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The Influence of Horizontal Corneal Diameter on Corneal Tomography and Belin/Ambrósio Enhanced Ectasia Display of Pentacam Corneal Tomography

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ME and MH designed the study. Author MH did the administrative support. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To detect the influence of WTW on corneal tomography parameters and Belin/Ambrósio Enhanced Ectasia Display indices.
Study Design: interventional, retrospective, non-controlled, non-comparative study.
Place and Duration of Study: Department of ophthalmology (Tanta university) and Eshrak Eye Hospital, between January 2019 and December 2021.
Methodology: we collected the preoperative Pentacam images of 126 patients (252 eyes) underwent Laser Vision Correction. Correlations were performed between WTW and Pentacam

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findings (anterior, posterior K readings, anterior, posterior Astigmatism, Thinnest location (TL), and BAD indices: Db, Db, Dt, Da, Dp, D).
Results: WTW shows a negative correlation with KM (*P* = < 0.001; r = -0.43), posterior KM (*P* = < 0.001; r = -0.51), Kmax (*P* = < 0.001; r = -0.43), posterior corneal astigmatism (*P* = 0.002; r = -0.218) and TL (*P* = 0.012; r 34 = -0.17), and a positive correlation with anterior corneal astigmatism (*P* = 0.038; r = 0.148), There was a negative correlation between the corneal diameter and Db (r = -0.35 ; *P* = <0.001), Dp (r = - 0.09 ; *P* = 0.02) and with final (D) (r = - 0.16; *P* = <0.095) and a positive correlation with Dt (r=+0.25. *P* =0.003).
Conclusion: Corneal diameter influences corneal curvature and pachymetry. It also influences BAD display; small diameter is associated with steep cornea and can give a false impression of corneal ectasia in BAD display.

Keywords: Cornea; pentacam; Belin/Ambrósio.

ABBREVIATIONS

KC : Keratoconus
KA : Keratometric Astigmatism
Km : Mean Keratometry
Kmp : Posterior Keratometry
Df : Deviation of the Front Elevation
Db : Deviation of the Back Elevation
Dp : Deviation in Average Pachymetric Progression
Dt : Deviation of the Corneal Thinnest Point
Da : Deviation in (ART max)
D : The Final D
TL : Thinnest Location
WTW : White to White

1. INTRODUCTION

As corneal refractive surgery advances, professional expectations are increasing, necessitating continuous development and refinement of preoperative screening and interpretation [1]. Scheimpflug tomography devices, such as the Pentacam (OCULUS Optikgerate GmbH, Wetzlar, Germany), are currently one of the most popular methods for corneal imaging. [2] Early and sensitive keratoconus (KC) detection using variable indices has been widely discussed, with various parameters' sensitivities and specificities of different parameters being compared with each other [3-5]. New algorithms and combined indices have been introduced with the aim of detecting (KC) earlier [6-7].

The corneal diameter (White-to-White) is the horizontal distance between the borders of the corneal limbus. WTW measurement has been used in several ocular conditions [8]. There are several methods to measure WTW manual and automated but there is no gold slandered however, the atlas topographers and IOL master 500 are considered accurate and interchangeable for measuring WTW [9]. WTW is also required for haptic size calculation in angle-supported intraocular lenses (IOLs), anterior chamber IOLs and phakic IOL implantation (ICL), and IOL calculation in cataract surgery (3rd and 4th generation formulas) [10]. Corneal Diameter has no rule as a single parameter when it comes to risk assessment of corneal refractive surgery or diagnosis of (KC).

The Belin Ambrosio enhanced ectasia display (BAD) map is based on information from Pentacam and includes a comprehensive map of the cornea for screening patients with all types of ectasia. [11] The BAD display incorporates elevation and pachymetry of the cornea into a single map, providing a comprehensive view of the cornea for quick and effective screening of patients [12].

(BAD) Indices are a screening method that uses a regression analysis that was created by a large, normative database, a total deviation value is calculated using specifically defined parameters (Db, Db, Dt, Da, Dp and Final D), and the results are color coded as white (normal), yellow (suspect), or red (abnormal) [11].

The BAD-D deviation threshold greater than 2.11 has a sensitivity of 99.59% and a specificity of 100% for diagnosing KC; a deviation threshold greater than 1.22 has a sensitivity of 93.62% and a specificity of 94.56% for detecting mild and subclinical disease. (10) BAD Final D is considered as one of the best Pentacam indicators for detecting (KC) and preclinical (KC) [13].

2. MATERIALS AND METHODS

This was an interventional, retrospective, non-controlled, non-comparative study performed at

Department of ophthalmology (Tanta university) and Eshrak Eye Hospital, between January 2019 and December 2021. Preoperative Pentacam findings (Pentacam HR; Oculus Optikgeräte, Wetzelar, Germany) of 126 patients (252 eyes) underwent laser vision correction (LVC) from January 1, 2020 to December, 2021 were evaluated. Exclusion criteria were poor quality acquisition; patients scheduled for redo laser vision correction due to regression and patients scheduled for combined surface ablation and crosslinking due to evident or highly suspicious corneal ectasia.

All data collected in the study were entered into an electronic database via Microsoft Excel 2010 (Microsoft Corp, Redmond, Washington,USA) including age, sex, keratometric astigmatism (KA), mean central keratometric reading (KM) , highest keratometric reading (Kmax), posterior KM, thinnest corneal location (TL), and horizontal corneal diameter (WTW).

To determine factors affecting the BAD deviation indices, correlations were done between the previous collected data and BAD deviation indices. BAD deviation indices included: Df (deviation of normality of the front elevation), Db (deviation of normality of the back elevation), Dt (deviation of normality of the corneal thinnest point), Da (deviation of normality of Ambrósio relational thickness), Dp (deviation of normality in average pachymetric progression), D (BAD final and total deviation is a multivariate index that provides the clinician with a comprehensive view of the cornea).

2.1 Statistical Analysis

Data was analyzed with SPSS Statistics Version 16 (IBM, Armonk, New York, USA). Continuous variables were reported as Mean ± Standard Deviation (SD). Correlations were examined with Spearman rank-correlation test. P-values less than 0.05 were considered statistically significant. Multivariate regression analysis was then performed, introducing, as independent variables, those that reached a significance level of less than 0.05 in univariate analysis. Variables that reached a significant level of less than 0.05 in multivariate analysis were considered significant.

3. RESULTS

This study included Pentacam results of 126 patients (252 eyes). The age of patients in years is 20-30 years, average: 23.9 ± 3.7. 48 patients were males (38.1%) and 78 were females (61.9%). Details of Pentacam findings of the studied cases were summarized in Table 1.

Correlation between BAD deviation indices and various Pentacam findings showed significant correlation with K readings (Km, posterior KM and Kmax), thinnest corneal location (TL) and corneal diameter (WTW) (Table 2).

There was a negative correlation between the corneal diameter and Db (r = - 0.35; $P < 0.001$), and with Dp (r = - 0.09; $P = 0.02$) and with final (D) (r = - 0.16; $P < 0.009$) and a positive correlation with Dt (R = +0.25; $P = 0.003$), i.e. patients with low corneal diameter tend to have higher values of Db, Dp, D and lower value of Dt. Further analysis showed a negative correlation between corneal diameter and pachymetry of TL ($P = 0.002$; r = -0.25) i.e. the smaller the corneal diameter the higher the pachymetry of the thinnest location. (Fig. 1)

Multivariate regression analysis (Table 3) showed that the final (D) has a negative correlation with the anterior Km, ($P = 0.015$; coefficient = -0.13), TL ($P < 0.001$; coefficient = -0.027), posterior km ($P = <0.001$; coefficient = -0.1) and positive correlation with KA (Astigmatism) ($P = 0.009$; coefficient = 0.11)

Multivariate regression analysis also showed significant negative correlation between Db with posterior KM ($P = 0.03$; coefficient = -0.48) and WTW ($P = 0.002$; coefficient= -0.52). Furthermore, Dp, Da and D had significant correlation to Km, posterior KM and TL. Dt had significant negative correlation to the TL only ($P = 0.001$; coefficient = -0.027).

4. DISCUSSION

Although refractive corneal surgery is very common, corneal ectasia remains a complication faced by physicians. Therefore, it has always been important for refractive surgeons to recognize cases of asymptomatic keratoconus that are difficult to distinguish from clinically normal eyes. [14] Pentacam examination is an important tool for preoperative examination of refractive surgery as a sensitive method for detecting at risk corneas and keratoconus. Investigating the factors that influence Corneal tomography and the BAD results has become very important for its proper interpretation.

The principal finding of this study is that horizontal corneal diameter correlates with all the k reading of the anterior and posterior surface of the cornea, thinnest location pachymetry as well as the anterior and the posterior astigmatism and could affect the results of BAD, small diameter associated with high k readings and high astigmatism, high TL pachymetry and high deviation indices (Db, Dp and D) and low (Dt).

Table 1 Criteria and Pentacam findings of studied cases

	Mean ± SD	Range
Age (years)	23.9 ± 3.7	20 to 32
Km (D)	43.3±1.5	39.4 to 46.7
KA (D)	1.6 ± 1	0 to 4.8
Kmax (D)	44.7 ± 1.6	40.6 to 48.1
Km(P) (D)	-6.3 ± -0.25	-7 to -5.6
TL (um)	541.9 ± 28.4	500 to 619
Y coordinate of TL (mm)	-0.22 ± 0.18	-0.55 to 0.5
Y coordinate of Kmax	0.16 ± 1.8	-4 to 4.5
WTW (mm)	11.8 ± 0.39 mm	10.8 to 13.2

** D = diopter; KA=Keratometric astigmatism; Km= mean keratometry; Kmax= maximum keratometry reading; Km(P) = mean keratometry of posterior surface; TL = thinnest corneal location; WTW = white to white corneal diameter*

WTW shows a negative correlation with KM (P < 0.001; r = -0.43), posterior KM (P < 0.001; r = -0.51), Kmax (P < 0.001; r = -0.43), posterior corneal astigmatism (P = 0.002; r = -0.218) and TL (P = 0.012; r 116 = -0.17), and a positive correlation with anterior corneal astigmatism (P = 0.038; r = 0.148)

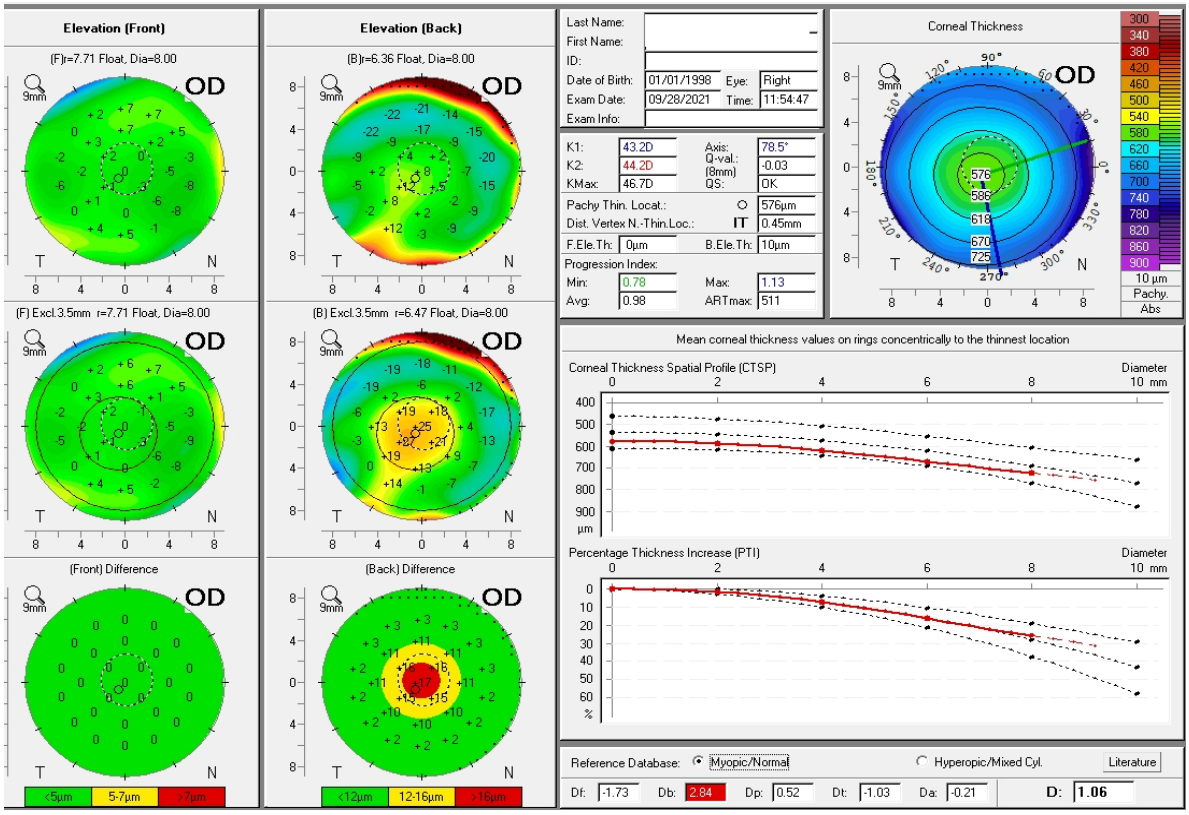

Fig. 1. Belin-Ambrosio display of a cornea with small (10.8 mm) diameter showing the small cornea pattern: the high (red) Db and low Dt and very good corneal thickness with thinnest location = 576 um

Table 2. P values of the correlation between various parameters and Belin-Ambrosio display (BAD) deviation indices

	K m	Km (P)	Kmax	Y Kmax	TL	WTW	KA	Y TL
Df	0.29	0.6	0.91	0.08	0.01(r= -0.16)	0.62	0.55	0.33
Db	0.74	0.002 (r= -0.19)	0.31	0.24	0.63	<0.001 (r= -0.35)	0.8	0.21
Dp	0.009 (r= 0.2)	<0.0001 (r= -0.39)	0.0013(r= 0.19)	0.42	<0.001 (r= -0.3)	0.02 (r= -0.09)	0.82	0.1
Dt	0.44	0.001 (r =0.2)	0.80	0.61	<0.001 (r= -0.99)	0.003 (r= 0.25)	0.11	0.9
Da	0.004 (r= 0.22)	0.003 (r=-0.23)	0.001 (r= 0.24)	0.09	< 0.001 (r= -0.58)	0.91	0.3	0.43
D	<0.001 (r= 0.33)	<0.001 (r= -0.34)	<0.001 (r= 0.38)	0.22	<0.001 (r= -0.54)	0.009 (r= -0.16)	0.004(r=0.18)	0.06 (r=-0.1)

** P values calculated with spearman rank correlation test; r = Spearman rho (Spearman correlation coefficient); Bold = significant*

** KA=Keratometric astigmatism; Km= mean keratometry; Kmax= maximum keratometry reading; Km(P) = mean keratometry of posterior surface; TL = thinnest corneal location; WTW = white to white corneal diameter*

Table 3. Results of multivariate regression analysis of correlation between various parameters and BAD deviation indices

BAD deviation index		coefficient	p-value
Db	Diameter	-0.52	0.002
	Km(P)	-0.48	0.03
Dt	Diameter	-0.020	0.25
	Km(P)	0.0008	0.76
	TL	-0.027	<0.001
Dp	Diameter	-0.020	0.11
	Km(P)	0.0008	<0.001
	TL	-0.027	<0.001
	Km	-0.6	<0.001
	K max	-0.08	0.03
Da	Km	-0.20	<0.001
	Km(p)	-0.1	<0.001
	Kmax	-0.08	0.82
	TL	-0.016	<0.001
D	Diameter	-0.059	0.34
	Km(P)	-0.1	<0.001
	TL	-0.027	<0.001
	Km	-0.13	0.015
	K max	-0.067	0.15
	KA	0.11	0.009

***** *BAD = Belin-Ambrosio Display; KA=Keratometric astigmatism; Km= mean keratometry; Kmax= maximum keratometry reading; Km(P) = mean keratometry of posterior surface; TL = thinnest corneal location; WTW = white to white corneal diameter; Bold = significant.*

Lin Q et al. [15] In a study conducted on 132 normal patients, they divided the patients into two groups, group A (diameter ≤ 11.5 mm), group B (diameter > 11.5 mm), they reached that the 2 groups were comparable regarding Df and Da. For other measurements, Group A had significantly higher K1, K2, Db, Dp, Dt and the final (D). Our study is consistent with their study regarding K1, K2, Db, Dp, and the final (D) but not with Dt, small corneas tend to have a steep anterior surface and more curved posterior surface and more thickness.

Multivariate analysis showed that small corneal diameter has been associated with high Db. But the impact on Dp, Dt and D was not significant in multivariate analysis and the influence on Dp, Dt and D is attributed to difference in corneal thickness and curvature between small and large diameter corneas.

The low (Dt) could be a clue for the clinician when facing a case with high BAD deviation indices (Db, Dp and D) that these high indices could be attributed to small corneal diameter and not real ectasia.

Dongqing et al. [16], In a study conducted on 122 normal patients suggested that individuals with low corneal diameter have a higher posterior keratometry that may influence the best fit sphere and the calculation of the elevation data. This agrees with our results, but we add that small corneal diameter in contrast to ectasia associated with increased pachymetry while large corneas tend to be thin.

Another important finding is that the main factors affecting the BAD deviation indices beside WTW are mean posterior Km, the mean anterior keratometry (Km), and thinnest corneal location (TL).

Cao KW et al. [17] conducted a study on 6744 myopic patients from China who had undergone prerefractive surgery examination, to investigate the influence of corneal diameter on BAD display results, they found that the proportion of suspicious and pathological results (color code yellow or red) in Df, Db, Dp, Da, and (D) are more with cases of low corneal diameter. Our study is consistent with their study regarding Db, Dp, Dt and final (D).

Boyd B. et al. [18] when comparing Tomographic Parameters between Chinese and North American population, they reached a conclusion that Corneal diameter had the greatest influence on pachymetric progression and final D, and more profoundly on the Chinese as the Chinese

population tend to have a smaller corneal diameter. In their results regression analysis also revealed statistically significant correlations between corneal diameter and k1, k2, Kmax, DF, Db, and final D on both Chinese and North American populations.

Finally, horizontal corneal diameter has an impact corneal curvature, pachymetry and BAD results, (Db, Dp, Dt, and final D) this is constant with lin Q. et al [15], Dongqing et al [16], Cao KW et al. [17], ,Boyd B. et al.[18] and it has a direct impact on Db and indirectly on Final (D), Dp, Dt this could be due to that influence all anterior and posterior K readings, the anterior and posterior astigmatism and TL pachymetry of the cornea.

5. CONCLUSION

Corneal diameter influences corneal curvature and pachymetry. It also influences BAD display; small diameter is associated with steep cornea and can give a false impression of corneal ectasia in BAD display, it is associated with high Db regardless of other indices and associated with high Dp and D and low Dt due to disparity in curvature and pachymetry between individuals with small corneas and normal population.

CONSENT

All authors declare that a written informed consent was obtained from the patients for publication of this study.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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