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Research Article

Best Fitted Sphere 10mm Float Versus Best Fitted Sphere 3mm Centered on the Thinnest Point Measurements; Accuracy for the Diagnosis of Keratoconus

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Abstract

Purpose: To evaluate the accuracy of 3 mm Best Fitted Sphere (BFS) centered on the thinnest point measurement to detect keratoconus and to compare this to BFSs with 10 mm float measurement.

Setting: Eye Research Center, Rassoul Akram Hospital, Iran University of Medical Sciences, Iran

Materials and Methods: In this cross sectional study, 42 eyes from 29 patients with confirmed keratoconus were compared with 49 normal eyes of 27 candidates of refractive surgery. Anterior and posterior corneal surfaces were analyzed using Orb scanIIz slit-scanning topography in both groups. BFSs with 10 mm float measurement and 3mm centered on the thinnest point measurement were compared.

Results: For detecting keratoconus, higher overall predictive accuracies (area under the curve =100%) for anterior and posterior BFS 3mm with center of the thinnest point compared to the anterior (98%) and posterior (99.5%) BFS 10 mm float measurements were achieved. There are no cutoff point using BFS 10 mm measurements for anterior float (range 42-43 diopters) and posterior float (range 52-54) for discriminating keratoconus from normal eyes. However, with a cutoff point of 45.4 diopters and 62.75 diopters for anterior and posterior BFS 3mm measurements, respectively, neither normal eyes, nor keratoconus eyes were misclassified.

Conclusion:

Compared to the BFS 10 mm float measurement, BFS 3 mm centered on the thinnest point effectively discriminates keratoconus from normal corneas.

Keywords: Best Fitted Sphere; Keratoconus; Orb Scan

Introduction

Keratoconus (KCN) is a bilateral non inflammatory corneal ectasia, it is characterized by a progressive increase in corneal curvature, with apical thinning and irregular corneal astigmatism [1,2]. Keratorefractive surgeries are widely used to correct the refractive error. However, any preexisting tendency to ectasia like keratoconus will be manifested and aggravated by keratorefractive surgeries [2,3].Thus the importance of recognizing such preexisting tendency towards keratectasia cannot be overemphasized. It is not only important to diagnose these cases of keratoconus that are clinically evident, but at the same time to identify those subclinical cases whose cornea is clinically not keratoconic but are detectable by imaging studies.

The Orb scan slit scanning topography system can provide useful and accurate information in detecting subtle topographic changes present in early keratoconus and documenting their progression by serial topographic analysis [4-6]. For refractive surgery screening, analyzing the elevation data using a Best Fitted Sphere (BFS) is the most widely used and convenient (i.e. easiest to read and understand). The instrument is routinely set on BFS 10 mm float. Using this setting, various parameters were suggested for detecting KCN [5-8].

Changes in corneal topography in most cases of keratoconus (i.e. cone) start in infer temporal Para center of cornea and it corresponds to the thinnest point of the cornea [1]. The importance of this study is that BFS measurements centered on this location and with lower diameter may enhance the protrusion of the cone from BFS and discriminate keratoconus from normal corneas more effectively. The aim of this study was to compare the BFS 10mm float and BFS 3mm centered on the thinnest point measurements in keratoconus and normal eyes. To our knowledge, this is the first study that compares orb scan indices in different BFS measurements in keratoconic and normal eyes.

Materials and Methods

In this cross sectional comparative study, 42 eyes from 29 patients with confirmed keratoconus (KCN group) and 49 control eyes of 27 normal subjects were enrolled. KCN group had clinical signs of keratoconus including cone and vogtstriae in slit lamp bio microscopy. The study was done in Rassoul Akram Hospital, Iran University of Medical Sciences in Tehran, Iran during 2009. Also the KCN eyes had typical topographic criteria defined for diagnosis of keratoconus.2Orbscan inclusion criteria for control group were absence of focal or inferior steepening of the cornea, Mean sim k < 47.2 D , inferior-superior difference < 1.4 , thinnest point > 470 mm , Irregularity 3mm < 1.5 , Anterior BFS measurement < 45 D , Posterior BFS measurement < 52 , Anterior/posterior BFS measurements < 1.21 , Ant elevation measurement < 25 , Post elevation measurement < 35 , absence of non orthogonal, asymmetric and broken bow tie astigmatisms. Exclusion criteria for both groups were corneal scarring, any signs or history of other corneal disease, history of previous ocular surgery or trauma, and history of contact lens usage in last 3 weeks. All patients underwent a cycloplegic refraction, slit lamp examinations and corneal imaging using orb scan (Orb scan II, Bausch & Lomb Inc., Rochester, NY, USA).

Recorded variables were anterior and posterior dioptric powers, anterior and posterior BFS 10 mm float measurements, anterior and posterior BFS 3 mm centered on thinnest point measurements, anterior and posterior corneal elevations, tachymetry of thinnest point, magnitude of the decent ration of the thinnest corneal point from the corneal geometric center (X,Y), mean keratometry (K), sim k (min and max), irregularity 3mm and 5mm, difference of the thinnest point tachymetry and thickest point in center of 7mm, inferior/superior difference of and mean astigmatism of the eyes. All of the orb scan measurements were performed by one of the two experienced technicians using an acquisition protocol recommended by the manufacturer. First, the default settings for BFS were used in all cases: floating alignment and full cornea fit zone (10 mm). The center of all maps was the apex determined by placid data. Then, the BFS with the diameter of 3mm was centered on the thinnest point using the “surface rotation” menu by clicking on the “tools” button on the main toolbar.

Data were analyzed using the SPSS software version 16 (IBM Corporation). The P values comparing the differences in variables between the groups of keratoconus and normal eyes were considered significant when values were less than 0.05. Three trials were used to calculate SD. The Kolmogorov-Smirnov test was employed to test the normal distribution of all continuous variables. Two samples independent t test was performed for normally distributed variables, and nonparametric tests were used if variables were not normally distributed. Receiver Operating Characteristic (ROC) curves were used to determine the test’s overall predictive accuracy (area under the curve) and to identify optimal corneal elevation cutoff points to maximize sensitivity and specificity in discriminating keratoconus from normal corneas.

Results

Twenty-seven normal subjects including 12 males (44.45%) and 15 females (55.55%), and 29 KCN patients including 15 males (51.73%) and 14 females (48.27%) were examined.

Table 1 shows orb scan parameters in normal and keratoconus eyes. There were significant differences between the normal and keratoconus eyes in all recorded indices including BFS 10mm float and BFS 3mm centered on thinnest point measurements.

	Normal eyes		**Keratoconus eyes**		**P**
	Mean	SD	Mean	SD	Value
BFS Ant 3 T (mm)	7.95	0.17	6.16	0.63	< .0001
BFS Ant 3 T (D)	42.49	0.91	55.32	5.63	< .0001
BFS Post 3 T (mm)	6.2	0.21	4.24	0.52	< .0001
BFS Post 3 T (D)	54.56	1.9	80.34	10.1	< .0001
Elevation Ant 3 T (mm)	0.001	0.002	0.005	0.012	< .0001
Elevation Post 3 T (mm)	0.003	0.006	0.01	0.004	< .0001
BFS Ant 10 F (mm)	8.12	0.15	7.36	0.41	< .0001
BFS Ant 10 F (D)	41.57	0.79	45.98	2.69	< .0001
BFS Post 10 F (mm)	6.68	0.15	5.84	0.37	< .0001
BFS Post 10 F (D)	50.55	1.12	58.01	3.78	< .0001
Elevation Ant 10 F (mm)	0.007	0.004	0.085	0.122	< .0001
Elevation Post 10 F (mm)	0.027	0.006	0.137	0.048	< .0001
Astigmatism (D)	1.05	0.67	5.99	2.97	< .0001
Sim K max (D)	43.06	0.99	56.18	6.44	< .0001
Sim K min (D)	42.02	0.99	50.18	5.09	< .0001
Sim K mean (D)	42.54	0.94	53.18	5.61	< .0001
Irregularity 3 mm	1.05	0.43	6.53	2.63	< .0001
Irregularity 5 mm	1.33	0.48	7.1	2.97	< .0001
Thinnest point thickness (microns)	534.73	30.86	392.07	68.58	< .0001
Thinnest point location: X	0.45	0.23	0.6	0.27	< .007
Thinnest point location: Y	0.45	0.29	0.64	0.43	< .026
Difference of center-7mmthickness (microns)	110.59	16.42	231.69	57.35	< .0001
INF/SUP difference of astigmatism (D)	0.29	0.28	5.73	4.47	< .0001
BFS = Best Fitted Sphere; D = diopters; Ant = Anterior; Post = Posterior; 3T = centered on 3mm thinnest point; INF/SUP = Inferior/Superior, F=Float.					

Table 1: Orb scans indices in keratoconus and normal eyes.

There was significant difference between the BFS 10 mm float and BFS 3mm centered on thinnest point measurements in keratoconus and normal eyes (table 2,3). ROC curves analyses (table 4) shows.

	BFS 10mm float	**BFS 3mm centered on thinnest point**	**P value**
Anterior BFS measurement (D)	41.57	42.49	< .0001
Posterior BFS measurement(D)	50.55	54.56	< .0001
Anterior elevation (mm)	0.007	0.001	< .0001
Posterior elevation (mm)	0.027	0.003	< .0001

Table 2: Comparison of the BFS 10mm float and BFS 3mm centered on thinnest point measurements in normaleyes.BFS: Best fitted sphere, D: diopters

	BFS 10mm float	BFS 3mm centered on thinnest point	P value
Anterior BFS measurement(D)	45.98	55.32	< .0001
Posterior BFS measurement(D)	58.01	80.34	< .0001
Anterior elevation (mm)	0.085	0.005	< .0001
Posterior elevation (mm)	0.137	0.010	< .0001

Table 3: Comparison of the BFS 10mm float and BFS 3mm centered on thinnest point measurements in KCN eyes.BFS: Best fitted sphere, D: diopters

	Area under the curve	Cutoff points
Anterior BFS 10mm float (D)	98%	42-43
Posterior BFS 10mm float (D)	99.5%	52-54
Anterior BFS 3mm centered on thinnest point (D)	100%	45.4
Posterior BFS 3mm centered on thinnest point (D)	100%	62.75
Anterior elevation on BFS 3mm centered on thinnest point (mm)	86%	0.0005-0.0155
Posterior elevation on BFS 3mm centered on thinnest point(mm)	93%	0.0035-8.44
Anterior elevation on BFS 10mm float (mm)	100%	0.022
Posterior elevation on BFS 10mm float (mm)	100%	0.052

Table 4: Area under the curve and cutoff points for different recorded variables.BFS: Best fitted sphere, D: diopters

Higher overall predictive accuracy of anterior and posterior BFS 3mm measurements centered on thinnest point (area under the curve =100%) compared to BFS 10 mm float measurements (area under the curve in anterior measurement = 98% and in posterior measurement = 99.5%). Using the anterior and posterior BFS 3mm measurements with a cutoff point of 45.4 and 62.75 diopters, respectively, neither normal eyes nor keratoconus eyes were misclassified. However, there was no cutoff point using BFS 10 mm float for discriminating keratoconus from normal eyes.

Discussion

Findings of the present study suggest that anterior and posterior BFS 3mm centered on the thinnest point effectively discriminates keratoconus from normal corneas and may detect subclinical keratoconus with more accuracy than routine BFS 10mm float measurements.

We defined a new reference surface showed that a BFS with 3 mm diameter and centered on the thinnest portion of the cornea will exaggerate the cone and results in a significantly steeper BFS, making discrimination of the abnormal cornea easier. The new BFS shows that the conical portion of the cornea is now more pronounced. Previous studies reported quantitative indices and diagnostic criteria for detecting keratoconus using different imaging tools [4-17]. Our findings are in line with previous studies that have shown various orb scan parameters are significantly different between the normal and keratoconus eyes. Lim et al [5]. reported that the mean values of maximum posterior elevation, thinnest corneal tachymetry, 3-mm irregularity, and 5-mm irregularity were significantly different between the controls, keratoconic, and the suspected keratoconus group. In both groups, the indices showed deviation from the normal ranges, although there was some degree of overlap. It was reported that anterior and posterior corneal curvatures were affected in keratoconus and keratoconus suspects [1-4] Rao and associates [6] reported a high sensitivity and specificity of 91% and 99% for thickness index [7]. showed that the mean values of irregularity index in 3 mm and 5 mm zones and the thinnest optical tachymetry were significantly different between the normal eyes and keratoconic eyes [9]. report that a posterior elevation of 40 micron or more has sensitivity of 57.7% and specificity of 89.9%, and suggest An anterior elevation ratio of 0.5122 mm or less had 99% sensitivity and 95.2% specificity while a ratio 16.5 mm or less had 80.1% sensitivity and 80.8% specificity in discriminating normal eyes from keratoconus and keratoconus suspects. Some studies reported special variables for differentiating KCN eyes without reporting the sensitivity and specifity [6]. Showed that a maximum central posterior elevation of 40 µm or more is a risk factor for formefruste keratoconus [5]. Showed that this value should be 46 µm. Prakash and Agarwal [17] suggested that anterior corneal elevation more than 25 µm and posterior corneal elevation more than 50 µm are indicative of early keratoconus. Controversies in the cut off points and criteria in these reports and those reported by others with orb scan and other instruments [10-17] shows that there is a large space for further research in this field. We showed that BFS 3mm centered on thinnest point measurements has 100 % sensitivity and specifity for discriminating the KCN eyes. Although the anterior and posterior elevations were significantly different between normal and keratoconus eyes, we couldn't find a specific cut off point for these variables. Since the BFS diameter was decreased, the BFS radius was increased and so the elevations were less evident. This is in contrast to the Belin et al [13] a concept that believes the exclusion of a circle from the central corneal 4 mm around the thinnest point enhances the ectasia. We scarified the elevations instead of BFS measurements and found it useful.

Our study has some limitations. The sample size of this study was small. Also, our values for elevations are different from other studies; this may result from specific inclusion criteria. We included patients with apparent clinical KCN and the result may be different if patients with subclinical KCN could be considered. However the results may help to determine corneal ectasia, the dreadful complication of refractive surgery. We didn't evaluate the dioptric corneal power. The average dioptric measurement over the thinnest 3mm of the cornea may have the same accuracy as the 3mm BFS.

Conclusion

In conclusion, the finding of our study showed that posterior BFS 3mm centered on thinnest point was significantly different in keratoconus than normal eyes. There was significantly difference between BFS 10mm float and BFS 3mm centered on thinnest point of cornea in keratoconus and normal eyes. ROC curves analyses showed higher overall predictive accuracy of posterior BFS 3mm centered on thinnest point for keratoconus. We examined BFS measurements in eyes with apparent clinical KCN. Future larger studies comparing the measurements in form frost KCN is needed to confirm our findings.

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