Research Article

High-Order Aberrations in Keratoconus and Keratoconus Suspect

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Abstract
Introduction: Keratoconus is the most common primary corneal disease. It is a bilateral ectatic corneal degeneration characterized by localized corneal thinning which leads to protrusion of the thinned cornea. **Patients and Methods: Study design:** A retrospective comparative study. **Ethical considerations:** The Local Research Ethics Committee, Faculty of Medicine, Minia University approved this study. The study adhered to the tenets of the Helsinki Declaration. **Results: Demographic Data:** The mean age of the entire cohort was 29.2±7.7 years (range: 18-54 years). Fifty-four patients (35.6 %) were males and 96(64.4%) were females. Fifty patients (33.33%) had clinical keratoconus, 50(33.33%) were keratoconus suspects and 50(33.33%) were normal subjects were recruited and included in the analysis. The mean age of the clinical keratoconus group was 29.2 ± 7 years (range 19-52 years). Twenty-six patients (52%) were males and 24(48%) were females. The mean age of the keratoconus suspect group was 30.7 ± 8.9 years (range 19-52 years). Thirteen patients (26%) were males and 37(74%) were females. The mean age of the normal control group was 27.6 ± 6.9 years (range 18-41 years). Fifteen subjects (30%) were males and 35(70%) were females. There is a significant difference in vertical coma, spherical aberrations, RMS HOA and RMS of total aberrations between the 3 groups. And there is a significant difference in RMS HOA and RMS of total aberrations between the KCS and normal group.
Keywords: Keratoconus, corneal disease, vertical coma.

Introduction
Keratoconus is the most common primary corneal disease. It is a bilateral ectatic corneal degeneration characterized by localized corneal thinning which leads to protrusion of the thinned cornea[(1)]

The disease is progressive, for moderate levels of keratoconus, a rigid gas permeable contact lens provides the best vision and for severe cases, keratoplasty needs to be performed. Therefore, techniques for detecting keratoconus and following the progression of the disease are valuable to the clinicians, as they lead to better patient management[(2)].

Screening early keratoconus patients is also essential in the field of refractive surgery as operating on an undetected keratoconic cornea (Keratoconus suspect (KCS)) is a major cause of post-Lasik complications[(3)].

Clinical keratoconus (KC) can be reliably detected with corneal topography or slit lamp examination. In contrast, detection of sub-clinical keratoconus in its earliest stages represent a diagnostic challenge and cause confusion[(4)].

A comprehensive approach of combining multiple corneal features is needed for early detection of subclinical keratoconus. One of the main tools that were used in detecting subclinical keratoconus is Videokeratoscopy., which had numerous limitations, especially compared with the newly developed elevation-based topography[(5)].

Morever, there are many other technologies that show different aspects in subclinical keratoconus, like biomechanics features and wave front aberrations[(6)].

Higher order aberrations (HOAs) between keratoconic and normal eyes shows significantly higher levels of ocular and corneal aberrations in comparison to normal eyes[7].

Based on results of these studies, HOAs can be used to distinguish early Keratoconus from normal and to grade the severity of Keratoconus[8].

Additionally, correlation between corneal topographic indices such as irregularity and keratometry with HOAs was demonstrated in a previous study[9].

Our aim of work is to compare high order aberrations (HOAs) between keratoconus (KC), Keratoconus Suspects (KCS) and normal eyes.

Patients and Methods

Study design:

A retrospective comparative study.

Ethical considerations:

The Local Research Ethics Committee, Faculty of Medicine, Minia University approved this study. The study adhered to the tenets of the Helsinki Declaration.

Electronic database Search and Study Population:

The electronic medical record system of Roaa Eye Center, Minia, Egypt was searched for 150 eyes: 50 eyes with clinical keratoconus and 50 eyes with keratoconus suspects, as well as 50 normal eyes of age-matched controls applying the following criteria:

Inclusion criteria:

Clinical keratoconus:

Age ≥ 18 years.

Patients diagnosed with keratoconus were classified according to Topographical keratoconus classification in pentacam

Keratoconus suspect eyes:

Age ≥ 18 years.

According to data reported in literature

1-Anterior and Back elevation.

Anterior elevation map differences between the BFS and the corneal contour between +12μm and +15μm

Back elevation map differences between the BFS and the corneal contour between +17μm and +20μm

2- Suspected D value.

3- High steep bow-tie.

Normal eyes:

Age ≥ 18 years.

Absence of any abnormality on front sagittal curvature, front elevation, back elevation, pachymetric or Belin-Ambrosio displays.

Exclusion criteria:

Quality Specification indicating unreliable examination (The QS must be OK).

Evidence of corneal or lens opacity on any of Scheimpflug images.

Evidence of pseudophakia, aphakia, intrastromal corneal rings or phakic IOL on Scheimp flug images.

History of previous corneal refractive surgery or cross-linking as indicated in the EMR system.

Study Parameters:

1- The following parameters were extracted from the EMR system and Pentacam. The Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) system uses a rotating Scheimpflug camera and a monochromatic slit-light source that rotate together around the optical axes of the eye for measuring the anterior segment topography .and then transferred into an Excel worksheet:

1- Patients' demographic data (age and sex) from EMR system.

2- Anterior and Back elevation from 4 maps refractive display

3- D value from Belin Ambrosio display.

4- Keratoconus grade from Topometric display.

5- Vertical and horizontal coma aberrations from Zernicke Polynomials display.

6- Spherical aberrations from Zernicke Polynomials display.

7- Trifoil aberrations from Zernicke Polynomials display.

8- Root mean square (RMS) values for high-order (HOA) and total-order aberrations (TOA) from Zernicke Polynomials display.

Results

Demographic Data:

The mean age of the entire cohort was 29.2 ± 7.7 years (range: 18-54 years). Fifty-four patients (35.6 %) were males and 96 (64.4%) were females. Fifty patients (33.33%) had clinical keratoconus, 50(33.33%) were keratoconus suspects and 50(33.33%) were normal subjects were recruited and included in the analysis. The mean age of the clinical keratoconus group was 29.2±7 years (range 19-52 years). Twenty-six patients (52%) were males and 24 (48%) were females. The mean age of the keratoconus suspect group was 30.7 ± 8.9 years (range 19-52 years). Thirteen patients (26%) were males and 37(74%) were females. The mean age of the normal control group was 27.6 ± 6.9 years (range 18-41 years). Fifteen subjects (30%) were males and 35 (70%) were females **(Table 1).**

Table1: Demographic data of the entire cohort and each study group.

		Entire Cohort	KC Group	KCS Group	NC Group
		n=150	n=50	n=50	n=50
Age	**Mean ± SD (yrs.)**	29.2±7.7	29.2±7	30.7±8.9	27.6±6.9
	Range (yrs.)	18-54	19-52	19-52	18-41
Sex	**M No. (%)**	54 (33.6)	26 (52)	13 (26)	15 (30)
	F No. (%)	96 (64.4)	24 (48)	37 (74)	35 (70)

There is a significant difference in vertical coma, spherical aberrations, RMS HOA and RMS of total aberrations between the 3 groups. And there is a significant difference in RMS HOA and RMS of total aberrations between the KCS and normal group.

Discussion

Keratoconus is a progressive disease of the cornea that leads to a decrease in visual acuity due to corneal thinning and irregular astigmatism. Although visual acuity can often be restored in most patients through the use of glasses or rigid contact lenses, complex corneal grafting procedures are ultimately indicated in approximately 10-20% of keratoconus patients[(10)].

Detection of suspect keratoconus among refractive surgery candidates is important because keratorefractive procedures may lead to postsurgical ectasia in these eyes. The increasing volume of patients interested in refractive surgery and the new treatment options available for keratoconus have generated a higher interest in achieving a better characte-rization of this entity[(11)]

The purpose of our study was to determine if the difference in corneal high order aberrations between keratoconus, keratoconus suspects and normal controls can be used for early detection of keratoconus to prevent postoperative ectasia .

In our study we chose to deal with corneal aberrations as it would seem more informative to evaluate corneal aberrations rather than the entire ocular aberrations (which include both corneal and internal aberrations) when dealing with corneal distortions and ectasia.

Furthermore, the anterior surface of the cornea represents the most important contributor to the optics of the eye due to the large difference in refractive indices.

Finally, corneal aberrations are not limited by pupil size as are ocular aberrations. Jafri *et al* compared the aberrations of the total eye not only of the cornea.[(12)]

We relied on the Amsler-Krumeich system for classifying keratoconus eyes, as it is the oldest and still the most widely used classification. This system was used by several studies[(13)].

The AK system grades keratoconus into 4 stages based on spectacle refraction, central keratometry, presence or absence of scarring and central corneal thickness[(14)].

Other studies such as the Collaborative Longitudinal Evaluation of Keratoconus (CLEK)

study used changes in vision, keratometry, biomicroscopic signs, corneal scarring, and vision-specific quality of life, as measures to define stage and severity of disease. Topographic analysis was not used in either the AK or CLEK classification[15] used topographic patterns described by Bogan's and colleagues for classification of keratoconus[16].

In addition, we included 50 keratoconus suspects who had abnormal anterior elevation in 4 maps refractive display as the anterior elevation map differences between the BFS and the corneal contour between +12μm and +15μm. And abnormal back elevation in 4 maps refractive display as Back elevation map differences between the BFS and the corneal contour between +17μm and +20μm, suspected D value in belin abmbrosio / enhanced ectasia display and high steep bow-tie in 4 maps refractive display in axial/sagittal curvature part.

Therefore, we believe that a comprehensive approach that includes: the corneal curvature map, elevation map, and corneal HOAs, should be evaluated collectively when diagnosing subclinical keratoconus and selecting eligible patients prior to refractive surgery.

Also, this early detection may aid in early management decisions of the disease (by methods such as collagen cross-linking) and thus improve quality of life by virtue of delaying (if not eliminating) the need for subsequent corneal transplantation.

Recommendations

We recommend that further studies should investigate more charachteristic features between KCS and normal eyes using different diagnostic corneal indices in order to improve early KC detection and to decrease post-LASIK complications.

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