ORIGINAL ARTICLE

The Consistency of Retinal Image Size Measurement Using Smartphone Application

Nura Syahiera Ibrahim, Firdaus Yusuf @ Alias, Norsham Ahmad

Department of Optometry and Visual Sciences, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Bandar Indera Mahkota, 25200 Kuantan, Pahang, Malaysia

ABSTRACT

Introduction: Unequal retinal image size (RIS) or aniseikonia is usually related with anisometropia. Higher differences of RIS may manifest symptoms such as dizziness, headache or disorientation. In worst case might cause suppression that leads to amblyopia. Current study aims to evaluate the consistency of aniseikonia measurement in Smart Optometry smartphone application among myopic, hyperopic, and astigmatic simulated anisometropia and real anisometropia groups. **Methods:** Fifteen real anisometropes (refractive error; -0.50 until -6.00 diopters; D) and fifteen emmetropes (refractive error: -0.25 until +0.50D) were recruited. Real anisometropes wore their habitual spectacle correction while each emmetropes were fitted using soft contact lenses of +4.00DS, -4.00DS and -4.00DC with base curve 8.6 and total diameter 14.2mm in random order to mimic myopic-, hyperopic- and astigmatic-anisometropia before testing. Participants with any ocular disease and binocular vision problem were excluded. The consistency of aniseikonia measurement was determined in two visits, separated by at least 24-hour interval. Three repetitive measurements were taken in each visit. **Results:** Independent t-test and paired t-test showed that real and simulated anisometropia gave insignificant aniseikonia percentage, $p>0.05$. ICC findings revealed moderate-to-good agreement for all simulated and real groups. Bland Altman analysis between two visits exhibited good agreement among all simulated group; myopic (mean difference 0.2047; 95%CI:-1.1386-1.549), hyperopic (mean difference 0.2200; 95%CI:-0.9286-1.3686) and astigmatic (mean difference 0.2533; 95%CI:-0.7114-1.2180). Real anisometropes demonstrated good agreement with bias value of 0.2247(95%CI:-0.9162-1.3656) using Bland Altman plot. **Conclusion:** Smart Optometry application provides consistent measurement of aniseikonia regardless any types of anisometropia.

Keywords: Aniseikonia, Anisometropia, Simulated anisometropia

Corresponding Author:
Norsham Ahmad, PhD
Email: ansham@iium.edu.my
Tel: +609-5705353

INTRODUCTION

Aniseikonia is a binocular condition and mainly thought to reflect disparities in retinal image size, shape or both that often accompany anisometropia (1,2). Anisometropia is a difference in refractive error between eyes which arise naturally or optically induced (3). Aniseikonia frequently related with differences in optical magnification specifically among anisometropia that consequently impaired binocular vision such as fusion and stereopsis (4). Pseudophakia, aphakia and patient that undergo corneal refractive surgery may experience symptoms such as headaches, asthenopia and reading difficulties contributed by aniseikonia. Measuring aniseikonia is comparing the differences of retinal image perceived between right eye (RE) and left eye (LE) in percentage (%). The bigger the % means the greater the aniseikonia which relates to the greater difference magnitude of refractive error between RE and LE.

Numerous devices and approaches have been widely used to measure aniseikonia (5). Each device either uses stereoscopic technique or direct comparison method in quantifying aniseikonia. For example, Space Eikonometer (American Optical Company, New York, United States) used stereoscopic method and acknowledged to be precise. Unfortunately, it had not been commercially available for decades. Regarding direct comparison tests, New Aniseikonia Test (NAT) (Handaya Co., Tokyo, Japan) and Aniseikonia Inspector (AI) (Optical Diagnostics, Culemborg, Netherlands) are available. The main task of direct comparison method is participants need to compare the size of different targets present on each eye and equalizing the targets either by modifying the size of target or placing size lenses in front of one eye (6). Past literatures concerning the clinical use of NAT reported that the NAT underestimated aniseikonia greater in horizontal meridian other than vertical meridian as most of their participants were able to tolerate the image differences (7,8).

Previous study found that aniseikonia was underestimated when measured with the first version of AI test regardless amount of lens-induced aniseikonia (9). The main factor of underestimating aniseikonia is a relative displacement of semicircles that make the size matching task confusing as reported by their participants. Anaglyphic dissociation may produce heterophoria which creates instability images thus making it challenging to equalize the size of semicircle (10). In contrast, the first version of AI offered conflicting finding as other study reported that AI also provided an accurate measurement of lens-induced aniseikonia at all meridians; oblique, vertical, and horizontal as well as suitable to be used among children (5,6).

To the best of literature search, aniseikonia measurement is not routinely examined in eye examination due to the absnce of gold standard measurement for aniseikonia and the accurate measurement is still debatable (10). However, since aniseikonia is the main issue by the anisometropias which includes difficulties in adapting with their optical aids (spectacles or contact lens), experts in technology and health-related fields develop a new diagnostic tool named Smart Optometry application (Smart-Optometry Ltd., Slovenia) to measure aniseikonia. . Mobile technology has potential advantages to make availability of healthcare to public with its portability, accessibility, easy to be administered, quick, easily understood and interpreted. Hence, current study seeks to investigate the consistency of this Smart Optometry application in measuring aniseikonia among real and induced anisometropia groups which potentially can be used in screening protocol.

MATERIALS AND METHODS

Study population

This study is a cross-sectional study which followed the tenet of the Declaration of Helsinki and ethical approval was attained. Informed consent was obtained after each participant had been briefed on the nature of this study. All participants with mean age of 22.7±1.82 years were recruited based on convenient sampling. Fifteen emmetropic participants with spherical equivalence ranged from -0.25D to +0.50D (11) were mimicked for anisometropia using soft contact lens. Another fifteen anisometropia participants with mean spherical equivalence of 1.65 ± 0.67 DS in one or both meridians also were enrolled in this study. All participants needed to have corrected visual acuity of (VA) 6/6, no ocular disease and normal stereopsis, 40 sec or arc (12).

Mimicked anisometropia

According to Young, Hall, Sulley, Osborn-Lorenz, & Wolffsohn, (2017), soft contact lenses with average diameter of 14.20 mm and base curve of 8.60 had good lens-cornea relationship (13). Conventional Aire CD 38 and Aire Toric 38 soft contact lenses with aforementioned parameters (Apple Vision Sdn. Bhd, Malaysia) were fitted on dominant eye of 15 emmetropes to induce anisometropic condition. 5 to 15 minutes of wear was ample for participants to adapt to ensure good contact lens-cornea relationship (14).

Higher anisometropia would produce greater difference of retinal image size between the eyes, which aniseikonia become measurable in this study. As such 4D is chosen to give greater effects as previous study mentioned that 1D of anisometropia was estimated to be equivalence of 1% of image size difference (15). Therefore, each emmetrope participant was fitted with three different power of contact lens; -4DS, +4DS and -4DCx90 monocularly on the dominant eye in randomized order to induce hyperopic, myopic and astigmatic anisometropia respectively.

Aniseikonia testing

Aniseikonia was measured using application named Smart Optometry Apps Version 3.3.1 (Smart-Optometry Ltd., Slovenia) viewed with android smartphone (Oppo Electronics Corporation, China) with dimension of 7.1 x 143.1 x 7.68 mm, resolution 720 x 1280 pixels (16) and brightness was automatically set to 80% when in test and room illumination is kept constant 282-308 lux throughout this study (photopic condition).

This aniseikonia features composed of a direct comparison between red and green semi brackets on black background with fixation target at the centre as illustrated in Figure 1. The dichoptic technique (by wearing red-green filter) is applied in this feature to ensure red bracket and green bracket are perceived by RE and LE respectively, to ensure direct comparison possible. Both semi brackets might vary in sizes in anisometropia cases and the goal was to equalize both brackets. The difference of size indicates percentage (%) of aniseikonia. The measurement was taken as an average of three measurements to eliminate any response bias (17).

After being fitted with soft contact lens of -4DS on the dominant eye, participants needed to hold the smartphone at about 40cm, angled so that it paralleled

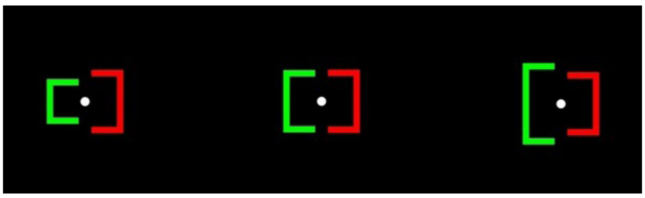

Figure 1: Aniseikonia feature in Smart Optometry application. Figure (a) (left side) shows the retinal image perceived by the LE is smaller than RE, (b) (middle) equal sizes perceived by RE and LE and (c) (right side) shows the retinal image perceived by the RE is smaller than LE. The unequal sizes in (a) and (b) is due to unequal refractive power between RE and LE (anisometropia).

to the patient's face with the room was well illuminated. Participants were directed to fixate on the central dot while adjusting the slider button to align the brackets. The aniseikonia was tested along vertical and horizontal meridian.. . The percentage of aniseikonia will be displayed once participant perceived both red-green bracket is equal in size. All participants attended two visits, separated by at least 24-hour to assess the consistency of the measurement (12). Three repetitive measurements were taken in for each power in every visit. Same procedures were repeated for +4DS and -4DCx90. Procedure involving real myopic anisometropia was similar, except that the participants wore their habitual spectacle correction with vertex distance of 14mm.

Statistical analysis

Statistical analysis was conducted using IBM Statistical Package for Social Science (SPSS) Statistic for Windows, version 20 (IBM Corp., Armonk, N.Y., USA). 1) Independent t-test was utilized to compare the aniseikonia percentage between myopic anisometropic participants and simulated myopic anisometropia only. 2) Paired t-test was performed to compare aniseikonia percentage obtained in both visits would produce consistent findings. 3) Bland Altman analysis and Intraclass Correlation Coefficient (ICC) were tested to evaluate the agreement of aniseikonia percentage between two visits.

RESULTS

Comparison between myopic anisometropes & simulated myopic anisometropes

Data was collected from 30 participants (15 emmetropes and 15 anisometropes) of mean age 22.70±1.82 years.
Current study found that aniseikonia percentage obtained from real myopic anisometropia (2.61 ± 2.05%) statistically showed no significant difference with simulated myopic anisometropia (3.51 ± 2.38%), $t(28)=1.12$, $p>0.05$ (Table I).

Consistency of aniseikonia measurement using paired t-test

A paired sample t-test was conducted to compare aniseikonia percentage between two visits for every measurement obtained by Smart Optometry application. In the first visit, three measurements of aniseikonia were compared with three measurements of aniseikonia in second visit for every simulated myopic, hyperopic and astigmatic anisometropia as well as real myopic anisometropia.

Table I: Comparison of aniseikonia between real and simulated myopic anisometropia

	Real myopic anisometropia Mean ± SD (n=15)	Simulated myopic anisometropia Mean ± SD (n=15)	p-value (independent t-test)
Aniseikonia	2.61 ± 2.05	3.51 ± 2.38	0.27

Simulated myopic anisometropia showed no significant difference of aniseikonia on each measurement between both visits. There was no significant difference in aniseikonia percentage for measurement 1 [(1.49 ± 4.06%), $t(14)=1.42$, $p>0.05$], measurement 2 [(-0.03 ± 4.66), $t(14)=-0.02$, $p>0.05$] and measurement 3 [(1.39 ± 3.71), $t(14)=1.45$, $p>0.05$] for both visits. For simulated hyperopic anisometropia, aniseikonia percentage was consistently similar when measured with Smart Optometry application in three measurements in both visits; measurement 1 [(1.97 ± 4.14), $t(14)=1.85$, $p>0.05$]; measurement 2 [(0.47 ± 3.01), $t(14)=0.61$, $p>0.05$]; measurement 3 [(-0.52 ± 4.38), $t(14)=-0.46$, $p>0.05$]. Similarly, simulated astigmatic anisometropia also exhibited consistent aniseikonia percentage as three measurements taken in two visits had no significant difference between each other, measurement 1 [(0.19 ± 3.47), $t(14)=0.22$, $p>0.05$], measurement 2 [(0.10 ± 2.10), $t(14)=0.19$, $p>0.05$], measurement 3 [(0.18 ± 2.87), $t(14)=0.24$, $p>0.05$]. Additionally, aniseikonia percentage in real myopic anisometropia also demonstrated consistent percentage of aniseikonia between two visits, measurement 1 [(-0.15 ± 2.76), $t(14)=0.22$, $p>0.05$], measurement 2 [(-0.03 ± 2.87), $t(14)=0.05$, $p>0.05$], measurement 3 [(1.13 ± 3.37), $t(14)=1.29$, $p>0.05$]. These findings suggested that Smart Optometry application provided consistent percentage of aniseikonia among real and simulated myopic anisometropia as well as hyperopic and astigmatic anisometropia.

Agreement of aniseikonia percentage between 2 visits in each simulated myopic, hyperopic and astigmatic anisometropia

Contact lens-induced myopic anisometropia showed good agreement between two repeated measurements with ICC value of 0.75 (95% CI: 0.24, 0.92). Bland Altman demonstrated that the bias between both measurements was 0.20 (95% CI: -1.14 - 1.55). The difference between the paired data was plotted in Figure 2 against their mean to assess the limit of agreement in their performance. From the Bland Altman plot, it showed that the aniseikonia measurement in simulated myopic anisometropia provided good agreement between first and second visits. The graph plotted portrayed only one outlier outside the limit of agreement (4.96,-4.55).

Simulated hyperopic anisometropia also demonstrated good agreement, provided the ICC value of 0.79 (95% CI: 0.36, 0.93). Bland Altman test revealed the mean difference between both visits were 0.22 (95% CI: -0.93 – 1.37). All data occupied the upper and lower agreement (4.29,-3.85) as illustrated in Figure 3 thus, producing good agreement between first and second visits.

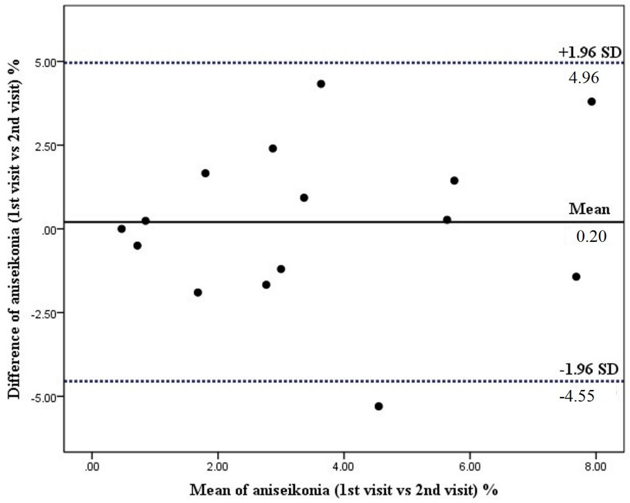

Figure 2: Limit of Agreement (LoA) of aniseikonia measurement for simulated myopic anisometropia

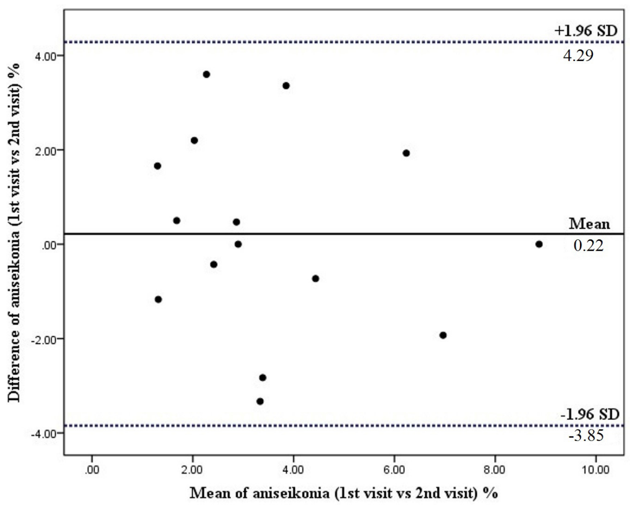

Figure 3: Limit of Agreement (LoA) of aniseikonia measurement for simulated hyperopic anisometropia

However, simulated astigmatic anisometropia exhibited moderate agreement with the ICC value of 0.51 (95% CI: -0.52, 0.84). Majority of the data were located between upper and lower agreement of Bland Altman plot with the mean difference of aniseikonia between both visits was 0.25 (95% CI: -0.71, - 1.22; Figure 4). It showed that the aniseikonia measurements in simulated astigmatic anisometropia were in agreement between the first and second visits, with only one outlier present outside the limit of agreement (3.67,-3.16).

Aniseikonia testing among real anisometropes displayed good agreement of ICC value 0.76 (95% CI: 0.27, 0.92). Most of data were within limit of agreement (4.26, -3.81) with one outlier as illustrated in Bland Altman plot (Fig. 5) which depicts good agreement with mean difference of 0.22 (95% CI: -0.92, 1.37).

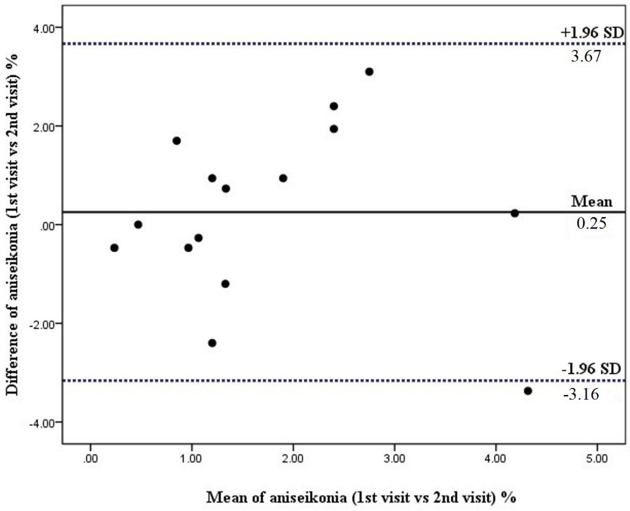

Figure 4: Limit of Agreement (LoA) of aniseikonia measurement for simulated astigmatic anisometropia

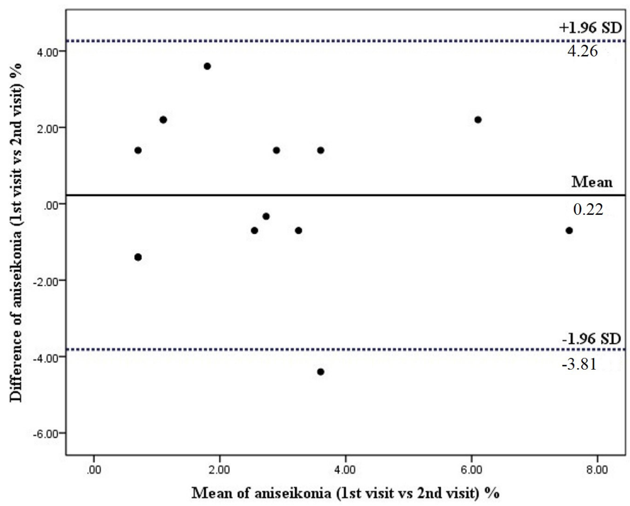

Figure 5: Limit of Agreement (LoA) of aniseikonia measurement for real myopic anisometropia

DISCUSSION

Concerning the issue of aniseikonia, current study decided to measure the percentage of aniseikonia between two visits in each simulated and real anisometropia groups in order to compare the consistency of aniseikonia measurement in Smart Optometry application. Current study discovered that the aniseikonia percentage reading between simulated and real myopic anisometropia was similar even though different mode of optical correction was used when measuring aniseikonia. Difference between spectacle correction and contact lens becomes significant when the magnitude of ocular correction exceeds about ±4 D (18), but current study focused on 4D and below. Current findings also revealed that the measurement of aniseikonia by Smart Optometry application were consistent between two visits for every measurement taken, with regard to different types of anisometropia. Due to that reason, it is noteworthy that the Smart Optometry application provides consistent results of aniseikonia with three measurements taken on two visits which might be useful as screening test.

The agreement between two readings of ICC can be categorized into; below 0.50 (poor), 0.50 until 0.75 (moderate), 0.75 until 0.90 (good) and higher than 0.90 (excellent) (19). Based on Table II, current findings revealed moderate-to-good agreement for all intended simulated anisometropia groups, with myopic (ICC = 0.75), hyperopic (ICC = 0.79) and astigmatic (ICC = 0.51) as well as real anisometropia group that also showed good agreement (ICC = 0.76). Moderate agreement between two visits in simulated astigmatic anisometropia might be contributed by astigmatism that induced image blur irrespective of myopia or hyperopia (20).

Table II: Reliability measures and Bland Altman analysis for aniseikonia measurement for simulated and real anisometropia groups

Groups	Mean difference	SD	95% CI for mean	95% CI for agreement	ICC for aniseikonia value (95% CI)	*p* -value
Simulated anisometropia						
Myopic	0.22	2.43	-1.14, 1.55	-4.55, 4.96	0.75 (0.24-0.92)	<0.05
Hyperopic	0.25	2.07	-0.93, 1.37	-3.85, 4.29	0.79 (0.36-0.93)	<0.05
Astigmatic	0.25	1.74	-0.71, 1.22	-3.16, 3.67	0.51 (-0.52-0.84)	>0.05
Real anisometropia	0.22	2.06	-0.92, 1.37	-3.81, 4.26	0.76 (0.26, 0.91)	<0.05

The mean differences of aniseikonia percentage among real anisometropia 0.22(95% CI: -0.92, 1.37) and simulated anisometropia; myopic 0.20 (95% CI: -4.55, 4.96), hyperopic 0.22 (95% CI: -3.85, 4.29) and astigmatic 0.25 (95% CI: -3.16, 3.67), found from Table II and Bland Altman plots were slightly higher than previous finding that measured aniseikonia among anisometropia participants which revealed mean difference of 0.19 (95% CI: -2.66, +2.66) using Aniseikonia Inspector (AI) version 1 (12). A possible reason for the discrepancy is the inconsistent of viewing condition might considered variability in aniseikonia score (9). Even though both Smart Optometry application and AI devices applied the same direct comparative approach of red green anaglyph but different viewing condition and mode were used for example smartphone and desktop respectively.. As such, Smart Optometry application is possible to be used as aniseikonia measurement as it eliminates the need to carry heavy instruments due to easy to install, ready to access, yet provides us consistent result of measurement.

Another device used to measure aniseikonia was New Aniseikonia Test (NAT). NAT showed mean difference or bias of aniseikonia measurement of 0.17% when tested in anisometropia group which was slightly lower from current finding (8). Even though same method of direct comparison anaglyph used between NAT and Smart Optometry application, however the viewing display mode were differed from one another. Unlike the Smart Optometry application, the NAT was presented in a booklet rather than smartphone.. The aniseikonia was determined by choosing an existing pair of red green semi brackets that appeared most equal in size when tested with NAT. Meanwhile, Smart Optometry application measured the aniseikonia by aligning the size of red-green semi brackets into the same size. People who were used in controlling touch screens were able in handling the smartphone. The method in smart optometry found to be more attractive (similar to touch screen games on the smartphones) might be easier to understand by the children. Since the application provide us with consistent results of measurement, it might be beneficial to further this study in children and in clinical experiment of aniseikonia.

In summary, apps are becoming more relevance in eye care professional specifically Smart Optometry which is innovative in digitalizing eye assessments. The essential advantage of this smartphone application is the convenience of the tools in a digital form. As the tools are on a tablet, health practitioner doesn't have to carry around a diverse set of physical tools. Smart Optometry application works best for general screening, assisting health practitioner in consulting patients regarding further needed eye exams for the final diagnosis.

CONCLUSION

The feature of aniseikonia in Smart Optometry smartphone application proves to be capable in providing consistent measurement of aniseikonia. Since it is cost effective, assessable and easy to administer, this Smart Optometry smartphone application might be valuable addition in clinical setting and useful in identifying patients presenting with symptoms relating to aniseikonia.

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REFERENCES

1. Scheiman M, Wick B. Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders. 2nd ed. Philadelphia: Lippincott; 2002. 519-549 p.
2. Gobin L, Rozema JJ. Predicting refractive aniseikonia after cataract surgery in anisometropia. J Cataract Refract Surg. 2008;34:1353–61.
3. South J, Gao T, Collins A, Turuwhenua J, Robertson K, Black J. Aniseikonia and anisometropia : implications for suppression and amblyopia. Clin

Exp Optom. 2019;1–10.
4. Rutstein RP, Roderick RJ, Wilson JA, Gordon A. Aniseikonia Induced by Cataract Surgery and Its Effect on Binocular Vision. Optom Vis Sci. 2015;92(2):201–7.
5. Weise KK, Marsh-Tootle W, Corliss D. Evaluation of computer-based testing for aniseikonia in children. Optom Vis Sci. 2010;87(11):883–9.
6. de Wit GC, Remole A. Clinical management of aniseikonia: An overview. Clinical. 2003;39–40.
7. McCormack G, Peli E, Stone P. Differences in tests of Aniseikonia. Investig Ophthalmol Vis Sci. 1992;33(6):2063–7.
8. Antona B, Barra F, Barrio ANA. The Validity and Repeatability of the New Aniseikonia Test. Optom Vis Sci. 2006;83(12):903–9.
9. Rutstein RP, Corliss DA, Fullard RJ. Comparison of Aniseikonia as Measured by the Aniseikonia Inspector and the Space Eikonometer. Optom Vis Sci. 2006;83(11):836–42.
10. Ogle KN. Researches in Binocular Vision. New York and London.; 1964.
11. Hu YY, Wu JF, Lu TL, Wu H, Sun W, Wang XR, et al. Effect of cycloplegia on the refractive status of children: The shandong children eye study. PLoS One. 2015;10(2):1–10.
12. Antona B, Barra F, Barrio A, Gonzalez E, Sanchez I. Validity and repeatability of a new test for aniseikonia. Investig Ophthalmol Vis Sci. 2007;48(1):58–62.
13. Young G, Hall L, Sulley A, Osborn-Lorenz K, Wolffsohn JS. Inter-relationship of soft contact lens diameter, base curve radius, and fit. Optom Vis Sci. 2017;94(4):458–65.
14. Weissman B, Barr J, Harris M, McMahon T, Rah M, Secor G, et al. Clinical Practice Guidelines: Care of the Contact Lens Patient. 2nd (ed). Am Optom Assoc. 2006;46.
15. Rutstein RP, Daum KM. Anomalies of binocular vision: diagnosis & management. Mosby Incorporated; 1998.
16. Chappuis A, Rerabek M, Hanhart P, Ebrahimi T. Subjective evaluation of an active crosstalk reduction system for mobile autostereoscopic displays. In: SPIE-IS&T Electronic Imaging. 2014. p. 1–13.
17. Garcia-Perez MA, Peli E. Aniseikonia Tests : The Role of Viewing Mode , Response Bias , and Size – Color Illusions. 2015;4(3).
18. Charman WN. Visual Optics [Internet]. Third Edit. Contact Lens Practice. Elsevier Ltd; 2018. 28-42.e2 p. Available from: http://dx.doi.org/10.1016/B978-0-7020-6660-3.00003-4
19. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med [Internet]. 2016;15(2):155–63. Available from: http://dx.doi.org/10.1016/j.jcm.2016.02.012
20. Kulkarni V, Puthran N, Gagal B. Correlation between stereoacuity and experimentally induced graded monocular and binocular astigmatism. J Clin Diagnostic Res. 2016;10(5):NC14-NC17.