Clinical, tomographic, and biometric differences between regular and irregular astigmatism in Iraq refractive surgery candidates: a cross-sectional study

Diferenças clínicas, tomográficas e biométricas entre o astigmatismo regular e o irregular em candidatos à cirurgia refrativa no Iraque: um estudo transversal

Marrwan Hisham Mohmmed[1], **Mustafa Tawfeeq Halboos**[2], **Noor Hamad**[1]

[1] Optical Techniques Department, College of Health and Medical Techniques, Al-Mustaqbal University, 51001, Babylon, Iraq.
[2] Department of Surgery, College of Medicine, Babylon University, Babylon, Iraq.

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Corresponding author:
Marrwan Hisham Mohammed
E-mail: marrwan.hisham@uomus.edu.iq

Institution:
Ameer Moumnean Surgery Hospital, Al-Najaf, Iraq.

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Emmerson Badaró, Universidade Federal de São Paulo, São Paulo, SP, Brazil
https://orcid.org/0000-0001-8813-3972

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ABSTRACT

Objective: To compare visual acuity, corneal tomography, and ocular biometry between regular and irregular astigmatism in Iraqi refractive surgery candidates and to examine relationships among key parameters.

Methods: Retrospective cross-sectional study of consecutive adults screened for refractive surgery at Ameer Moumnean Surgery Hospital (Al-Najaf, Iraq) between January and March 2026. Astigmatism was classified as regular (with-the-rule, against-the-rule, or oblique) or irregular based on tomographic/curvature-pattern assessment. Outcomes included uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) in logMAR, spherical equivalent (SE), keratometry (K1, K2, Kmax), central corneal thickness (CCT), intraocular pressure (IOP), and axial length (AL) measured using Pentacam HR and IOLMaster.

Results: Of 454 eyes, 304 (67.0%) were classified as regular and 150 (33.0%) as irregular astigmatism. Compared with regular astigmatism, irregular astigmatism was associated with worse uncorrected visual acuity (0.58 ± 0.14 *versus* 0.34 ± 0.11 logMAR) and best-corrected visual acuity (0.39 ± 0.17 *versus* 0.07 ± 0.14 logMAR), more myopic spherical equivalent (-3.44 ± 2.45 *versus* -1.74 ± 2.05 D), steeper corneal curvature (Kmax 50.97 ± 2.87 *versus* 45.76 ± 1.57 D), thinner central corneal thickness (525.67 ± 34.85 *versus* 541.36 ± 31.28 µm), and longer AL (24.36 ± 0.91 *versus* 24.06 ± 0.83 mm) (all $p < 0.001$), whereas IOP did not differ ($p = 0.881$). Spherical equivalent showed a moderate inverse correlation with AL (Spearman $\rho = -0.454$; $p < 0.001$; $R^2 = 0.222$), and central corneal thickness showed a weak inverse correlation with Kmax ($\rho = -0.149$; $p = 0.0015$; $R^2 = 0.035$).

Conclusions: In Iraqi refractive surgery candidates, irregular astigmatism was associated with substantially poorer visual acuity, markedly steeper corneal curvature, thinner corneas, and slightly longer axial length. These findings support comprehensive corneal tomography and biometry as part of refractive surgery screening.

RESUMO

Objetivo: Comparar a acuidade visual, a tomografia da córnea e a biometria ocular entre o astigmatismo regular e o irregular em candidatos iraquianos à cirurgia refrativa e examinar as relações entre os principais parâmetros.

Métodos: Estudo transversal retrospectivo com adultos consecutivos submetidos a triagem para cirurgia refrativa no Hospital Cirúrgico Ameer Moumnean (Al-Najaf, Iraque), entre janeiro e março de 2026. O astigmatismo foi classificado como regular (com a regra, contra a regra ou oblíquo) ou irregular com base na avaliação tomográfica e no padrão de curvatura. Os desfechos incluíram acuidade visual não corrigida (UCVA) e acuidade visual melhor corrigida (BCVA) em logMAR, equivalente esférico (SE), ceratometria (K1, K2, Kmax), espessura central da córnea (CCT), pressão intraocular (PIO) e comprimento axial (AL), medidos com o Pentacam HR e o IOLMaster.

Resultados: Dos 454 olhos, 304 (67,0%) foram classificados como astigmatismo regular e 150 (33,0%) como astigmatismo irregular. Em comparação com o astigmatismo regular, o astigmatismo irregular foi associado a pior acuidade visual não corrigida (0,58 ± 0,14 *versus* 0,34 ± 0,11 logMAR) e a melhor acuidade visual corrigida (0,39 ± 0,17 *versus* 0,07 ± 0,14 logMAR), equivalente esférico mais miópico (-3,44 ± 2,45 *versus* -1,74 ± 2,05 D), curvatura corneana mais acentuada (Kmax 50,97 ± 2,87 *versus* 45,76 ± 1,57 D), espessura central da córnea mais fina (525,67 ± 34,85 contra 541,36 ± 31,28 µm) e comprimento axial (AL) maior (24,36 ± 0,91 *versus* 24,06 ± 0,83 mm) (todos $p < 0,001$), enquanto a PIO não apresentou diferença ($p = 0,881$). O equivalente esférico apresentou uma correlação inversa moderada com o comprimento axial (AL) (ρ de Spearman = -0,454; $p < 0,001$; $R^2 = 0,222$), e a espessura central da córnea apresentou uma correlação inversa fraca com o Kmax ($\rho = -0,149$; $p = 0,0015$; $R^2 = 0,035$).

Conclusões: Em candidatos à cirurgia refrativa no Iraque, o astigmatismo irregular foi associado a uma acuidade visual substancialmente pior, curvatura corneana marcadamente mais acentuada, córneas mais finas e comprimento axial ligeiramente maior. Esses achados apoiam a realização de tomografia e biometria corneanas abrangentes como parte da triagem para cirurgia refrativa.

INTRODUCTION

Astigmatism is one of the most prevalent types of refractive errors in the world, contributing to a significant cause of vision loss when not properly corrected.[1] It is caused by differences in power between meridians, resulting in blurred vision.[2] Astigmatism is divided into two types: regular astigmatism, in which the principal meridians are at right angles, and irregular astigmatism, in which the principal meridians are not at right angles, with a non-symmetric or irregular curvature of the cornea.[3] Regular astigmatism is usually easily correctable with glasses or contact lenses, whereas in the case of irregular astigmatism, it is usually caused by irregularities in the shape of the cornea, for which a higher degree of optical correction is typically necessary.[4] The cornea is responsible for the major contribution to the total power of refraction of the eye, contributing two-thirds of its power.[5] Changes in its curvature as well as thickness play a pivotal role in the development of astigmatism, especially in those conditions in which there is instability of the biomechanical structure of the cornea.[6] New advances in imaging techniques, including corneal topography as well as tomography, have enabled a better evaluation of astigmatism by facilitating better imaging of the shape of the cornea. Parameters such as flat keratometry (K1), steep keratometry (K2), maximum keratometry (Kmax), and central thickness of the cornea (CCT) are commonly used for characterizing abnormal states of the cornea.[7] Irregular astigmatism is often associated with corneal ectatic disorders such as keratoconus, in which the thinning and protrusion of the cornea lead to irregular corneal curvature and compromised visual quality.[8,9] Studies have found that high keratometric readings, especially a high Kmax, are key markers for spotting corneal steepness and early signs of ectasia. Thinner corneas and irregular pachymetric patterns are also important clues for detecting corneal instability and irregular astigmatism. With recent advances in corneal imaging and AI-powered diagnostic tools, identifying subtle corneal abnormalities and the risk of ectasia has become even more precise in recent years.[9,10] In addition to corneal factors, a range of ocular biometric parameters can influence refractive errors and astigmatism.[11] Axial length is a critical factor for refractive error and is a major contributor to myopia. A number of studies have established a strong relationship between axial length and spherical equivalent refractive error. In fact, the axial length is a critical factor for the development of myopia. In addition to axial length, the relationship between corneal curvature, refractive error, and axial length could influence the variations in astigmatism.[12] In addition, astigmatism contributes markedly to visual impairment; irregular forms often reflect corneal ectasia and require advanced imaging for safe refractive surgery.[9,10] Data from Middle Eastern populations on the clinical and tomographic characteristics of astigmatism in refractive surgery candidates remain limited.[11] In preoperative refractive screening, distinguishing regular from irregular astigmatism is clinically important because irregular astigmatism is more often associated with reduced optical quality, corneal asymmetry, and potential ectatic risk, all of which may influence surgical eligibility and counseling. However, the extent to which visual, refractive, tomographic, and biometric parameters differ between regular and irregular astigmatism in Iraqi patients has not been well characterized. Therefore, the aim of the present study was to compare visual acuity, refractive status, corneal curvature, central corneal thickness, intraocular pressure, and axial length between regular and irregular astigmatism in Iraqi refractive surgery candidates, and to examine the relationships among selected ocular parameters.

METHODS

Study design and participants

This retrospective cross-sectional observational study reviewed the medical records of consecutive adults who underwent refractive surgery screening at Ameer Moumnean Surgery Hospital, Al-Najaf, Iraq, between January and March 2026. The study protocol was approved by the Institutional Review Board of Al Mustaqbal University (OPT.7.4.2026 Data: January 25, 2026) and adhered to the tenets of the Declaration of Helsinki. Patient identifiers were removed before analysis. One eye per patient was randomly selected to avoid inter-eye correlation bias. Eligible records included adults (≥ 18 years) who underwent routine preoperative assessment including refraction, visual acuity testing, corneal tomography,

and ocular biometry. All participants were requested to discontinue wearing rigid contact lenses for 4 weeks and soft contact lenses for 2 weeks prior to the examination. Eyes with prior ocular surgery, corneal trauma, active ocular disease, corneal scarring, or incomplete data were excluded.

Ophthalmic examination

Uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) were recorded and expressed in logMAR. Refractive error was obtained using automated refraction and recorded as sphere, cylinder, axis, and spherical equivalent (SE = sphere + cylinder/2). Corneal curvature (K1, K2, and Kmax) and central corneal thickness (CCT) were measured using a Pentacam HR (Oculus GmbH, Wetzlar, Germany). Axial length (AL) was measured using an IOLMaster optical biometer (Carl Zeiss Meditec, Jena, Germany). Intraocular pressure (IOP) was measured using a non-contact tonometer (Topcon CT-1, Topcon Corporation, Tokyo, Japan).

Classification of astigmatism

Astigmatism was classified according to the dominant steep meridian and the tomographic curvature pattern. Regular astigmatism was assigned when the corneal map showed a symmetric bow-tie configuration with two approximately orthogonal principal meridians. Regular subtypes were defined as with-the-rule (WTR; steep meridian 60°-120°), against-the-rule (ATR; steep meridian 0°-30° or 150°-180°), and oblique astigmatism (steep meridian 31°-59° or 121°-149°). Eyes were classified as irregular astigmatism when tomography showed an asymmetric or skewed curvature pattern that was not adequately described by two orthogonal principal meridians, such as an asymmetric bow-tie, inferior/superior focal steepening, skewed radial axes, or localized irregular steepening, together with at least one objective surface-irregularity criterion (Supplementary Material - Table S1). The objective criteria were surface asymmetry index (SAI) >0.50 D and/or irregular astigmatism index (IAI) >0.50 D. These indices were used as supportive quantitative markers of corneal surface asymmetry and irregularity, and the final classification was made by combining the index values with the tomographic map pattern.[13,14]

Statistical analysis

Effect size was calculated using Hedges g. Confidence intervals represent the 95% confidence interval for the mean difference. Comparisons between groups were performed using the independent samples t-test. $p < 0.05$ was considered statistically significant.

Analyses were conducted using IBM SPSS Statistics, version 26 (IBM Corp., Armonk, NY, USA). Continuous variables are reported as mean ± standard deviation (SD) and categorical variables as counts and percentages. Group comparisons between regular and irregular astigmatism were performed using Welch's independent-samples t-test, reporting mean differences with 95% confidence intervals (CI), and standardized effect sizes (Hedges' g). Comparisons across the four astigmatism patterns (ATR, WTR, oblique, irregular) were assessed using Kruskal-Wallis tests with posthoc Mann-Whitney tests versus the irregular group with Holm adjustment. Correlation analyses were performed for the full cohort and stratified by astigmatism group (regular versus irregular). Spearman's (ρ) was used for rank-based associations, and Pearson's r was additionally reported for linear associations shown in scatter plots. To test whether correlation coefficients differed between groups, Fisher's r-to-z transformation was applied (two-sided). To avoid intereye correlation bias, one eye per patient was randomly selected prior to analysis (454 eyes from 454 patients). Because this was a retrospective cross-sectional study based on available records, no a priori sample size calculation was performed. Based on the achieved sample size (304 regular and 150 irregular astigmatism eyes), the study had approximately 80% power at a two-sided α of 0.05 to detect standardized mean differences of about $d \approx 0.28$, indicating adequate power for moderate between-group effects but more limited sensitivity for detecting small differences. A twosided P value < 0.05 was considered statistically significant.

RESULTS

A total of 454 eyes from 454 patients were included in this retrospective cross-sectional study, with one eye selected per patient. Of these, 304 eyes (67.0%) were classified as regular astigmatism and 150 eyes (33.0%) as irregular astigmatism. The mean age did not differ significantly between the regular and irregular astigmatism groups (34.73 ± 10.00 *versus* 33.51 ± 9.74 years, p = 0.218; Table 1). When stratified by astigmatism pattern, irregular astigmatism represented the largest subgroup (n = 150; 33.0%), followed by with-the-rule astigmatism (n = 115; 25.3%), against-the-rule astigmatism (n = 104; 22.9%), and oblique astigmatism (n = 85; 18.7%) (Figure 1).

Compared with eyes with regular astigmatism, eyes with irregular astigmatism demonstrated significantly worse uncorrected and BCVA, more myopic spherical

Table 1. Comparison of demographic and clinical parameters between regular and irregular astigmatism groups

Variable	Regular astigmatism (n = 304) (Mean ± SD)	Irregular astigmatism (n = 150) (Mean ± SD)	Mean difference (regular - irregular) (95%CI)	p-value	Effect size (Hedges g)
Age, years	34.73 ± 10.00	33.51 ± 9.74	1.22 (-0.71-3.15)	0.218	0.12
UCVA, logMAR	0.34 ± 0.11	0.58 ± 0.14	-0.24 (-0.26--0.21)	p < 0.001	-1.94
BCVA, logMAR	0.07 ± 0.14	0.39 ± 0.17	-0.32 (-0.35-0.29)	p < 0.001	-2.16
SE (D)	-1.74 ± 2.05	-3.44 ± 2.45	1.71 (1.25-2.16)	p < 0.001	0.78
K1 (D)	43.04 ± 1.30	44.23 ± 2.05	-1.19 (-1.55-0.83)	p < 0.001	-0.75
K2 (D)	44.53 ± 1.48	47.16 ± 2.38	-2.63 (-3.05-2.21)	p < 0.001	-1.44
Kmax (D)	45.76 ± 1.57	50.97 ± 2.87	-5.21 (-5.71-4.72)	p < 0.001	-2.50
IOP, mmHg	15.22 ± 3.06	15.27 ± 3.12	-0.05 (-0.66-0.56)	0.881	-0.01
AL, mm	24.06 ± 0.83	24.36 ± 0.91	-0.30 (-0.48-0.13)	p < 0.001	-0.35
CCT, µm	541.36 ± 31.28	525.67 ± 34.85	15.69 (9.07-22.31)	p < 0.001	0.48

SD: standard deviation; 95%CI: 95% of confidence interval; UCVA: uncorrected visual acuity; BCVA: best-corrected visual acuity; SE: spherical equivalent; K1: flat keratometry; K2: steep keratometry; Kmax: maximum keratometry; IOP: intraocular pressure; AL: axial length; CCT: central corneal thickness.

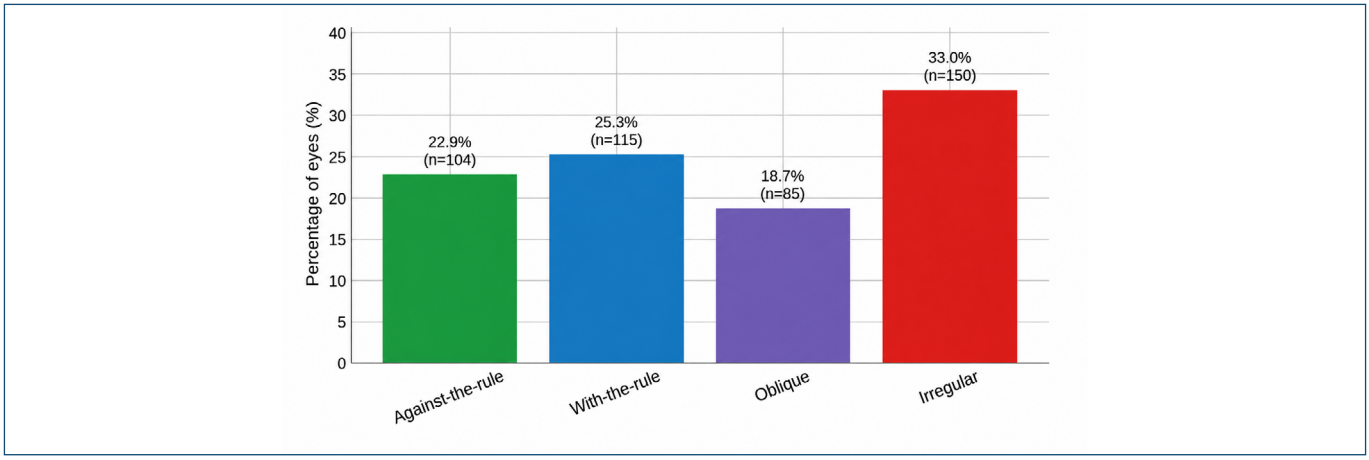
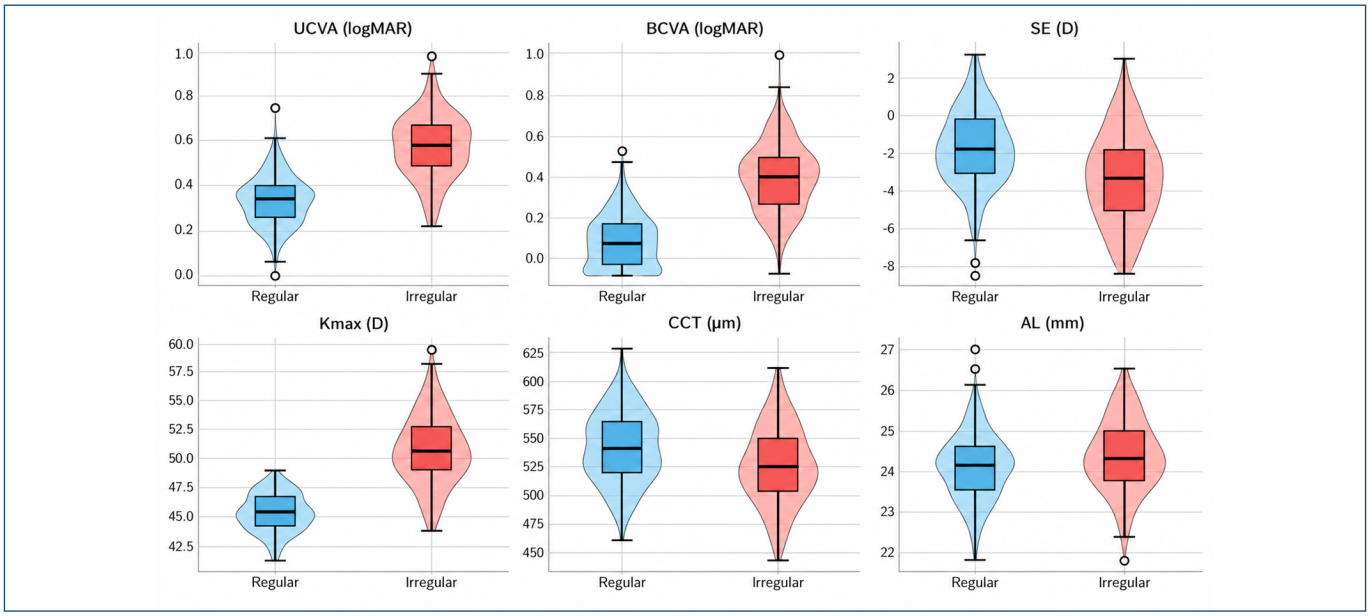


Figure 1. Distribution of astigmatism patterns in the study sample (n = 454 eyes). Bars show percentages; labels show percentage and number.

equivalent, steeper corneal curvature, thinner central corneal thickness, and slightly longer axial length (all p < 0.001; Table 1). In contrast, IOP did not differ significantly between the two groups (p = 0.881). The largest between-group differences were observed for Kmax and visual acuity measures, indicating that irregular astigmatism was associated with both clinically and statistically distinct tomographic and functional abnormalities.

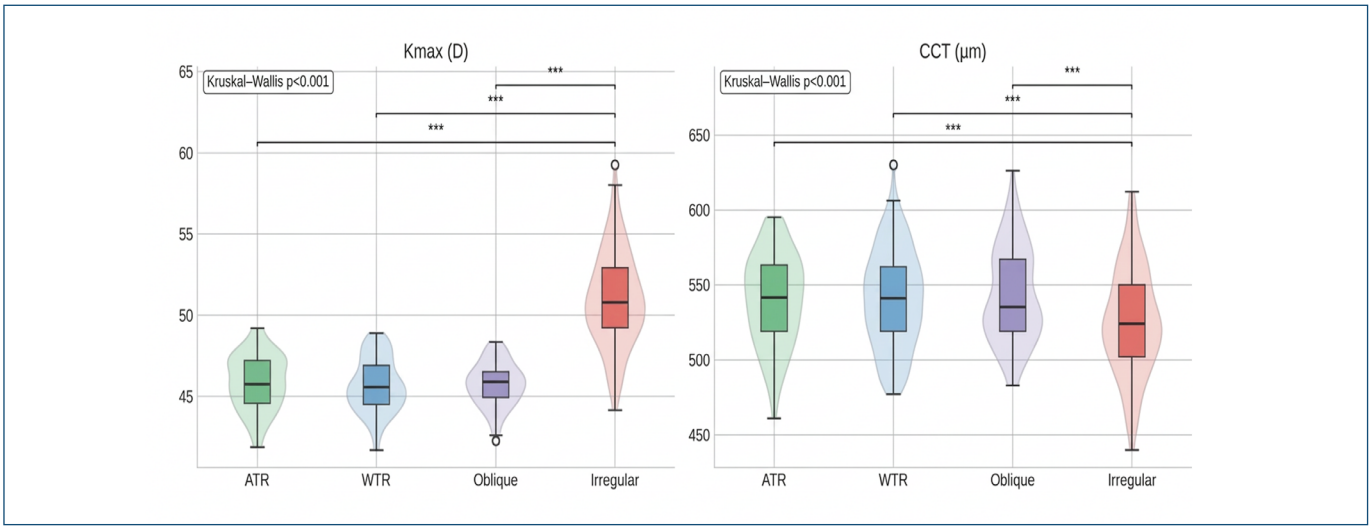
Overall, eyes with irregular astigmatism demonstrated a distinctly less favorable clinical and tomographic profile than eyes with regular astigmatism, including substantially poorer UCVA and BCVA and a more myopic refractive state (Table 1; Figure 2).

Tomographically, irregular astigmatism was characterized by marked corneal steepening, reflected by large, standardized differences in Kmax, and was also associated with thinner central corneal thickness (CCT) and a modestly longer axial length (AL); in contrast, IOP did not differ meaningfully between groups (Table 1). An analysis of subjects' ocular characteristics (ATR, WTR, oblique, irregular) did not show a significant difference in age and sex distribution across the four patterns as they were comparable (Kruskal-Wallis p = 0.416; χ^2 p = 0.103). The comparison of visual acuity and refractive status, however, did show a significant difference, primarily because the irregular group had worse UCVA/BCVA and had more myopic SE than the other three groups (overall p < 0.001). The Kmax and CCT data also showed a significant difference between the four patterns, with irregular astigmatism having a higher Kmax and a lower CCT than each of the regular subtypes (Figure 3). The correlation analysis further supports the differences found in the visual acuity and refractive status; there was a moderate inverse correlation analysis between SE and AL (Spearman ρ = -0.454; p < 0.001) that accounted for 22.2% of SE variability (R^2 = 0.222) (Figure 4A), indicating that SD values were more myopic when the values of AL were greater. When stratified by astigmatism group, the SE-AL association remained significant in both regular and irregular astigmatism (regular: Spearman ρ = -0.461; P < 0.001; irregular:



UCVA: uncorrected visual acuity; BCVA: best-corrected visual acuity; SE: spherical equivalent; Kmax: maximum keratometry; CCT: central corneal thickness; AL: axial length.

Figure 2. Key clinical, tomographic and biometric parameters by astigmatism type (regular, n = 304 eyes; irregular, n = 150 eyes). For each panel, the violin plot depicts the distribution (kernel density), and the overlaid boxplot shows the median (center line), interquartile range (box), and 1.5×IQR whiskers. Parameters shown include uncorrected visual acuity, best-corrected visual acuity, spherical equivalent, maximum keratometry, central corneal thickness, and axial length.

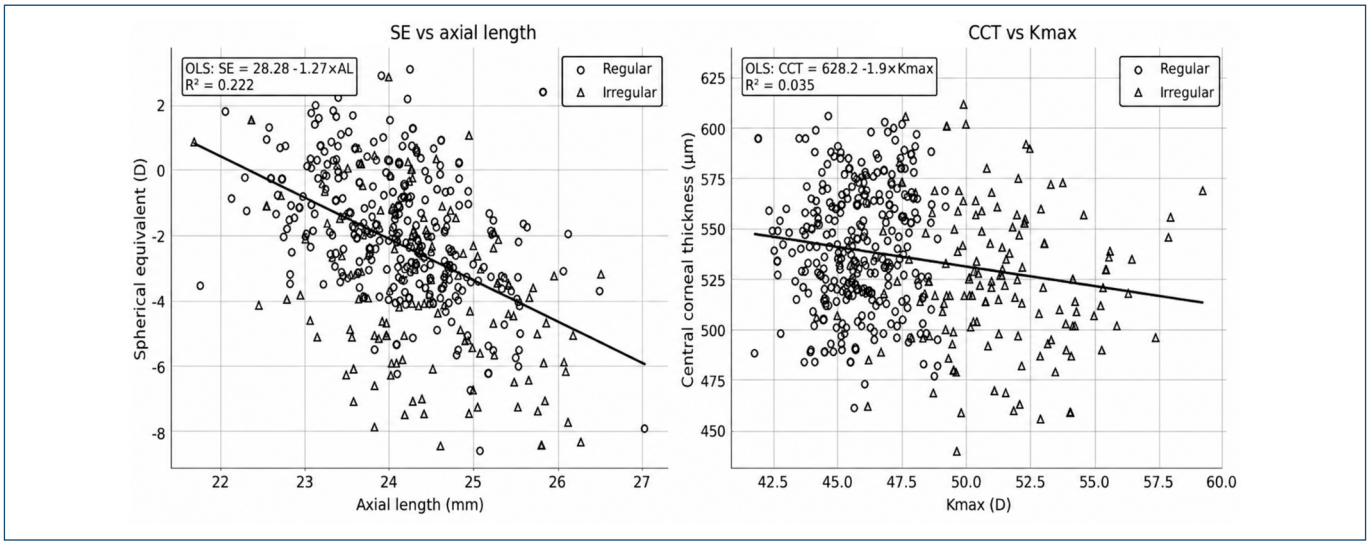


Kmax: maximum keratometry; CCT: central corneal thickness; ATR: against-the-rule; WTR: with-the-rule.

Figure 3. Maximum keratometry and CCT across astigmatism patterns (against-the-rule, with-the-rule, oblique, irregular). Kruskal-Wallis p-values are shown within panels; post-hoc comparisons *versus* Irregular use Holm-adjusted Mann-Whitney tests (*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$).

Spearman $\rho = -0.373$; $p < 0.001$); however, Fisher's r-to-z testing (based on Pearson r) did not show evidence that the strength of the SE–AL correlation differed between groups ($z = -0.49$; $p = 0.624$). In contrast, CCT demonstrated a weak inverse association with Kmax (Spearman $\rho = -0.149$; $p = 0.0015$), with a limited explanatory contribution ($R^2 = 0.035$) (Figure 4B). In group-stratified analyses, the Kmax–CCT association was weak and not statistically significant within either group, and Fisher's r-to-z testing did not indicate a between-group difference in correlation strength ($p = 0.281$). After Holm adjustment for multiple comparisons in Table 1, all main differences (UCVA, BCVA, SE, keratometry, CCT, and AL) remained statistically significant, whereas age and IOP remained non-significant.

As shown in table 2, when analyzed according to astigmatism pattern, age, and sex distribution were broadly comparable among the ATR, WTR, oblique, and irregular



SE: spherical equivalent; CCT: central corneal thickness; Kmax: maximum keratometry.

Figure 4. Scatterplots showing relationships between (A) spherical equivalent and axial length (AL) and (B) central corneal thickness and maximum keratometry. Black line shows overall OLS fit; points are colored by astigmatism type.

Table 2. Demographic and clinical characteristics according to astigmatism pattern

Variable	Against-the-rule (n = 104)	With-the-rule (n = 115)	Oblique (n = 85)	Irregular (n = 150)	p-value
Female	58 (55.8)	52 (45.2)	53 (62.4)	83 (55.3)	p = 0.730
Male	46 (44.2)	63 (54.8)	32 (37.6)	67 (44.7)	
Age, years	35.54 ± 9.81	34.46 ± 10.20	34.12 ± 10.03	33.51 ± 9.74	p = 0.197
UCVA, logMAR	0.34 ± 0.12	0.35 ± 0.12	0.33 ± 0.09	0.58 ± 0.14	< 0.001
BCVA, logMAR	0.07 ± 0.13	0.08 ± 0.15	0.05 ± 0.12	0.39 ± 0.17	< 0.001
SE (D)	-1.85 ± 2.27	-1.54 ± 1.99	-1.85 ± 1.84	-3.44 ± 2.45	< 0.001
Kmax (D)	45.84 ± 1.68	45.72 ± 1.62	45.71 ± 1.34	50.97 ± 2.87	< 0.001
CCT (µm)	540.53 ± 30.44	540.60 ± 32.40	543.41 ± 31.02	525.67 ± 34.85	< 0.001

Age, Kruskal-Wallis and gender, Chi-squared.
*UCVA: uncorrected visual acuity; BCVA: best-corrected visual acuity; SE: spherical equivalent; Kmax: maximum keratometry; CCT: central corneal thickness.
Results expressed as n (%).

groups. Irregular astigmatism was the largest subgroup and showed the least favorable clinical profile overall. In contrast, the three regular astigmatism subtypes showed relatively similar demographic and baseline clinical characteristics.

Clinically, most eyes classified as irregular astigmatism exceeded commonly used screening thresholds for abnormal corneal steepening: 91.3% had Kmax > 47 D and 80.0% had Kmax > 48.7 D, compared with 23.7% and 2.0% in the regular group, respectively

DISCUSSION

Irregular astigmatism is an important clinical finding in refractive surgery screening because it often reflects underlying corneal structural abnormalities rather than a simple refractive variant.[15] In the present study, irregular astigmatism accounted for 33% of eyes and was associated with significantly poorer visual acuity, steeper corneal curvature, thinner central corneal thickness, and slightly longer axial length compared with regular astigmatism.

The results from this study suggest that irregular astigmatism has a separate functional and tomographic profile from regular astigmatism, and that this difference could be an indicator for some patients regarding whether or not they would qualify for refractive surgery and if they would be safe having the procedure done. Of all patients, 33% enrolled in this study had some form of irregular astigmatism, which is similar to the percentage of irregularly shaped corneas seen in other clinical refractive surgery populations, when using advanced imaging techniques to assess corneal shape. In addition, prior studies have shown that reports of irregular astigmatism frequently relate to a clinically evident abnormality seen on the cornea, such as due to early asymmetry of the cornea or transformation into an ectatic state that cannot be detected using traditional keratometers.[8,9] Ueno et al.[16] found that the existence of irregular astigmatism may be due to the distribution of abnormal curvature across the cornea, which would have a negative impact on visual quality for patients who wanted to have refractive surgery.

[16] Similarly, Hilgert et al.[17] indicated that irregular corneal morphology may represent early forms of keratoconus, or similar ectatic disorders.[17] Therefore, the high prevalence of irregular astigmatism identified in this study may suggest that current tomographic screening techniques are able to detect early abnormalities in corneal shape.

A key finding from our investigation was an average Kmax of 50.97 ± 2.87 D for the irregular astigmatic group compared with an average Kmax of 45.76 ± 1.57 D for those with regular astigmatism; these averages exceed the normative range of healthy corneas, where values typically fall between approximately 43 and 46 D, and exceed established criteria for corneal ectasia (>47 D).[18-20] Of the irregular astigmatism eyes in this study (where 90% had Kmax > 47 D), a considerable number likely demonstrate early ectatic morphology rather than isolated refractive astigmatism (as noted by other studies using Scheimpflug tomography regarding the ability to use Kmax and pachymetric distribution). The structural abnormalities found in the irregular astigmatic eyes were corroborated by significantly worse uncorrected/best corrected visual acuity than in regularly astigmatic eyes. This result supports other research that has found that irregularities of corneal curvature create increased higher order aberration that cannot be effectively corrected using traditional eyeglasses or soft contact lenses.[21] An aberrant corneal surface interferes with the normal optical characteristics of the cornea and consequently affects the quality of the retinal image, negatively influencing visual function.[19] Therefore, patients with irregular astigmatism commonly report visual distortion and decreased contrast sensitivity despite having received refractive correction. Another noteworthy finding was the significantly lower CCT in the irregular astigmatism group. A lower CCT is a known characteristic of corneal ectasia, which includes the most common type of ectatic disorder, keratoconus, and has been incorporated as a parameter in several objective tomographic-based screening protocols for detecting keratoconus.[20,22] The current study showed that there was a weak inverse correlation between CCT and Kmax, which indicates that corneal thickness alone does not account for all of the variance in corneal curvature. The evidence gathered supports the notion that a multi-parameter tomography approach to evaluating corneal structural integrity produces more reliable outcomes compared to simply using single values for measurement of cornea.[7,23] There was also evidence of a moderate, but significant inverse correlation between axial length and - spherical equivalent refraction (indicating that longer eyes are typically associated with higher degrees of myopia). In general, these findings are reflective of those described in previous population-based studies, namely that the increase in length of the eye along its axis is a major contributor toward developing myopia.[11,24,25] Many authors have reported a large number of similar associations between ocular biometric typological characteristics (e.g., refractive error) and corresponding refractive errors.[11,12]

The implications of this study's findings for refractive surgery screening and patient selection are substantial from a clinical viewpoint. Eyes with irregular astigmatism frequently have tomographic features associated with an increased likelihood of developing postoperative ectasia, such as steep keratometry and low corneal thickness. Therefore, those eyes may not be good candidates for LASIK surgery, particularly where there are other risk factors present. Other options, including photorefractive keratectomy (PRK), topography-guided therapies, and conservative optical correction may be more appropriate depending on the individual corneal profile.[8,9] Multimodal tomography and AI-based corneal imaging technologies are now providing improved detection of subtle corneal abnormalities and enhanced identification of ectasia susceptible corneas.[23,26] The structural differences between regular and irregular astigmatism may also be explained by biomechanical changes in the cornea. Corneal ectatic abnormalities are defined by stromal thinning and localized corneal protrusion due to decreased biomechanical stability of the corneal tissue.[6,9] The changes in biomechanics can create an asymmetric shape in the curvature of the cornea and produce progressive steepening in the cornea, leading to the irregular astigmatism patterns seen in tomographic images. Study limitations include: a retrospective analysis design; being conducted at a single site, meaning results may not be generalizable; and no a priori sample size calculation; results may be underpowered to detect smaller differences between groups; the distribution of irregularly and regularly shaped eyes between groups could produce a statistically inefficient comparison for some of the analysis. The classification of irregularly shaped eye based on tomographical pattern characteristics can provide a more adequate method for classifying an irregularly shaped eye, however there are many valid approaches for defining an irregularly shaped eye. Therefore, more prospective studies utilizing multimodal, standardized criteria and equal subject recruitment in future studies is warranted.[27]

CONCLUSION

Candidates for refractive surgery in Iraq presented with significantly lower levels of vision than those with regular astigmatism. Similarly, the corneal curvature was found to be significantly steeper, the corneal thickness was found to be significantly thinner, and the axial length was found to be slightly longer. Overall, these results provide strong support for comprehensive use of corneal computerized tomography and ocular biometry as part of preoperative assessment procedures prior to refractive surgery.

AUTHOR CONTRIBUTION:

All authors contributed to the conception and design of the study, acquisition and analysis of data, interpretation of the results, and drafting and critical revision of the manuscript. All authors approved the final version of the manuscript.

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SUPPLEMNTARY MATERIAL

Table S1. Criteria used to classify regular and irregular astigmatism

Category	Definition used in this study	Objective/supportive criteria
With-the-rule regular astigmatism	Symmetric bow-tie pattern with two approximately orthogonal principal meridians; steep meridian 60°-120°	No asymmetric/skewed tomographic pattern suggesting irregular astigmatism
Against-the-rule regular astigmatism	Symmetric bow-tie pattern with two approximately orthogonal principal meridians; steep meridian 0°-30° or 150°-180°	No asymmetric/skewed tomographic pattern suggesting irregular astigmatism
Oblique regular astigmatism	Symmetric bow-tie pattern with two approximately orthogonal principal meridians; steep meridian 31°-59° or 121°-149°	No asymmetric/skewed tomographic pattern suggesting irregular astigmatism
Irregular astigmatism	Asymmetric or non-orthogonal curvature pattern, asymmetric bowtie, inferior/superior focal steepening, skewed radial axes, or localized irregular steepening	SAI >0.50 D and/or IAI >0.50 D, interpreted together with the tomography map pattern

SAI: surface asymmetry index; IAI: irregular astigmatism index.