BENHA MEDICAL JOURNAL bmj

Print ISSN 1110-208X

Online ISSN 2357-0016

Original article

Comparison between Anterior Segment Optical Coherence Tomography and Pentacam in the Diagnosis of Keratoconus

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Received:

Accepted

Abstract

Background: Keratoconus is a prevalent ectatic disorder marked by progressive bilateral corneal thinning, resulting in a conical corneal shape. This non-inflammatory thinning primarily occurs in the infero-temporal region, serving as a key diagnostic feature for keratoconus. **This study aimed** to compare the efficacy of Anterior Segment Optical Coherence Tomography (AS-OCT) in detection of subclinical keratoconus with the efficacy of Pentacam. **Methods:** This was a comparative cross-sectional study designed to compare the efficacy of AS-OCT in detection of subclinical keratoconus with the efficacy of Pentacam. The study included 30 eyes of patients aged between 18-40 years old from both sexes, presenting with astigmatism more than -2.00 Diopters. The methodology involved a Corneal thickness measurements were obtained using AS-OCT and Pentacam Scheimpflug imaging. Data collection adhered to specific inclusion and exclusion criteria. **Results**: Association between pentacam diagnosis and other studied parameters showed a significantly higher measurement of autorefraction cylinder, K1 and K2 readings keratoconus cases compared to free and suspect groups. Another significantly higher distribution of positive slit lamp findings in keratoconus group compared to suspect and free groups. Association between Optical Coherence Tomography (OCT) diagnosis and the other parameters studied showed a significantly higher measurements of autorefraction cylinder in keratoconus and suspect cases compared to the free group. There was a significantly greater prevalence of the "ask for Laser-Assisted in Situ Keratomileusis " complaint within the free group as opposed to the suspect and keratoconus groups. OCT results compared to pentacam results as true positive, false positive, true negative and false negative. **Conclusion:** AS-OCT provides reliable pachymetric maps and Pentacam demonstrates elevation and curvature maps giving it the upper hand in detecting subclinical keratoconus. AS-OCT can be used in the screening of highly astigmatic corneas for detecting early keratoconus.

Keywords: Anterior Segment Optical Coherence Tomography; Keratoconus; Optical Pentacam.

Introduction

Keratoconus is the most common ectatic disorder, characterized by bilateral and progressive corneal thinning. The cornea takes on a conical shape due to non-inflammatory protrusion and thinning. Focal corneal thinning occurs in the infero-tempozral corneal location, and this distinctive thinning pattern aids in diagnosing keratoconus (1).

Moderate and severe stages of keratoconus are clinically and topographically diagnosable, while distinguishing subclinical keratoconus from normal cases is challenging. Suspected cases benefit from Anterior Segment Optical Coherence Tomography (AS-OCT), which offers reliable pachymetry maps capable of detecting keratoconus, ectasia, and corneal thinning before Laser-Assisted In Situ Keratomileusis (LASIK) (2).

Post-LASIK ectasia, a rare and vision-threatening complication, requires the identification of absolute and relative risk factors and their LASIK-specific cut-off values. Key risk factors for keratectasia include abnormal preoperative corneal topography suggestive of keratoconus (3).

The Pentacam HR (Oculus) employs a rotating Scheimpflug camera system to analyze high-resolution anterior segment images. It facilitates topographic assessment of corneal surfaces, elevation changes, anterior chamber characteristics, and corneal aberrations (4).

AS-OCT offers extensive analysis of anterior segment applications, encompassing anterior chamber biometry, angle evaluation, and LASIK-related measurements. It also aids in assessing the LASIK flap's postoperative status (5).

In keratoconus patients, Optical Coherence Tomography (OCT) pachymetry maps accurately detect characteristic abnormal thinning using four parameters based on the central 5-mm diameter. These parameters include Inferior–Superior Ratio (I–S) (average inferior octant thickness minus average superior octant thickness), IT–SN (average inferotemporal octant thickness minus average superonasal octant thickness), Minimum (thinnest corneal thickness), and Minimum–maximum (minimum pachymetry minus maximum pachymetry) (6).

Asymmetrical changes in these four parameters can identify global and focal thinning. Keratoconus is suspected with asymmetry exceeding -45 µm for I–S or IT–SN, Minimum thickness less than 470 µm, or a Minimum–maximum difference greater than -100 µm. A single abnormal parameter raises suspicion, while two or more confirm diagnosis. This method demonstrates sensitivity and specificity akin to the topographic keratometry, I-S, astigmatism, and skew percentage (KISA) (7).

The purpose of this study was to compare the efficacy of AS-OCT in detection of subclinical keratoconus with the efficacy of the Pentacam.

Patients and methods

This was a comparative cross-sectional study designed to compare the efficacy of AS-OCT in detection of subclinical keratoconus with the efficacy of Pentacam.

The study included 30 eyes of 18 patients aged between 18-40 years old from both sexes, presenting with astigmatism more than -2.00 diopters (D) to the outpatient clinic at Benha University Hospital and Giza memorial institute of Ophthalmic research.

The study was conducted in the period between October 2022 to October 2023.

An informed written consent was obtained from the patients. Every patient received an explanation of the purpose of the study and had a secret code number. The study was done after being approved by the Research Ethics Committee, Faculty of Medicine, Benha University.

Code Number: MS.20-12-2022

Exclusion criteria were history of previous ocular surgery, any ocular abnormalities, other than refractive error, eyes with late keratoconus changes, such as corneal scars or hydrops because they do not pose a diagnostic challenge, systemic medications that could affect the cornea.

Methodology:

All patients were subjected to the following: **Patient History:** Personal history: name, age, sex, occupation, special habits, past medical history: diabetes mellitus, hypertension, rheumatoid arthritis, asthma and cardiac disease, past surgical history: history of any surgical procedures, history of blood transfusions and history of trauma.

Full ophthalmologic examination: Uncorrected and best corrected visual acuity, cycloplegic refraction, slit lamp examination includes careful corneal examination searching for keratoconus or corneal scarring, complete dilated fundus examination, the corneal thickness were measured using Pentacam High-Resolution (HR) (Oculus) and the AS-OCT (Optovue), all measurements were taken between 10 AM and 3 PM (at least 2 hours after awaking), when corneal thickness was considered stable, contact lens wearers were asked to cease lens wearing for 1 week prior to data collection. Anterior segment OCT was used to detect corneal thickness then, Pentacam Scheimpflug imaging was done to assess corneal thickness, curvature, and elevation by the same investigator. The corneal thickness measurements were measured using the Oculus Pentacam HR (Oculus, Lynnwood, WA, USA) and the Fourier Domain OCT (FD-OCT) (Optovue, Inc., Fremont, CA).

Imaging devices: AS- OCT: The OCT-based corneal topographer, a 1310 nm swept-source device, captured 8192 points

during 0.34 second for 16 radial scans of the corneal topography. The success rate of precisely digitizing the corneal surfaces, patterns of the color-coded maps, central corneal thickness (CCT), and central axial power were compared between OCT and Pentacam. The pachymetry map was divided into zones by octants and annular rings. We approached OCT pachymetry maps diagnosis for early keratoconus using four parameters based on the central 5-mm diameter of the pachymetry map (Figure 1).

Figure 1: Anterior Segment Optical Coherence Tomography used in this study.

These four parameters are:

I–S: The average inferior octant thickness (I) minus the average superior octant thickness (S)

IT–SN: the average inferotemporal octant thickness (IT) minus the average superonasal (SN) octant thickness

Minimum: the thinnest corneal thickness.

Minimum–maximum: the minimum pachymetry minus the maximum pachymetry.

Using these four parameters, we got diagnostic cut-off points for these parameters.

Keratoconus was diagnosed when: asymmetry that is more than −45 µm for I–S or IT–SN, minimum thickness of less than 470 µm, minimum– maximum difference more than −100 µm. One abnormal parameter was keratoconus suspect. Two or more abnormal parameters provided a definitive keratoconus diagnosis (Figure 2).

Pentacam: It was approached via 4 Maps Refractive

Figure 2: Pentacam used in this study.

Keratoconus: Red on Red Maximal curvature, Maximal Elevation anterior and posterior surface and thinnest point coincide, inferior position of thinnest point, pattern recognition: island pattern (Keratoconus) / Asymmetrical bowtie with skewed radial axis by 22 degree.

Free: Red on Blue (maximal curvature and minimal elevation values coincide), symmetrical bowtie pattern (Astigmatism) in elevation- and curvature maps.

Sagittal Curvature Map: Inferior steepening $K_{inferior}$ - $K_{superior}$

< +1.4 D is suspicious.

< + 1.9 D is pathological.

Elevation Maps difference anterior / posterior surface

Normal: Anterior elevation > 6 μm. Posterior elevation > 8 μm.

Suspicious: Anterior elevation 8 -12 μm. Posterior elevation 12 -20 μm.

Pathological: Anterior elevation < 12 μm. posterior elevation < 20 μm.

Pachymetry: Thinnest point < 500 μm, inferior position of the thinnest point, relative pachymetry: < -5 % at the thinnest point (for untreated corneas).

Belin/Ambrosio-Enhanced-Ectasia
Display: Elevation maps with exclusion zone, Pachymetric Progression, Indices.

Sample size: Calculated using epi info soft calculator version 3 (8) based on Elhenawi et al.,2018 study results (odds ratio =17). C.I 95% power of the study 80% the minimal calculated sample size is 22 eyes and increased to 30. The patients presented to the outpatient clinic at Benha University Hospital and Giza memorial institute of Ophthalmic research (9).

Statistical analysis

Statistical analysis was done by SPSS v25 Armonk, NY: IBM Corp). Descriptive statistics included mean and standard deviation (± SD) for numerical data and frequency/percentage for non-numerical data. Analytical statistics encompassed the use of the Shapiro-Wilk test to assess data normality, repeated ANOVA for parametric variables with repeated measures, Kruskal-Wallis test was used to assess the difference between more than two study group non parametric variables, Chi-Square test was used to examine the relationship between two qualitative variables. P-value considered significant if <0.05 at a 95% confidence level.

Results

The current study was carried on 30 subjects underwent OCT and pentacam examination to compare efficacy of AS-OCT in detection of subclinical keratoconus with the efficacy of the Pentacam. Their mean age of the studied subjects was 29.1±7.5 years. Half of the studied subjects (50%) were under 30 years old, while the other half (50%) were over 30 years old. Females represented 53.3% while males were 46.7%. Table 1

According to complaint, (76.7%) complained of wanting to undergo LASIK, (16.7%) complained of a change in their spectacle prescription, and (6.7%) were for follow-up purposes. In terms of slit lamp findings, (83.3%) had no findings and (16.7%) had positive slit lamp findings (Vogt striae, Fleischer ring). The mean autorefraction cylinder of the studied subjects was -3.8 D with a standard deviation of 0.9 D, and the median was -4.1 D. The range of values for the autorefraction cylinder measurement was -4.6 to -2.1 D. The mean K1 reading of the studied subjects was 43.7 D with a standard deviation of 1.9 D. The median K1 reading was 43.3 D, and the range of values was 41.1 to 48.1 D. The mean K2 reading of the studied subjects was 46.5 diopters (D) with a standard deviation of 2.7 D. The median K2 reading was 46.4 D, and the range of values was 42.3 to 51.9 D. Table 2

According to visual acuity of the studied subjects, the majority of subjects had a BCVA of 6/9 (53.3%), (33.3%) had a BCVA of 6/6, while a smaller proportion had a BCVA of 6/60 (13.3%). According to pentacam diagnosis, (76.7%) had a free diagnosis, (20%) were diagnosed with keratoconus, and (3.3%) of cases were classified as suspect. According to OCT diagnosis, (46.7%) had a free diagnosis, (26.7%) were diagnosed with keratoconus and (26.7%) of cases were classified as suspect. Table 3

Table 1: Demographic data in the studied subjects

Variable		Toral cases (n=30)
Age (years)	Mean ± SD	29.1±7.5
	Median (Range)	29 (18-40)
Age groups, n (%)	<30 years	15 (50%)
	>30 years	15 (50%)
Gender, n (%)	Female	16 (53.3%)
	Male	14 (46.7%)

Table 2: Classification of the eyes according to complaint, Slit lamp finding, Autorefraction Cylinder, K1, K2 reading in the studied subjects

Variable		Toral cases (n=30)
Complaint, n (%)	Ask for lasik	23 (76.7%)
	Change spectacle	5 (16.7%)
	Follow up	2 (6.7%)
Slit lamp findings, n (%)	Negative	25(83.3%)
	Positive	5(16.7%)
Autorefraction Cylinder (D)	Mean ± SD	-3.8±0.9
	Median (Range)	-4.1(-4.6--2.1)
K1 reading (D)	Mean ± SD	43.7±1.9
	Median (Range)	43.3(41.1-48.1)
K2 reading (D)	Mean ± SD	46.5±2.7
	Median (Range)	46.4(42.3-51.9)

Table 3: Visual acuity, Pentacam, OCT diagnosis in the studied subjects

Variable		Toral cases (n=30)
BCVA, n (%)	6/60	4 (13.3%)
	6/9	16 (53.3%)
	6/6	10 (33.3%)
Pentacam diagnosis, n (%)	Free	23(76.7%)
	Keratoconus	6(20%)
	Suspect	1(3.3%)
OCT diagnosis, n (%)	Free	14(46.7%)
	Keratoconus	8(26.7%)
	Suspect	8(26.7%)

Discussion

AS-OCT is a non-invasive imaging modality that provides high-resolution cross-sectional images of the anterior segment of the eye, including the cornea. It enables detailed visualization of corneal layers and structures, facilitating early detection of changes associated with keratoconus (10).

Pentacam, on the other hand, employs Scheimpflug imaging to capture detailed information about the cornea's anterior and posterior surfaces (11).

In the present study the mean age of the participants in the study was 29.1±7.5 years. Fifty percent of the participants were under 30 years old, and an equal percentage (50%) were over 30 years old. Females accounted for 53.3%, while males comprised 46.7% of the sample.

Confirming our findings, Said and colleagues in (2023) carried out a study to assess and included 110 eyes divided into two groups: KC eyes and normal eyes. The study group included 62 eyes with topographic evidence of KC. The control group included 48 eyes of normal subjects with no topographic evidence of KC (12).

In line with the current study, a study done in 2018 included 40 eyes of healthy young adults (22 females, 18 males) with high myopic astigmatism (-4.038 D± 1.194). The mean age ± SD was 24.1 ± 5.702 (range: 16-31) years (9).

In the current study, the mean autorefraction cylinder was recorded as -3.8±0.9 diopters. The median value, represented by -4.1 diopters within a range of -4.6 to -2.1 diopters. This indicates a significant level of astigmatism, which is consistent with the expected astigmatic changes in keratoconus.

A study in (2014) found a similar range of cylinder values in keratoconus patients, showing the significance of astigmatism as a diagnostic parameter (13).

In the current study, the mean K1 reading was measured at 43.7 diopters (D) with a standard deviation of 1.9 D. The median K1 reading, which stood at 43.3 D, along with the range of values spanning from 41.1 to 48.1 D. The mean K2 reading was recorded at 46.5 diopters (D) with a standard deviation of 2.7 D. The median K2 reading, noted as 46.4 D, and the range of values spanning from 42.3 to 51.9 D.

Similar findings have been reported in other studies in 2013, who demonstrated that the mean K1 and K2 values were significantly steeper in keratoconus eyes compared to normal eyes, emphasizing the importance of these readings in diagnosing keratoconus (14).

In a study by Thulasidas and colleagues in (2020), they found that both devices were capable of detecting keratoconus-related changes. The mean K1 and K2 values they reported were comparable to the current study findings, supporting the consistency of these parameters in diagnosing keratoconus.

In 2021scientists found statistically significant differences in keratometric measurements between Scheimpflug imaging and AS-OCT in normal eyes, but they did not attempt to define interchangeability in keratoconic eyes. This agrees with our approach of comparing the two techniques specifically in the context of keratoconus (15).

Then in 2021 researchers studied corneal thickness (CCT) and total corneal thickness (TCT) in keratoconus eyes using both Pentacam and AS-OCT measurements and found poor agreement between the two methods, which supports our focus on comparing the efficacy of the two techniques in detecting subclinical keratoconus (16).

It was demonstrated that there is a good agreement between methods in measuring central corneal thickness (CCT) up to a certain threshold, beyond which Pentacam measurements tended to be overestimated (17).

In line with the current study, it was indicated in 2008 that OCT pachymetry can serve as a diagnostic indicator for keratoconus. They found that OCT pachymetry is sensitive and specific, comparable to topographic parameters like KISA % (18).

In contrast, it was suggested that OCT pachymetry maps yield more accurate results, particularly for post-LASIK corneas (19).

It was shown that both CCT and TCT measurements increased in patients with severe dry eye disease when measured using Pentacam or AS-OCT (20).

In concurrence with the present study, some researchers underscored the significance of AS-OCT in the diagnosis of keratoconus and the evaluation of keratoconus suspects. They propose that AS-OCT holds value for the diagnosis of keratoconus and the assessment of patients pre-refractive surgery (21).

Conclusion

In conclusion, our study demonstrates that AS-OCT and Pentacam technologies demonstrated distinct diagnostic patterns where AS-OCT provides reliable pachymetric map while Pentacam further demonstrates elevation and curvature maps giving it the upper hand in detecting subclinical keratoconus. Nevertheless, a significant p value was detected using kappa agreement for AS-OCT and pentacam results which shows that AS-OCT can be used in the screening of highly astigmatic corneas for detecting early keratoconus.

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To cite this article: Ahmed R. Mohamed, Amr I. Sharawy, Ahmed A. Shebl Comparison between Anterior Segment Optical Coherence Tomography and Pentacam in the Diagnosis of Keratoconus. BMFJ XXX, DOI: 10.21608/bmfj.2024.278024.2045