Correlation between Central Corneal Thickness, Corneal Curvature and Axial Length of The Eye in Myopic & Hypermetropic Patients

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Abstract

Background: The refractive errors are the most common cause of visual deterioration worldwide. Correction of refractive errors can be divided into optical & surgical methods with global tendency toward the surgical correction of refractive errors which is highly dependent on determining the central corneal thickness.

Objectives: the study was done to assess the relation between the central corneal thickness corneal curvature and axial length of the eye in myopic, and hypermetropic patients.

Patients and methods: The patients in this study were selected from the outpatient clinic of ophthalmology department, Qena University Hospital, South Valley University. The data collection sheet enclosed personal data (age, gender), visual acuity, refraction, keratometry, axial length of the eye, & central corneal thickness of 140 patients.

Results: In this study most of the cases were females (65%) in the age group (7-39y). Myopia is the most common refractive error (68%). Increasing axial length of the eye is associated with increase in myopic refraction& mild flattening of corneal curvature. Steepening of corneal curvature is associated with mild decrease of the central corneal thickness. No significant correlation detected between axial length of the eye & central corneal thickness.

Conclusion: Myopia is the most common refractive error. There is mild negative correlation between central corneal thickness & corneal curvature. Axial length of the eye has mild negative correlation with corneal curvature. While no significant correlation was detected between central corneal thickness & axial length of the eye.

Keywords: Refractive errors; Central corneal thickness; Axial length of the eye.

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Introduction

The World Health Organization (WHO), states that the most common vision problem is refractive errors. It occurs when the shape of the eye keeps light from focusing correctly on the retina. Refractive error proves to be a significant health issue as it is the second leading cause of vision loss globally (**Resnikoff et al., 2008**). Moreover, a person's vision-related daily activities may become difficult with refractive errors (**Pan et al., 2012**).

There are several options available to correct refractive errors dividing into optical and surgical methods. The preferred methods in all age categories are glasses and contact lenses (**Garamendi et al., 2005**). Spectacles are more accessible and safer. Whereas, contact lenses provide full range vision but offer an increased risk of eye infection if proper maintenance is not ensured. Nowadays, the reliance on contact lenses and glasses is reduced by the presence of refractive eye surgery, which enhances eye refraction. Laser-Assisted in Situ Keratomileusis (LASIK) is the commonly performed procedure among the surgical options **(Alhibshi et al.,2021).**

With the recent surge in corneal refractive surgeries, there is a renewed interest in understanding the correlation between corneal curvature and central corneal thickness (CCT) with other ocular biometric parameters such as axial length (AL) and refraction **(Olsen et al., 2007)**. The various ocular biometric parameters are interdependent. In spite of innumerable studies, the correlation remains elusive, as the results are quite variable. The correlation between different parameters varies with the population studied. There is a need to vividly study our population, for a better understanding of the ocular biometric properties of Egyptian eyes. Hence, a prospective cross- sectional study has been undertaken to correlate the association of CCT, corneal curvature, and AL with refractive error.

Patients and methods

This prospective, cross-sectional study was performed with the approval of the local ethics committee. Informed consent was obtained from all individuals before participation.

The patients in this study were selected from the outpatient clinic of ophthalmology department, Qena University Hospital, South Valley University. Age group between 7-39 years old, of both sexes. The study was carried out during the period from April 2021 to April 2022.

The study included two groups

Group A patients who are hypermetropic (<+8.00)

Group B patients who are myopic (<-8.00)

Inclusion criteria

1.Age group between 7-40 years old.
2.Patients with clear cornea.
3.clear lens.
4.no history of ocular surgery.

Exclusion criteria

1. Corneal opacity.
2. Cataract.
3. Pregnancy.
4. Contact lens wearer.
5. Diabetes milletus.
6.Keratoconus
7. Systemic auto immune diseases.

All participants underwent ophthalmic examination of both eyes including:

1-Visual acuity (VA): The VA was determined using Landolt's broken rings, for both uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA).

2-Autorefracto-keratometry:For assessment of the cycloplegic refraction & corneal curvature K1, K2 (NIDEK, ARK1, 2019, Japan).

3-Slit lamp examination: Careful anterior segment examination was done to examine the eyelids, the cornea, the conjunctiva, the lens & the anterior chamber of the eye.

4-Ophthalmoscopy: For fundus examination.
5-A scan: For measurement of the axial length (AL) of the eye (Quantel medical, Aviso, 2018, France).
6- Overall thicknesses of the cornea was measured using AS-OCT by spectralis (Heidelberg Engineering GmbH, Heidelberg, Germany).

Ethical Considerations

The current study has been approved by the Ethics Committee of Faculty of Medicine, South Valley University, Qena, Egypt and the ethical approval number is SVU-MED-OPH026-1-21-4-195.An official latter was taken to approach the director of ophthalmology department in SVU hospital for permission to conduct the study.Security of data base. Written consent was obtained from all patients.

Statistical analysis

Sample size is 140 patients. Data was collected & recorded and analyzed using IBM-SPSS (Statistical Package for Social Science. Ver.25. Standard version. Copyright © SPSS Inc., NY, USA. 2015). Descriptive statistics: Means, standard deviations, medians, ranges and percentages were calculated.
Correlation analysis was used to test the association between variables (person's Rank Correlation). p-value was considered significant when it is equal or less than 0.05.

Results

The study was done on 140 patients, 49 males (35%) and 91 females (65%) who presented to the outpatient clinic by refractive errors**, (Fig.1**). The percentages of myopia and hypermetropia were presented in (**Fig.2**).

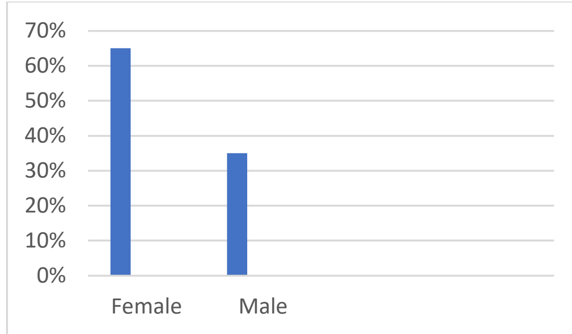

Fig.1. Percent of male to female in the study group.

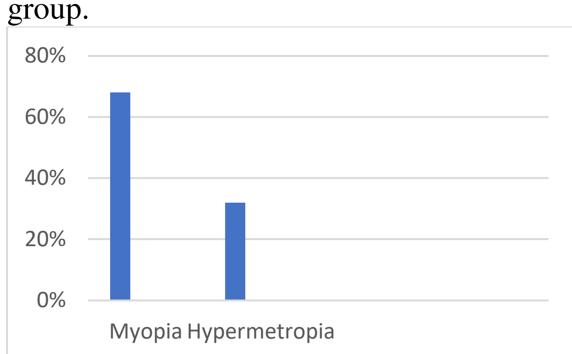

Fig.2. Percent of myopic to hypermetropic patients in the study group.

Table 1. Descriptive statistics of the continuous variables in the study in the right eye of hypermetropic patients

Descriptive Statistics			
Variables	**Minimum**	**Maximum**	**Mean ± Std. Deviation**
Age (years)	7	39	21.29± 9.661
Sphere (diopters)	+0.5+	+7.75	+1.98± 3.302
Cylinder (diopters)	00.0	+6.00	+1.1436 ± 1.08397
Corneal curvature K1(diopter)	40.25	43.75	42.4821 ± 1.63115
Corneal curvature K2(diopter)	40.50	44.50	43.9643 ± 1.57503
Axial length (mm)	20.6	23	22.82 ± 1.409
Central corneal thickness (um)	439	558	535.88 ± 27.633

This table shows that the mean age by years for the participants is 21.29y± 9.661 with minimum age is 7 years and maximum age is 39 years. Regarding the mean sphere in the RT eye, it is+1.983D ± 3.302 with minimum sphere is+ 0.5 and maximum sphere is +7.75D. While the mean cylinder is +1.1536D± 1.08397 with minimum cylinder is 00.00 & maximum cylinder is+ 6.00D. The mean of corneal curvature1 (K1) is 42.4821D ± 1.63115 with minimum K1 is 40.25D& maximum K1 43.75D, while the mean of the corneal curvature 2 (K2) is 43.9643D ± 1.57503 with minimum K2 is 40.5D& maximum K2 is 44.5D. As regard the axial length of the RT eye the mean is 22.82mm ± 1.409 with the minimum (AL) is 20.6mm & the maximum is 23.00mm, where the mean of the central corneal thickness (CCT) is 535.88um ± 27.633 with the minimum CCT is 439um & the maximum CCT is 558um, (**Table.1**).

Table 2. Descriptive statistics of the continuous variables in the study in the right eye of myopic patients

Descriptive Statistics			
Variables	**Minimum**	**Maximum**	**Mean ± Std. Deviation**
Age (years)	7	39	21.29± 9.661
Sphere (diopters)	-0.5	-7.75	-.2.136± 3.302
Cylinder (diopters)	00.0	-6.00	-1.1636- ± 1.08397
Corneal curvatureK1(diopters)	42.25	46.75	44.4821 ± 1.63115
Corneal curvatureK2 (diopters)	42.50	47.50	45.9643 ± 1.57503
Axial length (mm)	23.2	28	25.82 ± 1.409
Central corneal thickness(um)	435	556	530.88 ± 29.533

This table shows that the mean age by years for the participants is 21.29y± 9.661 with minimum age is 7 years and maximum age is 39 years. Regarding the mean sphere in the RT eye, it is-2.136 ± 3.302 with minimum sphere is -0.5D and maximum sphere is -7.75D. while the mean cylinder is -1.1636D ± 1.08397 with minimum cylinder is 00.00 & maximum cylinder is -6.00D. The mean of corneal curvature1 (K1) is 44.4821D ± 1.63115 with minimum K1 is 42.25D& maximum K1 46.75D, while the mean of the corneal curvature 2 (K2) is 45.9643D ± 1.57503 with minimum K2 is 42.5D& maximum K2 is 47.5D. As regard the axial length of the RT eye the mean is 25.82mm ± 1.409 with the minimum (AL) is 23.2mm & the maximum is 28.00mm, where the mean of the central corneal thickness (CCT) is 530.88um ± 29.533 with the minimum CCT is 435um & the maximum CCT is 556um, (**Table.2**).

Table 3. Correlation between CCT, AL, corneal curvature (1&2), sphere & cylinder measures in the study patients in the right eye

Variables		Corneal curvature 1	Corneal curvature 2	Axial length	Central corneal thickness
Sphere	r*	-.184-*	-.117-	-.799-**	-.095-
	P value	.029	.168	.000	.273
	N	140	140	140	136
Cylinder	r*	-.021-	-.372-**	-.178-*	.102
	P value	.806	.000	.036	.238
	N	140	140	140	136
Corneal curvature 1	r*	1	.870**	-.215-*	-.174-*
	P value		.000	.011	.043
	N	140	140	140	136
Corneal curvature 2	r*	.870**	1	-.240-**	-.173-*
	P value	.000		.004	.05
	N	140	140	140	136
Axial length	r*	-.215-*	-.240-**	1	.028
	P value	.011	.004		.750
	N	140	140	140	136

***Pearson's Rank Correlation Coefficient, *means ($p < 0.05$).**

Table.3 and **Fig. (3-9)** showed that:

1. There is strong positive correlation between corneal curvature 2 and corneal curvature 1where (r =.823** and P value = 0.000) figure 3.
2. There is mild negative correlation between axial length and corneal curvature 1where (r -.215-* and P value = 0.01) figure 4.
3. There is mild negative correlation between central corneal thickness and corneal curvature 1where (r =-.174-* and P value = 0.04) figure 5.
4. There is mild negative correlation between corneal curvature 1 and sphere (r =-.184* and P value = 0.029) figure 6.
5. There is mild negative correlation between axial length and cylinder where (r =-.178-* and P value = 0.036) figure 7.
6. There is negative correlation between axial length and corneal curvature 2where (r -.240-** and P value = 0.004) figure 8.
7. There is mild negative correlation between central corneal thickness and corneal curvature 2where (r =-.173-* and P value = 0.05) figure 9.
8. There is no significant correlation between axial length & central corneal thickness in the RT eye.

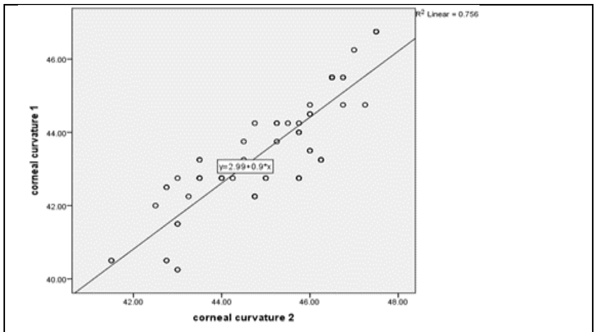

Fig.3.Correlation between corneal curvature 1 and corneal curvature 2 in the RT eye

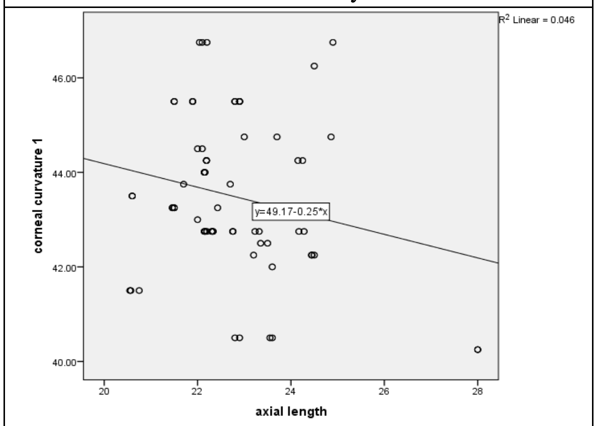

Fig.4. Correlation between corneal curvature 1 and axial length in the RT eye.

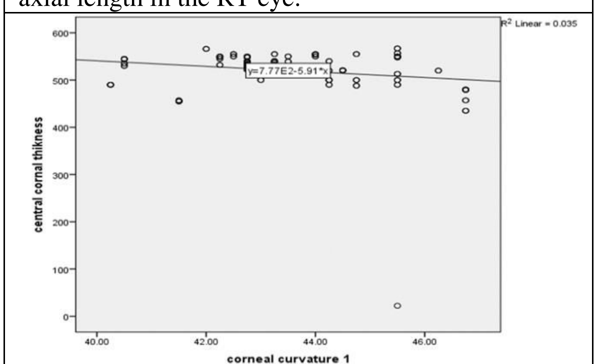

Fig.5. Correlation between central corneal thickness and corneal curvature1

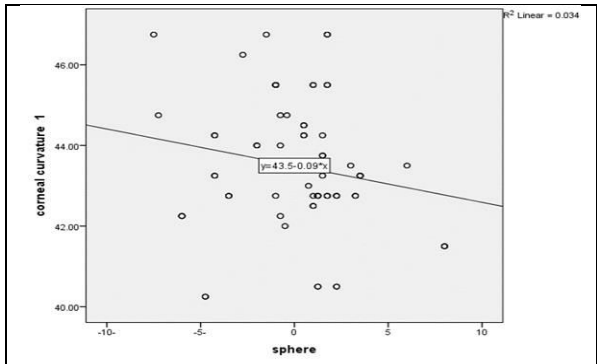

Fig.6. Correlation between corneal cuvature1 & sphere in the RT eye

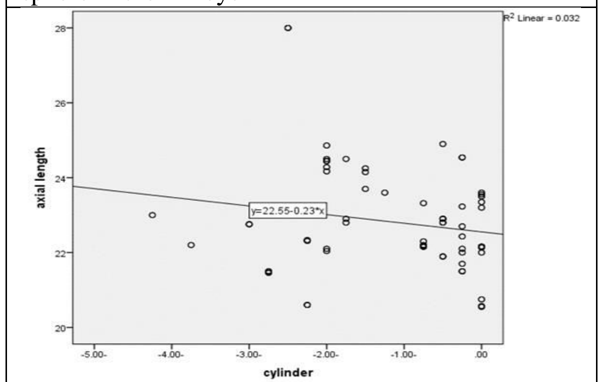

Fig.7. Correlation between axial length & the cylinder in the RT eye.

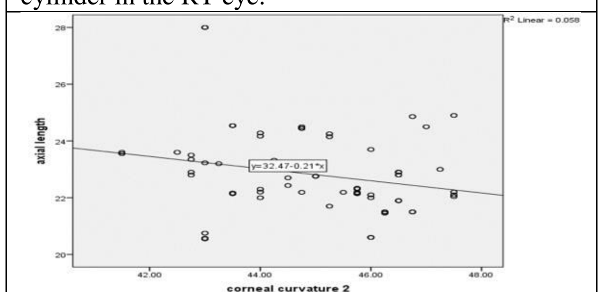

Fig.8. Correlation between axial & corneal curvature 2 in the RT eye

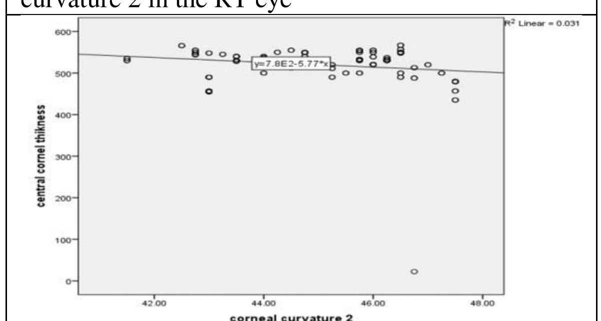

Fig.9. Correlation between central corneal thickness & corneal curvature 2 in the RT eye.

Table 4. Descriptive Statistics of the continuous variables in the study in the left eye of hypermetropic patients

Descriptive Statistics			
Variables	Minimum	Maximum	Mean ±Std. Deviation
Sphere (diopters)	+0.5	+7.75	+1.963 ± 3.54610
Cylinder (diopters)	00.0	+6.00	+1.3333 ± 1.49876
Corneal curvature K 1 (diopters)	40.00	43.5	42.6444 ± 1.69075
Corneal curvature K 2 (diopters)	41.00	44.5	43.3074 ± 1.53624
Axial length (mm)	20.22	23.00	22.95 ± 1.531
Central corneal thickness(um)	438	557	535.88 ± 27.633

This table shows that the mean sphere in the LT eye, it is +1.963D ± 3.54610 with minimum sphere is+ 0.5D and maximum sphere is +7.75D. while the mean cylinder is +1.3333D ± 1.49876 with minimum cylinder is 00.00 & maximum cylinder is +6.00D. The mean of corneal curvature1 (K1) is 42.6444D ± 1.69075 with minimum K1 is 40.00 D& maximum K1 43.5D, while the mean of the corneal curvature 2 (K2) is 43.3074D ± 1.53624 with minimum K2 is 41.00 D& maximum K2 is 44.5D. As regard the axial length of the LT eye the mean is 22.95mm ± 1.531with the minimum (AL) is 20.22 mm & the maximum is 23.00mm, where the mean of the central corneal thickness (CCT) is 535.88± 27.633with the minimum CCT is 438um & the maximum CCT is 557um (**Table.4**).

Table 5. Descriptive Statistics of the continuous variables in the study in the left eye of myopic patients

Descriptive Statistics			
Variables	**Minimum**	**Maximum**	**Mean ±Std. Deviation**
Sphere (diopters)	-0.5	-7.75	-2.153± 3.53610
Cylinder (diopters)	00.0	-6.00	-1.3533- ± 1.49376
Corneal curvature K1(diopters)	43.00	46.50	44.6434 ± 1.69065
Corneal curvature K2(diopters)	44.00	47.5	45.3084 ± 1.53634
Axial length (mm)	23.22	28	25.95 ± 1.561
Central corneal thickness (um)	436	553	530.88 ± 29.533

This table shows that the mean sphere in the LT eye, it is -2.153D ±3.53610 with minimum sphere is -0.5D and maximum sphere is -7.75D. while the mean cylinder is -1.3533D ± 1.49376 with minimum cylinder is 00.00 & maximum cylinder is -6.00D. The mean of corneal curvature1 (K1) is 44.6434D ± 1.69065 with minimum K1 is 43.00D& maximum K1 46.5D, while the mean of the corneal curvature 2 (K2) is 45.3084D ± 1.53634 with minimum K2 is 44.00D& maximum K2 is 47.5D. As regard the axial length of the LT eye the mean is 25.95mm ± 1.561with the minimum (AL) is 23.22 mm & the maximum is 28.00mm, where the mean of the central corneal thickness (CCT) is 530.88um ± 29.533with the minimum CCT is 436um & the maximum CCT is 553um, (**Table.5**).

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Table 6. Correlation between CCT, AL, corneal curvature (1&2), sphere and cylinder measures in the study patients in the LT eye

Variables		Corneal curvature 1	Corneal curvature 2	Axial length	Central corneal thickness
Age	**r***	.026	.020	.013	-.064-
	P value	.766	.816	.884	.459
	N	135	135	135	135
Sphere	**r***	.017	.118	-.857-**	-.010-
	P value	.843	.174	.000	.909
	N	135	135	135	135
Cylinder	**r***	.139	-.318-**	-.210-*	-.103-
	P value	.108	.000	.014	.235
	N	135	135	135	135
Corneal curvature 1	**r***	1	.823**	-.365-**	-.257-**
	P value		.000	.000	.003
	N	135	135	135	135
Corneal curvature 2	**r***	.823**	1	-.387-**	-.185-*
	P value	.000		.000	.032
	N	135	135	135	135
Axial length	**r***	-.365-**	-.387-**	1	-.001-
	P value	.000	.000		.995
	N	135	135	135	135
Central corneal thickness	**r***	-.257-**	-.185-*	-.001-	1
	P value	.003	.032	.995	
	N	135	135	135	135

***Pearson's Rank Correlation Coefficient, *means ($p < 0.05$).**

Table.6 and **Fig.(10-16)** showed:

1. There is mild negative correlation between central corneal thickness and corneal curvature 1where (r =-.257-** and P value = 0.003) figure 10.
2. There is moderate negative correlation between axial length and corneal curvature 1 where (r= -.365-**and P value = 0.000) figure 11.
3. There is mild negative correlation between corneal curvature 1 and sphere (r =-.875** and P value = 0.029). figure12.
4. There is negative correlation between axial length and corneal curvature 2where (r -.378-** and P value = 0.004). figure 13.
5. There is moderate negative correlation between corneal curvature 2and cylinder where (r =-.318-** and P value = 0.000) figure 14.
6. There is mild negative correlation between corneal thickness and corneal curvature 2where (r =-.185-* and P value = 0.032) figure 15.
7. There is strong positive correlation between corneal curvature 2 and corneal curvature 1where (r =.823** and P value = 0.000) figure 16.

There is no significant correlation between axial length & central corneal thickness, (**Table.5**).

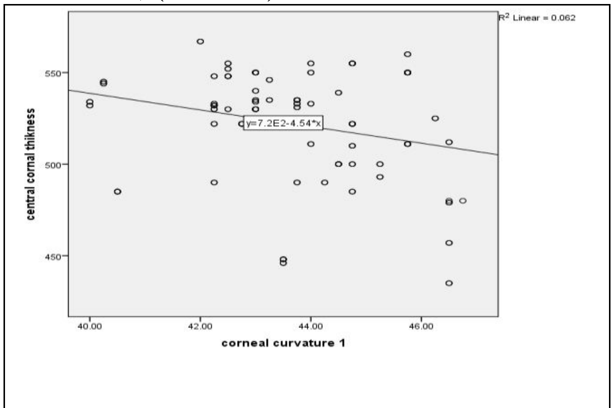

Fig.10. Correlation between central corneal thickness and corneal curvature 1in the LT eye.

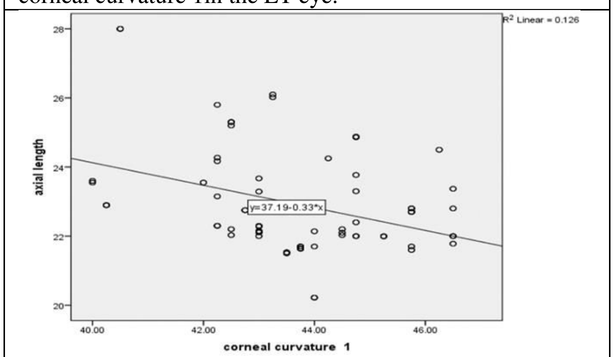

Fig.11. Correlation between axial length & corneal curvature 1in the LT eye

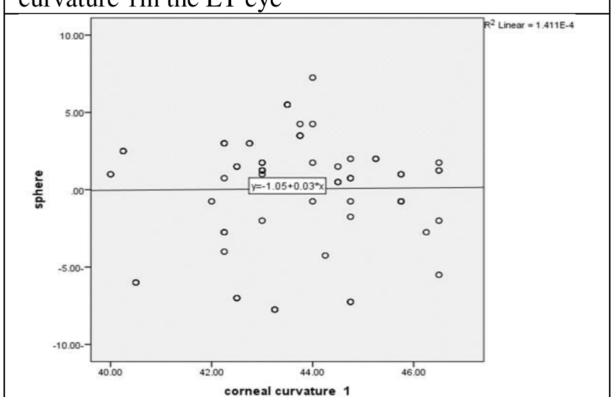

Fig.12. Correlation between the sphere & corneal curvature 1in the LT eye

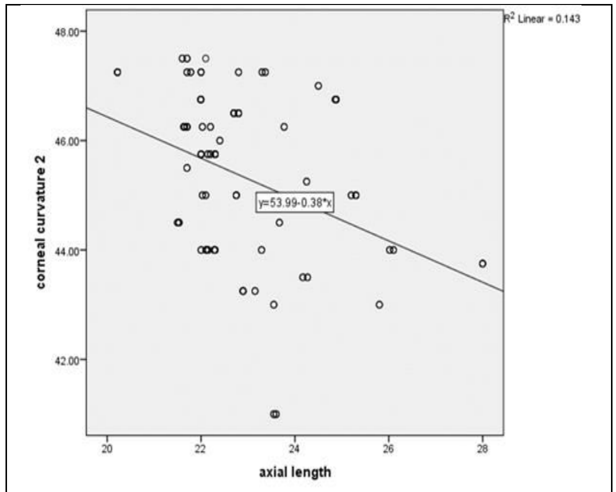

Fig.13. correlation between corneal curvature 2 and axial length in the LT eye

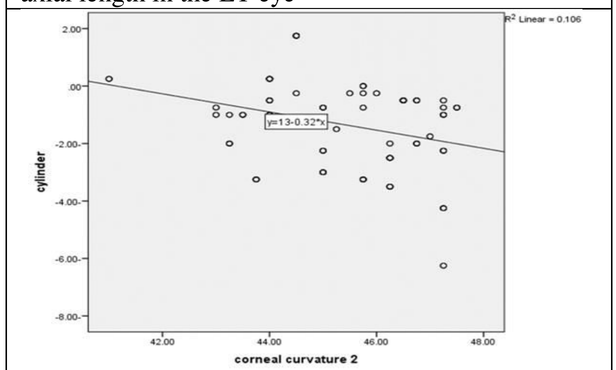

Fig.14. Correlation between cylinder & corneal curvature 2 in the LT eye

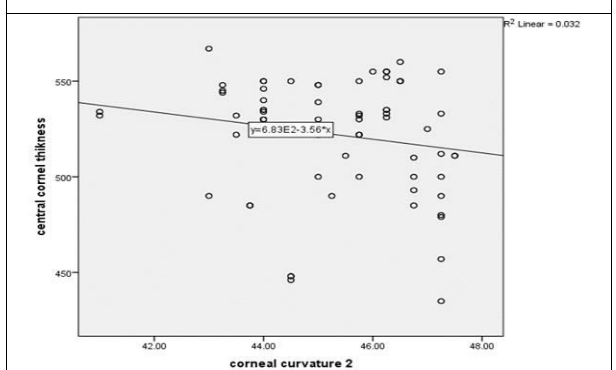

Fig.15. Correlation between central corneal thickness & corneal curvature 2 in the LT eye

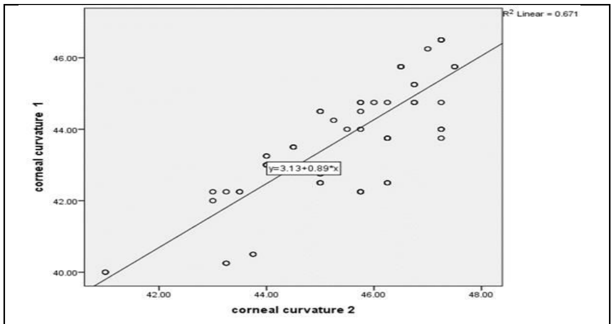

Fig.16. Correlation between corneal curvature 1 & 2 in the LT eye

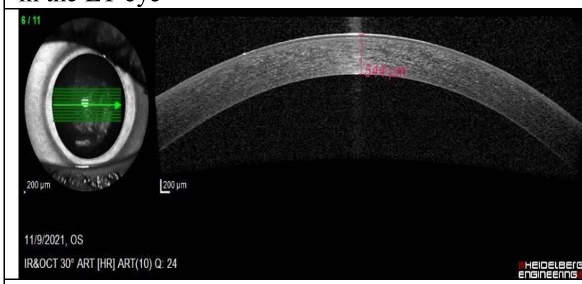

Fig.17. Central corneal thickness in hypermetropic patient.

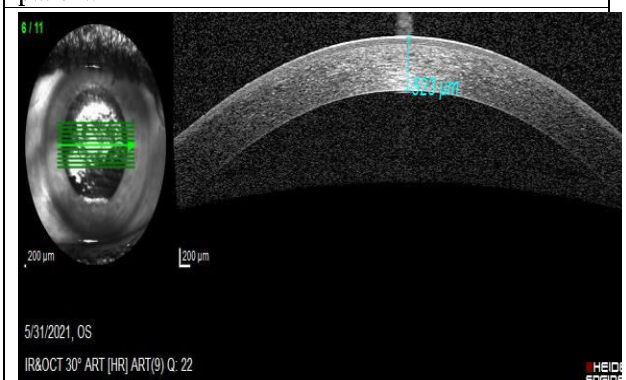

Fig.18. Central corneal thickness in myopic patient.

Discussion

Due to the increasing popularity of correction of refractive defects by excimer laser, central corneal thickness (CCT) has come to have higher prognostic significance for determination of the success of surgery and probable post-surgical complications **(Wei et al., 2014).**

A thin cornea leads to underestimation of the intraocular pressure (IOP) whereas a thick cornea results in overestimation. Due to the relationship between central corneal thickness (CCT) and IOP, low CCT values may lead to a delay in the diagnosis and treatment of glaucoma which may in turn lead to visual impairment and blindness **(Mashige,2013;Wei et al., 2014).**

We have carried out a prospective analytic study over 280 eyes (140 patients) of the Egyptians to verify the correlation between the central corneal thickness, corneal curvature & axial length of the eye.

In our study the mean of corneal curvature 1 (K1) of hypermetropic patients in the Rt & Lt eyes was (42.4821± 1.63115 D), (42.6444D ± 1.69075) respectively while the mean of corneal curvature 2 (K2) of hypermetropic patients in the Rt & Lt eyes was (43.9643 D ± 1.57503), (43.3074 D ± 1.53624) respectively. The mean of corneal curvature 1 (K1) of myopic patients in the Rt & Lt eyes was (44.4821 D ± 1.63115), (44.6434 D± 1.69065) respectively while the mean of corneal curvature 2 (K2) of myopic patients in the Rt & Lt eyes was (45.9643 D ± 1.57503), (45.3084 D ± 1.53634) respectively.

The mean of axial length of hypermetropic patients in the Rt & Lt eyes was (22.82 mm ± 1.409), (22.95 mm ± 1.531) respectively while the mean axial length of myopic patients in the Rt & Lt eyes was (25.82 mm ± 1.409), (25.95 mm ± 1.561) respectively. Our study shows that the mean of central corneal thickness of hypermetropic eyes was (535.88 um ± 27.633) & the mean of CCT of myopic eyes was (530.88 um ± 29.533).

In our study we have found that there is mild negative correlation between CCT & corneal curvature (K1, K2) which is in agreement with **(Kadhim et al.,2016; Krishnan et al., 2019).** While Shimmyo and the Tajimi study reported that CCT was positively correlated with keratometry in 1976 Americans and 2868 Japanese **(Shimmyo et al., 2003;Tong et al., 2004).**

The study of **(Kotb and Eissa, 2021)**on Egyptian adults has shown that the greater the myopic error, the steeper the cornea, with weak positive correlation between refractive error & corneal power.They also found that the central corneal thickness has shown a weak non-significant negative correlation with the absolute value of SE, meaning that the greater the myopic refractive error, the thinner the cornea (r = −0.027, p-value = 0.314). In contrast, Eyesteinsson reported no correlation between CCT and keratometry values in 925 Caucasians **(Eyesteinsson et al., 2002).**

The numerous discrepancies in the research carried out are explained by small sample size, different method of measuring the CCT, & with the decrease of the average values of the refractive error, the mean KM values have increased in the myopic group **(Chang et al., 2001**;**Kadhim et al., 2016).**

In our study we have found no significant correlation between CCT & axial length of the eye probably due to small sample size. There appears to be no consensus concerning the relationship between CCT and axial length. Corresponding to **(Chen et al., 2009)** there is no correlation between CCT and axial length.The study of Nigerian novices has found that the regression analysis shows an inverse trend in the association between CCT and AL though not statistically significant **(Hahn et al., 2003).**

There was a positive correlation between CCT with AL (r= 0.211; p=0.008) in the study of (Krishnan et al, 2019). This shows that axial myopes tend to have thicker corneas. In our study a mild negative correlation between axial length of the eye & corneal curvature (K1, K2) has been detected while a strong negative correlation has been reported by **(Arora et al.,2015)** where eyes with increased axial length have flatter corneas.

Chang et al., (2001) studied the cornea in myopic adults. CCT was evaluated by specular microscopy. They found that mean corneal thickness was 533 (SD ± 29) μm and reported thinner corneal thickness in more myopic eyes (r=0.16, P=0.021) and in cases with longer axial lengths.

A contradicting finding of a flatter cornea with increasing AL has also been reported. A subject in whom the myopia is due to the elongation of the eyeball in the initial period of ocular growth in childhood is associated with a flatter cornea. In those with adult-onset myopia, the posterior segment enlargement does not affect the anterior segment structures and are, hence, often associated with a steeper cornea. The first mechanism is Van Alphen's "size factor" and the latter reasoning is Scott and Grosvenor's "stretch factor" hypothesis **(McBrien and Adams, 1997; Kinge and Midelfart, 1999; Mutti et al., 2006;Olsen et al., 2007).**

The limitations of our study include small sample size, manual estimation of the CCT by anterior segment OCT, the study included children & adults

Conclusion

Myopia is more common than hypermetropic refractive error. There is negative correlation between central corneal thickness and corneal curvature 1.There is negative correlation between corneal thickness and corneal curvature 2.There is negative correlation between axial length and corneal curvature 1.There is negative correlation between axial length and corneal curvature 2. There is strong positive correlation between corneal curvature 2 and corneal curvature 1.There is no significant correlation between axial length & central corneal thickness.

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