

ACCURACY AND DIAGNOSTIC PERFORMANCE OF SMARTPHONE-BASED REFRACTION APPLICATIONS COMPARED TO STANDARD CLINICAL REFRACTION

Ayesha Sadiq^{*1}, Muhammad Anwar Awan², Sidra Anwar³

^{*1}Optometrist MS rehabilitation student at the superior university, Lahore

^{*2,3} Consultant Optometrist at College of Ophthalmology and Allied Vision Sciences, King Edward Medical University, Lahore

^{*1}su91-msrsw-f24-094@superior.edu.pk, ^{*2}anwarawan@coavs.edu.pk, ^{*3}sidraanwar@coavs.edu.pk

DOI: <https://doi.org/10.5281/zenodo.23007628>

Keywords

Objective Refraction, Refraction, PEEK Acuity, Smartphone based refraction, Subjective refraction.

Article History

Received: 01 June 2026

Accepted: 23 August 2026

Published: 28 September 2026

Copyright @Author

Corresponding Author: *

Ayesha Sadiq

Abstract

Background: Smartphone-based refraction applications have emerged as accessible and cost-effective tools for estimating refractive errors, but their accuracy and diagnostic performance compared with standard clinical refraction remain uncertain across different patient populations and refractive conditions.

Objective: To evaluate the accuracy and diagnostic performance of smartphone-based refraction applications in comparison with standard clinical refraction methods.

Methods: This prospective comparative clinical study was conducted over six months in the Department of Ophthalmology after IRB approval. Thirty-four patients with refractive complaints were enrolled after written informed consent. Each participant underwent objective refraction using an autorefractometer followed by subjective refinement with a trial lens set, which served as the reference standard. Refraction was then assessed using the PEEK Acuity smartphone application under standardized conditions. Data were analyzed using SPSS v27, with agreement assessed by paired t-tests and Intraclass Correlation Coefficient (ICC); $p \leq 0.05$ was considered significant.

Result: A total of 34 participants included 19 (55.9%) females and 15 (44.1%) males. OD visual acuity was 6/12 in 44.1% and 6/9 in 32.4%, while OS was 6/12 in 41.2% and 6/9 in 32.4%. Objective and subjective refraction had a median spherical value of -0.75 D, whereas PEEK Acuity showed a more myopic median of -1.25 D. Significant differences were found among the three methods for both OD ($\chi^2=36.683$, $df=2$, $p<0.001$) and OS ($\chi^2=38.095$, $df=2$, $p<0.001$). PEEK Acuity differed significantly from objective and subjective refraction in both eyes (all adjusted $p<0.001$), while objective and subjective refraction did not differ significantly (OD $p=0.86$; OS $p=1.00$).

Conclusion: The findings indicate that objective and subjective refraction showed excellent agreement, while PEEK Acuity consistently produced

significantly more myopic refractive estimates than standard clinical refraction.

1. INTRODUCTION

Uncorrected refractive error (URE) is a leading cause of avoidable visual impairment worldwide and disproportionately affects low- and middle-income countries, where shortages of eye-care professionals, inadequate infrastructure, and financial barriers limit access to refractive services.[1-4] Refractive errors occur when the optical power of the eye does not appropriately focus light on the retina and include myopia, hyperopia, astigmatism, and presbyopia.[5] Clinical refraction remains the reference approach for determining refractive status.[6] Objective methods, including autorefractometry and retinoscopy, provide an initial estimate without requiring patient responses, while subjective refraction uses patient feedback to refine the prescription and optimize visual acuity, binocular balance, and comfort. Autorefractometry is rapid and repeatable but generally requires subjective refinement.[7-9]

Digital health technologies have increasingly transformed ophthalmic care through teleophthalmology, artificial intelligence (AI), mobile applications, and cloud-based systems. Smartphone-based refraction uses various optical and computational approaches, including subjective alignment, wavefront analysis, eccentric photorefraction, computer vision, computational imaging, and AI.[10-12] These systems aim to estimate spherical, cylindrical, and axis components of refractive error with minimal equipment and examiner dependence.[13, 14] AI and machine-learning techniques may further improve measurement consistency by analyzing ocular images, pupil characteristics, fixation behaviour, and retinal reflexes.[15] However, performance may be affected by smartphone hardware, camera and display quality, ambient illumination, fixation, accommodation, patient cooperation, refractive status, and software calibration.[16-18]

Peek Vision primarily provides visual acuity screening, referral tracking, and community eye-care management rather than directly generating spectacle prescriptions. Other applications, such as VisionApp, combine visual acuity and other ophthalmic assessments with refractive estimation. Rigorous clinical evaluation of smartphone-based refractive assessment is necessary to determine whether these technologies can provide sufficiently accurate and reliable measurements compared with standard clinical refraction. Establishing their diagnostic performance and agreement may support their appropriate use as accessible screening and referral tools in community eye care, tele-optometry, and resource-limited settings.

Methods

This prospective comparative clinical study was conducted in the Ophthalmology Department of a teaching hospital over a period of six months following approval of the study synopsis. A total of 34 patients were enrolled using conventional sampling. The sample size was calculated using G*Power Software version 3.1.9.4, based on an effect size of 0.5, α error probability of 0.05, and power of 0.95. Each participant underwent standard clinical refraction, beginning with objective refraction using an autorefractometer followed by subjective refinement with a trial lens set to determine best-corrected visual acuity (BCVA), which served as the reference standard. Subsequently, refractive assessment was performed using the PEEK Acuity smartphone application under standardized lighting and testing conditions. Sphere, cylinder, axis, and spherical equivalent measurements were recorded for both methods. Smartphone measurements were repeated twice and averaged to assess repeatability. Data were entered and analyzed using SPSS version 27. Quantitative variables were summarized as mean $\pm$ standard deviation, while qualitative variables were presented as frequencies

and percentages. Paired *t*-tests were used to compare refractive measurements between standard clinical refraction and PEEK Acuity, while reliability was assessed using the Intraclass Correlation Coefficient (ICC). A *p*-value of ≤ 0.05 was considered statistically significant.

Results

Among 34 participants (19 female [55.9%], 15 male [44.1%]), objective and subjective refraction showed close agreement, with median spherical error of -0.75 D in both eyes (OD: objective -0.75 ± 0.32 D, range 1.25 D; subjective -0.75 ± 0.26 D, range 1.00 D; OS: objective -0.75 ± 0.29 D; subjective -0.75 ± 0.24 D), whereas PEEK Acuity produced more myopic and variable readings (median -1.25 ± 0.43 D, range 1.75 D,

both eyes). Shapiro-Wilk testing confirmed non-normal distribution for all measurements (all $p < 0.05$). Visual acuity was predominantly 6/9–6/12 in both eyes (OD: 76.5%; OS: 73.6%). The Kruskal-Wallis test showed a significant overall difference among the three refraction methods for both eyes (OD: $H = 36.683$, $df = 2$, $p < 0.001$; OS: $H = 38.095$, $df = 2$, $p < 0.001$), and pairwise comparisons confirmed PEEK Acuity differed significantly from both objective and subjective refraction in each eye (all adjusted $p < 0.001$), while objective and subjective refraction did not differ significantly from each other (OD adjusted $p = 0.86$; OS adjusted $p = 1.00$) indicating that PEEK Acuity has lower agreement with standard clinical refraction techniques.

Table 1: Descriptive Statistics

Descriptive Statistics				
	Median $\pm$ SD	Range	Minimum	Maximum
Objective Refraction Sphere OD	-0.75 ± 0.32	1.25	-1.75	-0.50
Objective Refraction Sphere OS	-0.75 ± 0.29	1.00	-1.50	-0.50
Subjective Refraction OD	-0.75 ± 0.26	1.00	-1.50	-0.50
Subjective Refraction OS	-0.75 ± 0.24	0.75	-1.25	-0.50
PEEK Acuity Refraction OD	-1.25 ± 0.43	1.75	-2.50	-0.75
PEEK Acuity Refraction OS	-1.25 ± 0.43	1.75	-2.50	-0.75

For the right eye (OD), the median objective refraction was -0.75 ± 0.32 D, with a range of 1.25 D (minimum -1.75 D, maximum -0.50 D), while the subjective refraction was -0.75 ± 0.26 D, with a range of 1.00 D (minimum -1.50 D, maximum -0.50 D). For the left eye (OS), the median objective refraction was -0.75 ± 0.29 D, with a range of 1.00 D (minimum -1.50 D,

maximum -0.50 D), and the subjective refraction was -0.75 ± 0.24 D, with a narrower range of 0.75 D (minimum -1.25 D, maximum -0.50 D). In contrast, PEEK Acuity refraction recorded a median spherical error of -1.25 ± 0.43 D in both eyes, with a wider range of 1.75 D and values extending from -2.50 D to -0.75 D.

Table 2: Comparative Statistics for Refraction in Right Eye

Pairwise Comparisons of Study Group					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
PEEK Acuity-Objective	32.44	7.01	4.63	< 0.001	< 0.001
PEEK Acuity-Subjective Refraction	-39.91	7.01	-5.70	< 0.001	< 0.001
Objective-Subjective Refraction	-7.47	7.01	-1.07	0.29	0.86

PEEK Acuity differed significantly from objective refraction (test statistic = 32.44, SE = 7.01, standardized test statistic = 4.63, adjusted $p < 0.001$) and from subjective refraction (test statistic = -39.91, SE = 7.01, standardized test statistic = -5.70, adjusted $p < 0.001$). In contrast, objective

and subjective refraction did not differ significantly (test statistic = -7.47, SE = 7.01, standardized test statistic = -1.07, adjusted $p = 0.86$).

Table 3: Comparative Statistics for Refraction in Left Eye

Pairwise Comparisons of Study Group					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
PEEK Acuity-Objective	33.90	7.01	4.84	< 0.001	< 0.001
PEEK Acuity-Subjective Refraction	-40.22	7.01	-5.74	< 0.001	< 0.001
Objective-Subjective Refraction	-6.32	7.01	-0.90	0.37	1.00

Compared with objective refraction, PEEK Acuity showed a significant difference (test statistic = 33.90, SE = 7.01, standardized test statistic = 4.84, adjusted $p < 0.001$). Likewise, PEEK Acuity differed significantly from subjective refraction (test statistic = -40.22, SE = 7.01, standardized

test statistic = -5.74, adjusted $p < 0.001$). However, no statistically significant difference was observed between objective and subjective refraction (test statistic = -6.32, SE = 7.01, standardized test statistic = -0.90, adjusted $p = 1.00$).

Table 4: Comparative Statistics between study Groups

Study Group	Objective Refraction	PEEK Acuity	Subjective Refraction	H	X2	P-Value
Right Eye (Mean Rank)	59.82	27.38	67.29	26.68	15.61	< 0.001
Left Eye (Mean Rank)	60.69	26.79	67.01	38.10	16.02	< 0.001

The table shows that there were statistically significant differences between the PEEK Acuity and Subjective Refraction measurements for both eyes. For the right eye, the mean ranks were 59.82 for PEEK Acuity, 27.38 for Subjective Refraction, and 67.29 for the third measurement, with $H = 15.61$, $\chi^2 = 26.68$, and $p < 0.001$. Similarly, for the left eye, the mean ranks were 60.69, 26.79, and 67.01, with $H = 16.02$, $\chi^2 = 38.10$, and $p < 0.001$.

Discussion

The present study evaluated the agreement of PEEK Acuity with objective and subjective clinical refraction among 34 participants. The findings demonstrated that objective and subjective refraction produced almost identical median spherical errors of -0.75 D in both eyes, whereas PEEK Acuity produced a more negative median value of -1.25 D. The close agreement between objective and subjective refraction in the present study is expected because subjective refraction is generally refined on the basis of objective findings and represents the patient's best visual response under clinical testing conditions. The overall Kruskal-Wallis analysis demonstrated significant differences among the three methods for both OD ($H = 36.683$, $df = 2$, $p < 0.001$) and OS ($H = 38.095$, $df = 2$, $p < 0.001$). Pairwise analysis further demonstrated that PEEK Acuity differed significantly from objective refraction and subjective refraction in both eyes (adjusted $p < 0.001$), whereas objective and subjective refraction did not differ significantly (OD, adjusted $p = 0.86$; OS, adjusted $p = 1.00$).

These findings are particularly interesting when compared with previous research on PEEK Acuity.

Bastawrous et al., in the original validation study, found that PEEK Acuity provided visual acuity measurements that agreed well with ETDRS and Snellen charts, with mean differences of approximately 0.07 and 0.08 logMAR, respectively. The authors concluded that PEEK Acuity was accurate and repeatable for visual acuity measurement.[19] Similarly, a later study comparing smartphone-based visual acuity applications with the Snellen chart found no significant difference between PEEK Acuity and Snellen visual acuity and reported a strong correlation ($ICC = 0.980$).[20]

The difference observed in the present study may therefore reflect an important distinction between visual acuity assessment and refractive error determination. PEEK Acuity was originally developed and validated primarily as a smartphone-based visual acuity test rather than as a replacement for objective or subjective refraction. The original validation demonstrated good agreement with established visual acuity charts, but the outcome assessed was monocular visual acuity rather than spherical refractive error.[21]

The present findings are also consistent with evidence showing that the performance of smartphone-based visual acuity tools can vary according to the clinical population and purpose of testing. In children, Zhao et al. reported good overall correlation between PEEK Acuity and standard clinical visual acuity assessment, with ICC values of 0.88 and 0.85 for the first and second eyes, respectively. However, the authors emphasized that PEEK Acuity was primarily useful for visual acuity assessment and screening rather

than replacing comprehensive ophthalmic examination.[22] Likewise, a pediatric validation study in Paraguay found high specificity but relatively low sensitivity for referral, demonstrating that although PEEK Acuity can be useful in screening, it does not eliminate the need for comprehensive clinical assessment.[23]

The predominance of visual acuity between 6/9 and 6/12 in the present sample also indicates that most participants had relatively mild reductions in visual acuity. This is relevant because small differences in acuity or refractive estimation may become more apparent when participants are clustered within a relatively narrow range of visual performance. Previous research has similarly suggested that agreement between smartphone-based and conventional visual acuity measurements may become less consistent in eyes with refractive error or reduced vision.[20] Therefore, the wider variability observed with PEEK Acuity in the current study may have clinical relevance, particularly if its results are used to infer the magnitude of refractive correction rather than simply to screen visual acuity.

An important strength of the present study is the use of both objective and subjective refraction as clinical comparators and the analysis of each eye separately. The non-parametric approach was appropriate because Shapiro-Wilk testing demonstrated non-normal distributions. Furthermore, the pairwise analysis clearly identified where the overall differences originated. However, the findings should be interpreted within the context of the relatively small sample of 34 participants.

Overall, the findings suggest that PEEK Acuity may be useful as a rapid and accessible visual acuity screening tool, but its refractive estimates should not be considered interchangeable with objective or subjective clinical refraction. The absence of a significant difference between objective and subjective refraction supports the reliability of the conventional clinical methods, whereas the significant and consistently more myopic PEEK Acuity results indicate a potential systematic bias when the application is used for refractive estimation. Therefore, PEEK Acuity may have

value in primary screening and resource-limited settings, but patients requiring determination of their precise refractive correction should undergo standard objective and subjective refraction. This interpretation is broadly consistent with the original validation literature, which supports PEEK Acuity for accurate visual acuity measurement rather than as a standalone replacement for comprehensive refractive assessment.[21]

Conclusion

The present study concluded that PEEK Acuity demonstrated significant differences from both objective and subjective clinical refraction in determining refractive error. In contrast, objective and subjective refraction showed close agreement, with no statistically significant difference between them. Although PEEK Acuity may provide a useful, rapid, and accessible approach for visual acuity screening, its refractive measurements cannot be considered interchangeable with standard clinical refraction.

REFERENCES

1. Babu L, Kumaran SL, Gupta D. Comparison of Self Refraction accuracy with Cycloplegic Subjective Refraction in Young Adults. *Niger Med J*. 2023;64(3):365-72.
2. Beesley J, Davey CJ, Elliott DB. Subjective refraction and prescribing styles used by UK optometrists. *Ophthalmic Physiol Opt*. 2025;45(5):1113-25.
3. Fukushima M, Hirota M, Yukimori T, Hayashi A, Hirohara Y, Saika M, et al. Evaluation of objective and subjective binocular ocular refraction with looking in type. *BMC Ophthalmol*. 2024;24(1):170.
4. Nieves-Moreno M, Carracedo-Rodriguez G, Pinero-Llorens DP, Batres Valderas L, Recalde-Maestre S, Garcia-da-Silva J, et al. Prevalence and Risk Factors for Myopia in Primary School Children in Madrid: A School-Based Cycloplegic Refraction Study. *Int J Environ Res Public Health*. 2025;22(12).

5. Kang MT, Hu Y, Wang N, Fu J, Zhou A, Liu Y, et al. Deep Learning Prediction of Childhood Myopia Progression Using Fundus Image and Refraction Data. *JAMA Netw Open*. 2026;9(1):e2553543.
6. Kangari H, Hashemi H, Rahmani S, Ahmadian E, Yekta A, Khabazkhoob M. Autorefractometer versus subjective refraction in high astigmatism. *Int J Ophthalmol*. 2025;18(3):504-9.
7. Kaur K, Gurnani B. Subjective Refraction Techniques. *StatPearls*. Treasure Island (FL)2026.
8. Luo G, Lee CY, Wang Z, Shivshanker P, Jiang Y, Pundlik S. Subjective Refraction Test Using a Smartphone for Vision Screening. *J Vis Exp*. 2024(212).
9. Kullachi KA, Nadeem M, Ammara HUE, Jamil MH, Rafique K, Shaukat T. Novel insights into the efficacy of Itone Vs. Hylo eye drops in tear film instability of keratoconus. *Rawal Medical Journal*. 2026;51(1):156.
10. Marks DL, Stack RA, Brady DJ. Digital refraction distortion correction with an astigmatic coherence sensor. *Appl Opt*. 2002;41(29):6050-4.
11. Salvador-Roger R, Venkataraman AP, Mico V, Dominguez-Vicent A, Esteve-Taboada JJ. Optometrist-guided versus self-driven subjective refraction using tunable optics: quantifying the professional's impact. *J Optom*. 2026;19(3):100611.
12. Sarayar R, Yulia DE, Rahayu T, Kekalih A. Comparative Analysis of the Efficacy of 1% Tropicamide and 1% Cyclopentolate Eye Drops for Cycloplegic Refraction in Indonesian Paediatric Population. *Br Ir Orthopt J*. 2026;22(1):34-45.
13. Martinez-Abad A, Yebana-Rubio P, Plaza-Puche AB, Rodriguez AE, Jose-Martinez M, Pinero DP, et al. Comparison of refractive parameters provided by a new open field aberrometer and the subjective refraction. *BMC Ophthalmol*. 2026;26(1).
14. Shaukat T, Iqbal AB, Ashraf A, Asad I, Riaz R. Knowledge and awareness regarding keratoplasty and eye donation in high risk occupations. *Ophthalmology Pakistan*. 2024;14(1):24-8.
15. Moreno JRA, Mico V, Albarran Diego C. Subjective refraction using power vectors by updating a conventional phoropter with a Stokes lens for continuous astigmatic power generation. *Ophthalmic Physiol Opt*. 2023;43(5):1029-39.
16. Musa MJ, Zeppieri M. Subjective Refraction Technique: Astigmatic Dial. *StatPearls*. Treasure Island (FL)2026.
17. Musa MJ, Zeppieri M. Principles and Technique of Fogging During Subjective Refraction. *StatPearls*. Treasure Island (FL)2026.
18. Nadeem M, Kullachi Ka, Ammara Hu, Shaukat T. Evaluation Of The Effects Of Flaxseed For Mild To Moderate Dry Eye Treatment In Polycystic Ovarian Syndrome. *Tpm-Testing, Psychometrics, Methodology in Applied Psychology*. 2025;32(S7 (2025): Posted 10 October):1306-10.
19. Bastawrous A, Rono HK, Livingstone IAT, Weiss HA, Jordan S, Kuper H, et al. Development and Validation of a Smartphone-Based Visual Acuity Test (Peek Acuity) for Clinical Practice and Community-Based Fieldwork. *JAMA Ophthalmology*. 2015;133(8):930-7.
20. Bhaskaran A, Babu M, Abhilash B, Sudhakar NA, Dixitha V. Comparison of smartphone application-based visual acuity with traditional visual acuity chart for use in tele-ophthalmology. *Taiwan J Ophthalmol*. 2022;12(2):155-63.
21. Bastawrous A, Rono HK, Livingstone IA, Weiss HA, Jordan S, Kuper H, et al. Development and Validation of a Smartphone-Based Visual Acuity Test (Peek Acuity) for Clinical Practice and Community-Based Fieldwork. *JAMA Ophthalmol*. 2015;133(8):930-7.

22. Zhao L, Stinnett SS, Prakalapakorn SG. Visual Acuity Assessment and Vision Screening Using a Novel Smartphone Application. J Pediatr. 2019;213:203-10.e1.
23. de Venecia B, Bradfield Y, Trane RM, Bareiro A, Scalamogna M. Validation of Peek Acuity application in pediatric screening programs in Paraguay. Int J Ophthalmol. 2018;11(8):1384-9.

