Research Article

Journal of
Medical Research and Surgery

Onah ES, et al., J Med Res Surg 2025, 6:5

Sensitivity and Specificity of Smartphone-Based Auto-Refractor, Tabletop Auto-Refractor and Retinoscopy in the Determination of Refractive Errors Among Adolescents Attending Eye Clinic of a Tertiary Hospital in Enugu

Onah E.S[1,2], Eze G.C[3,4*], Onah A.I[5], Edoga C.E[3,4]

[1]Ophthalmology Department, David Umahi Federal University Teaching Hospital Uburu, Ebonyi State, Nigeria.
[2]Ophthalmology Department, David Umahi Federal University of Health Sciences Uburu, Ebonyi State, Nigeria.
[3]Ophthalmology Department, Enugu State University of Science and Technology Teaching Hospital Parklane, Enugu, Nigeria.
[4]Ophthalmology Department, College of Medicine, Enugu State University of Science and Technology, Enugu, Nigeria.
[5]Pharmaceutical Microbiology Department, David Umahi Federal University of Health Sciences Uburu, Ebonyi State, Nigeria.

Correspondence to: Eze G.C, Ophthalmology Department, College of Medicine, Enugu State University of Science and Technology, Enugu. Email: chizglo1@gmail.com

Received date: October 12, 2025; **Accepted date:** October 24, 2025; **Published date:** October 31, 2025

Citation: Onah ES, Eze GC, Onah AI, et al. Sensitivity and Specificity of Smartphone-Based Auto-Refractor, Tabletop Auto-Refractor and Retinoscopy in the Determination of Refractive Errors Among Adolescents Attending Eye Clinic of a Tertiary Hospital in Enugu. *J Med Res Surg.* 2025;6(5):131-135. doi:10.52916/jmrs254188

ABSTRACT

Objective: Globally about 2.3 billion people have Refractive Errors (RE). Visual experience contributes to overall development in children and adolescents; thus the need for early correction of refractive errors. Smartphone-Based Auto Refractor (SBAR) have some features that overcomes some of the challenges associated with Retinoscopy and Tabletop Auto- Refraction (TTAR).

Methods: The study was a hospital based comparative cross-sectional study. Selections were by simple random sampling. Sensitivity and specificity of SBAR were determined and compared in non-cycloplegic and cycloplegic states with TTAR and Retinoscopy.

Results: A total of 292 adolescents (584 eyes) comprising 162 (55.5%) females and 130 (44.5%) males were studied. Mean age was 16.6 + 0.76years (13-19 years). SBAR showed average sensitivity of (85%) in non-cycloplegic state and (93%) in cycloplegic state with average specificity of (80.6%) and (79.3%) in non-cycloplegic and cycloplegic states respectively.

But TTAR showed average sensitivity of (84.8%) in non-cycloplegic state and (87.1%) in cycloplegic state with average specificity of (84.2%) and (82.0%) in non-cycloplegic and cycloplegic states respectively. Retinoscope was the gold standard for comparison of other instruments.

Conclusion: The NETRA Smartphone-based auto-refractor measured refractive errors with similar sensitivity and specificity as tabletop auto-refractor both in non-cycloplegic and cycloplegic states but not up to retinoscopy.

Keywords:

Retinoscopy, Sensitivity, Specificity, Refractive errors, Adolescents, Smartphone-based auto refractor.

Introduction

Refractive errors are conditions in which the optical system of the eye cannot focus parallel beams of light on the retina resulting in blurred perception of images which requires refractive correction to see images clearly [1]. It is the most common ocular problems affecting all age groups with myopia, hypermetropia and astigmatism the most common types. Generally, in children and adolescents, visual experience contributes tremendously to their psychological, physical, and intellectual development; thus, uncorrected refractive error would not only lead to amblyopia and strabismus, but affect psychosocial domain of this age group. Therefore, early detection and correction of refractive errors certainly confers enormous quality of life benefits [1,2]. Globally, more than 2.3 billion people have Refractive Errors (REs) [1]. In a systematic review and meta-analysis study on the prevalence of refractive error reported as an Estimated Pool Prevalence (EPP) across the world according to WHO regions among children and adolescents less than twenty years, the EPP of myopia, hyperopia, and astigmatism were found to be high. In sub-Saharan Africa, the prevalence of refractive errors and visual impairment was also quite significant [3]. Nigerian National Blindness Survey, reported that uncorrected refractive errors accounted for much of mild, moderate as well as severe visual impairment, and even blindness.

However, prevalence of refractive error shows a great variation across geographic, racial, age, and ethnic boundaries. And this has enormous impact on the strategies utilized in addressing it, more so in low and middle-income countries where there are limited resources to target those mostly affected, including specifically, the poor living in under-served areas and those with inadequate primary eye care services or facilities. Paramount in these strategies, are the tools for the assessment and correction of refractive errors; such that despite being easily detected, measured and corrected, many countries have inadequate refractive services [4]. This is largely due to limited number of relevant eye care personnel who have retinoscopic skills in addition to lack of auto-refractors, mainly due to cost [5]. Predominant treatment method for refractive error is spectacles obtained through refraction with retinoscopy, auto refraction, or subjective method. However, there are numerous challenges associated with these methods. For instance, streak retinoscopy considered the gold standard technique for refraction has some difficulties like the need for a dark room in its procedure, time consuming, discomfort to the patient, dilation of pupil especially in children and adolescents as well as a relative long learning curve [6]. Also, auto- refractor has issues of being bulky, subject positioning, periodic calibrations, and cost [7]. The Smartphone-based auto refractor is a low-cost refractive assessment tool that requires minimal training (self-test), no dark room, and no calibration. Also given its portability and ease of positioning, may present significant advantages over retinoscopy and tabletop autorefraction [8-11]. Therefore, this study is aimed at comparing the sensitivity and specificity of Smartphone-based auto-refraction with that of table top auto-refraction and streak retinoscopy to see if it could serve as a reliable alternative to Table top auto-refraction and streak retinoscopy.

Materials and Method

This was a hospital-based comparative cross-sectional study done over ten month period on 292 adolescents (584 eyes) aged 13-19 years with refractive errors attending eye clinic of Enugu State University of Science and Technology Teaching Hospital Parklane (ESUTTHP). A list of adolescents attending the eye clinic each day formed the study sample frame from which the study subjects were drawn. Inclusion criteria was primarily on adolescents with one or more line of LogMAR chart improvement with pinhole (PH) visual acuity while those with media opacity, amblyopia, systemic diseases and other ocular pathologies were excluded. The study adhered to the tenets of the Helsinki declaration and the National code of health research on studies involving human subjects. Approval of ethical clearance (No:ESUTHP/C-MAC/RA/034/VOL.11/143), for the study was obtained from the ESUTTHP Health Research and Ethics committee before commencement of the study and confidentiality of the subjects were maintained. Visual acuity was checked on consented subjects using Log Mar chart and their socio-demographic data with brief clinical history taken, followed by a detailed ocular examination and diagnosis. Simple random sampling using balloting method was done and they then underwent non-cycloplegic and cycloplegic retinoscopy, Smartphone-based auto-refraction and tabletop auto-refraction respectively. Cycloplegia was achieved using 1% cyclopentolate over 60 minutes, to dilate the pupil. Maximum cycloplegia was established when pupil is dilated to ≥ 6 mm or pupillary light reflex became absent) [12]. Three consecutive refraction measurements were obtained the same day for each eye of every subject without any gap in between the measurements of non-cycloplegic and cycloplegic test. Then an average of the three measured values were taken and recorded for each eye in the study proforma; ensuring that no two measurements of one instrument for each eye of the subject varied by more than 0.50 diopter (D) so as to avoid inconsistency [13]. The measured refractive values were categorized into non-cycloplegic and cycloplegic and entered into the Statistical Package for Social Science (SPSS) version 23.0 from Chicago IBM Co., Armonk, NY) cleaned and analyzed. The sensitivity and specificity of the three study devices were compared and presented on histogram side by side in both states of the eyes. For all comparisons done, the level of significance was put at $p<0.05$.

Results

A total of two hundred and ninety- two adolescents (584 eyes) were enrolled in the study and had their refractive errors measured using Smartphone-based auto refractor, tabletop auto refractor and retinoscope under non-cloplegic and cycloplegic states.The mean age of the study participants was 16.6 ± 0.76 years, (age range of 13-19 years). They comprised of 162 (55.5%) females and 130 (44.5%) males; giving a female to male ratio of 1.3:1. While those aged 19 years constituted majority 58 (19.9%) of the study participant, those aged 17 years were the least 30 (10.3%). Of all the study groups, 170 of them (58.2%) had secondary level of education, followed by 62 (21.2%) with primary level of education and 60 (20.6%) with tertiary level of education. Five hundred and thirty-two (91.1%) of the 584 eyes studied had various degrees of uncorrected visual impairment (VI) according to WHO definition of visual impairment [7]; ranging from mild VI: 114 (19.5%), moderate VI: 340 (58.2%) and severe VI: 78 (13.4%). With PH, about 80% achieved normal VA, 20% were between mild and moderate VA and there was none with severe VA. However, total of 52 (8.9%) of the 584 eyes studied had normal vision in an unaided visual acuity test using Log MAR chart despite having an improvement of one or more Log MAR line with Pinhole test

Figure 1 shows that under non-cycloplegic state of the eyes, the Smartphone-based auto-refractor (SPBAR) was (88.6%, 78.6%, 83.3% and 89.4%) sensitive in measuring refractive error among myopes, hypermetropes,myopic astigmatics and hypermetropic astigmatics respectively. The sensitivity of TTAR was found to be (81.8%) for myopes, (78.6%) for hypermetropes, (87.1%) among myopic astigmatics and (91.5%) among the hypermetropic astigmatics.

In the cycoplegic state of the eyes, the sensitivity of Smartphone-based auto refractor was (93.5%) among myopes, (93.3%) among hypermetropes, (95%) among myopic astigmatics and (90%) obtained among hyperopic astigmatic patients. The tabletop auto refractor was (80.6%) sensitive among the myopes, (86.7%) among hypermetropes, (93.7%)among the myopic astigmatics and (87.5%) among hypermetropic astigmatic patients (Figure 2).

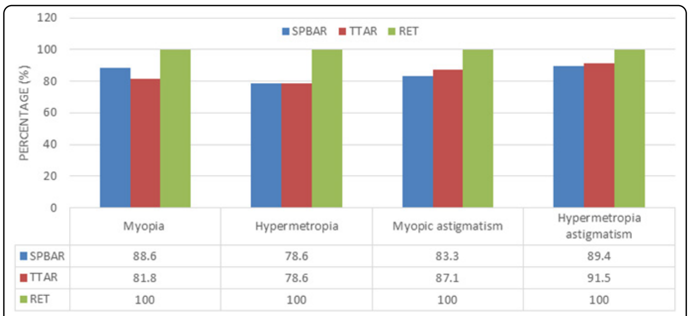

Figure 1: Percentage distribution of refractive error detected (sensitivity) using the three instruments in the non-cycloplegic state.

On comparing the non-cycloplegic and cycloplegic states of the studied eyes, Smartphone based auto refractor, was more sensitive in measuring refractive error among myopes in the cycloplegic state (93.5%) than in the non-cycloplegic state (88.6%). This finding was similar across the various refractive error types (Figure 3).

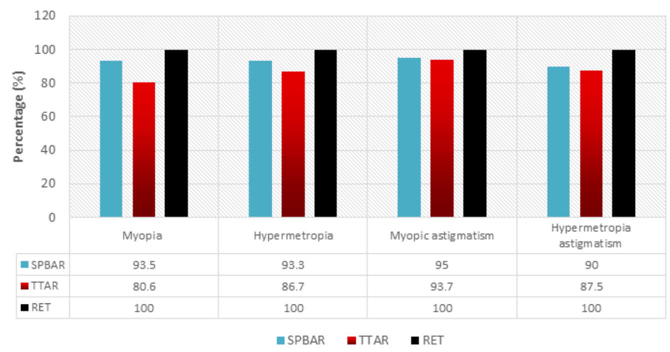

Figure 2: Percentage distribution of refractive error detected (sensitivity) using the three instruments in the cycloplegic state.

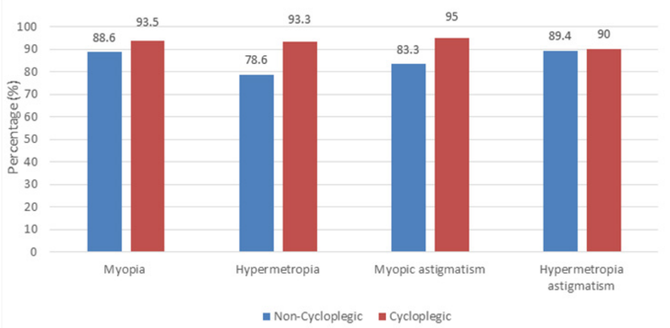

Figure 3: Smartphone-based auto refractor refractive error detection (sensitivity) comparison between the non-cycloplegic and cycloplegic states.

SPBAR alone in non-cycloplegic state of the eyes, had equal specificity in measuring refractive errors among the myopes (75%) and hyperope (75%) but the measurement for myopic astigmatism (88.2%) is slightly higher than in hypermetropic astigmatism (84.3%). The results obtained in cycloplegic state had similar pattern to that of non -cycloplgic with equal specificity of (75%) for myopes and hypermetropes but that for myopic astigmatism (85.3%) slightly higher than that of hypermetropic astigmatism (81.9%) (Figure 4).

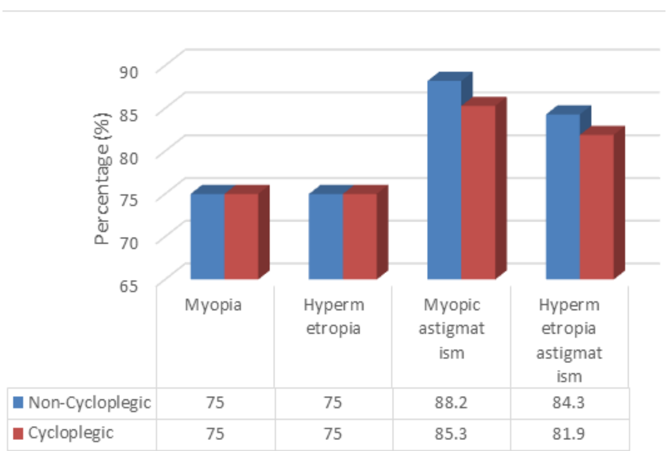

Figure 4: Specificity of smartphone auto refractor in the non-cycloplegic and cycloplegic states.

For TTAR, the specificity was also equal among myopes (75%) and hypermetropes (75%) but higher for myopic astigmatics (89.7%) and hypermetropic astigmatism (88%) with a slight difference under non cycloplegic state. But in cycloplegic state, the specificity was also equal for myopes (75%) and hyperopes

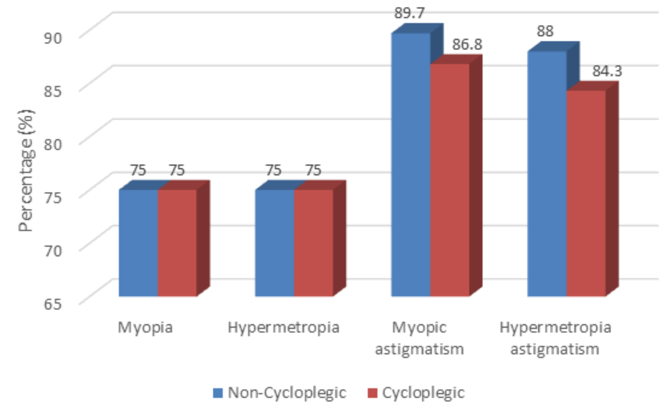

Figure 5: Specificity of table top auto refractor in the non-cycloplegic and cycloplegic states.

(75%) but slightly higher for myopic astigmatics (86.8%) than for hypermetropic astigmatics (84.3%) (Figure 5).

Discussion

Visual impairment and blindness due to uncorrected refractive error is a substantial public health problem in many parts of the world. In this study, the Smartphone-based auto refractor compared closely to TTAR but not retinoscopy in non-cycloplegic state of the eyes in their degree of sensitivity in measuring different types of uncorrected refractive error (88.6%, 78.6%, 83.3% and 89.4%, for myopia, hypermetropia, myopic astigmatism and hypermetropic astigmatism respectively. Similar findings were also seen in other studies such as the work of Andrew et al which compared NETRA Smartphone auto refractor with Subjective refraction in measuring refractive error among 20 white adolescents aged 18 to 21 years and founded sensitivity of 88% with NETRA compared to Subjective refraction [14]. Also Veerendranath et al, in their work which compared NETRA with retinoscopy among white children found NETRA to have sensitivity of62% when compared to the gold standard [15]. Vitor et al which used NETRA-G a Smartphone-based auto refractor to measure uncorrected refractive errors among white teenager populations, found 70% sensitivity of the study instrument while YEE-FONG et al compared three auto refractors with subjective refraction in non-cycloplegic and cycloplegic states among 117 children aged 8 to 15 years and found the three auto refractors (Retinomax, Canon RK and Grand Seiko) to have sensitivity of 100%, 92% and 91% in non cycloplegic state and 84%, 86% and 80% in cycloplegic state respectively [16,17]. The differences in the sensitivity across these studies could be accounted for by variations in sample size, age, race and methods of selection of these study participants, study techniques as well as differences in the study instruments compared. In another study, Anita et al [12] compared auto refractometer, retinoscope and subjective method in myopic and hypermetropic patients, and found the sensitivity of auto refractor to be 78% while that of retinoscopy was 87% and both correlated well with the results of subjective refraction among the myopes and the hypermetropes. Their findings which concluded that auto-refractometer is an invaluable tool for screening large number of cases in busy ophthalmological clinics [12], compared favorably to the findings of the present study which showed high sensitivity of Smartphone-based auto refractor when compared to tabletop auto refractor (already approved for use in regular ophthalmology clinic) in non-cycloplegic state.

Most of the authors reported on the sensitivity of their study instruments but not the specificity. The findings of the present study showed that SPBAR had an average specificity of (80.7%) in measuring uncorrected refractive errors under non-cycloplegic state;comparing closely to TTAR which had (82.0%) under the same state [3-5,12,18,19]. This is similar to the works of Aina et al which compared focometer and auto refractor in measuring uncorrected refractive errors among students aged 13 to 21 years in underserved community in sub Saharan Africa. They found high sensitivity (73.6%) and specificity (91.9%) for focometer relative to auto refractor [16]. The slight difference in specificity found in this study when compared to that of Aina et al may be due to differences in study instruments as well as study designs. The high sensitivity and specificity of the test instrument found in our study then suggests that NETRA Smartphone-based auto refractor compares closely to Table top auto-refractor and can effectively measure uncorrected refractive error in both ophthalmology clinic and refractive error screening programs among adolescents under non-cycloplegic state.

In this study,the NETRA Smartphone-based auto-refractor in cycloplegic state of the eyes, showed higher sensitivity in measuring all types of refractive errors (myopia, hypermetropia, myopic astigmatism and hypermetropic astigmatism respectively) than tabletop auto refractor. This means that refractive errors can be effectively detected with high degree of sensitivity in cycloplegic state of the eyes using Smartphone-based auto refractor. This finding is consistent with other studies which found auto refractors (Smartphone inclusive) to have high sensitivity in detecting refractive errors in cycloplegic state though with varied subtle differences in their degree of sensitivity [13-15,18,19]. These varied differences in these studies may be accounted for by varied differences in these study designs, participant selections, study techniques, age and race of these participants as well as variation of study instruments. The present study also showed high specificity of SPBAR in measuring all types of refractive errors (myopia, hypermetropia, myopic astigmatism and hypermetropic astigmatism) under cycloplegic state. Retinoscopy which is the gold standard upon which sensitivity and specificity of the other two instruments (Smartphone-based auto refractor and tabletop auto refractor) were compared had 100% sensitivity and specificity in the detection of various types of refractive error in a cycloplegic state.

Placing the sensitivity and specificity of Smartphone-based auto refractor and tabletop auto refractor side by side in both non-cyclpolegic and cycloplegic states in this study, it was found that Smartphone-based auto refractor have consistently compare closely with Tabletop auto refractor in measuring all types of refractive error in these two refractive states. Although tabletop auto refractor had slightly higher sensitivity in measuring refractive error types in cycloplegic state,the specificity of both SPBAR and TTAR were quite close than the sensitivity and consistent across all refractive error types measured in both cycloplegic and non-cycloplegic state. The findings in this study are similar to that of Yee Fong which compared three auto refractors with Subjective refraction in non cycloplegic and cycloplegic states with high sensitivity and specificity. However, these differences in the sensitivity and specificity can be accounted for by the variations in their sample size of 117, age range of 7-12 years among the white populations as well as differences in their study technique and test instruments. The finding of this study which agrees to a reasonable extent to other studies [17,18,20,21] implies that Smartphone-based auto refractor has high level of sensitivity and specificity in measuring all types of refractive errors in non- cycloplegic and cycloplegic states.

Conclusion

The sensitivity and specificity of NETRA Smartphone-based auto-refractor compared closely with tabletop auto-refractors but not retinoscope in measuring refractive errors. However, though the Smartphone does not measure up to the retinoscope which is the gold standard, the sensitivity and specificity in its refractive measurements were consistent in both non-cycloplegic and cycloplegic states. Therefore, it can effectively serve as a reliable alternative to tabletop auto-refractor but not retinoscope in measuring and diagnosing refractive errors in busy ophthalmic clinics and refractive error screening programs.

Conflict of Interest

There is no conflict of interest as there is no form of financial donation/contribution from any source.

Acknowledgment

The author appreciates the immeasurerable supports of the head and the entire staff of the Department of Ophthalmology, Enugu State University of Science and Technology Teaching Hospital, Parklane Enugu in ensuring the success of this work.

References

1. Rakhi D, Lalit D. Refractive error blindness. *Bull World Health Organ.* 2001;79(3):237-43.

2. Ibeinmo O, Adedayo A, Megbelayin E. Refractive error pattern of children in South-South Nigeria: A tertiary hospital study. *Sky J Med Med Sci.* 2013;1(3):10-14.

3. Hassan H, Akbar F, Abbasali Y, et al. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. *J Curr Ophthalmol.* 2018;30(1):3-22.

4. Kovin SN, Jyoti J. Uncorrected refractive errors. *Indian J Ophthalmol.* 2012;60(5):432-437.

5. Luigi B, Michael M, Luisa CL, et al. Improving access to refractive and eye health services. *Community Eye Health.* 2016;28(91):54.

6. Deepikadevi SN, Sundararajan D, Namitha BK, et al. Comparing the effect of conventional method of retinoscopic refraction with computerized automated refraction in various refractive error patients. *Int Arch Integr Med.* 2017;4(10):105-110.

7. Kenneth JC, Mark R. Evaluation of the SVOne: A handheld, smartphone-based autorefractor. *Optom Vis Sci.* 2015;92(12):1133-1139.

8. Rob M. Newly launched mobile eye-test device could lead to prescription virtual-reality screens. *MIT News.* 2015;2-10.

9. Handan A, Soner K, Cemal C. Comparison of the refractive measurements with hand-held autorefractometer, table-mounted autorefractometer and cycloplegic retinoscopy in children. *Korean J Ophthalmol.* 2015;29(3):178-184.

10. Luigi B, Michael M, Luisa CL, et al. Improving access to refractive and eye health services. *Community Eye Health.* 2016;28(91):54.

11. Christian E, Hessom R, Selvaraj S, et al. Refractive error in Nigerian adults: Prevalence, type, and spectacle coverage. *Invest Ophthalmol Vis Sci.* 2011;52(5):449-456.

12. Anita G, Saroj B, Inderjit K, et al. Comparison of autorefractometer, retinoscope and subjective method in myopic and hypermetropic patients. *Int J Contemp Med Res.* 2017;4(3):77-83.

13. Shuyu X, Minzhi L, Haidong Z, et al. Comparison of refractive measures of three autorefractors in children and adolescents. *Optom Vis Sci.* 2017;94(9):894-902.

14. Vitor P, Rahul M, Solaka H, et al. NETRA-G: Towards a subjective self-refraction. Presented at: Optical Society of America; 2014;13-14.

15. Benoit T, Marie-Christine G, Nikola B, et al. Comparing the Netra smartphone refractor to subjective refraction. *Clin Exp Optom.* 2019;12(3):121-152.

16. Aina AS, Oluleye TS, Olusanya BA. Comparison between focometer and autorefractor in the measurement of refractive error among students in underserved communities of sub-Saharan Africa. *Eye (Lond).* 2016;30(2):1496-1501.

17. Yee-Fong C, Ai-Hong C, Pik-Pin G. A comparison of autorefraction and subjective refraction with and without cycloplegia in primary school children. *Am J Ophthalmol.* 2006;142(1):68-74.

18. Tuncer I, Zengin MO, Karahan E. Comparison of the Retinomax handheld autorefractor versus table-top autorefractor and retinoscopy. *Int J Ophthalmol.* 2014;7(3):491-495.

19. Ihsan Y, Abdullah O, Zeynep A, et al. Comparison of the Plusoptix A09 and Retinomax K-Plus 3 with retinoscopy in children. *J Pediatr Ophthalmol Strabismus.* 2020;20(10):16-20.

20. Yesim O, Nesrin G, Ozlen O, et al. A comparison of different autorefractors with retinoscopy in children. *J Pediatr Ophthalmol Strabismus.* 2012;49(6):370-377.

21. Agarwal A, Bloom DE, DeLuise VP, et al. Comparing low-cost handheld autorefractors: A practical approach to measuring refraction in low-resource settings. *PLoS One*. 2019;14(10):21-50.