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ORIGINAL RESEARCH

Comparison of Self-Test Refraction, Autorefraction, and Subjective Refraction

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Purpose: To compare the performance of a self-refraction device (EyeQue Vision Check 2, EyeQue, USA) with autorefraction (OPD-Scan III, NIDEK) and subjective cycloplegic refraction in measuring refractive errors.

Methods: This descriptive study included 80 eyes from 40 patients. Measurements were obtained using the portable EyeQue device, OPD-Scan III, and subjective cycloplegic refraction performed by an experienced examiner. Spherical equivalent (SE), cylindrical power, and axis values were analyzed using power vector decomposition (M, J0, J45) to improve accuracy in comparing methods. The main outcome was the agreement between self-refraction, autorefraction, and subjective refraction.

Results: The EyeQue device showed lower variability and greater homogeneity in spherical measurements but exhibited lower precision for cylindrical power and axis than subjective refraction. Power vector analysis revealed that EyeQue overestimated spherical equivalent (M) and produced higher J0 values, suggesting a tendency to alter cylindrical correction. Although comparable to OPD-Scan in spherical refraction, EyeQue demonstrated inconsistencies in astigmatism correction, particularly in J45 components.

Conclusion: The EyeQue device is a promising tool for large-scale screenings due to its affordability and portability. However, its limitations in astigmatism and axis measurements indicate that subjective refraction should complement rather than replace it. Therefore, further refinement and validation in diverse populations are recommended.

Keywords: self-refraction, autorefraction, subjective refraction, power vector analysis, teleophthalmology

Introduction

Refractive error is one of the main preventable causes of blindness worldwide. Myopia, in particular, is projected to affect nearly 50% of the global population by 2050, with high myopia being associated with an increased risk of glaucoma, retinal detachment, cataracts, and irreversible visual impairment. Still, access to an eye care provider is not always possible, especially in resource-poor areas where the population needs constant access to healthcare. Furthermore, the global shortage of trained eye care professionals exacerbates this issue, particularly in underserved regions. Therefore, uncorrected refractive errors can cause immediate and long-term consequences for children and adults, such as amblyopia, poor school performance, reduced work productivity, or unemployment. This can lead to *significant* economic and social problems in several aspects of a person's life.[1]

Cycloplegic subjective refraction remains the gold standard for determining refractive error and the need for spectacle correction.[2–6] To assist with subjective refraction and, consequently, the prescription of spectacles, automated refraction

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(AR) devices have been increasingly refined and are becoming more portable Additionally, aberrometry devices now provide progressively more accurate AR.[5–10]

More recently, self-refraction has been studied to correct refractive errors in adults, especially in areas with limited access to eye care providers.[10–17] These devices have been shown to provide clinically useful correction in adults. The EyeQue is a portable self-administered refraction device that uses a smartphone to determine spherical and cylindrical values. However, despite its potential, no studies have comprehensively assessed its reliability compared to autorefraction and subjective cycloplegic refraction.[11–17]

Therefore, this study aims to compare spherical, cylindrical, and spherical equivalent (SE) values using a portable autorefraction device (EyeQue, USA), standard autorefraction (OPD SCAN III, NIDEK, Japan), and subjective cycloplegic refraction (SCRx). Additionally, we employ power vector analysis to enhance the precision of refractive error comparisons across these methods.

Methods

Study Design

This descriptive cross-sectional study was conducted at the Hospital Oftalmológico de Brasília (HOB) between July 2019 and January 2020 with volunteers known to have refractive errors. The study was divided into two stages: selecting patients based on predetermined inclusion and exclusion criteria and the subsequent collection and analysis of refractive data. Ethical approval for the study was obtained from the Institutional Review Board (IRB) and adhered to Clinical and Surgical Ethical Standards, Good Clinical Practices (NIDA, USA), and the Declaration of Helsinki. All patients signed informed consent to participate in this study.

Study Population

The study population consisted of young, healthy adults between 18 and 40 years of age with refractive errors who were either ophthalmologists or employees at HOB. Participants with high ametropia (spherical equivalent ≤ −6.00D or ≥ +4.00D), irregular astigmatism, or any previous ocular pathology that could affect refraction measurements were excluded. Data collected included age, gender, and refractive measurements (spherical, cylindrical, and SE) from three methods: self-administered autorefraction (EyeQue, USA), autorefraction (OPD-Scan III, NIDEK, Japan), and subjective cycloplegic refraction (SCRx) performed by an experienced examiner.

Assessment

Each patient underwent objective and subjective measurements, totaling three ancillary tests in the following order: portable self-administered device (EyeQue), autorefraction (OPD-Scan III), and subjective cycloplegic refraction. Cycloplegia was induced by administering three doses of 1% tropicamide eye drops at 5-minute intervals, with evaluations performed 20 minutes after the last dose. The choice of tropicamide instead of cyclopentolate was based on its accessibility, shorter duration of action, and patient tolerance despite its potential to underestimate hyperopia.

Automated Refraction Devices

EyeQue

The EyeQue is a portable autorefractor that leverages augmented reality to measure visual acuity and refractive error. It includes an optical adapter that connects to a smartphone and an application, enabling accessible, self-administered vision assessments. Data acquisition relies on a refractive scanning method, where the user interacts with the app by adjusting digital lines displayed on the screen until alignment is achieved. This process allows the device to compute spherical and cylindrical refractive errors, including the axis. The device estimates eyeglass prescriptions but does not measure accommodation status or higher-order aberrations, which can impact accuracy.

OPD-Scan III

The OPD-Scan III (NIDEK, Japan) is an automated refractor and aberrometer that uses retinoscopy to scan the retina with an infrared slit beam and provide spherical and cylindrical values. The light is projected onto the retina in a grid-like pattern, then reflected and captured by multiple pairs of rating photodetectors, which calculate the time delay between the central and peripheral reflexes to determine the eye's refractive error. Unlike the EyeQue device, OPD-Scan III integrates aberrometry, which allows for a more detailed analysis of refractive errors and higher-order aberrations.

Statistical Analysis

Refractive data were compiled in an Excel spreadsheet, and the statistical analyses were performed using R software (version 3.5.3) and SPSS (version 24.0 for Windows, IBM, Armonk, NY, USA). Differences among the three methods were calculated in absolute values. The normality of the data was assessed using the Kolmogorov–Smirnov test. An ANOVA test was used to compare differences among the groups if variables were normally distributed. A Kruskal–Wallis test was used if variables were not normally distributed. A p-value of < 0.05 was considered statistically significant.

Power Vector Analysis (PVA) was applied to enhance the comparison of cylindrical corrections among methods, allowing refractive errors to be represented in vectorial components (M, J0, and J45). This approach minimizes the influence of variations in axis positioning between devices.

Results

This study included 80 eyes of 40 patients, *50% male*. Among the participants, 19.55% were myopes, and 5.13% were hyperopes. Table 1 shows differences in mean spherical refractive error (SPH), mean cylindrical error (CYL), mean cylindrical axis (AXIS), and mean spherical equivalent (SE) for the EyeQue, OPD-Scan III, AR, and SCRx methods.

Comparison of Spherical and Cylindrical Measurements

Both ARSE methods yield statistically significantly more myopic results when compared to SCRx ($p < 0.05$), but the EyeQue produced more myopic results compared to the OPD-Scan III. The differences between ARSE and SCRx SE were calculated as absolute values of SE. When all groups were analyzed, the EyeQue group showed the highest absolute difference between methods.

The EyeQue device showed behavior like the other devices in pathology distribution, except for SCRx, which revealed more emmetropic patients than hyperopic ones. Additionally, the EyeQue device exhibited a performance similar to the OPD-Scan III in pathology distribution, as illustrated in Figure 1.

Table 1 Summary Statistics for Spherical Refractive Error (SPH), Cylindrical Error (CYL), and Cylindrical Axis (AXIS) Across Devices

Measure	EyeQue	SR (Subjective Refraction)	OPD-Scan III	AR (Auto-Refractor)
SPH Mean	1.76	1.22	1.49	1.55
SPH Std Dev	1.6	2.62	2.12	2.84
CYL Mean	916	794	891	935
CYL Std Dev	894	1.144	1.071	1.158
AXIS Mean	85.08	85.9	69.85	98.05
AXIS Std Dev	58.31	74.62	63.11	69.42

Notes: Mean values are in diopters (D) for SE and CYL, and degrees (°) for AXIS. Standard deviation (Std Dev) indicates variability. Statistical comparisons were performed using ANOVA for normally distributed data and Kruskal–Wallis for non-parametric variables. Post-hoc tests were applied when significant differences were found.
Abbreviations: SE, Spherical equivalent (D); CYL, Cylindrical power (D); AXIS, Cylindrical axis (°); EyeQue, Portable Auto-Refractor; SR, Subjective Refraction; OPD, OPD-Scan III; AR, Auto-Refractor.

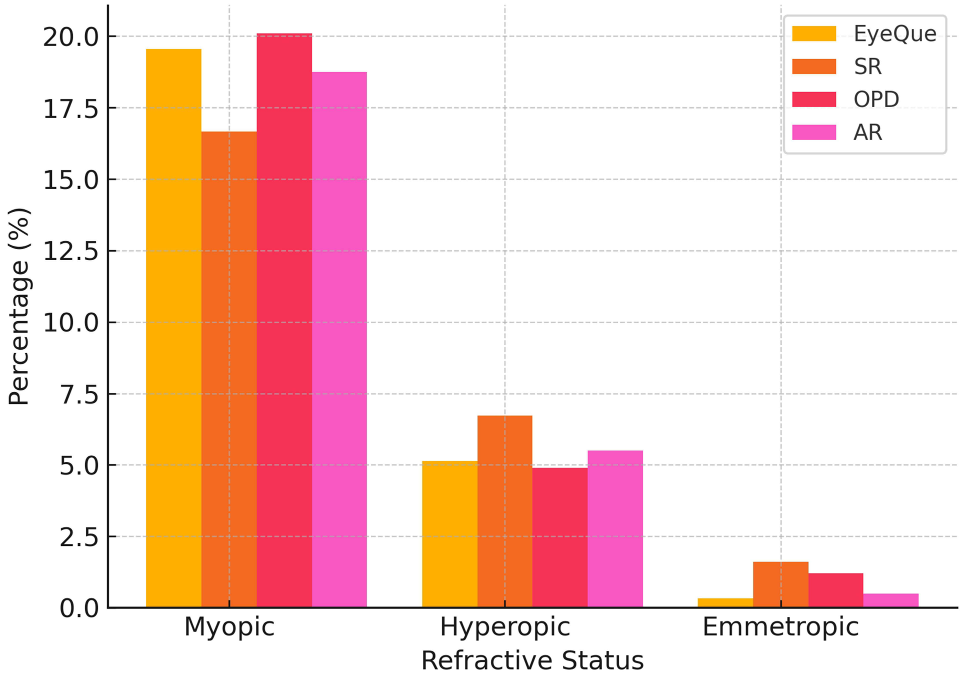

Figure 1 A bar graph showing the distribution of refractive status across devices.

For spherical (SPH) measurements in the right eye, the EyeQue device displayed higher values than the other devices. As shown in Figure 2, EyeQue also had fewer outliers than SR, OPD, and AR. The standard deviations indicate that EyeQue had the least variability around the mean, suggesting that it is the most homogeneous device in comparison.

When analyzing the left eye's SPH measurements, the EyeQue device again exhibited less variability around the mean than other devices (Figure 2). Although the values were generally higher, with fewer outliers, they were more similar to the other devices than the right eye results.

For cylindrical (CYL) measurements, Figure 2 indicates that the EyeQue device had a higher mean than SR and OPD but a lower mean than AR. Upon examining the standard deviations for the CYL variable, the EyeQue device demonstrated significantly lower variability than the other devices, indicating more consistent and centered results. This consistency is likely since 50% of its data ranged between 0.5 and 1. Furthermore, the minimum and first quartile values for EyeQue were the highest among the devices, although its maximum value was the lowest.

Except for the SR device, all other devices showed a similar average CYL value, as illustrated in Figure 2. Once again, the standard deviations highlight that the EyeQue device exhibited the least variation around the mean, making it the most stable device for CYL measurements. The minimum CYL value for the EyeQue device was 0, and 75% of its values were below one across all devices. The EyeQue device consistently demonstrated results similar to those of the other devices regarding the first quartile and maximum values, except for SR.

Figure 2 describes the CYL results for both eyes, showing the devices' comparative performance.

Power Vector Analysis (PVA)

Refractive errors were converted into vectorial components using power vector analysis to enhance comparability. Table 2 presents the calculated values of M (mean spherical equivalent), J0 (Jackson cross-cylinder at 0°/90°), and J45 (Jackson cross-cylinder at 45°/135°) for each method.

The EyeQue device exhibited a higher M value than other methods, indicating a tendency to overestimate the spherical equivalent. J0 values were also elevated for EyeQue and SR, suggesting a potential shift in cylindrical correction. J45 values showed significant variations, particularly for the AR and OPD-Scan III methods, which may reflect differences in axis alignment among devices.

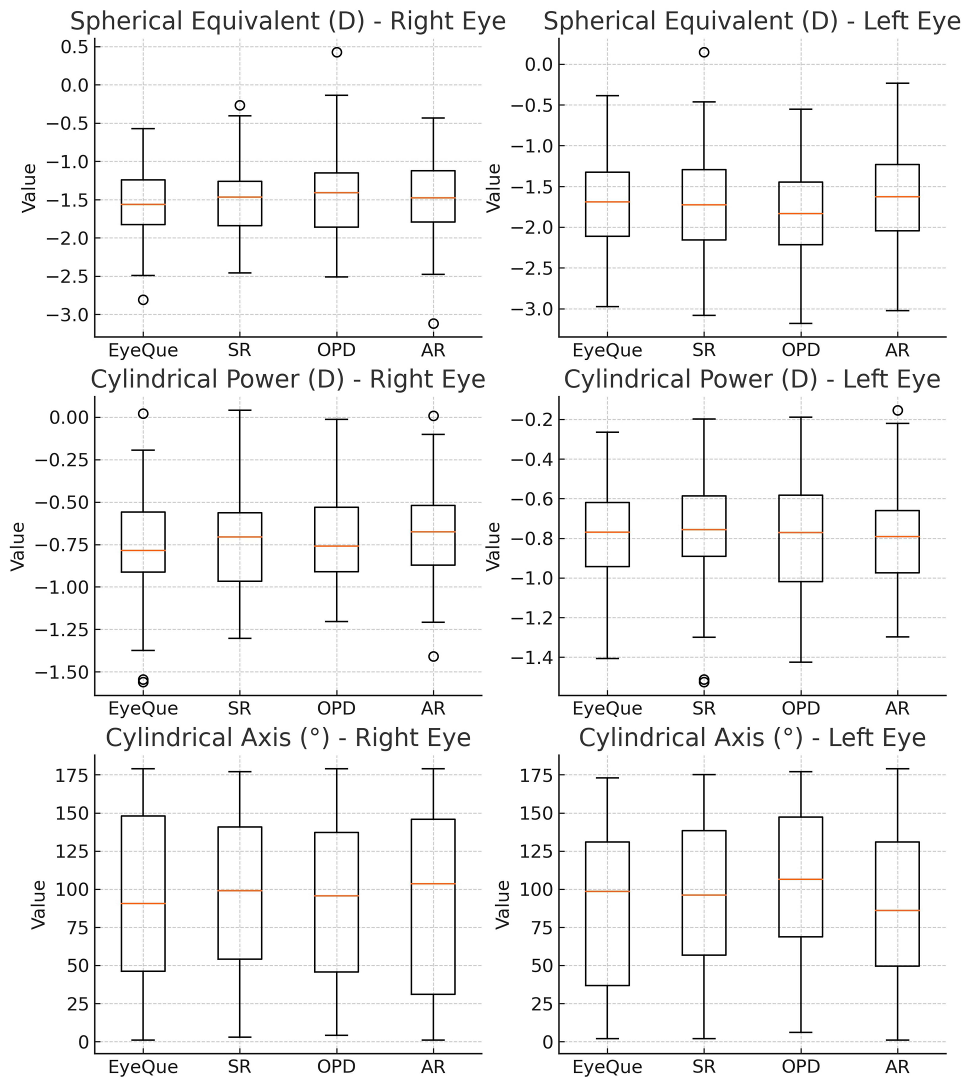

Figure 2 Boxplots comparing refractive measurements across devices. Spherical Equivalent (D) – Right Eye, Spherical Equivalent (D) – Left Eye, Cylindrical Power (D) – Right Eye, Cylindrical Power (D) – Left Eye, Cylindrical Axis (°) – Right Eye, Cylindrical Axis (°) – Left Eye.

Statistical comparisons demonstrated significant differences between methods for all power vector components ($p < 0.05$). Post-hoc analyses revealed that while EyeQue and OPD-Scan III produced similar spherical equivalent values, the EyeQue device showed significant deviations in astigmatic correction (J0 and J45) compared to SR.

Table 2 Mean Values of Power Vector Components (M, J0, J45) for Each Refractive Method. M Represents the Mean Spherical Equivalent; J0 Corresponds to the Jackson Cross-Cylinder Component at 0°/90°; J45 Corresponds to the Jackson Cross-Cylinder Component at 45°/135°

Method	SPH_Mean	CYL_Mean	AXIS_Mean	M	J0	J45
EyeQue	1.76	916	85.08	2.218	0.4512622840063	−0.07827101017246074
SR	1.22	794	85.9	1.617	0.3929411636703922	−0.05662368668108799
OPD	1.49	891	69.85	1.9355	0.3397687408794291	−0.28814484677190977
AR	1.55	935	98.05	2.0175	0.44916425456867537	0.12964460041886153

Discussion

Considering all the results from the right eye, the EyeQue device's mean is closer to the one for the SR and the OPD devices, although it is distant from the AR device's mean, which can show EyeQue's efficiency. Regarding the standard deviation, there is a considerable difference: it can be noted that EyeQue has a lower standard deviation, ie, its values vary less around the mean when compared to the values for the other devices. In other words, EyeQue is the most homogeneous device among the four. This stability in spherical measurements suggests that self-refraction devices could be useful in specific screening settings, particularly for monitoring myopia progression.[8–11]

New devices can efficiently provide greater screening of children with the possibility of monitoring and quantifying the progression of myopia in a faster and more skillful manner, as the screening capacity of portable methods and accessible technologies are easy to disseminate. Replicable can significantly improve ophthalmological care for geographically large and remote areas. This allows for greater efficiency in ophthalmological care in a significant way for myopic individuals.

Once it is known that between the first quartile (27.5) and the third quartile (144.5) are 50% of the observations, it is seen that EyeQue has a median AXIS of 80 degrees (half of the values are below 80 degrees). There is a huge difference in that result when compared to the values from the other devices: SR has a median of 90 degrees, while OPD has that of 96 and AR 101 degrees. As 25% of the lowest values are below the first quartile, it can be noted that the lowest values for the EyeQue device are higher than those of the other devices.

Considering all the AXIS results from the left eye, the EyeQue device has a mean of 85.08 degrees, close to the obtained mean for SR (85.9) but distant from the OPD and AR devices (which have a mean of 69.85 and 98.05, respectively). There is a considerable difference when analyzing the standard deviation: it is noted that EyeQue has a lower standard deviation, which means that its values vary less around the mean when compared to the other devices. In other words, this device is the most homogeneous among the four. Given that there are 50% of the values between the first quartile (38.5) and the third quartile (139.0), the EyeQue device has a median of 70 degrees (ie, 50% of the values are found below that number), which is quite different when compared to the values from the other devices. The SR device has a median of 80 degrees, while OPD's is 56 degrees and AR of 90 degrees. The lowest values for EyeQue are also the highest among the four devices, considering that 25% of the observations are found below the first quartile (38.5).

The EyeQue device behaved similarly to the other devices regarding the refractive status distribution, except for subjective refraction, where a difference must be valued. The variability of repeatability between devices and retinoscopy points to results such as those evaluated in other studies. Numerous studies prove that several devices can reproduce retinoscopy and the conventional autorefractor, being safe in screening and progression of myopia as an example of efficiency. Like EyeQue, equipment such as Retinomax and Canon NC have already been evaluated and demonstrate safety in this evaluation scenario.[8–11]

The EyeQue device showed a much lower variability for the right eye than the other devices for the CYL measure, given that the data for the device in question were between 0.5 and 1. This finding was further confirmed by Power Vector Analysis (Table 2), which demonstrated that the EyeQue device had higher J0 values compared to the other methods, indicating systematic differences in cylindrical correction.

Except for SR, the other devices behaved similarly regarding the mean and maximum values and the first quartile for the CYL measure for the left eye. However, the difference was not as great as observed for the right eye.

In addition, the EyeQue is the most stable device, as it has a lower standard deviation than other devices. However, despite this relevant characteristic, it is not considered reliable and efficient when used on the left eye because many measures still have distant and different values from those of other devices. Axis measurements also demonstrated variability across devices, particularly in J45 values, suggesting that self-refraction may have limitations in astigmatic axis estimation.

The values for the SPH measure in the left and right eye for the EyeQue device showed less variability around the mean when compared to the other three devices. In general, however, they showed higher values.

Several studies have evaluated the accuracy of self-refraction (SR) compared to traditional subjective refraction (CSR) and cycloplegic autorefraction (CAR). In a study comparing SR using DialVision eyeglasses and CSR, Babu et al found that SR provided acceptable visual acuity but with significant under-correction compared to CSR, especially in duo-chrome testing, where 92% of participants were undercorrected.[11] Our results similarly showed a tendency for SR to underestimate refractive errors, aligning with Babu's findings that comprehensive eye exams are essential for achieving precise refractive outcomes.[11]

In contrast, Zhao et al found no significant difference between SR and CSR regarding visual acuity outcomes in children aged 5 to 11. This suggests that, in younger populations, SR may be a viable alternative for refractive correction, particularly where access to eye care is limited. Our study, however, focused on adults, where the performance of SR devices like EyeQue showed more variability, consistent with the adult findings of Annadanam et al, who demonstrated that SR using the USee device also resulted in acceptable, though not superior, visual outcomes when compared to CSR.[12–14]

Further, Camp et al explored the use of self-refraction devices like AdSpecs and the I-Test Vision Screener in adults, finding that SR correlated well with CSR for most refractive powers, except in cases of high myopia, where SR tended to be less accurate. This correlates with our findings, where we noted a similar trend of over- and underestimation in high refractive errors with SR.[13]

Our findings of lower variability in cylindrical and axis measurements for EyeQue are consistent with Zhu et al, who found the OPD-Scan III more consistent than subjective refraction in these areas, highlighting the challenge SR devices face with cylindrical corrections. Similarly, Ilechie et al showed that while SR is effective for spherical errors, it struggles with astigmatism, a limitation also observed in our study. These results emphasize that although SR devices like EyeQue are promising for spherical errors, they still lag in precision for astigmatism correction.[15,16]

He et al focused on urban Chinese children and compared visual and refractive outcomes of self-refraction (SR) to non-cycloplegic autorefraction and cycloplegic subjective refraction. In this study, SR achieved visual acuity comparable to that obtained with cycloplegic subjective refraction (CSR) in over 90% of the cases, with discrepancies in children presenting with higher cylindrical errors and those who did not habitually wear glasses.[17]

This study's limitations include a homogeneous sample of young adults, excluding more complex refractive cases like keratoconus and presbyopia, which may limit the generalizability of the results. Additionally, the controlled clinical setting does not fully reflect real-world conditions. However, these factors were necessary to ensure reliable comparisons between devices.

The EyeQue device shows promise as a practical tool for screening refractive errors, particularly in remote or resource-limited areas. Its portability, ease of use, and reproducibility make it valuable for large-scale public health initiatives. However, it should complement, rather than replace, subjective refraction for precision. Future improvements should focus on refining cylindrical power and axis estimation to enhance accuracy.

The EyeQue device demonstrated strong potential as a practical tool for screening refractive errors, particularly in resource-limited or remote areas. Its homogeneity and lower variability, especially in spherical measurements, make it suitable for large-scale screenings. However, despite its consistency, EyeQue still lacks the precision needed for astigmatism and axis measurements compared to subjective refraction and OPD-Scan. Power Vector Analysis confirmed that the device systematically overestimated cylindrical correction (J0) and exhibited variability in axis alignment (J45), reinforcing the need for cautious interpretation when using self-refraction in clinical or prescription settings.

Ethics

This study was approved by the Institutional Review Board (IRB) of Hospital Oftalmologico de Brasília, Brasília, *DF* CAAE number: 42915320.3.0000.5667.

Disclosure

None of the authors has a financial or proprietary interest for this study.

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