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Original Article

THE IMPACT OF REFRACTIVE ERRORS ON THE ANTERIOR CHAMBER PARAMETERS IN A SAMPLE OF EGYPTIAN INDIVIDUALS

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Abstract
Purpose: *To investigate the effect of refractive errors on anterior chamber parameters in an Egyptian population sample. In addition, we aimed to determine the impact of varying degrees of refractive error on the results of Pentacam and optical biometer measurements of the anterior chamber.* ***Design & Setting:*** *Cross sectional comparative observational study was conducted at Alforsan Eye Center, Assiut, Egypt.* ***Methods:*** *This study included a total of 80 eyes from a sample of 42 Egyptian subjects. The participants aged 18 to 41 years attended the eye centre for routine examinations, prescription glasses, or refractive surgery. Subjects with a history of previous contact lens wearing, ocular trauma, keratoconus, uveitis, or those who had undergone prior ophthalmic or refractive operations were all excluded from the research. The best adjusted and unaided visual acuity, as well as an autorefractometer reading, were obtained. Following a slit lamp examination conducted by the same operators (MS) in a single session, all subjects underwent scanning utilising the NIDEK AL-scan optical biometer and Pentacam oculus (to measure Keratometry (K) measurements, anterior chamber depth (ACD), white to white (WTW) line assessment.* ***Results:*** *Subjects with emmetropia had the shallowest anterior chambers compared to those with myopia. Additionally, the utilization of the Pentacam revealed a statistically significant positive correlation between ACD and keratometry (K2) in the high myopia group. However, a statistically significant negative association was detected in the hypermetropia cohort. The use of the AL-scan biometer demonstrated a statistically negative significant correlation between ACD and K2 in low/moderate myopia, hypermetropia, and emmetropia groups. The study revealed that the ACD, K-readings, and WTW measurements obtained from either the Pentacam or the NIDEK AL-scan optical biometer were comparable in all groups.* ***Conclusions:*** *This study demonstrated the existence of a diverse correlation, ranging from positive to negative, between the various anterior chamber parameters and the refractive state of the eye. In addition, the results of the NIDEK AL-scan optical biometer and the Pentacam for ACD and K readings and WTW measurements were comparable.*

Keywords: *Refractive errors, Anterior chamber depth, Keratometry, White to white*

1. Introduction
Accurate measurement of various anterior segment variables, such as anterior chamber depth (ACD), corneal power (K-readings), and White-to-White (WTW) distance, is essential for diagnosing a wide range of conditions and performing procedures like

cataract surgeries, glaucoma surgeries, refractive invasive procedures, and post-operative monitoring [1]. The evaluation of ACD plays a critical role in the contemporary biometric calculations used for the determination of intraocular lens (IOL) power [2]. In addition to its use in surgical planning, optical coherence tomography (OCT) has been utilised for the assessment of IOL power during phakic IOL implantation [3]. The ACD is also implicated as a possible diagnostic factor for glaucoma [4]. Furthermore, a noticble ACD alteration has been found following photorefractive keratectomy procedures [5]. In ophthalmic practise, accurate corneal curvature measurement is essential because the cornea accounts for two-thirds of the eye's total optical signal [6]. There are various keratometry methods that can be used. Manual measurement of preoperative corneal astigmatism with a keratometer requires practise, and the operator's interpretation of the measured values may vary. Automatic tools may be utilized, including the autorefractor keratometer, optical biometers, three Placido disk-based corneal topographers, and Pentacam and Sirius Scheimpflug camera [7]. White-to-white (WTW) distance refers to the horizontal corneal size measured between the edges of the corneal limbus. This distance was formely used in medical settings to diagnose and treat ocular disorders such as congenital glaucoma, microcornea, and megacornea. The WTW distance is now routinely considered during cataract procedures. It is a parameter utilised in IOL power calculating equations, particularly new generation formulations such as the Holladay 2, Hill-RBF 2.0, Olsen, and Barrett Universal II equations. It is believed to influence corneal astigmatism after cataract surgery. More significantly, it is now taken into account when planning surgical operations for refractive cataracts [8]. Scheimpflug cameras, such as the Pentacam, and optical biometers are just two contemporary devices employed for imaging the anterior segment of the eye and accurately measuring parameters such as ACD, K-reading, and WTW. The objective of our study is to evaluate the impact of refractive errors on these aforementioned parameters. Moreover, this study aims to compare the results obtained from the Pentacam and optical biometer measurements in relation to different types of refractive errors.

2. Methods

2.1. *Study design and subjects*

The Institutional Review Board of the Faculty of Medicine, Assiut University, approved this cross-sectional comparative observational study. The study adhered to the Declaration of Helsinki. All subjects provided written informed consent. The participants included in this visited Alforsan Eye Centre between 2021 and 2022 for either a casual examination, a prescription for glasses, or refractive surgery. Those with a history of contact lens use, ocular trauma, keratoconus, uveitis, or ocular surgery were excluded from the study. Each patient's previous ocular and general medical history was reviewed. The visual acuity and an autorefractometer (TOPCON co., JAPAN) measurement were performed. Prior to the scanning, the anterior portion of the eyes underwent a slit lamp evaluation. Then, in a single session, the same operator performed both pentacam oculus HR and NIDEK AL-scan optical biometer scanning. Refractive errors were graded based on the spherical equivalent (SE) as follows: "myopia" of SE ≤ -0.25 D; "hyperopia" of SE $\geq +0.25$ D, low myopia (< -3.00 D), moderate myopia (SE -3.00 to -6.00 D), high myopia (SE > -6.00 D), low hyperopia SE $\geq +0.25$ to $+2.75$ D, moderate hyperopia SE + 3.00 to + 5.00 D, and high hyperopia > + 5.00 D. Astigmatism was defined as a cylinder error of 1.0D or more.

2.1.1. AL-scan optical biometer

This instrument was introduced by NIDEK incorporation (NIDEK CO., LTD. JAPAN) to measure six variables, including ACD, WTW, K-readings, axial length, pupil size, and central corneal thickness, using the partial coherent interferometry (PCI) concept combined with scheimpflug imaging. Double-mire rings were projected onto the cornea at the 2.4 mm and 3.3 mm zones to measure keratometry values, while the scheimpflug imaging technique was used to measure CCT and ACD [9], fig. (1). After focusing on the iris, a computerised image of the front surface of the eye was captured for WTW assessment. The WTW separation was then calculated when the limbus was immediately identified, fig. (2).

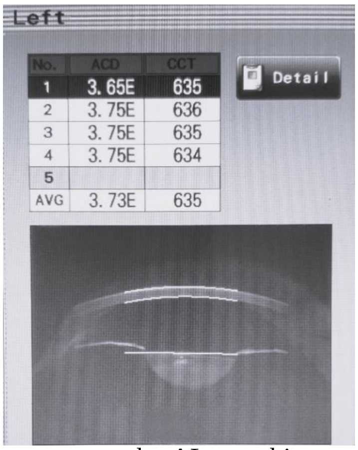

Figure 1: Demonstration for ACD measurement by AL-scan biometer (measured as distance between the white lines at the external corneal surface and anterior lenticular surface measuring the external ACD and the distance between the white lines at the internal corneal surface and the anterior lenticular surface measuring the internal ACD)

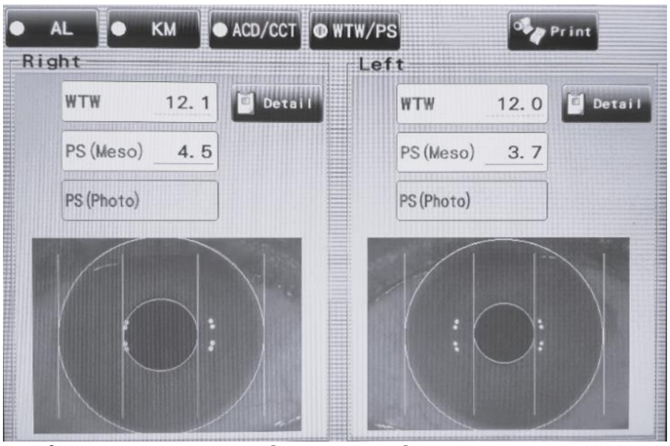

Figure 2: Demonstration for WTW measurent by AL-scan biometer.

2.1.2. Pentacam Oculus (Wavelight oculyzer II): (Oculus Optikgeräte GmbH Co. Germany)

On the Pentacam, an LED emitting a 475 nm Scheimpflug blue light captures images of the anterior segment. It captures 50 images over the course of approximately two seconds. After extracting roughly 2,760 true elevation values from the collected images, IT generates 138,000 true elevation values for the front and back corneal regions, from limbus to limbus, and the middle portion of the cornea [10]. Therefore, it determines the cornea's k-values. The Pentacam HR calculates ACD from the corneal endothelial lining along a line from the cornea's apex to the lens' anterior side. Caliber brakes were manually placed on the Scheimpflug picture of the horizontal plane of the studied eye to assess WTW horizontally. After placing the calipers on the corneoscleral junctions, a line was automatically created connecting the two spots. The WTW value is represented by the length of this line, fig. (3).

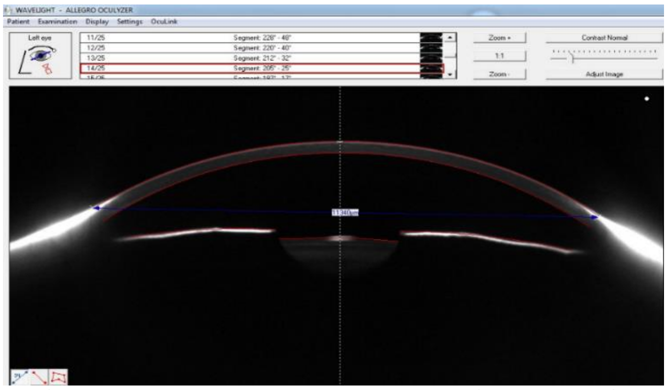

Figure 3: Demonstration for WTW measurement over the sheimpflug image of pentacam.

2.2. *Statistical analysis*

Data was collected and analysed using SPSS (Statistical Package for the Social Science, version 20, IBM, and Armonk, New York). Quantitative data were expressed as mean ± standard deviation (SD) and compared using the ANOVA test (between different groups) and Student t-test (between Pentacam and AL-scan optical biometer measurements in the same group). The nominal data were expressed as numbers (n) and percentages (%). The confidence level was kept at 95%; hence, the *P*-value was considered significant if < 0.05.

3. Results

The study was conducted on 80 eyes of 42 patients. The mean age of the studied patients was 29.90 ± 5.88 years, ranging between 18 and 41 years. Of the studied patients, 25 (59.5%) were females, and 17 (40.5%) were males. These patients did not have any eye diseases. There was one diabetic patient and one hypertensive patient. Except for four patients, all patients originated from the governorate of Assiut. Table (1) displays the refraction parameters and the number of patients in each group.

Table 1: Refraction parameters in the study groups

	Low/Moderate myopia (n= 20)	High myopia (n= 20)	Hypermetropia (n= 20)	Emmetropia (n= 20)
Refraction (Sphere)	-2.68 ± 1.11	-7.76 ± 1.76	3.14 ± 1.40	-0.12 ± 0.34
Refraction (Cylinder)	-1.45 ± 0.82	-1.70 ± 1.28	0.05 ± 0.63	-0.39 ± 0.13
Spherical Equivalent (SE)	-3.26 ± 1.32	-8.59 ± 1.91	3.05 ± 1.35	-0.28 ± 0.37

3.1. *Anterior chamber depth among the studied groups*

There were significant differences between the studied groups in terms of anterior chamber depth either by Pentacam or AL-scan optical biometer. Patients with myopia had the highest internal and external anterior chamber depth, while hypermetropic patients had the least depth. In each separate group, measurements of anterior chamber depth using either the Pentacam or the AL-scan optical biometer were comparable in each group ($p > 0.05$), tab. (2).

Table 2: Anterior chamber depth among the studied groups

	Low/moderate myopia (n= 20)	High myopia (n= 20)	Hypermetropia (n= 20)	Emmetropia (n= 20)	*P1* value
Internal ACD (mm) Pentacam	3.09 ± 0.05	3.13 ± 0.27	2.72 ± 0.30	2.73 ± 0.28	< **0.001**
AL-scan biometer	3.11 ± 0.23	3.13 ± 0.26	2.74 ± 0.33	2.81 ± 0.21	< **0.001**
***P2* value**	0.76	0.97	0.30	0.82	
External ACD (mm) Pentacam	3.63 ± 0.23	3.68 ± 0.27	3.26 ± 0.28	3.37 ± 0.25	< **0.001**
AL-scan biometer	3.64 ± 0.23	3.67 ± 0.25	3.29 ± 0.33	3.35 ± 0.20	< **0.001**
***P2* value**	0.91	0.90	0.76	0.73	

Data expressed as mean (SD), ***P* value** was significant if < 0.05**,** ***P1* value** compares between different groups**,** ***P2* value** compares between Pentacam and AL-scan biometer at the same group**.**

3.2. *K readings among the studied groups:*

There were no significant differences between the groups as measured by either the Pentacam or AL-scan biometers for K levels. The measurement of K readings by either the Pentacam or the AL-scan biometer was found to be comparable in each group ($p > 0.05$), tab. (3).

Table 3: *K* readings among the studied groups

	Low/Moderate myopia (n= 20)	High myopia (n= 20)	Hypermetropia (n= 20)	Emmetropia (n= 20)	*P1* value
***K1*(D)** Pentacam	42.70 ± 1.27	40.73 ± 9.69	39.93 ± 9.51	38.34 ± 13.23	0.53
AL-scan biometer	42.75 ± 1.29	40.91 ± 9.73	39.83 ± 9.46	42.81 ± 1.71	0.44
***P2* value**	0.90	0.95	0.97	0.14	
***K2* (D)** Pentacam	43.84 ± 1.57	44.21 ± 1.85	43.54 ± 1.33	41.14 ± 9.82	0.22
AL-scan biometer	44.18 ± 1.44	42.05 ± 10.01	43.67 ± 1.39	43.56 ± 1.55	0.60
***P2* value**	0.48	0.35	0.74	0.28	

Data expressed as mean (SD), ***P* value** was significant if < 0.05**,** ***P1* value** compares between different groups**,** ***P2* value** compares between Pentacam and AL-scan biometer at the same group**.**

3.3. *WTW among the studied groups*

Pentacam or AL-scan biometer measurements of WTW revealed no statistically significant differences between the groups. In each separate group, measurement of WTW by Pentacam or AL-scan biometer was found to be comparable ($p > 0.05$), tab. (4). There was a significant positive correlation between internal ACD and K2 in Pentacam in the high myopia group ($r = 0.40$, $p < 0.001$). In addition, there was a significant negative correlation in the hypermetropia group ($r = -0.69$, $p < 0.001$), tab. (5). Regarding the AL-scan biometer, there was a negative correlation between internal ACD and *K*2 in the low/moderate myopia group (r= -0.63, p 0.001), hypermetropia group ($r = -0.59$, $p < 0.001$) and emmetropia group ($r = -0.65$, $p < 0.001$), tab. (6).

Table 4: WTW among the studied groups

WTW (mm)	Low/Moderate myopia (n= 20)	High Myopia (n= 20)	Hypermetropia (n= 20)	Emmetropia (n= 20)	*P1* value
Pentacam	11.46 ± 2.72	11.76 ± 0.50	11.69 ± 0.38	11.82 ± 0.28	0.86
AL-scan biometer	11.38 ± 2.71	11.17 ± 2.67	11.99 ± 0.19	11.84 ± 0.36	0.49
***P2* value**	0.92	0.33	0.09	0.87	

Data expressed as mean (SD), ***P* value** was significant if < 0.05**,** ***P1* value** compares between different groups**,** ***P2* value** compares between Pentacam and IOL at the same group**.**

Table 5: Correlation between internal ACD and *K* 2 measurements in Pentacam

	ACD and *K2* in Pentacam	
	***r* value**	***P* value**
Low/Moderate myopia	- 0.01	0.93
High Myopia	**0.40**	**< 0.001**
Hypermetropia	**- 0.69**	**< 0.001**
Emmetropia	0.02	0.29

Data expressed as *r*-value (strength of correlation)**,** ***p*-value (**significance of correlation). *P*-value was significant at < 0.05

Table 6: Correlation between internal ACD and *K* 2 measurements in AL-scan biometer

	ACD and *K2* in Al-scan biometer	
	r value	***P value***
Low/moderate myopia	**- 0.63**	**< 0.001**
High myopia	0.06	0.79
Hypermytropia	**- 0.59**	**< 0.001**
Emmetropia	**- 0.65**	**< 0.001**

Data expressed as *r*-value (strength of correlation)**,** ***p*-value** (significance of correlation), ***P*-value** was significant if < 0.05.

4. Discussion

Accurate measurement of the eye's anterior segment parameters is essential for diagnosing a variety of diseases and for cataract surgeries, glaucoma, refractive surgeries, and postoperative follow-up. When determining the IOL power, accurate measurements of the Anterior chamber depth (ACD), corneal power (K-readings), and White-to-White (WTW) are crucial, particularly with the most recent generations of biometric algorithms. For patients with significant refractive error requesting refractive surgery, measuring the ACD and WTW is crucial to the success of the procedure. Errors in analysing these variables prior to surgery could result in unintended refractional complications [11].

4.1. *Anterior chamber depth (ACD)*

In our study, there were significant differences between groups in anterior chamber depth as measured by either the Pentacam or AL-scan biometer. Myopic patients had the greatest anterior chamber depth, while hypermetropic patients had the least. Similar results were reported by O'Donnell et al. [12], who examined the anterior chamber depth in 40 individuals with myopia and 30 individuals without refractive errors and found comparable results. They found ACD = 3.17 ± 0.29 mm in the first group and ACD = 2.92 ± 0.31 mm in the second group, which were statistically significant differences. In addition, Chen et al. [13] found that eyes with more myopic refractive error tend to have a deeper anterior chamber (r = 0.651, p < 0.001). Alrajhi et al. [14] studied 252 myopic patients between the ages of 18 and 39, dividing them into three groups based on their degree of myopia: low myopia (<− 3.00 D), moderate myopia (−3.00 to −6.00 D), and high myopia (>− 6.00 D). The parameters of the anterior chamber were measured using Pentacam. The study revealed that ACD was lower among those with low myopia compared to those with moderate myopia. Consistent with the study by Fatma et al. [15], there were significant differences in ACD between emmetropic, hypermetropic, and myopic eyes in children and adolescents. After adjusting for age, it was found that myopic children had a deeper ACD than their emmetropic and hyperopic counterparts (both < 0.0001). In contrast, there was no significant difference in ACD between emmetropic and hyperopic children (> 0.05). Some studies have shown that this deeper ACD may be related to the eyeball elongation that occurs in myopia. As the eyeball becomes longer, the distance between the lens's front surface and the cornea's back surface increases, resulting in a deeper ACD. However, it is important to note that even among individuals with the same degree of myopia, there can be individual variation in ACD. Additional factors, including age, gender, and ethnicity, can influence ACD. Therefore, deep anterior chamber is not necessarily a reliable indicator of myopia. Our study revealed that Pentacam and AL-scan biometer measurements of anterior chamber depth were comparable ($p > 0.05$). This result can be explained by the fact that both devices utilise sheimpflug technology. Nevertheless, this was proven by comparing pentacam to other common optical biometers like IOL master, as Shajari et al. [16] found no statistically significant difference between Pentacam HR and IOL master in ACD value in healthy unoperated eyes. Domínguez-vicent et al. [17], Muzyka-Woźniak et al. [18], and Fernández-Vigo et al. [19] studies agreed that there is minimal insignificant difference between both devices in ACD value. On the contrary, Utine et al. [20] found that IOL master ACD values were 0.11mm less than Pentacam ACD values. The mean difference between IOL master and Pentacam measurements was 3.16% of the mean ACD calculated across all measurements. However, this difference is insufficient to affect the refractive outcome significantly. Off-axis measurement is a significant source of error that can arise during ACD evaluation. Only a slight deviation from the correct direction (perpendicular to the four major surfaces in the eye's optical axis) affects the ACD measurement results [21]. Therefore, patient alignment is of maximum importance. The slight offset in measurement results obtained by the different devices in this study may be explained by different axes of measurement.

4.2. *K-reading*

According to Mashige and Oduntan et al. [22], the corneal parameters and their correlations with refractive error in a sample of 600 black South African participants did not differ significantly between the studied groups as measured by K readings obtained with either the Pentacam or AL-scan biometer. They found no correlation between SE and corneal power (referring to it as anterior corneal curvature (ACC) ($r = -0.03$, p-value = 0.48). In addition, Chen et al. [13] and Krishnan et al. [23] found no significant correlation between spherical equivalent and corneal power, which aligns with our findings. However, Arora et al. [24], in their study on a sample of 500 eyes from subjects aged between 20 and 40 years, found a statistically significant correlation between SE and corneal curv-ature (CC) ($r = 0.159$, $p < 0.01$ and $r = 0.184$, $p < 0.01$) in the right eye and left eye, respectively. There are some differences in the findings of different investigations, and many factors that could explain these discrepancies in findings, including age groups, refractive error variations, sample size, demographics, nationalities, statistical power of the research, and different testing techniques. In our study, it was found that the measurement of *K*-readings either by Pentacam or by AL-scan biometer was comparable. Evaluation of corneal curvature at multiple zones in the AL-scan biometer (2.4 and 3.3-mm zones) may be a reason for the similarity of measurements between it and Pentacam. These findings align with research by Yu J et al. [25] that found no statistically significant differences between the optical biometers, including the AL-scan device and Pentacam, in terms of the flattest and steepest K-readings. Laursen et al. [26] compared keratometry using five different instruments. There were insignificant differences between the average K-readings of Pentacam and IOL master, which were generally insignificant. In contrast, Dong et al. [27] discovered considerable differences between the two devices' flat K1 and steep K2 results. His research focused on a Chinese group. Moreover, investigations by Woodmass et al. [28] and Elbaz et al. [29] discovered that the average K value for Pentacam is lower than that of the IOL master, which was explained by the Pentacam algorithm's consideration of the posterior corneal surface curvature. Intriguingly, the correlation between ACD and K2 in different refractive error groups using either Pentacam or AL-scan biometer varied, indicating that these relationships are not always consistent and can vary depending on other variables such as age, ethnicity, axial length, and sample size.

4.3. *White to white line (WTW)*

In our study, there were no significant differences in WTW as measured by Pentacam or Al-scan biometers between the groups. These findings concurred with those of K. Singh et al. [30] indicating that the corneal size in the emmetropia cohort was not significantly different from that in the lower myopia group and that the corneal size in the median myopia group was not distinguishably different from that in the higher myopia group. Conversely, Rüfer et al. [31] and Hashemi et al. [32] studied patients whose eyes had various refractive conditions, and it appeared that myopic eyes may have a smaller corneal size. In addition to different ocular measurements, it is believed that several other factors influence WTW, including differences in measuring tools, race, age groups, and sex. Domnguez-Vicent et al. [17] discovered a negligible difference between WTW measured by Pentacam HR and IOL master (mean difference, 0.07 ± 0.10mm). This finding is consistent with our results that found a comparable measurement of WTW distance between Pentacam and AL-scan biometer. Although Elkateb and Swelem et al. [33] used the same manual technique in measuring the WTW distance in Pentacam scheimpflug images in a study done in Egypt comparing it with IOL master automatic measures, they found that mean WTW by Pentacam (mean 11.93 ± 0.43 mm) is higher than WTW by IOL master (mean 11.66 ± 0.27mm). They also explained the difference because manual measurements over sheimpflug images are highly subjective, and detecting the true corneoscleral junction within the reflected light noise at the scleral side is difficult. Shajari et al. [16] discovered a greater value of WTW by IOL master (mean 12.0 ± 0.3mm) than by Pentacam (mean 11.8 ± 0.4mm). Contrary to our findings, the Pentacam HR survey (Oculus, Germany), which integrates an iris camera, may assess WTW electronically. There may be some limitations to the current study. In addition to the relatively small sample size, the spectrum of refractive error was relatively broad for the myopia group and narrow for the hyperopia group in each study cohort. In addition to the elderly in the group with hyperopia, the distribution of survey respondents also includes the young in the group with myopia. Our findings may not apply to individuals of other races. Due to differences in eyeball size, WTW variance, and refractive error distributions, it is anticipated that extrapolating and applying the findings of this study to other races will be challenging.

5. Conclusion

The findings of this study demonstrated a diverse correlation between refractive errors and anterior chamber parameters ranged from positive to negative. with no significant differences between the tested groups and between two devices used in the study (Pentacam and AL-scan optical biometer) in terms of ACD, K-reading, and WTW.

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