COMPARISON OF HIGHER ORDER ABERRATIONS IN KERATOCONIC EYES WITH REGULAR HIGH ASTIGMATIC EYES

DR Usman Memon 1 DR Rennie Kapoor 1 DR Zalak Shah 2 DR Helly Shah 1 DRBN Kinnari Kalaria 1
1 Nagar School of Optometry, Ahmedabad 2 Nagri Municipal Eye Hospital, Ahmedabad PIN 380008

ABSTRACT

TITLE: Comparison of higher order aberrations in keratoconic eyes with regular high astigmatic eyes.

PURPOSE: The purpose of the study is to quantify HOAs by comparing topometric measurement and anterior corneal aberrations in eyes with keratoconus and with regular high astigmatism using placido based topographer

OBJECTIVE: To understand and correlate the value and type of aberration in regular as to keratoconic induced astigmatism.

STUDY DESIGN: Cross sectional observational comparative study.

METHODS: study performed on 30 eyes as per inclusion criteria with mild to moderate keratoconus with astigmatism >3.0D and 30 eyes with regular high astigmatism with astigmatism >3.0D. Topographic indices and the total corneal wavefront were measured by placido’s disc based topographer which measures aberrations using ray tracing techniques. The wavefront aberrations upto fourth order and low, high and total RMS were analysed and compared between these groups.
**RESULTS:** All topometric indices were higher in keratoconus eyes compared to regular high astigmatism eyes (P<0.01). Higher order aberrations in regular high astigmatic eye, oblique trefoil, vertical coma, spherical aberration and secondary astigmatism were -0.10±0.14, 0.01±0.15, 0.23±0.08 and -0.07±0.06 respectively which were significantly higher in keratoconic eyes as compared with regular high astigmatism as to 0.65±0.41, -1.17±0.85, -0.51±0.38 and 0.31±0.32 respectively (P<0.01). All RMS values were found increased in keratoconic eyes (P<0.01). No significant difference was found in lower order aberrations between both the groups (P>0.05).

**CONCLUSION:** Oblique trefoil, Vertical coma, Spherical aberrations and Secondary astigmatism aberrations may useful for differentiating regular high astigmatism verses irregular high astigmatic eye.

**KEYWORDS:** Keratoconus, Regular high astigmatism, Topography, Higher order aberrations.

**Abbreviations:**

**HOAs** : Higher Order Aberrations.

**SE** : Spherical Equivalent.

**RMS** : Root Mean Square.

**I-S** : Inferior Superior Ratio.

**WTR** : With The Rule Astigmatism.

**ATR** : Against The Rule Astigmatism.

**TWA** : Total Wavefront Aberration.

**LOW RMS**: Root Mean Square of lower order aberrations

**HIGH RMS**: Root Mean Square of higher order aberrations

**TOTAL RMS**: Root Mean Square of total aberrations.
Aberrations\textsuperscript{1} are deviations from normal vision, such as blurring in an image. Most people are familiar with the terms farsightedness, nearsightedness, presbyopia and astigmatism. These are considered lower order aberrations and make up 85\% of the human eye’s vision imperfections\textsuperscript{2}. However, another category of refractive errors that has not received much attention until recently is higher order aberrations. All eyes have at least some degree of higher-order aberrations\textsuperscript{1}. With advancements in technology, it’s now possible to quantify corneal higher order aberrations and diagnose optical imperfections with precision.

The wave aberration\textsuperscript{3} defines how the phase of light is affected as it passes through the eye’s optical system, and is usually defined mathematically by a series of \textbf{Zernike polynomials}.

Zernike polynomials are used to classify and represent optical aberrations because they consist of terms of same form as the types of aberrations observed when describing the optical properties of the eye.
Higher order aberrations can be responsible for specific visual complaints such as: Glare, Halos, Starburst effect, Ghost images, Blurring etc. The optical system of eye often has several different higher order aberrations working together. This is more applicable in cases with higher corneal astigmatism like keratoconus. It is sometimes hard to single out individual symptoms that may point to specific and accurate diagnosis. Therefore it is important to accurately classify and measure higher order aberrations, especially in cases of high astigmatism and keratoconus.

FIGURE 1:

FIGURE 2:
The different wavefront measuring principles are available to measure aberrations\(^3\).

A **Hartmann-Shack aberrometer** is an outgoing wavefront aberrometer. It measures the shape of the wavefront that is reflected out of the eye from a point source on the fovea. An array of microlenslets is used to subdivide the outgoing wavefront into multiple beams which produce spot images on a video sensor. The displacement of each spot from the corresponding non-aberrated reference position is used to determine the shape of the wavefront.

A **Tscherning, or ray-tracing**, aberrometer measures an ingoing wavefront. It projects a thin laser beam into the eye, parallel to the visual axis, and determines the location of the beam on the retina by using a photodetector. Once the position of the first light spot on the retina is determined, the laser beam is moved to a new position, and the location of the second light spot on the retina is determined. Aberrations in the optical system cause a shift in the location of the light spot on the retina.

**Automated retinoscopy** is based on dynamic skiascopy. The retina is scanned with a slit-shaped light beam, and the reflected light is captured by an array of rotating photodetectors over a 360° area. The time difference of the reflected light is used to determine the aberrations.

Many aberrometers are available which measures the ocular aberrations. For early detection of keratoconus corneal aberrations are useful. Commercially available topographer measures the corneal wavefront based on Ray tracing techniques.

Keratoconus is a bilateral slowly progressive non-inflammatory corneal disorder characterised by anterior corneal protrusion and thinning of the central stroma\(^4\,^5\). The incidence of the dieses is approximately 1 in 2000 in general population\(^6\).

As the disease progresses, the anterior corneal structure changes and causes an increase in the refractive powers of the central cornea, asymmetry in the curvature between the upper and the lower cornea (with the lower cornea having a higher curvature) and a shifting of the meridian of the curve away from the horizontal plane\(^7\). These changes cause an irregularity of the cornea resulting in high astigmatism. The hallmark sign of keratoconus is irregular astigmatism\(^7\).

Due to large difference between the refractive index of air and that of the cornea\(^7\), the anterior cornea is a major contributor in refractive system of eye. Therefore, it accounts to
large percentage of optical imperfections, especially when it is distorted. Appropriate classification and measurement of anterior corneal aberrations is vital in effective management of cases of distorted cornea or keratoconus. This study therefore, attempts to compare topographic parameters and higher order aberrations in keratoconic and high astigmatic eyes.

**PURPOSE AND OBJECTIVE**

The purpose of the study is to quantify HOAs by comparing topometric measurement and anterior corneal aberrations in eyes with keratoconus and with regular high astigmatism using placido based topographer.

Objective of the study was to understand and correlate the value and type of aberration in regular as to keratoconic induced astigmatism.

**REVIEW OF LITERATURE**

- **Feizi et al and Bahram Einollahi** studied correlation between corneal topographic indices and higher-order aberrations in keratoconus. The study includes 77 normal eyes of 77 control subjects and 66 eyes of 36 keratoconic patients. The Galilei Scheimpflug analyzer was used to measure higher order aberrations of the corneal surface. The study reports significantly increased levels of HOAs. All Zernike coefficients up to the 4th order except for horizontal trefoil, and vertical and horizontal tetrafoil were significantly greater in the keratoconus group than in normal eyes (P<0.05). Root mean square (RMS) of higher order aberrations up to the 6th order and total higher order aberrations were significantly higher in the keratoconus group (P<0.05). Centrally located corneal HOAs are significantly greater in keratoconic eyes than normal controls. The study concludes that anterior and inferior displacement of the cornea
causes the majority of higher order aberrations observed in keratoconus. (Journal Of Ophthalmic And Vision Research 2013; 8 (2):113-118)

- Ariela Gordon-Shaag and Michel Millodot studied aberrations and topography in normal, keratoconus-suspect, and keratoconic eyes. They included total of 92 eyes from 78 subjects; grouped as 21 eyes of 14 subjects with suspected keratoconus, 23 eyes of 16 subjects with manifest keratoconus, and 48 normal eyes of 48 subjects (without keratoconus) using the L80 wave+, an instrument which can measure corneal topography and aberrations simultaneously with a large dynamic range making it possible to evaluate higher order aberrations to the seventh order of the Zernike polynomial function series. All ocular and corneal higher order aberrations were found to be significantly higher for keratoconic eyes as compared with normal eyes, but for suspected keratoconus the results were mixed. Corneal aberrations were higher than ocular aberrations due to compensation from the internal aberrations. Although corneal vertical coma and, to a lesser extent, ocular vertical coma were found to be good indicators for the detection of keratoconic eyes, the traditional corneal topographic value such as the inferior-superior dioptric asymmetry remains an important predictor for identifying suspected keratoconus. However ocular vertical coma and ocular higher order total root mean square also represent a good means of identifying suspected keratoconus. (Optometry And Vision Science 2012; 89 (4))

- Hatice Nur Colak et al studied comparison of corneal topographic measurements and high order aberration in keratoconus and normal eyes. They included Eighty cases diagnosed with mild (group 1), moderate (group 2), and advanced (group 3) stage keratoconus according to Amsler-Krumeich Classification and 81 healthy (control group)
cases were retrospectively examined. The mean keratometric measurements central corneal thickness values (CCT), higher order aberration (HOA), total wavefront aberration (TWA), coma, trefoil, and spherical aberration measurements were performed using Sirius topography equipment. Anterior high order corneal aberration were significantly increased in eyes with moderate and advanced keratoconus. The study concludes that anterior higher order corneal aberration measurements are a useful tool to guide the physician in diagnosis and classification of keratoconus. (Journal British Contact Lens Association 2016)

- **Buhren et al studied defining subclinical keratoconus using corneal first-surface higher-order aberrations.** They included twenty-three eyes (group 1) newly diagnosed with keratoconus; 10 eyes (group 2) asymptomatic fellow eyes that showed neither major topographic anomaly nor clinical signs of keratoconus; 127 healthy eyes of 74 patients served as negative controls (group 3). A seventh order Zernike decomposition of first-surface aberrations was performed. Clinically normal fellow eyes with early keratoconus showed significant differences in first-surface aberration compared to that of normal eyes and could therefore be considered as eyes with subclinical keratoconus. (American Journal Of Ophthalmology 2007; 143 (3): 381-389)

- **Jafri et al studied higher order wavefront aberration and topography in early and suspected keratoconus.** This study included 70 eyes, diagnosed using topography (Tomey TMS-1) and aberrometry (Alcon LADARWave). Topography and clinical evaluation were used to classify the eyes into three groups: 50 normal eyes, 10 eyes with early keratoconus and 10 eyes with suspected keratoconus. Data is analyzed to determine if measurement of higher order aberrations could separate eyes with early and suspected keratoconus from normal eyes. The product of the inferior-superior (I-S) topographic value in combination with the wavefront vertical coma also was evaluated to determine whether this could distinguish normal eyes from eyes with early
and suspected keratoconus. Differences in vertical coma, root mean square coma, and secondary astigmatism for three groups were statistically significant. Although both vertical coma and the I-S topographic value were useful for distinguishing among the three study groups, a combination of wavefront aberrometry and videokeratography appears to be the most sensitive way for distinguishing among normal eyes, eyes with suspected keratoconus, and eyes with early keratoconus. (Journal Of Refractive Surgery 2007;23 (8): 774-781)

METHODOLOGY

The cross sectional observational comparative study carried out at Shree C.H Nagri Eye Hospital of Ahmedabad. Thirty eyes of 26 subjects with keratoconus and 30 eyes of 19 subjects with regular high astigmatism between July 2018 to January 2019 were enrolled in the study. Counselling of all patients was done to educate them about the purpose of the study.

Inclusion Criteria:-

Pre-diagnosed keratoconus patient. They presented with at least one of the following signs: Stromal thinning, Fleischer’s ring, or Vogt’s striae observed by slit lamp examination and topography with symmetric bow-tie pattern with or without skewed axes, inferior or central steepening, mean keratometry >47 D to <51 D and inferior superior (I-S) value >1.4D according
to the Rabinowitz and McDonnell criteria. All keratoconus patients had mild to moderate keratoconus with astigmatism >3 D to < 7 D with age 5 to 30 years.

In the normal group only ocular abnormality was refractive error and having corneal astigmatism >3 D to < 7 D with normal topography (i.e regular bowtie pattern, mean keratometry <47 D, mean I-S <1.4 D) with age 5 to 30 years were included.

**Exclusion Criteria:**

Patients with keratoconus and/or higher corneal astigmatism with ocular, systemic and developmental ailments.

For keratoconus group patient who had corneal scarring, cataract, or other corneal disease except keratoconus and those with contact lens warphage or who had undergone corneal surgery were excluded.

**Method:**

Complete ophthalmic examination that includes slit lamp biomicroscopy, best spectacle corrected visual acuity using snellen chart, intraocular pressure measurements and fundus examination was performed for all recruited patients. Soft contact lens user participants were asked to stop wearing soft contact lenses for at least two weeks and rigid gas permeable contact lenses for at least four weeks before obtaining measurements.

The total corneal wavefront was measured by Zeiss Atlas 9000 topographer (Carl Zeiss Meditec AG) which is based on placido’s disc principle which measure aberrations using ray tracing techniques. The wavefront aberrations described using Zernike polynomials.

All the measurement were taken by a skilled person to avoid examiner specific errors.

**Topographic procedure:**

The patient was properly positioned on the chin rest and forehead strap. The patient was asked to blink several times than open both eyes and stare at fixed target after obtaining proper alignment the automatic release mode started the scan. The
measurement results were checked under a quality specification window; only the measurement with high quality were included. Topographic data such as Simulated flat keratometry, steep keratometry, astigmatism over 3mm zone mean inferior superior ratio (I-S) was recorded.

Corneal aberrometric parameters were also analysed over 6.0mm aperture. The Higher order aberration (HOA) were quantified using the root mean square(RMS) as index of image quality. The wavefront aberrations up to 4th order, HOAs RMS and total RMS (RMS of lower and higher order aberrations) of mild to moderate keratoconus eyes and regular high astigmatism eyes were recorded and analyzed.

**FIGURE 3:** Corneal wavefront aberrations described by Zernike polynomials measured with Atlas 9000 topographer.
FIGURE 4: Topography map of regular high astigmatic subject with symmetric bowtie pattern on axial curvature map.

FIGURE 5: Topography map of keratoconus subject showing mild asymmetric bowtie with inferior superior ratio is >1.50D.
Data including age, Spherical equivalent (SE) Refraction, keratometry reading, Zernike coefficients and root mean square (RMS) of HOAs and total RMS were expressed as mean±standard deviation. Independent student t-test (Unpaired) was used to compare HOAs between the study groups. P values less than 0.05 were considered as statistically significant.
Total 45 subjects were included in the study. In that 27 subjects were male and 18 subjects were female. Thirty eyes of mild to moderate keratoconus (26 subjects) and 30 eyes of normal regular high astigmatism (19 subjects) were evaluated and analyzed (can be presented by a graph as well).

**GRAPH 1: Age Distribution.**

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Keratoconus group</th>
<th>Normal group</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.5</td>
<td>18</td>
<td>20.40</td>
</tr>
<tr>
<td>18</td>
<td>18.73</td>
<td></td>
</tr>
<tr>
<td>18.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBJECTS</td>
<td>NUMBER OF EYES</td>
<td>MEAN VALUE</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------</td>
<td>------------</td>
</tr>
<tr>
<td>Keratoconus</td>
<td>30</td>
<td>18.73</td>
</tr>
<tr>
<td>Regular high astigmatism</td>
<td>30</td>
<td>20.40</td>
</tr>
</tbody>
</table>

Above graph 1 showing mean age of keratoconus was 18.73±4.59 and 20.40±6.76 of regular high astigmatism subjects. There was no statically significant difference in age group between keratoconus group and regular high astigmatism group (P=0.268).

TABLE 1: Refraction, Keratometry readings, Keratometric Astigmatism and Mean I-S in the study groups.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Normal Group</th>
<th>Keratoconus Group</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphere (D)</td>
<td>-1.48±0.83</td>
<td>-3.01±1.11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cylinder (D)</td>
<td>-3.85±0.54</td>
<td>-3.10±0.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Spherical Equivalent (D)</td>
<td>-3.41±0.80</td>
<td>-4.56±0.88</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean K (D)</td>
<td>43.5 5±1.57</td>
<td>46.82±1.56</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Keratometric Astigmatism (D)</td>
<td>4.14±0.56</td>
<td>4.87±1.05</td>
<td>0.001</td>
</tr>
<tr>
<td>Mean I-S (D)</td>
<td>0.22±0.72</td>
<td>2.27±2.28</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Above Table 1 compares refractive data and topometric data between the groups. All values were found higher in keratoconus group.
Table 2 showing no significant difference between the group in lower order aberrations: Z(2,-2) Oblique Astigmatism, Z(2,2) With the rule / Against the rule astigmatism (P>0.05).

Third order aberrations were vertical coma Z(3,-1) and oblique trefoil Z(3,-3) found higher in keratoconus group (P<0.01) and no significant difference found in horizontal coma Z(3,1), and Z(3,3) horizontal trefoil (Table 3).

In fourth order aberration the Spherical Aberration Z(4,0) and Secondary Astigmatism Z(4,2) were found higher in keratoconus group (P<0.01) and no difference found in Oblique Quatrefoil Z(4,-4), oblique Secondary Astigmatism Z(4,-2) and horizontal quatrefoil Z(4,4) (P>0.05) (Table 3)

We also compared the root mean sphere (RMS) of lower order aberration (LOW RMS), higher order aberration (HIGH RMS) and total RMS between the groups. All RMS values increased in keratoconus eyes (P<0.01) (Table 4).

TABLE 2: Comparison of Zernike coefficients of lower order aberrations between the normal and keratoconic eyes.

<table>
<thead>
<tr>
<th>Lower Order Aberrations</th>
<th>Normal Group (µm)</th>
<th>Keratoconus Group (µm)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z(2,-2) Oblique Astigmatism</td>
<td>0.07±2.02</td>
<td>0.24±3.42</td>
<td>0.81</td>
</tr>
<tr>
<td>Z(2,2) WTR/ATR Astigmatism</td>
<td>-3.47±2.08</td>
<td>-3.65±1.81</td>
<td>0.722</td>
</tr>
</tbody>
</table>
GRAPH 2: The mean oblique astigmatism in keratoconus group was $0.24 \pm 3.42$ and $0.07 \pm 2.02$ in regular high astigmatism group ($P > 0.05$).
GRAPH 3: The mean With the rule astigmatism / Against the rule astigmatism in keratoconus group was -3.65±1.81 and -3.47±2.08 in regular high astigmatism group (P>0.05).

TABLE 3: Comparison of Zernike coefficients of higher order aberrations (HOAs) between the normal and keratoconic eyes.

<table>
<thead>
<tr>
<th>Higher Order Aberrations</th>
<th>Normal Group (µm)</th>
<th>Keratoconus Group (µm)</th>
<th>P-Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z(3,-3) Oblique Trefoil</td>
<td>-0.10±0.14</td>
<td>0.65±0.41</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Z(3,-1) Vertical Coma</td>
<td>0.01±0.15</td>
<td>-1.17±0.85</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Z(3,1) Horizontal Coma</td>
<td>0.04±0.25</td>
<td>0.06±0.79</td>
<td>0.869</td>
</tr>
<tr>
<td>Z(3,3) Horizontal Trefoil</td>
<td>0.00±0.13</td>
<td>0.13±0.49</td>
<td>0.171</td>
</tr>
<tr>
<td>Z(4,-4) Oblique Quatrefoil</td>
<td>0.004±0.04</td>
<td>0.02±0.20</td>
<td>0.612</td>
</tr>
<tr>
<td>Z(4,-2) Oblique 2nd Astigmatism</td>
<td>0.01±0.05</td>
<td>-0.02±0.45</td>
<td>0.731</td>
</tr>
<tr>
<td>Z(4,0) Spherical Aberration</td>
<td>0.23±0.08</td>
<td>-0.51±0.38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Z(4,2) WTR/ATR 2nd Astigmatism</td>
<td>-0.07±0.06</td>
<td>0.31±0.32</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Z(4,4) Horizontal Quatrefoil</td>
<td>-0.04±0.07</td>
<td>-0.05±0.19</td>
<td>0.811</td>
</tr>
</tbody>
</table>

P<0.01 statically significant.
a= unpaired t-test*
GRAPH 4: The mean oblique trefoil in keratoconus group was 0.65±0.41 and -0.10±0.14 in regular high astigmatism group (P<0.01).
GRAPH 5: The mean vertical coma in keratoconus group was -1.17±0.85 and 0.01±0.15 in regular high astigmatism group (P<0.01).

GRAPH 6: The mean horizontal coma in keratoconus group was 0.06±0.79 and 0.04±0.25 in regular high astigmatism group (P>0.05).
GRAPH 7: The mean horizontal trefoil in keratoconus group was $0.13\pm0.49$ and $0.00\pm0.13$ in regular high astigmatism group ($P>0.05$).

GRAPH 8: The mean oblique quatrefoil in keratoconus group was $0.02\pm0.20$ and $0.004\pm0.04$ in regular high astigmatism group ($P>0.05$).
GRAPH 9: The mean oblique 2\textsuperscript{nd} astigmatism in keratoconus group was -0.02±0.45 and 0.01±0.05 in regular high astigmatism group (P>0.05).

GRAPH 10: The mean spherical aberration in keratoconus group was -0.51±0.38 and 0.23±0.08 in regular high astigmatism group (P<0.01).
The mean secondary astigmatism in keratoconus group was 0.31±0.32 and -0.07±0.06 in regular high astigmatism group (P<0.01).

The mean horizontal quatrefoil in keratoconus group was -0.05±0.19 and -0.04±0.07 in regular high astigmatism (P>0.05).

<table>
<thead>
<tr>
<th></th>
<th>Keratoconus group</th>
<th>Normal group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WTR/ATR 2ND ASTIGMATISM</strong></td>
<td>0.31</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

**TABLE 4:** Comparison of Root Mean Squares (RMS) between the normal and keratoconic eyes.
GRAPH 13: The mean lower order RMS in keratoconus group was 5.18±0.95 and 4.44±0.58 in normal regular astigmatism group (P 0.01).
GRAPH 14: The mean higher order RMS in keratoconus group was 2.00±0.72 and 0.46±0.10 in normal regular high astigmatism group (P<0.01).

GRAPH 15: The mean total RMS of keratoconus group was 5.60±0.96 and 4.48±0.58 in normal regular high astigmatism (P<0.01).
DISCUSSION

Visual aberrations may be low or high order aberration. Myopia astigmatism and hypermetropia make up the low order aberrations while oblique astigmatism, coma, trefoil and spherical aberrations count as higher order aberrations. Higher order aberrations cannot be corrected with spherocylinder glasses.

Optical aberration resulting reduced visual quality and blurred images. Higher order aberrations can have important effect on retinal image quality in subjects. The optical properties of the corneal surface are highly important in determining the retinal image because about 80% of all aberrations occur on the anterior surface of the cornea. Thus corneal aberration measurement have become increasingly in ophthalmology and optometry.

Previous studies compared normal eyes with astigmatism <1.5 diopters with keratoconus eyes. In our study we compared regular high astigmatism (normal eyes) with keratoconus who had mild asymmetric bowtie on topography with high astigmatism >3.00D.

In this study we used placid based topographer to analyze anterior corneal aberrations. Anterior corneal surface which is most effective surface of the optical system in keratoconus eye. Our aim of the study was to compare corneal aberrations in regular high astigmatism subjects and keratoconus. Previous study compared aberrations at 6mm apertures so that results can be comparable so we had also measured aberrations at 6mm aperture because it was reported that aberrations are increased with increasing pupil size.

Lower order aberrations are Z(2,-2) oblique astigmatism, Z(2,2) WTR/ATR astigmatism. In present study we could not find significant difference in keratoconus and regular high astigmatism eyes in lower order aberrations.

Sepehr feizi et al studied oblique trefoil, vertical coma, spherical aberration and Z(4,2) secondary astigmatism was -0.15±0.22, 0.004±0.37, 0.23±0.09 and -0.04±0.12 in normal group and in keratoconus group was 0.48±1.07,-1.78±1.73, -0.59±1.09 and 0.11±0.61 respectively. They found all these aberrations were significantly increased in keratoconus eyes(P<0.01) In our study oblique trefoil, vertical coma, spherical aberration and oblique
secondary aberration was -0.10±0.14, 0.01±0.15, 0.23±0.08 and -0.07±0.06 in normal group and in keratoconus group was 0.65±0.41, -1.17±0.85, -0.51±0.38 and 0.31±0.32 respectively (P<0.01). Result of our study is similar to Sepehr feizi study.

Ariela Gordon-Shaag et al compared aberration in normal eyes with keratoconus suspect and keratoconus eye. In their study vertical coma and high RMS in normal group was -0.040±0.22 and 0.390±0.43 and in keratoconus group was -1.542±0.69 and 1.980±0.85 respectively. They found all these aberrations were significantly increased in keratoconus eyes (P<0.01). In our study vertical coma and high RMS in normal group was 0.01±0.15 and 0.46±0.10 and in keratoconus group was -1.17±0.85 and 2.00±0.72 respectively (P<0.01). Our results are co-relate with Ariela Gordon-Shaag et al study.

Hatice Nur Colak et al compared total coma, total trefoil, total spherical aberrations in normal and keratoconus eyes. We compared Zernike polynomials between the groups so result are not exactly comparable. They found increased corneal aberrations in keratroconus eyes similar to present study. Jens Buhren et al reported coma aberration was significantly increased in keratoconus eyes.

The result of our study also demonstrated that horizontal coma, trefoil and quadrefoil aberrations were not significantly higher in keratoconus eyes compared to regular high astigmatism group (P>0.01).

**LIMITATION**

The measurement obtained only single center with single instrument. We measured aberrations at one pupil size (6mm) so that comparison with other studies could be made. Aberrations at different pupil size may beneficial to co relate between both the groups.

The larger sample size, would perhaps have been beneficial to differential between the groups.

**CONCLUSION**
Oblique trefoil, Vertical coma, Spherical aberrations and Secondary astigmatism aberrations may useful for differentiating regular high astigmatism verses irregular high astigmatic eye.

Horizontal trefoil, horizontal coma, horizontal quatrefoil has lesser impact on keratoconus.

Anterior and inferior displacement of cornea causes the majority of higher order aberrations observed in keratoconus.

REFERENCES

1) Troy Bedinghaus. Signs of higher order aberrations 2018. available at www.verywellhealth.com


conflict of interest : NIL