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Original Article

Custom Anterior Segment Optical Coherence Tomography Indices for Detection of Corneal Ectasia

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Abstract

Introduction: Corneal thinning and changes in the corneal thickness profile are major symptoms of corneal ectasia. The anterior segment optical coherence tomography is currently widely used, and the development of additional indices may lead to improvements in the diagnostics of keratoconus.

Aim: To determine the diagnostic value of newly developed custom anterior segment OCT indices in diagnosing corneal ectasia.

Patients and methods: Two sets of patients were included in the current study - healthy controls in the first and patients with corneal ectasia in the second, 80 eyes per group of 43 patients each. The groups were age- and sex-matched. Each patient underwent a standard ophthalmological examination (visual acuity, tonometry, slit lamp examination, fundus biomicroscopy), a corneal topography with OCULUS Keratograph 5M, and an anterior segment optical coherence tomography with RTVue-100. Besides the indices automatically generated by the software of the device, we measured the following custom parameters: partial corneal area (PCA), partial chamber area (PCA), and an index that reflects the relation between the two (CpC). All measurements were performed in two axial pachymetric scans, one vertical and one horizontal using the built-in software.

Results: A statistically significant difference was found between the two groups (p<0.001, confidence Interval 95%) for all the proposed indices in both the vertical and the horizontal scans. The ROC analysis showed promising results for differentiation between the groups with the area under the curve (AUC) in the range from 0.892 for the vertical partial anterior chamber area to 0.984 for the vertical CpC index.

Conclusions: The proposed indices can be used to differentiate between normal and ectatic corneas.

Keywords

anterior segment OCT, corneal ectasia, keratoconus

INTRODUCTION

Keratoconus is the most common corneal ectatic disease. It is noninflammatory[1,2], bilateral, and is characterized by corneal thinning that leads to protrusion and irregular change of corneal shape. Until recently, diagnosing corneal ectasias was based on several clinical features – the patient's refractive error, standard keratometry, presence of Vogt striae, Fleischer's ring, Munson's sign, and some others. The topographic maps[3,4] and topometric indices[5-7] that are

genereted by the corneal topographs/tomographs have led to improvement in the diagnostics of keratoconus.

Nowadays, the anterior segment optical coherence tomography (AS-OCT) is a widespread technology which plays an important role in diagnosing many ocular diseases, such as corneal distrophies[8], glaucoma[9-11], ocular tumors[12,13], keratits[14-16], etc. In patients with ectasia, it offers information that is mainly related to the corneal thickness[17,18] and epithelial thickness[19,20]. The current study provides novel indices that may aid in the diagnosis of corneal ectasia.

AIM

The aim of the current study was to determine the diagnostic capablities of the newly developed anterior segment optical coherence tomography indices in diagnosing corneal ectasia.

PATIENTS AND METHODS

Two sets of patients were included in the current study - healthy controls in the first and patients with corneal ectasia in the second, 80 eyes per group of 43 patients each. The groups were age- and sex-matched.

Inclusion criteria for the ectasia group were:
- Kmax values above 47 diopters
- Corneal astigmatism above 3 diopters
- Asymmetrical topographical map consistent with corneal ectasia

Inclusion criteria for the control group were:
- Kmax values under 47 diopters
- Symmetrical topographical map consistent with corneal astigmatism

Exclusion criteria for the ectasia group were:
- Significant corneal scarring
- Corneal hydrops
- Previous crosslinking.

Exclusion criteria for the control group were:
- Corneal astigmatism greater than 3 diopters
- Myopia or hyperopia greater than 5 diopters
- History of keratitis
- Ocular surgery.

Each patient underwent a standard ophthalmological examination (visual acuity, tonometry, slit lamp examination, fundus biomicroscopy), a corneal topography with OCULUS Keratograph 5M (Oculus, Germany), and an anterior segment OCT with OptoVue RTVue-100 (OptoVue, USA). In addition to the indces that were automatically generated by the software of the device, we measured the following custom parameters: partial corneal area (PCA), partial chamber area (PCA), and an index that reflects the relation between the two (CpC). Using the built-in software of the device, we measured the area occupied by the cornea **(Fig. 1)** in an axial pachymetry scan. The measurements were performed for the horizontal and vertical scans. The partial anterior chamber area **(Fig. 2)** was measured after connecting the two opposite sides of the posterior corneal surface. The results were given in square millimeter.[2] We noticed a reduction in the partial corneal area accompanied by an increase in the partial chamber volume. The CpC index reflects the relation between the two (partial corneal area divided by the partial chamber area).

The statistical analysis was performed using SPSS version 15 included the following statistical tests: Mann-Whitney U test, the independent-samples *t*-test, and ROC (Receiver Operating Characteristic Analysis).

RESULTS

We examined 80 eyes of 43 patients in each group. Each group consisted of 23 men and 20 women. The average age of the control group was 34.40 years, while in the ectasia group it was 34.56 years **(Table 1)**.

Mean values, standard deviation, minimum and maximum value of the examined parameters are shown in **Table 2**. In the control group, the partial corneal area had

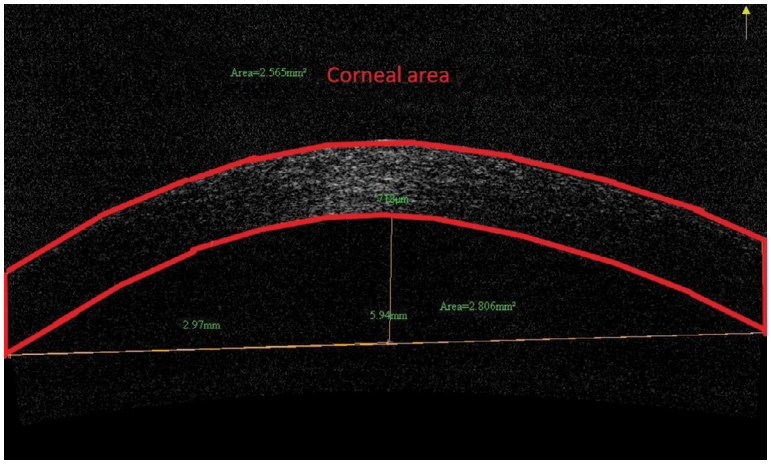

Figure 1. Partial corneal area in a pachymetric scan.

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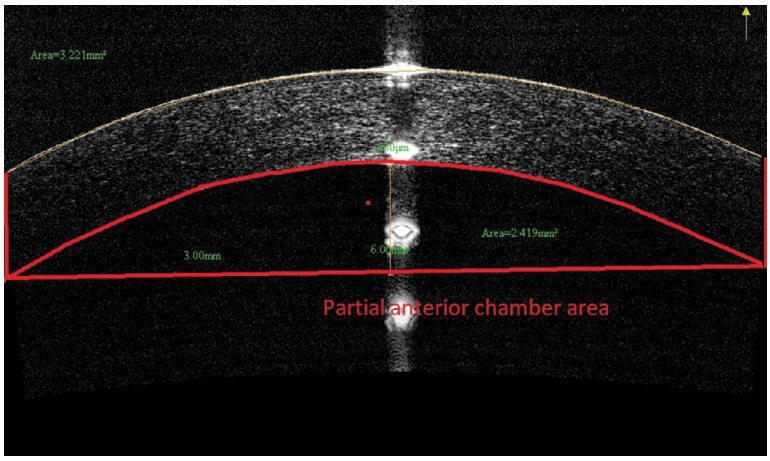

Figure 2. Partial anterior chamber area in a pachymetric scan.

Table 1. Demographic characteristics

	Avg. age	St. dev.	Median	Min	Max
Control group	34.4	11.427	32	19	66
Ectasia group	34.56	11.591	32	19	66

Table 2. Mean values, standard deviation, range, and results

Index	Group with ectasia n=80				Control group n=80				*p*	
	Mean	St. dev.	Min	Max	Mean	St. dev.	Min	Max		
Partial corneal area Horizontal*	2.886	0.241	2.246	3.598	3.328	0.198	3.038	3.949	F=2.441	0.001
Partial corneal area Vertical*	2.859	0.233	2.354	3.355	3.323	0.196	3.024	3.999	F=4.865	0.001
Partial chamber area Horizontal**	2.903	0.267	2.422	3.837	2.532	0.113	2.271	2.838	Z=−9718	0.001
Partial chamber area Vertical**	2.884	0.255	2.473	3.782	2.563	0.116	2.315	2.870	Z=−8715	0.001
CpC (horizontal)**	1.003	0.126	0.723	1.316	1.317	0.094	1.089	1.579	Z=−10713	0.001
CpC (vertical)**	1.000	0.127	0.679	1.232	1.299	0.093	1.109	1.565	Z=−10758	0.001

* Independent sample *t*-test; ** Mann-Whitney U-test

higher mean values when compared to the partial anterior chamber area. It was exactly the opposite in the group with ectasia. When it comes to the CpC index, the mean values were higher in the control group for both the vertical and the horizontal one **(Table 2)**.

After performing the Shapiro-Wilk test, only the data for partial corneal area showed a normal distribution, so we used the independent-samples *t*-test to compare the means. For the rest of the parameters, we used Mann-Whitney U-test. The null hypothesis was rejected for all of the suggested indices ($p<0.001$ and confidence interval of 95%).

We performed a ROC analysis **(Table 3)**. The horizontal partial corneal **(Fig. 3)** area had an AUC of 0.931, sensitivity of 0.859, specificity of 0.841, and cut-off value of 3.121. The vertical one had a higher AUC – 0.945. The sensitivity and specificity were 0.872 and 0.841, respectively, with a cut-off value of 3.135.

In comparison with the two partial corneal areas, there was a greater difference between the two examined partial chamber areas **(Fig. 4)**. The horizontal one had AUC of 0.938 and specificity, sensitivity, and cut-off values of 0.897, 0.864, and 2.643, respectively. The vertical partial chamber area had a lower AUC of 0.892. The sensitivity and specificity were 0.846 and 0.975, respectively, while the cut-off value was almost the same (2.664).

The two CpC indices that showed the relation between the corneal area and the chamber area in the scan had a higher AUC of 0.982 (for the horizontal) and 0.984 (for the vertical) **(Fig. 5)**. The two indices had the same cut-off value (1.189) and specificity (0.920), but different sensitivity – 0.936 for the horizontal and 0.946 for the vertical.

Table 3. ROC analysis of partial corneal area, partial chamber area and CpC index

Variable	Area	Std. Errora	Cut-off	Sensitivity	Specificity
Partial corneal area H	0.931	0.021	3.121	0.859	0.841
Partial corneal area V	0.945	0.017	3.135	0.872	0.841
Partial chamber area H	0.938	0.019	2.643	0.897	0.864
Partial chamber area V	0.892	0.026	2.664	0.846	0.795
CpC vertical	0.984	0.007	1.189	0.949	0.92
CpC horizontal	0.982	0.009	1.189	0.936	0.92

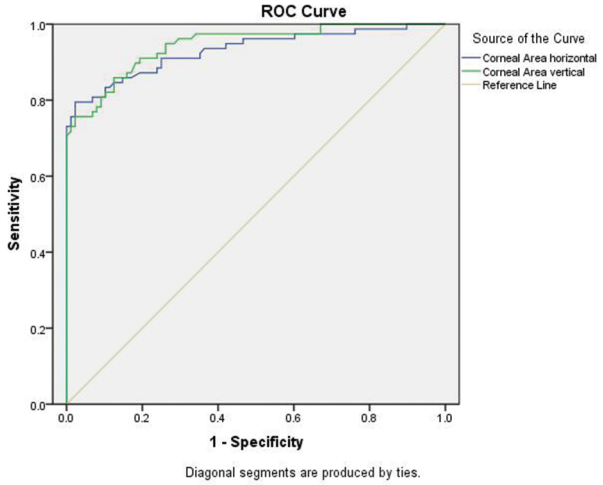

Figure 3. Area under the curve for the partial corneal area horizontally and verically.

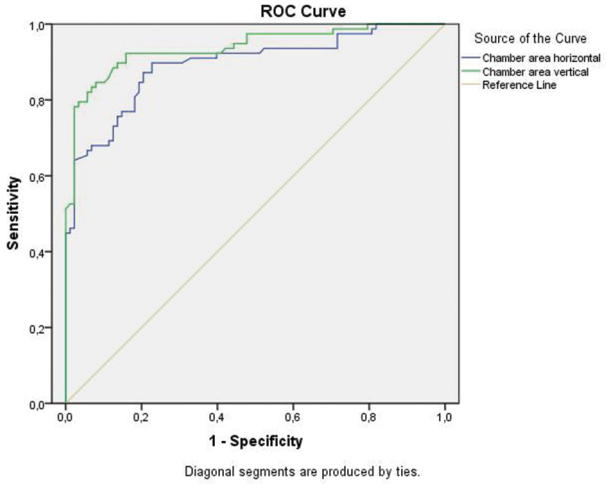

Figure 4. Area under the curve for the partial chamber area horizontally and verically.

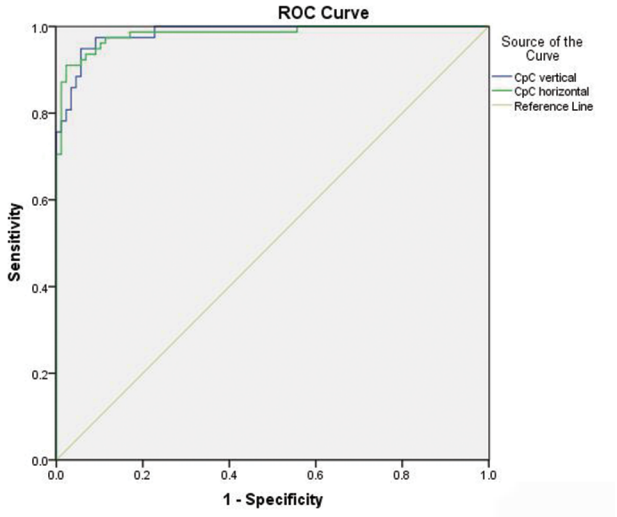

Figure 5. Area under the curve for the CpC index, horizontally and verically.

DISCUSSION

In the current study, all of the newly developed custom indices have shown decent performance with AUC above 0.900. The measurements were done manually using the software of the device, which may have caused some inaccuracy in the obtained values for the partial chamber and corneal area.

We couldn't find any comparable research to compare our findings to in the existing literature. However, the partial corneal area shares a similarity with the Pentacam's corneal volume and the partial chamber area to the anterior chamber volume.[7,21-24] The main difference between the proposed indices and Pentacam's ones is that the partial corneal and partial chamber areas are two dimensional. In contrast, the corneal and chamber volume are three-dimensional and they represent better the corneal shape and the changes that are observed in patients with corneal ectasia. Patients with corneal ectasia have lower corneal volume[7,21] and higher chamber volume[7,21-24]. This is also confirmed by our results.

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The vertical CpC index was the best performing index in the study. We noticed a decrease in the partial corneal area and an increase in the partial chamber area in patients with ectasia. In this context, it seems reasonable to conclude that the index reflecting this relation is the best performing one.

CONCLUSIONS

The patients with corneal ectasia had lower partial corneal area, higher partial chamber area, and lower CpC index compared to the healthy controls. The proposed indices are an excellent tool in the diagnostics of corneal ectasia.

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Индивидуальные индексы оптической когерентной томографии переднего сегмента для выявления эктазии роговицы

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Резюме

Введение: Истончение роговицы и изменение профиля толщины роговицы являются основными симптомами эктазии роговицы. В настоящее время широко используется оптическая когерентная томография переднего сегмента глаза, и разработка дополнительных показателей может привести к улучшению диагностики кератоконуса.

Цель: Определить диагностическую ценность недавно разработанных индивидуальных ОКТ-показателей переднего сегмента в диагностике эктазии роговицы.

Пациенты и методы: В настоящее исследование были включены две группы пациентов: здоровые лица в первой (контрольная группа) и пациенты с эктазией роговицы во второй, по 80 глаз в группе по 43 пациента в каждой. Группы были сопоставимы по полу и возрасту. Каждому пациенту было проведено стандартное офтальмологическое обследование (острота зрения, тонометрия, исследование с помощью щелевой лампы, биомикроскопия глазного дна), топография роговицы с помощью OCULUS Keratograph 5M и оптическая когерентная томография переднего сегмента с помощью RTVue-100. Помимо индексов, автоматически сгенерированных программным обеспечением устройства, мы измерили следующие пользовательские параметры: частичную площадь роговицы (PCA), частичную площадь камеры (PCA) и индекс, отражающий соотношение между ними (CpC). Все измерения проводились в двух аксиальных пахиметрических сканах, одном вертикальном и одном горизонтальном, с использованием встроенного программного обеспечения.

Результаты: Между двумя группами была обнаружена статистически значимая разница (p<0.001, доверительный интервал 95%) по всем предложенным показателям как при вертикальном, так и при горизонтальном сканировании. ROC-анализ показал многообещающие результаты для дифференциации между группами с площадью под кривой (AUC) в диапазоне от 0.892 для вертикальной парциальной площади передней камеры до 0.984 для вертикального индекса CpC.

Заключение: Предложенные индексы могут быть использованы для дифференциации нормальной и эктазированной роговицы.

Ключевые слова

ОКТ переднего сегмента, эктазия роговицы, кератоконус