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# A cross-sectional study of corneal topography and ocular parameters in patients with myopia

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ABSTRACT

**Background:** Myopia is a leading cause of visual impairment. This study aims at determining the changes in corneal asphericity, central corneal radius of curvature, anterior chamber depth, lens thickness, vitreous chamber depth, and axial length with increasing myopia.

**Materials and Methods:** Spherical equivalent refractive error of each myopic eye was determined and grouped into three, according to increasing powers of myopia. Corneal asphericity (Q value) and central corneal radius of curvature were determined using corneal topography. Anterior chamber depth, lens thickness, vitreous chamber depth, and axial length were determined using Ascan. Changes with increasing myopia was assessed.

**Result:** Among 80 myopic eyes of age group 6 to 40 years, more patients were between 21 to 30 years. 60% of them were males. 60% were low myopes (<-3D), 32% were moderate myopes (-3D to -6D) and 8% were high myopes (>-6D). Mean Q values were -0.49±0.09, -0.39±0.04 and -0.28 ±0.04 for low, moderate and high myopes respectively. Mean values of apical radius of curvature of cornea were 7.66±0.07, 7.53±0.08 and 7.35±0.07 for low, moderate and high myopes respectively. Mean values of anterior chamber depth were 3.19±0.09, 3.32±0.09, 3.88±0.08; vitreous chamber depth were 19.82±0.67, 21.66±0.24, 22.66±0.45 and axial length were 23.01±0.76, 24.98±0.32,26.54±0.51 for low, moderate and high myopes respectively. A statistically significant positive correlation of increasing degrees of myopia was observed with Q value, anterior chamber depth, vitreous chamber depth and axial length; and a statistically significant negative correlation with the apical radius of curvature.

**Conclusion:** In myopic eyes, a statistically significant relation exists between corneal asphericity and spherical equivalent refractive error such that, there is a tendency for the cornea to flatten less rapidly in the periphery with increasing myopia and eyes with higher levels of myopia have steeper central corneal curvature, with deep anterior and vitreous chamber and greater axial length.



## 1. Introduction

Myopia is a refractive error in which the light rays that enter parallel to the optical axis are brought into focus in front of the retina with accommodation being at rest. It can be due to the eyeball being elongated in the anteroposterior axis, or by an excessive corneal curvature or in the presence of lens with an increased optical power.[1] The image of the object which is projected anterior to the retina requires corrective lenses to displace the image posteriorly, thus producing a clear retinal image.[2] Refractive errors are the leading cause of moderate to severe visual impairment throughout the world, as many a times it goes undiagnosed and uncorrected. It is also the second most common cause of avoidable

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blindness.[3] The prevalence rate of myopia has increased throughout the world, and according to WHO, it is seen to increase from 22% in 2000 to 52% by 2050.[4] Myopia paves the way to ocular morbidity especially in school-going children and in young adults.[5] Myopia is caused by a wide variety of factors, ranging from genetic to environmental factors. Environmental factors are considered to be the major causative and most modifiable factors for myopia, especially in school going children, while genetic factors are responsible for a small proportion. Increased amount of time spent outdoors is found to be protective against the development and progression of incident myopia.[6] Single nucleotide polymorphisms (SNP)-based heritability estimation showed a heritability range from 25% to 35% 2050. It is more prevalent in developed and industrial areas and can affect individuals belonging to all age groups.[7] High myopia-associated genes were collagen type I, alpha 1 (COL1A1), transforming growth factor beta 1 (TGFB1), transforming growth beta-induced factor (TGIF), lumican (LUM), hepatocyte growth factor (HGF), myocilin (MYOC), paired box 6 (PAX6), and uromodulin-like 1 (UMODL1).[8]

At birth, most infants are born hypermetropic, but when the eyes grow they gradually become less hypermetropic and by the age of 5-8 years the eyes are emmetropic. The process of emmetropization refers to the adjustment in the length of the optical axis to the optical characteristics of the lens and cornea after the end of the second year of life. The development of myopia occurs when there is an overshooting of the process of emmetropization. The major structural change that takes place in myopic eyes is axial elongation, due to which alterations occur in the scleral extracellular matrix (ECM), which results in various changes in the shape of the sclera.[9]

Mild myopia is up to −1.5 D, moderate up to −6.0 D, and high myopia is −6.0 D or more. Pathological myopia occurs with greater than −8.0 D.[10] Complications of high myopia are open angle glaucoma, nuclear, cortical and posterior sub capsular types of cataract, retinal tears which may lead to a retinal detachment, myopic maculopathy which includes lacquer cracks, Foster Fuchs spot, choroidal neovascularization, chorioretinal atrophy and posterior staphyloma.[11]

Myopia is considered to be a public health problem causing visual loss and is a risk factor for various other ocular conditions.[12] Comparing the quality of life of those with low and moderate myopia, patients with a high degree of myopia suffer an impaired quality of life.[13] Hence it is important to diagnose as well as correct myopia at earlier years of life.

Correction of myopia include both non-surgical and surgical measures.[14] Non surgical measures consists of optical devices like spectacles and contact lenses.[15] Now a days surgical options for correction of myopia has gained popularity especially the refractive surgery.

Refractive surgical procedures includes radial keratotomy,[16] Excimer laser refractive surgery and intraocular surgery. Excimer laser assisted refractive surgery consists of laser-assisted sub epithelial keratectomy (LASEK) and laser-assisted in-situ keratomileusis (LASIK).[17] Both these procedures utilize laser to change the shape of the corneal tissue in order to correct the underlying refractive error by creating flaps prior to laser treatment of corneal stromal tissue. The flap in LASEK is more superficial and epithelial, whereas in LASIK it is thicker as it includes some stromal tissue from the anterior portion. The invention of femtosecond laser technique has helped to promote microkeratome free refractive surgeries. Both femtosecond laser-assisted laser in situ keratomileusis (FS-LASIK) and small incision lenticule extraction (SMILE)[18] have become the preferred surgical choice for many patients and the surgeons who perform refractive surgeries. Intraocular options include phakic intraocular lenses (pIOLs) which is another remedial method for the surgical correction of high myopia and in those with thinner corneas. Three types of lenses can be used for this purpose : anterior chamber angle-supported, anterior chamber iris-fixated, and posterior chamber phakic IOLs.[19] Therapeutic measures for slowing or halting the progression of myopia include progressive additional lenses,[20] peripheral defocusing lenses, contact lenses, overnight orthokeratology (Ortho-K),[21] multifocal soft contact lenses, outdoor activities,[22] and pharmaceutical agents like 0.01% Atropine.[23]

Assessment of the shape of the cornea is important for both cataract and refractive surgery, to screen the candidates and for analyzing its postoperative outcomes.[24] Advances in corneal mapping technology in the form of computer-aided corneal topography, or videokeratoscopes, has lead to the complete and accurate descriptions of the corneal shape prior to any procedure. The corneal topography provides clinicians and researchers with a wide range of graphical and numerical representations of the human corneal shape.[25] The cornea which is the major refractive component of the human eye, contributes to roughly about 70% of the total refractive power of the eye. The human cornea is a quadric surface with surface asphericity. The Q value, which is a quantified indicator of the aspherical degree, is defined as the radial change that occurs from centre to periphery of a quadric surface.[26] Corneal asphericity refers to the rate of change of curvature along the corneal surface from apex to periphery.

The typical shape of the human cornea is that of a prolate ellipse- which suggests that the cornea flattens from apex to periphery, and that the light rays that enters the centre of cornea tend to converge on a point in front of the peripheral rays to produce a negative spherical aberration. Normal cornea has a Q value of -0.26. Understanding asphericity is important in adaptation following any refractive surgery. The modification of spherical aberration caused by contact lenses and corneal warpage induced by rigid lenses also have been studied.[27] It is predicted that the postoperative outcome in terms of corneal shape in all myopic corneas after excimer laser surgery would be increased oblateness.[28] Newer strategies are there to control asphericity in order to keep the spherical aberration to the minimum. There is a strong correlation between the change in corneal shape and the introduction of higher-order aberrations (HOAs) which in turn leads to poor night vision, glare, halo and poor quality of visual acuity thereby causing a long term negative effect on the patient.[29] The shape of cornea which can be determined roughly by the corneal asphericity is also important for prescribing an orthokeratology lens which is used to decrease the progression of myopia.[30]

Not many studies regarding asphericity and degree of myopia has been reported from Kerala and since refractive surgeries like SMILE and LASEK are on the rise, the preoperative assessment of corneal asphericity helps to predict postoperative outcomes and can give better results. This study aims at determining the corneal asphericity for myopic patients and assessing the change in the value of corneal asphericity with increasing degrees of myopia. This study highlights on the importance of assessing the corneal asphericity value for myopic patients since it has an implication in contact lens wear and refractive surgery. The main aim of this study is to analyse the change in corneal asphericity.

The second objective is to assess the changes of ocular parameters like central corneal radius of curvature, lens thickness, axial length, anterior and vitreous chamber depth with increasing degrees of myopia.

## 2. Materials and Methods

A cross-sectional study was conducted for a period of one year from 3/6/2020 to 2/6/2021 with the IEC number B6-155/2019/MCTCR(1) at Ophthalmology out patient department, at Government medical college Thrissur, Kerala among patients diagnosed with myopia.

The study included patients > 6years up to 40 years with myopic spherical equivalent refractive error ranging from -0.5D up to -10D and with corneal cylindrical power ⩽ -1.50D. Whereas, the study excluded those not giving consent for the study and those not cooperating for measurements. Specifically, the study excluded patients with dry eyes, irregular astigmatism, corneal lesions and lens defects, uveitis and infections of the eye, anomalies of the face & orbit, open angle glaucoma, keratoconus, pseudophakia, aphakia, vitreous hemorrhage.

According to a study conducted by Leo G. Carney et al.,[31] the proportion of patients having corneal asphericity was 95%.

Sample size - Z2 pq/d2 (d- 5% of p)

= 1.96 x 1.96 x 95 x 5/ 22.56

Sample size: 80 eyes

A written informed consent was taken from all patients who participated in this study. Preliminary examination of visual acuity for distance was done with Snellen's chart and a pinhole improvement was also noted.[32] Manifest refraction was performed for all patients with tropicamide (0.8%) with phenylephrine hydrochloride (5%) eye drops, and for those less than the 18 years of age, a cyclopegic like homatropine hypobromide (2%) eye drops was used. Further, post mydriatic refractive correction test was done for these patients. Subjects were divided into three groups:

Low myopes (SE <-3D), Moderate myopes (SE -3D to -6D), High myopes (SE> -6D).[33]

Corneal asphericity (Q value) and central corneal radius of curvature were determined using placido disk based corneal topography with a computerised videokeratoscope.

A scan (Amplitude scan) was done to determine lens thickness, axial length, anterior chamber and vitreous chamber depth. Changes in each parameter was studied with increasing degrees of myopia.[34]

## 3. Results

Statistical analysis was performed using SPSS software. The mean and standard deviation was calculated in different levels of refractive errors and assessed using ANOVA and Post Hoc test. Correlations were examined using Pearson correlation test. Values of p<0.05 were considered statistically significant in all the tests.

In this study a total of 80 eyes were studied, and the following were my observations.

**Table 1:** Distribution of age

| Age | Frequency | Percentage |
|---|---|---|
| 6-12 | 20 | 25 |
| 13-20 | 21 | 26 |
| 21-30 | 22 | 28 |
| 31-40 | 17 | 21 |

**Table 2:** Distribution of gender

| Gender | Frequency | Percentage |
|---|---|---|
| Male | 48 | 60 |
| Female | 32 | 40 |

**Table 3:** Distribution of grades of myopia

| Myopia Grade | Frequency | Percentage |
|---|---|---|
| Low myope | 48 | 60 |
| Moderate myope | 26 | 32 |
| High myope | 6 | 8 |
| Total | 80 | 100 |

**Table 4:** Mean values of Q value (Corneal asphericity) and other ocular parameters such as apical ROC (apical radius of curvature in mm), ACD (Anterior chamber depth in mm), Lens thickness in mm, VCD (Vitreous chamber depth in mm) and Axial length in mm with increasing degrees of myopia

| Variables | Degrees of myopia | | | | | |
|---|---|---|---|---|---|---|
| | Low myope | | Moderate myope | | High myope | |
| | Mean | SD | Mean | SD | Mean | SD |
| Q value | -0.49 | 0.09 | -0.36 | 0.04 | -0.28 | 0.04 |
| Apical ROC | 7.66 | 0.07 | 7.53 | 0.08 | 7.35 | 0.07 |
| ACD | 3.19 | 0.09 | 3.32 | 0.09 | 3.88 | 0.08 |
| Lens Thickness | 3.45 | 0.25 | 3.47 | 0.25 | 3.56 | 0.27 |
| VCD | 19.82 | 0.67 | 21.66 | 0.24 | 22.66 | 0.45 |
| Axial length | 23.01 | 0.76 | 24.98 | 0.32 | 26.54 | 0.51 |

## 4. Results of statistical analysis

One way Anova test showed statistically significant differences in the following parameters between the three grades of myopia.

**Table 5:** One way Anova test was applied to obtain P-values

| Ocular parameters | P value |
|---|---|
| Q value | <0.001 |
| Apical radius of curvature | <0.001 |
| Anterior Chamber Depth (ACD) | <0.001 |
| Vitreous Chamber Depth (VCD) | <0.001 |
| Axial Length | <0.001 |
| Lens thickness | 0.300 |

P-values of Q value (corneal asphericity), Apical radius of curvature, Anterior Chamber Depth, Vitreous Chamber Depth and Axial Length were <0.001 and P-value of Lens Thickness was 0.300

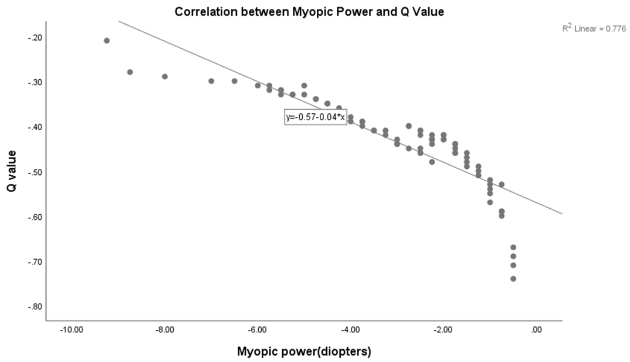


**Figure 1:** Scatter diagram depicting correlation of increasing degrees in myopia with Q-value

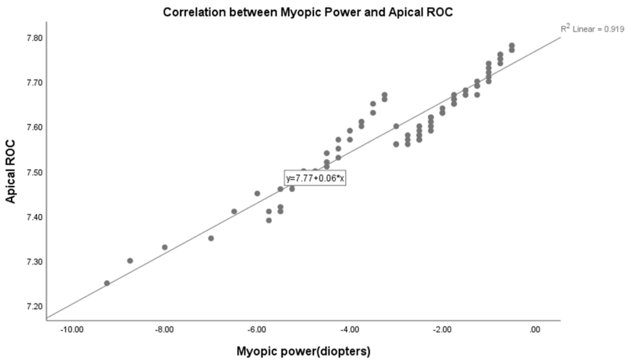


**Figure 2:** Scatter diagram depicting correlation of increasing degrees in myopia with Apical radius of curvature (ROC)

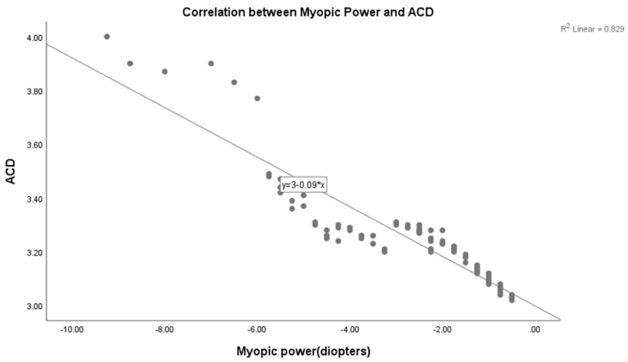


**Figure 3:** Scatter diagram depicting correlation of increasing degrees in myopia with Anterior chamber depth (ACD)

## 5. Discussion

This study was conducted among 80 myopic eyes of age group ranging from 6 to 40 years with more patients belonging to the age group 21 to 30 years. The percentage of males and females were 60% and 40% respectively. 60% of the patients were low myopes with refractive error of <-3D. 32% were moderate myopes with a refractive error in between -3D to -6D. 8% were high myopes with a refractive error of >-6D. Mean Q values were -0.49±0.09, -0.39±0.04 and -0.28 ±0.04 for low, moderate and high myopes respectively. Thus, the mean Q value increased with increasing degrees of myopia, which was similar to the result obtained in the studies conducted by D G Horner et al[35] and Zhengwei Zhang et al.[36] Mean values of apical radius of curvature of cornea were 7.66±0.07, 7.53±0.08 and 7.35±0.07 for low, moderate and

**Table 6:** Correlation coefficients of increasing degrees of myopia with Q value and other ocular parameters like apical radius of curvature, axial length, lens thickness, anterior chamber depth (ACD) and Vitreous chamber depth (VCD)

| Parameters | Pearson Correlation coefficient | Type of correlation |
|---|---|---|
| Myopia vs Q value | 0.881 | High positive |
| Myopia vs Apical ROC | -0.958 | Very high negative |
| Myopia vs ACD | 0.910 | Very high positive |
| Myopia vs VCD | 0.960 | Very high positive |
| Myopia vs Axial length | 0.974 | Very high positive |
| Myopia vs lens thickness | 0.117 | Negligible correlation |

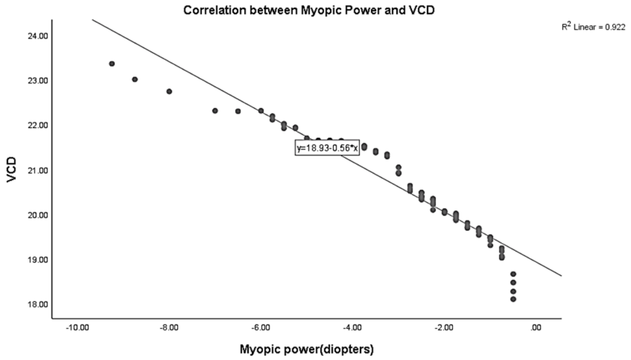


**Figure 4:** Scatter diagram depicting correlation of increasing degrees in myopia with Vitreous chamber depth (VCD)

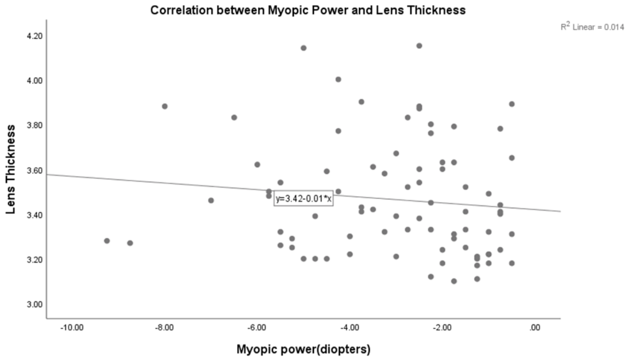


**Figure 6:** Scatter diagram depicting correlation of increasing degrees in myopia with lens thickness

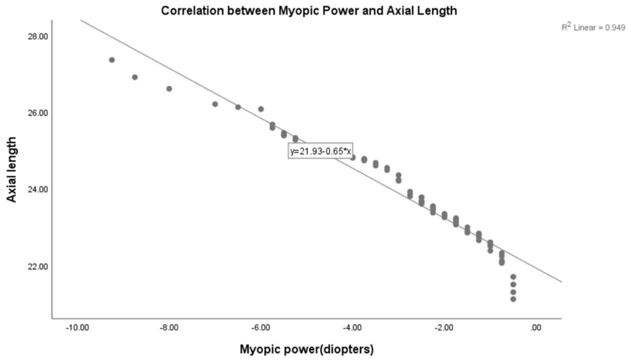


**Figure 5:** Scatter diagram depicting correlation of increasing degrees in myopia with Axial length

high myopes respectively indicating that apical radius of curvature decreased with increasing degrees of myopia. Whereas the mean values of anterior chamber depth were 3.19±0.09, 3.32±0.09, 3.88±0.08; vitreous chamber depth were 19.82±0.67, 21.66±0.24, 22.66±0.45 and axial length were 23.01±0.76, 24.98±0.32,26.54±0.51 for low, moderate and high myopes respectively, therefore showing an increase with increasing degrees of myopia. This study also showed a statistically significant positive correlation of increasing degrees of myopia with Q value, axial length, anterior chamber and vitreous chamber depth and statistically a significant negative correlation of increasing degrees of myopia with apical radius of curvature, and all these with p<0.05. The lens thickness showed negligible correlation with increasing degrees of myopia.

This study determined a statistically significant positive correlation between corneal asphericity (Q value) and myopic spherical equivalent refractive error ($\rho$=0.881, p<0.001), which was in accordance with the study conducted by Carney L G et al.[31] A study conducted by W.R Davis et al[25] found that corneal asphericity was less prolate among myopes which also was similar to our study. Koray Budak et al[37] found that higher the degree of myopia, the negative asphericity increased, and the corneal radius of curvature decreased, as in our study. This study also determined that axial length, anterior chamber and vitreous chamber depth were positively correlated with myopia and significantly increased as myopia increased, that is ($\rho$=-0.910, p<0.001), ($\rho$=0.96, p<0.001) and ($\rho$=-0.974, p<0.001) respectively, which was similar to the studies conducted by Carney L G et al[31] and Wadhwa et al.[38] The positive correlation of vitreous chamber depth with increase in degrees of myopia was similar to that obtained in the study conducted by Ruozhong Xie et al.[39] A Study done by Majumder C, Tan YC[40] determined a statistically significant increase in axial length and corneal curvature similar to this study, but there was no significant difference noted in anterior chamber depth with increase in degrees of myopia, which was contradictory to this study.

In the recent years, the number of corneal refractive surgical procedures performed worldwide has been increasing at steady pace.

The renowned interest in the analysis of human corneal topography has accompanied this rise in the number of such refractive surgical procedures, which in turn helps to determine the postoperative outcome in regard to the corneal shape and the resulting visual performance. Knowledge of the shape of the normal human cornea and the extent of variation in corneal topography between individuals is also vital for designing contact lenses, schematic eye modelling, and ocular aberration analysis.[41]

In this study, the corneal asphericity (Q value) and apical radius of curvature of the cornea was obtained using placido disc based corneal topography, however, newer machines like Orbscan and Pentacam gives more accurate results. The ocular biometric values were obtained using Ascan ultrasonography in this study; but more accurate results are obtained with immersion technique or the optical technique.

## 6. Conclusion

The study has shown that in myopic eyes, a statistically significant relation exists between corneal asphericity and myopic spherical equivalent refractive error indicating that, there is a tendency for the cornea to flatten less rapidly in the periphery with increasing degrees in myopia. The study also confirmed that eyes with higher levels of myopia have increased central corneal curvature, deeper anterior and vitreous chamber and greater axial length.

## 7. Source of Funding

None.

## 8. Conflict of Interest

None.

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