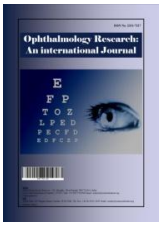

Ophthalmology Research: An International Journal

13(1): 30-40, 2020; Article no.OR.58721
ISSN: 2321-7227

Comparison for K_{mean} and Astigmatism for Orbscan IIz and Pentacam at Different Stages of Keratoconus - A Clinical Study

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Authors' contributions

This work was carried out in collaboration between both authors. Author EP designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author CK took the measurements and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/OR/2020/v13i130160
Editor(s):
(1) Kota V. Ramana, University of Texas Medical Branch, USA.
Reviewers:
(1) Kiril Slaveykov I-st, Trakia University, Bulgaria.
(2) Mridula V. Amarnath, Chinmaya Mission Hospital, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58721

Original Research Article

Received 22 April 2020
Accepted 29 June 2020
Published 11 July 2020

ABSTRACT

Aims: To compare results of Orbscan IIz and Pentacam at different stages of keratoconus on K_{mean} and Astigmatism.
Sample and Study Design: 94 keratoconus patients were included in the study, of which 52 were men and 42 women. Keratoconus patients were screened with Orbscan IIz and Pentacam before undergoing corneal collagen cross-linking. The patients were distributed according to different keratoconus stages.
Place and Duration of Study: University of West Attica Dept Biomedical Sciensce Course Optics & Optometry in collaboration with Athens "Ophthalmiatrio" Clinic during the period between October 2017 to January 2019.
Methodology: Topographic maps correlation of two types of corneal topographers Orbscan IIz and Pentacam. The K_{mean} values and the Astigmatism presented at different stages of keratoconus were compared.
Results: A Sample of 188 eyes were measured having, 20 eyes (10.6%) with subclinical keratoconus, the correlation coefficient r for K_{mean} values between Orbscan IIz and Pentacam was

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0.9758 (P<0.0001), 44 eyes (23.3%) at stage 1 with the correlation coefficient r=0.8482 (P<0.0001), 33 eyes (17.6%) at stage 2 with the correlation coefficient r=0.8147 (P<0.0001), 67 eyes (35.6%) at stage 3 with the correlation coefficient r=0.797 (P<0.0001), 10 eyes (5.3%) at stage 4 with the correlation coefficient r=0.8455 (P=0.0021), 8 eyes (4.4%) with iatrogenic keratoectasia after refractive surgery having correlation coefficient r=0.928 (P=0.0009).

Conclusion: Statistical differences between Orbscan IIz and Pentacam were found for K_{mean} in all stages of keratoconus. The performance for Kmean measurement of the corneal topographers Orbscan IIz and Pentacam is satisfactory for both systems in various stages of keratoconus having a very strong correlation (Correlation coefficient r ranged from 0.9758 to 0.7970). Statistical differences between Orbscan IIz and Pentacam were evident also at the Astigmatism measurements at stage 3 and 4.

Keywords: Keratoconus; corneal topography comparison; Orbscan IIz; Pentacam.

1. INTRODUCTION

Keratoconus is a non-inflammatory conical ectasia, essentially of unknown etiology, which causes lesions in the various corneal layers and causes distorted vision [1]. Ectasia is produced by stromal stretching which involves bilateral thinning of the cornea, leading to bulging and distortion. The cornea contains fibers of collagen that hold the cornea in place and prevent it from bulging. In keratoconus, these collagen fibers become weak and cannot keep the cornea in its proper shape. This condition may be caused by a decrease in antioxidants in the cornea, which allows free radical damage to occur, weakening the cornea [2,3]. The condition is divided into four stages and the exact study of the cornea is the most important test for diagnosis, monitoring and treatment. Symptoms of keratoconus include, blurred or distorted vision, sudden worsening or clouding of vision, frequently change of eyeglass prescription, sensitivity to light and glare, difficulty driving at night, itchy eyes, particularly when combined with the above symptoms [4].

The cornea on the anterior surface is normally more curved in the center than in the periphery (hyperbolic surface - prolate), with an average value of asphericity Q = -0.26 ± 0.18 [5]. The curvature radius of the central cornea on the anterior surface is 7.8mm and on the posterior 6.5mm. The asphericity of the cornea helps to reduce spherical aberration and the formation of a smooth rather than abrupt union with the eye bulb [5].

Keratoconus, or keratoidoconus, is characterized by progressive deformation of its surface. It is a degenerative disease, in which the shape of the cornea gradually acquires an abnormal conical shape (Fig. 1), ie a protrusion is created, causing abnormal astigmatism and, consequently, deformation of the light refracted in inside of the eye [6-7].

1.1 Causes

In its classic form is basically a multifaceted disease with main causes:

- Inheritance. [8-15]
- Atopic diseases (allergic rhinitis, eczema, asthma) and eye rubbing are some of the other reasons that appear to be strongly linked to the disease [16-19]
- Connective tissue disease [20]
- Down, Marfan syndrome [21]
- No other associated systemic or ocular disease [21-22]
- Some rare associations exist as a result of a chromosomal translocation, abnormal enzyme function, and loss of collagen and/or ground substance [22-23]
- Leber congenital amaurosis [24]
- Diabetics although they develop less severe forms of the disease [25]
- Rigid gas permeable (RGP) contact lens wear [26-28]

1.2 Stages and Classification

Keratoconus, classification system [29-32], is distinguished in the following stages of development:

- Subclinical or suspected keratoconus (*forme fruste*) [33-34]
- 1st Stage: Mild keratoconus
- 2nd Stage: Moderate keratoconus
- 3rd Stage: Advanced keratoconus
- 4th Stage: Serious keratoconus

An additional classification of keratoconus can be made based on the shape of the cone, so it is distinguished into [29-35]:

- Forme Fruste keratoconus
- Nipple cone keratoconus
- Oval cone keratoconus
- Globus keratoconus

1.3 Corneal Topography

1.3.1 Slit-scanning corneal topography

Orbscan IIz Is a system of slit-scanning technology essentially using Placido disc technology for curvature topography in combination with slit scanning technique for elevation topography map. The combination of these two techniques is aimed at improving the topography of the anterior corneal surface curvature [36-39].

1.3.2 Pentacam

Another method of altimeter estimation is one that uses a rotating Scheimpflug camera and is used in Pentacam Comprehensive Eye Scanner topography system.

Pentacam topography can produce curvature and altimeter maps from the anterior and posterior surface of the cornea and perimeter maps of the cornea and anterior chamber. It may still be photograph the crystalline lens in sections, revealing opacities. They are measured 25,000 true elevation points and data analysis is very reliable. Reconstructing an image, unlike the Orbscan IIz device, is much easier precisely because all the visual cross-sections have one thing in common, the center of rotation. The test is quick and accurate, takes place without eye contact, and takes just 2 seconds to create a complete picture of the anterior hemisphere [40-41].

1.4 Purpose

The aim of this study is to compare the topographic maps between Pentacam and Orbscan IIz devices in keratoconic patients at each stage of the disease, in order to prove which topographic system offers the most reliable topographic record and contributes more effectively to the diagnosis and categorization of keratoconus.

2. METHODOLOGY

The corneal topography study in patients with keratoconus, was performed at the "*Athens Ophthalmiatrio Clinic"* during the period between October 2017 and April 2019.

2.1 Exclusion Criteria

- Patients with a background of active disease in the anterior segment (eg, herpetic keratitis), recurrent or chronic uveitis, or any form of cataract
- Concurrent infection
- Severe corneal scarring or opacification
- History of poor epithelial wound healing
- Severe ocular surface disease (ex. dry eye)
- Systemic diseases or syndromes (eg, autoimmune disorder, connective tissue disease, diabetes mellitus, Down's syndrome)
- Other ocular pathologies
- Patients with a background of active disease in the anterior segment (eg, herpetic keratitis), recurrent or chronic uveitis, or any form of cataract
- Intraocular pressure > 21 mm Hg or glaucoma
- Previous ocular surgery
- Age over 21
- Rigid contact lenses worn until 1 week before pre-operative time

3. RESULTS AND DISCUSSION

A total of 94 keratoconus patients were included in the study, of which 52 were men and 42 women (Fig. 1). The mean age of the total sample was 26 ± 1.5 years. From the 188 eyes 6 were normal. More specifically, in 6 patients (4 men and 2 women) the image of the cornea was normal in one of the two eyes, ie they presented a one-sided keratoconus. 8 eyes were diagnosed with iatrogenic keratoectasia after refractive surgery (in the present study, cases with iatrogenic ectasia will form a separate group, as the keratoconus appeared secondarily). Excluding the 6 normal corneas and the 8 with iatrogenic keratoectasia, the remaining 174 eyes were diagnosed and classified at various stages of keratoconus. Topographic maps were taken with the ORBSCAN IIz / Bausch & Lomb and Allegro Oculyzer/Wavelight (PENTACAM) devices.

Of the total sample of 188 eyes, 20 eyes (10.6%) presented subclinical keratoconus, 44 eyes (23.3%) keratoconus stage 1, 33 eyes (17.6%) stage 2, 67 eyes (35.6%) stage 3, 10 eyes

(5.3%) stage 4, 8 eyes (4.4%) iatrogenic keratoectasia after refractive surgery and 6 eyes (3.2%) had a normal cornea.

Of the total sample of keratoconus patients, 34 patients had reported a family history of keratoconus while taking the history prior to the ophthalmological examination. In 11 patients reported findings associated with the disease, such as eye rubbing, intolerance to contact lenses, history of genetic syndromes. Some cases were diagnosed by chance during the

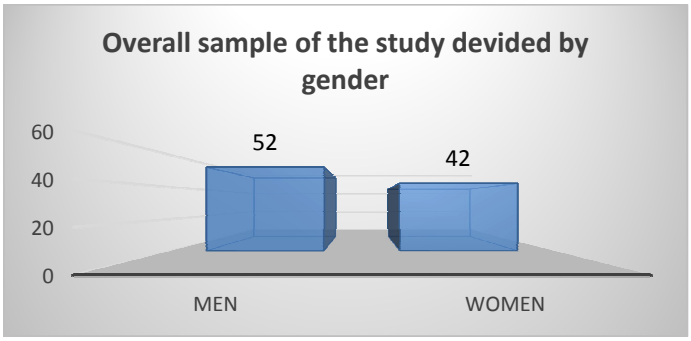

Fig. 1. Keratoconus patients sample according to sex

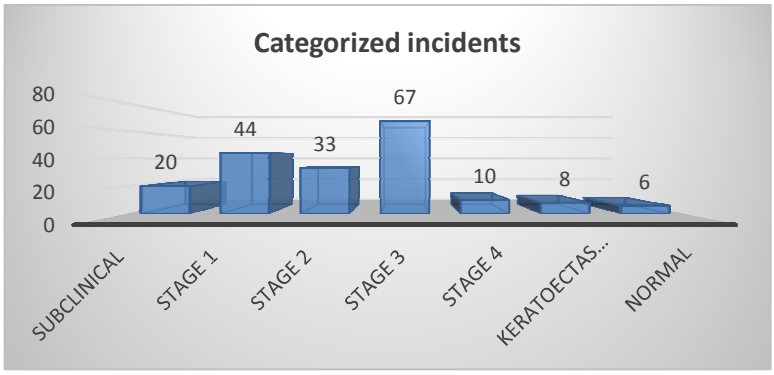

Fig. 2. Keratoconus patients sample according to stage of Keratoconus

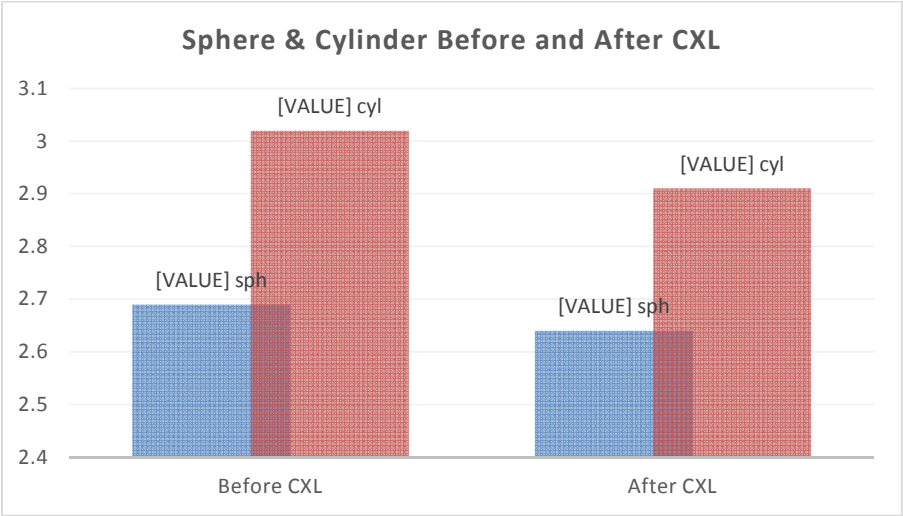

Fig. 3. The mean sphere and astigmatism of the keratoconus eyes before and after cross-linking (CXL)

usual formal ophthalmological examination or during the examination of the suitability of candidates for refractive surgery.

Of the 182 keratoconus eyes, the cone was found in the lower area of the cornea around 6 o'clock in 151 eyes (83%), in the center of the cornea in 23 eyes (12.6%) and in the upper area of the cornea around 12 o'clock in 8 eyes (4.4%).

All patients included in the study underwent corneal collagen cross-linking (CXL) surgery after evaluated with both of the corneal topographers [42-45]. The mean sphere and astigmatism of the keratoconic eyes (182 eyes) before surgery were -2.69Ds and -3.02Dcyl respectively, while after surgery -2.64Ds and -2.91cyl respectively (Fig. 3). Postoperatively, visual acuity was improved compared to preoperative UCVA by 2 lines in the Snellen chart.

A comparison was made between the two topographers regarding the calculation of the average corneal curvature (K_{mean}) in the central 3 mm and astigmatism in each stage of the disease separately. The following are comparative tables with the statistical analysis of the measurements of the two topographers for the K_{mean} and Astigmatism indicators at each stage of the keratoconus.

The K_{mean} of Orbscan IIz at different stages was *(44.43- 45,86- 46,86- 50,35- 54,21- 42,23)* and for Pentacam *(44.66- 46,04-- 46,99- 50,73- 56,04- 41,81)*. The K_{mean} curvature that the two devices had at all stages are very close to each other, as are their standard deviations, which informs us that the dispersion of the measurements is uniform. The mean difference between the two topographers varied *from (0.23- 0,17- 0,12- 0,37- 1,83- -0,42D).* The differences between them are considered statistically significant *(P=0.0384-P=0,0304-P=0,3484-P=0,0971-P=0,0098-P=0,0408),* except stages 2 & 3, however their correlation is very strong, *Correlation coefficient (r=0.9758-0.8482-0.8147-0.797-0.8455-0.928)*. Astigmatism value of Orbscan IIz was *(1.22-1.25-1.97-4.93-6.43-1.78)* and for Pentacam *(1.32-1.32-1.95-3.38-2.79-1.45)*. The mean difference between the two topographers is *(0.10-0.06-0.01-1.54-3.64-0.33D).* The differences between them are not considered statistically significant *(P=0.3691-*

Table 1. Subclinical stage

	Orbscan II K_{mean}	**Pentacam K_{mean}**
Sample size	20	20
Arithmetic mean	44,43	44,66
Standard Deviation	2,1009	2,1065
Paired sample t-test		
Mean difference		0,23
Test statistic t		2,225
Two-tailed probability		P=0,0384
Comparison of Kmean between Orbscan II and Pentacam		
Correlation coefficient r	0,9758	
Significance level	P<0,0001	
95% Confidence interval for r	0,9387 to 0,9906	
	Orbscan II Astigmatism	**Pentacam Astigmatism**
Arithmetic mean	1,22	1,325
Standard Deviation	0,5755	0,5552
Paired sample t-test		
Mean difference		0,105
Test statistic t		0,92
Two-tailed probability		P=0,3691
Comparison of Astigmatism between Orbscan II and Pentacam		
Correlation coefficient r	0,593	
Significance level	P=0,0059	
95% Confidence interval for r	0,2040 to 0,8203	

Table 2. Stage 1

	Orbscan II Kmean	**Pentacam Kmean**
Sample size	44	44
Arithmetic mean	45,8659	46,0432
Standard Deviation	0,9647	0,9392
Paired sample t-test		
Mean difference		0,1773
Test statistic t		2,239
Two-tailed probability		P=0,0304
Comparison of Kmean between Orbscan II and Pentacam		
Correlation coefficient r	0,8482	
Significance level	P<0,0001	
95% Confidence interval for r	0,7368 to 0,9147	
	Orbscan II Astigmatism	**Pentacam Astigmatism**
Arithmetic mean	1,2591	1,3227
Standard Deviation	0,4867	0,5216
Paired sample t-test		
Mean difference		0,06364
Test statistic t		1,176
Two-tailed probability		P=0,2461
Comparison of Astigmatism between Orbscan II and Pentacam		
Correlation coefficient r	0,7485	
Significance level	P<0,0001	
95% Confidence interval for r	0,5807 to 0,8553	

Table 3. Stage 2

	Orbscan II Kmean	**Pentacam Kmean**
Sample size	33	33
Arithmetic mean	46,8697	46,997
Standard Deviation	1,2556	1,2682
Paired sample t-test		
Mean difference		0,1273
Test statistic t		0,952
Two-tailed probability		P=0,3484
Comparison of Kmean between Orbscan II and Pentacam		
Correlation coefficient r	0,8147	
Significance level	P<0,0001	
95% Confidence interval for r	0,6545 to 0,9049	
	Orbscan II Astigmatism	**Pentacam Astigmatism**
Arithmetic mean	1,9727	1,9576
Standard Deviation	0,9606	0,8151
Paired sample t-test		
Mean difference		-0,01515
Test statistic t		-0,121
Two-tailed probability		P=0,9042
Comparison of Astigmatism between Orbscan II and Pentacam		
Correlation coefficient r	0,685	
Significance level	P<0,0001	
95% Confidence interval for r	0,4467 to 0,8325	

Table 4. Stage 3

	Orbscan II Kmean	**Pentacam Kmean**
Sample size	67	67
Arithmetic mean	50,3597	50,7388
Standard Deviation	2,6142	3,0352
Paired sample t-test		
Mean difference		0,3791
Test statistic t		1,683
Two-tailed probability		P=0,0971
Comparison of Kmean between Orbscan II and Pentacam		
Correlation coefficient r	0,797	
Significance level	P<0,0001	
95% Confidence interval for r	0,6868 to 0,8705	
	Orbscan II Astigmatism	**Pentacam Astigmatism**
Arithmetic mean	4,9343	3,3851
Standard Deviation	1,2133	1,3213
Paired sample t-test		
Mean difference		-1,5493
Test statistic t		-8,11
Two-tailed probability		P< 0,0001
Comparison of Astigmatism between Orbscan II and Pentacam		
Correlation coefficient r	0,241	
Significance level	P=0,0495	
95% Confidence interval for r	0,00079 to 0,4548	

Table 5. Stage 4

	Orbscan II Kmean	**Pentacam Kmean**
Sample size	10	10
Arithmetic mean	54,21	56,04
Standard Deviation	3,2614	3,0963
Paired sample t-test		
Mean difference		1,83
Test statistic t		3,262
Two-tailed probability		P=0,0098
Comparison of Kmean between Orbscan II and Pentacam		
Correlation coefficient r	0,8455	
Significance level	P=0,0021	
95% Confidence interval for r	0,4617 to 0,9627	
	Orbscan II Astigmatism	**Pentacam Astigmatism**
Arithmetic mean	6,43	2,79
Standard Deviation	0,9866	0,8252
Paired sample t-test		
Mean difference		-3,64
Test statistic t		-8,11
Two-tailed probability		P< 0,0001
Comparison of Astigmatism between Orbscan II and Pentacam		
Correlation coefficient r	0,3102	
Significance level	P=0,3831	
95% Confidence interval for r	- 0,3970 to 0,7863	

Table 6. Iatrogenic keratoectasia after refractive surgery

	Orbscan II Kmean	**Pentacam Kmean**
Sample size	8	8
Arithmetic mean	42,2375	41,8125
Standard Deviation	1,1439	1,2833
Paired sample t-test		
Mean difference		-0,425
Test statistic t		-2,503
Two-tailed probability		P=0,0408
Comparison of Kmean between Orbscan II and Pentacam		
Correlation coefficient r	0,928	
Significance level	P=0,0009	
95% Confidence interval for r	0,6455 to 0,9872	
	Orbscan II Astigmatism	**Pentacam Astigmatism**
Arithmetic mean	1,7875	1,45
Standard Deviation	0,712	0,5338
Paired sample t-test		
Mean difference		-0,3375
Test statistic t		-1,915
Two-tailed probability		P= 0,0970
Comparison of Astigmatism between Orbscan II and Pentacam		
Correlation coefficient r	0,7154	
Significance level	P=0,0460	
95% Confidence interval for r	0,02171 to 0,9441	

P=0.2461- P=0.9042- P<0,0001 - P<0,0001 - P= 0,0970) besides stages 3 & 4 and their correlation is strong, *Correlation coefficient (r=0.593- 0.7485- 0.685- 0.241- 0.3102- 0.7154).*

4. CONCLUSION

The comparison between the two topographers showed that the differences between them considered statistically significant in the calculation of keratometric values of the corneal surface, when the two devises are related at different stages of keratoconus for K_{mean}, except stages 2 & 3 where the sample was larger than the other stages. The Correlation coefficient r is very strong between the two topographers in all stages (Correlation coefficient r ranged from *0.9758 to 0.7970*). For astigmatism the differences between them considered statistically significant with an exception at Iatrogenic keratoectasia. At stage 4 the largest difference between Orbscan IIz and Pentacam is identified (Mean Difference = -3.64) and there is no significant correlation between them, since Pentacam values are much lower than Orbscan IIz values. Statistic t Test were performed at all stages with high values (*Test statistic t for each stage was: 2.225 / 2.239 / 0.952 / 1.683 / 3.262 / - 2.503,* showing that the greater the magnitude of T, the greater the evidence against the null hypothesis meaning there is greater evidence that there is a significant difference).

It should be noted that at all stages the Orbscan IIz measurements for astigmatism were closer to overall refraction values than the Pentacam measurements. In stage 4, the measurements of the Pentacam topographer were the ones that showed a big difference, reaching even 1/3 of the Orbscan IIz measurements and, consequently, of the overall refraction values. This may be due to incorrect estimates by the topographer due to the severe abnormalities and fluctuations of the corneal surface in the more advanced stages of keratoconus.

The results of the study are similar with those of previous reports [46-53] that compared Orbscan-II and Pentacam, finding differences between both devices suggesting that they are not interchangeable, although the Correlation coefficient r is very strong. This study present almost the same conclusion about the comparison of the two devices with previous studies [50-53] The limitation in this study is the number of patient measured in every stage of keratoconus. In order to established a good correlation between the two devices the number of patients should be the same in every stage.

We could say that the performance of the keratometric topographers is satisfactory with both systems, however Orbscan II has an advantage and this is probably due to the combination of Placido disc and slit scanning technologies, which contributes to the improved topography imaging of the corneal curvature. Corneal topography is a valuable diagnostic tool for diagnosing subclinical keratoconus and for tracking the progression of the disease.

CONSENT

As per international standard informed and written participant consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard written ethical permission has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/58721