusions: In order to obtain adequate refraction results, at the time of the cataract surgery a distinct attention should be drawn to ophthalmological biometric parameters which are continuously changing even in adulthood and to astigmatism above 1.0 D present in >32% of the population.
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Shot title: Astigmatism prevalence in normal population

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Abstract

Introduction: Our aim was to analyze the magnitude, the orientation and the age-related changes of corneal astigmatism and its correlation with biometric parameters in healthy eyes.

Patients and methods: Patients over 15 years were enrolled in our study. Exclusion criteria were previous ocular surgery, corneal disease or contact lens wearing. Axial length (AL), keratometric readings and anterior chamber depth (ACD) were assessed using IOLMaster.

Results: In our study 1092 eyes were examined. The mean age was 69.64±15.25 years (range: 15-100 years). AL was 23.32±1.49 mm and ACD was 3.17±2.03 mm. Higher AL and ACD values were observed in male patients. The overall astigmatism was 0.89±0.72 D. The magnitude of astigmatism was ≥0.5 D in 73.53% of the cases, ≥1.0 D in 32.78%, ≥1.5 D in 13.55% and ≥2.0 D in 6.86%. In our population 582 eyes (53.3%) showed with-the-rule astigmatism, 309 (28.3%) against-the-rule, 201 (18.4%) oblique astigmatism regardless to gender. Significant against-the-rule astigmatic shift was verified with aging. Significant correlation was found between age and ACD (r=-0.39, p<0.001), age and AL (r=-0.15, p<0.001), AL and flat (r=-0.54, p<0.001) and steep keratometric readings (r=-0.49, p<0.001).

Conclusions: In order to obtain adequate refraction results, at the time of the cataract surgery a distinct attention should be drawn to ophthalmological biometric parameters which are continuously changing even in adulthood and to astigmatism above 1.0 D present in >32% of the population.

Keywords: astigmatism, with-the-rule, against-the-rule

Introduction

It is commonly known, that the magnitude and orientation of astigmatism are continuously changing from birth (1-3). Only a few studies comprising large cohort of patients have been published on adulthood related astigmatic changes (4-8). Corneal astigmatism plays an important role in impairing visual acuity both in phakic and pseudophakic (9,10) eyes. In the past few years, the reduction of astigmatism during cataract operations has been of greater importance, which has a significant role in patient satisfaction after surgery as well. Previous publications have also reported significant pre-existing astigmatism calling for correction (4-6,11) in a high percentage of patients waiting for surgery, so it is not at all surprising that such surgical techniques are being emphasized especially with the appearance of advancing sophisticated techniques.

Our goal was to examine the magnitude, the orientation, the age- and gender-related changes of corneal astigmatism and their correlations with biometric parameters in a larger number of healthy patients.

Patients and methods

Our examinations were performed in patients presenting for eye examination at our clinic. An inclusion criterion was: >15 years of age, anatomically normal anterior segment of the eye examined by slit-lamp biomicroscope; exclusion criteria were previous ocular surgery, history of corneal disease, wearing of contact lenses and dry eye disturbing the examination.

Every eye was examined with IOLMaster (Carl Zeiss Meditec, Jena, Germany, software version 5.4). Axial length (AL) measurement was performed minimum 5 times in each eye (signal/noise ratio minimum 100), then 3 keratometric data were assessed in an automated mode and the mean calculated by the device was used for further computing. Subsequent to keratometric measurements anterior chamber depth (ACD) was also measured minimum 3 times.

When evaluating keratometric data, the orientation of corneal astigmatism was defined as against-the-rule (ATR) astigmatism in case of steep corneal curvature between 0-30 and 150-180 degrees, oblique astigmatism between 30-60 and 120-150 degrees, with-the-rule (WTR) astigmatism between 60-120 degrees.

The procedure of the examination was explained to the patients and the research protocol adhered to the tenets of the Declaration of Helsinki. Statistical analysis was performed with MedCalc 10.0 and Microsoft Excel softwares. Descriptive statistical results were described as mean± standard deviation (SD) and 95% confidence interval (95% CI) for the mean. Normality of data was tested by Kolmogorov-Smirnov test. If the normality was rejected ($p<0.05$), nonparametric test was used. Accordingly, certain groups and results were compared with Student's t-probe or Mann-Whitney U test, in case of comparing more than two groups ANOVA test was used. Spearman rank test was applied to explore correlations. P value below 0.05 was considered statistically significant.

Results

In present study, 1092 eyes of 675 patients were examined. The female/male rate was 399/276. The mean age of patients was 69.64±15.25 years (range: 15-100 years, 95% CI: 68.73-70.54 years), there was no difference between genders ($p=0.5$). Axial length was 23.32±1.49 mm (range: 18.74-38.45 mm, 95% CI: 23.23-23.41 mm), anterior chamber depth was 3.17±2.03 mm (range: 1.63-5.5 mm, 95% CI: 3.02-3.33 mm) in the examined population.

Regarding all biometric data obtained in our study and also age, Kolmogorov-Smirnov test rejects normality ($p<0.001$). The keratometric value of the flat meridian was 43.53±1.56 D (range: 37.85-49.3 D, 95% CI: 43.44-43.26 D), while that of the steeper meridian was 44.43±1.59 D (range: 39.25-49.06 D, 95% CI: 44.33-44.52 D). These values were gender dependent. Overall astigmatism was 0.89±0.72 D (range: 0-6.34 D, 95% CI: 0.85-0.94 D), showing no significant difference between male and female patients. The differences in some biometric parameters between males and females are shown in details by Table 1.

The magnitude of astigmatism was ≥0.5 D in 73.53% of the cases, ≥1.0 D in 32.78%, ≥1.5 D in 13.55%, ≥2.0 D in 6.86% and ≥3.0 D in 2.47%, and no significant deviation was found measured separately for men and women. The distribution of the astigmatic ranges measured in present population is shown by Table 2. WTR was observed in 582 cases (53.3%), ATR in 309 cases (28.3%) and oblique astigmatism in 201 cases (18.4%) of the investigated population. This rate showed no significant gender-dependence. The rate and orientation of astigmatism are presented by a graph in Figure 1.

A significant negative correlation was verified between age and ACD ($r=-0.39$, $p<0.001$), age and AL ($r=-0.15$, $p<0.001$), AL and flat keratometric ($r=-0.54$, $p<0.001$) and steep keratometric values ($r=-0.49$, $p<0.001$) in both genders. There was a weak but statistically significant correlation between age and the magnitude of astigmatism ($r=-0.08$, $p=0.01$).

In case we divide the examined population into age groups, significant differences independent of gender can be observed. The WTR rate of 86.6% detected in the 15-25 age group is continuously decreasing to 43% by the age of 80, meanwhile the rate of ATR increases from 0% to 34% (Figure 2).

Discussion

Astigmatism highly affects visual acuity in pseudophakic eyes as well (9,10), that is why its correction has been highly emphasized in cataract operations recently. Our data clearly show that almost one third of the population waiting for cataract surgery has ≥1.0 D corneal astigmatism. To obtain adequate refractive results, in such cases the correction of astigmatism seems to be reasonable.

A large number of data exist on childhood astigmatism, which shows astigmatism exceeding 1.0D in minimum 70% of the infants (12-14), with population-dependent prevalence (15). The literature describes far less prevalence in children (2,16,17). Other publications report an overall 0.65 D astigmatism at the age of 55 months (3). The rate of childhood astigmatism decreases with age (1,2,15,18,19); according to a longitudinal study, the most outstanding changes in the rate of astigmatism occur between the first and the second year of life,[1] and further decrease can be detected up to 6 years (1) and after (2,3). Other studies do not confirm such age-adjusted changes in children in various populations (13). Regarding the orientation of astigmatism, the WTR type is the most common in children (3,15), and in cases where astigmatism is >1.0 D it can even reach a rate of 90% in certain populations (13). Dobson's researches found ATR dominancy under 3.5 years and WTR dominancy above 5.5 years (2). Several studies verified predominant ATR in infants (1), and regarding the meridian of astigmatism found no significant changes between 1-4 years (1).

Only a few studies have been published on the investigation of astigmatic parameters in adulthood in a large cohort of patients (4-8), though data collected in Central Europe are still not known. Consequently, the rate of astigmatism is an average of 1.0 D (4-6,11,20), which complies well with our data. Regarding astigmatism prevalence, our data differ from those of Khan's (4), measured with IOLMaster: we observed similar values below 0.5 D; however, we detected more astigmatic values below 1.5 D (86.45% vs. 79.5%) and fewer above 1.0 D (32.78% vs. 40.4%). The later is distinctly high in the population waiting for cataract surgery in our study. Other publications report even higher values on the rate of astigmatism above 1.5 D (13.55% vs. 22%) (6). Hoffer's first study, carried out in a large cohort of patients, also observed <0.5 astigmatism in 40-45% of the patients (5), which is significantly higher than values detected in his further researches and in our study, however different measurement techniques were used. Two presently published studies (6,7) issued basically the same data in regarding the prevalence of <1.0 D astigmatism. In addition to significant differences observed in population-related childhood astigmatism, similar differences have been reported on adults (21), therefore our data measured in a Central-European population may be of an interest.

Regarding age-related changes, it is well known, that prevalence of astigmatism above 2.0 D is gradually increasing and that below 0.5 D is continuously decreasing with age (20). The orientation of corneal astigmatism however shifts with age: WTR common in youngsters is gradually shifting to ATR and oblique astigmatism (7,8,20-24). Thus, ATR prevalence is higher than WTR in adults (11,20), though in case of higher rate of astigmatism there is WTR dominance (7). Our measurements confirm these normal age-related changes, though their reason is still not clearly known. There are publications reporting on significant ATR astigmatism dominance above 60 years in diverse populations (25).

Only few of the studies aimed at assessing the correlation between other ocular biometric data in a large cohort of patients (5,7,22) The mean axial length was 23.43 mm (7), 23.56 mm (22), 23.65 mm (5) and some other studies also observed a slight decrease with aging (22,26). The overall flat keratometric data are around 43.4-43.5 D (4,6), steep keratometric data are about 44.0-44.5 D (4,6), similarly to our data. Our findings regarding the age-adjusted correlations with keratometric values, axial length, lens thickness and anterior chamber depth support the results of some previous studies (7,27,28). These changes, considered as part of aging, can partly be explained with the reduction in the length of the constituent collagen fibres in tissues (2). Differences in AL, ACD and keratometric values can be observed between genders, and it is also supported by other publications (7,8,26), however the magnitude and the orientation of corneal astigmatism is not gender dependent according to our data.

In summary, our keratometric data obtained from an adult population with a wide range of ages from Central Europe slightly differ from data found in the literature thus they add to the notion of the population dependent differences of astigmatism. Ophthalmological biometric parameters are continuously changing after birth and in childhood, and undergo further specific, though slower changes in adulthood. Corneal astigmatism in adulthood is above 1.0 D in one third of the population, therefore it requires a greater emphasis if adequate refractive results are to be obtained in cataract surgeries.

Legends for tables and figures

Table 1: Gender differences regarding biometric parameters. P values under 0.05 show significant differences in biometric parameters between genders. AL: axial length, ACD: anterior chamber depth, K1: flat keratometric data, K2: steep keratometric data.

Table 2. The distribution of astigmatism according to diopter zones (n=1092).

Figure 1. The distribution of astigmatism in the examined population presented in a graph (n=1092). Each point represents one patient. The distance from zero shows the magnitude of astigmatism and the orientation is depicted by the arrangement in degrees.

Figure 2. Distribution of with-the-rule (WTR), against-the-rule (ATR) and oblique astigmatism in the various age groups (n=1092).

References

1. Abrahamsson M, Fabian G, Sjöstrand J. Changes in astigmatism between the ages of 1 and 4 years: a longitudinal study. Br J Ophthalmol 1988; 72: 145-149.

2. Dobson V, Fulton AB, Sebris SL. Cycloplegic refraction of infants and young children: the axis of astigmatism. Invest Ophthalmol Vis Sci 1984; 25:83-87.

3. Fan DS, Rao SK, Cheung EY, Islam M, Chew S, Lam DS. Astigmatism in Chinese preschool children: prevalence, change, and effect on refractive development. Br J Ophthalmol 2004; 88: 938-941.

4. Khan MI, Muhtaseb M. Prevalence of corneal astigmatism in patients having routine cataract surgery at a teaching hospital in the United Kingdom. J Cataract Refract Surg 2011; 37: 1751-1755.

5. Hoffer KJ. Biometry of 7,500 cataractous eyes. Am J Ophthalmol 1980; 90: 360-368.

6. Ferrer-Blasco T, Montés-Micó R, Peixoto-de-Matos SC, González-Méijome JM, Cerviño A. Prevalence of corneal astigmatism before cataract surgery. J Cataract Refract Surg 2009; 35: 70-75.

7. Hoffmann PC, Hütz WW. Analysis of biometry and prevalence data for corneal astigmatism in 23,239 eyes. J Cataract Refract Surg 2010; 36: 1479-1485.

8. Ninn-Pedersen K. Relationships between preoperative astigmatism and corneal optical power, axial length, intraocular pressure, gender, and patient age. J Refract Surg 1996; 12: 472-482.

9. Hayashi K, Manabe S, Yoshida M, Hayashi H. Effect of astigmatism on visual acuity in eyes with a diffractive multifocal intraocular lens. J Cataract Refract Surg 2010; 36: 1323-1329.

10. Hayashi K, Hayashi H, Nakao F, Hayashi F. Influence of astigmatism on multifocal and monofocal intraocular lenses. Am J Ophthalmol 2000; 130: 477-482.

11. Riley AF, Grupcheva CN, Malik TY, Craig JP, McGhee CN. The Auckland Cataract Study: demographic, corneal topographic and ocular biometric parameters. Clin Experiment Ophthalmol 2001; 29: 381-386.

12. Howland HC, Sayles N. Photorefractive measurements of astigmatism in infants and young children. Invest Ophthalmol Vis Sci 1984; 25: 93-102.

13. Harvey EM, Dobson V, Miller JM, Schwiegerling J, Clifford-Donaldson CE, Green TK, Messer DH. Prevalence of corneal astigmatism in Tohono O'odham Native American children 6 months to 8 years of age. Invest Ophthalmol Vis Sci 2011; 52: 4350-4355.

14. Mohindra I, Held R, Gwiazda J, Brill J. Astigmatism in infants. Science 1978; 202: 329-330.

15. Fozailoff A, Tarczy-Hornoch K, Cotter S, Fozailoff A, Tarczy-Hornoch K, Cotter S, Wen G, Lin J, Borchert M, Azen S, Varma R; Writing Committee for the MEPEDS Study Group. Prevalence of astigmatism in 6- to 72-month-old African American and Hispanic children: the Multi-ethnic Pediatric Eye Disease Study. Ophthalmology 2011; 118: 284-293.

16. Tong L, Saw SM, Carkeet A, Chan WY, Wu HM, Tan D. Prevalence rates and epidemiological risk factors for astigmatism in Singapore schoolchildren. Optom Vis Sci 2002; 79: 606-613.

17. Gwiazda J, Scheiman M, Mohindra I, Held R. Astigmatism in children: changes in axis and amount from birth to 6 years. Invest Ophthalmol Vis Sci 1984; 25: 88-92.

18. Fulton AB, Dobson Y, Salem D, Mar C, Petersen RA, Hansen RM. Cycloplegic refraction in infants and young children. Am J Ophthalmol 1980; 90: 239-247.

19. Atkinson J, Bradick 0, French J. Infant astigmatism: its disappearance with age. Vision Res 1980; 40: 891-893.

20. Asano K, Nomura H, Iwano M, Ando F, Niino N, Shimokata H, Miyake Y. Relationship between astigmatism and aging in middle-aged and elderly Japanese. Jpn J Ophthalmol 2005; 49: 127-133.

21. Hashemi H, Khabazkhoob M, Yekta A, Jafarzadehpur E, Emamian MH, Shariati M, Fotouhi A. High prevalence of astigmatism in the 40- to 64-year-old population of Shahroud, Iran. Clin Experiment Ophthalmol 2012; 40: 247-254.

22. Gudmundsdottir E, Arnarsson A, Jonasson F. Five-year refractive changes in an adult population: Reykjavik Eye Study. Ophthalmology 2005; 112: 672-677.

23. Fledelius HC, Stubgaard M. Changes in refraction and corneal curvature during growth and adult life. A cross-sectional study. Acta Ophthalmol (Copenh) 1986; 64: 487-491.

24. Gudmundsdottir E, Jonasson F, Jonsson V, Stefánsson E, Sasaki H, Sasaki K. "With the rule" astigmatism is not the rule in the elderly. Reykjavik Eye Study: a population based study of refraction and visual acuity in citizens of Reykjavik 50 years and older. Iceland-Japan Co-Working Study Groups. Acta Ophthalmol Scand 2000; 78: 642-646.

25. Leung TW, Lam AK, Deng L, Kee CS. Characteristics of astigmatism as a function of age in a Hong Kong clinical population. Optom Vis Sci 2012; 89: 984-992.

26. Jivrajka R, Shammas MC, Boenzi T, Swearingen M, Shammas HJ. Variability of axial length, anterior chamber depth, and lens thickness in the cataractous eye. J Cataract Refract Surg 2008; 34: 289-294.

27. Leighton DA, Tomlinson A. Changes in axial length and other dimensions of the eyeball with increasing age. Acta Ophthalmol 1972; 50: 815-826.

28. Lowe RF, Clark BA. Posterior corneal curvature. Correlations in normal eyes and in eyes involved with primary angle-closure glaucoma. Br J Ophthalmol 1973; 57: 464-470.

Summary statement

In a large series of patients, the astigmatism was 0.89±0.72 D (range: 0-6.34 D, 95% CI: 0.85-0.94 D, >1.0 D in >32%), showing no significant difference between male and female. The magnitude of astigmatism was ≥0.5 D in 73.53% of the cases, ≥1.0 D in 32.78% and ≥1.5 D in 13.55%.

Figure 1
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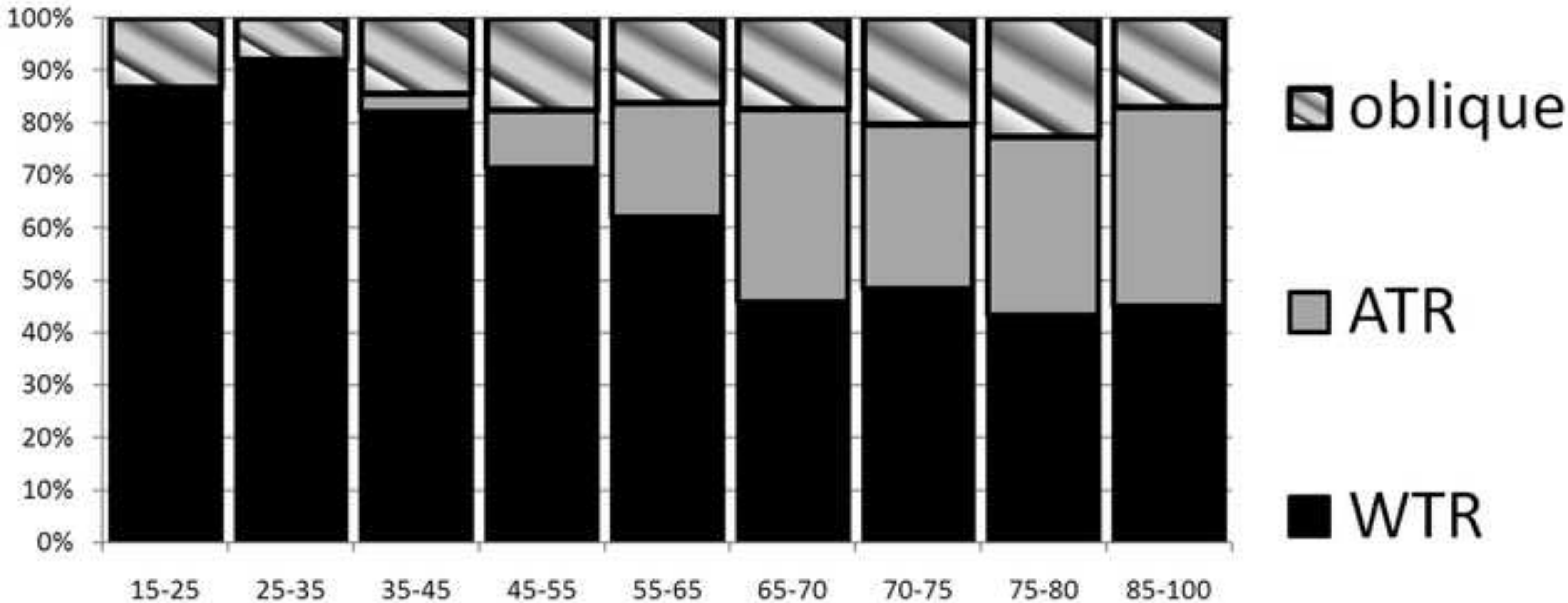

Figure 2
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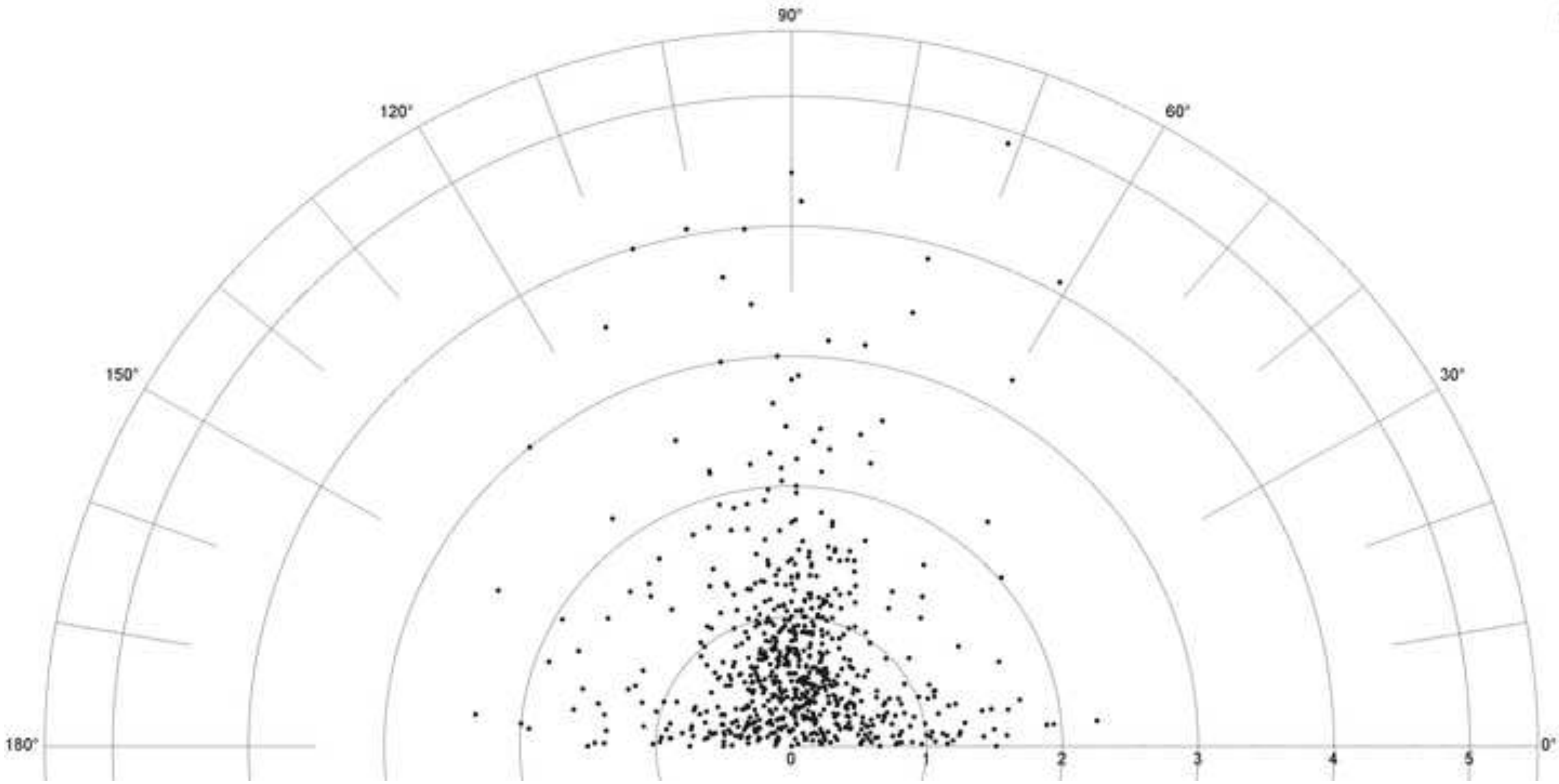

Table 1-2

	female			male			p
	mean± SD	range	95% CI	mean± SD	range	95% CI	
AL (mm)	23.14±1.59	18.74-38.45	23.01-23.26	23.5±1.37	18.74-32.54	23.39-23.61	<0.001
ACD (mm)	3.05±0.47	1.63-4.6	3.01-3.1	3.19±0.44	1.8-4.57	3.14-3.23	<0.001
K1 (D)	43.8±1.52	39.43-49.34	43.68-43.92	43.14±1.53	37.8-47.5	43.0-43.28	<0.001
K2 (D)	44.68±1.58	40.18-50.9	44.56-44.81	44.06±1.54	39.25-49.15	43.92-44.2	<0.001
astigmatism (D)	0.91±0.73	0-6.18	0.85-0.98	0.88±0.71	0-6.34	0.82-0.94	0.43

Table 1.

D range	n	%
0.0-0.49	289	26.46
0.5-0.99	445	40.75
1.0-1.49	210	19.23
1.5-1.99	73	6.69
2.0-2.49	37	3.39
2.5-2.99	11	1.01
3.0-3.49	11	1.01
>3.5	16	1.46

Table 2.