Scientific Research Publishing

Open Journal of Ophthalmology, 2022, 12, 107-120
https://www.scirp.org/journal/ojoph
ISSN Online: 2165-7416
ISSN Print: 2165-7408

Stereopsis, Aniseikonia, and Associated Symptoms in Patients with Bilateral Pseudophakia with and without Anisometropia: A Comparative Study

Marcelo Tannous[1], Daniel Dantas[2], Paulo Roberto de Arruda Zantut[1], David Tayah[1], Pedro Carricondo[1], Amaryllis Avakian[1], Milton Ruiz Alves[1]

[1]Departament of Ophthalmology and Otolaryngology of HOSPITAL das Clinicas from University of São Paulo Medical School, Sao Paulo, Brazil
[2]Department of Computer, Federal University of Sergipe, Aracaju, Brazil
Email: dr.tannous@hotmail.com

How to cite this paper: Tannous, M., Dantas, D., de Arruda Zantut, P.R., Tayah, D., Carricondo, P., Avakian, A. and Alves, M.R. (2022) Stereopsis, Aniseikonia, and Associated Symptoms in Patients with Bilateral Pseudophakia with and without Anisometropia: A Comparative Study. *Open Journal of Ophthalmology*, **12**, 107-120.
https://doi.org/10.4236/ojoph.2022.121011

Received: January 14, 2022
Accepted: February 25, 2022
Published: February 28, 2022

Abstract

Objectives: The study aimed to compare stereopsis, aniseikonia, and associated symptoms in bilateral pseudophakia with and without anisometropia. **Methods:** Patients with senile cataracts, previously scheduled for phacoemulsification with an IOL implant in both eyes were included in this cross-sectional study. Patients were divided into two groups: control group (n = 69) with an interocular post-surgical refraction difference in Spherical Equivalent (SE) < 1.0 D and anisometropia group (n = 42) with an interocular post-surgical difference in SE ≥ 1.00 D. Aniseikonia was evaluated by Aniseikonia Inspector™ 3 and stereopsis by Randot® Stereotest. Ten symptoms related to aniseikonia were evaluated with a questionnaire. Statistical evaluation of data included models of univariate, multivariate, and regression analyses. **Results:** Cataract surgery-induced aniseikonia was 0.64% ± 1.41% in control group and 0.62% ± 1.76% in anisometropia group with an insignificant difference (p = 0.766). Measured stereoacuity was 1.95 ± 0.17 log10 seconds of arc in the control group and 2.12 ± 0.22 log10 seconds of arc in the anisometropia group with a significant difference (p < 0.0001). The mean score of symptoms associated with aniseikonia was 1.41 ± 0.46 in the control group and 1.47 ± 0.45 in the anisometropia group, with an insignificant difference (p = 0.387). The contribution of independent variables in predicting stereopsis in the anisometropia group was the following: axial length difference (18.06%); refractive error difference (SE) (44.53%), aniseikonia (25.71%), and IOL power difference (11.71%). **Conclusions:** The study showed that stereopsis, aniseikonia, and associated symptoms did not stand for a substantial problem for visual comfort of bilateral pseu-

dophakia with anisometropia less than 3D.

Keywords

Cataract, Phacoemulsification, Pseudophakia, Aniseikonia, Depth Perception, Anisometropia

1. Introduction

Modern cataract surgery is currently one of the safest, most effective, and frequently performed surgical procedures in ophthalmology [1]. Cataract surgery can change eye refraction, thus allowing refractive error reduction and, in some cases, becoming spectacle independent [2]. However, in specific postoperative conditions, anisometropia-induced problems with binocular vision may occur [3]. Anisometropia may induce aniseikonia that occurs when "the images presented to the cortex from the two eyes are abnormally unequal in size, shape or luminance" [4]. Levels of tolerance of aniseikonia vary greatly. By and large, 1% is unlikely to be symptomatic. Two percent to 8% were highly likely to be symptomatic [5].

Despite a general agreement on the safety limits of surgically induced anisometropia, several clinical studies have described high inter-variability in the tolerance of anisometropia and perceived aniseikonia [6] [7] [8] [9]. Linksz and Lubkin demonstrated the astonishing capacity of some monocular aphakia pre-intraocular lens (IOL) to fusion up to 25% image disparity [10]. The limits of the potential human capacity to achieve various degrees of stereoacuity in the presence of high aniseikonia remain to be determined [11] [12].

Stereopsis is the ability to perceive depth, and it occurs due to the fusion of two slightly dissimilar images by stimulating two disparate retinal elements within the Panum's fusional area of two eyes [13]. Stereopsis is influenced by Visual Acuity (VA), pupillary diameter, cataract, presbyopia, and age-related retinal ganglion cell loss [14] [15]. Stereopsis loss impacts the performance on certain motor abilities necessary for everyday tasks within the near and large range, e.g. at the near range during the precise manipulation of objects [16], and regarding large disparity range [17] such as driving cars and playing sports [18].

In a population of pseudophakic patients, Kramer *et al.* [12] reported symptoms attributable to aniseikonia in 40.2%. Rutstein *et al.* [9] reported that aniseikonia increased after the first cataract surgery and returned to near baseline in 1 month (±1 week) after the second cataract surgery. The increase in aniseikonia occurred together with an increase in anisometropia, resulting in poor overall stereopsis. Such aniseikonia showed substantial variance and could not be predicted by the degree of induced anisometropia.

In this study, we attempted to measure aniseikonia, stereoacuity and visual symptoms associated with aniseikonia to analyze the relation of aniseikonia with anisometropia and its effects on stereopsis and visual symptoms.

2. Material and Methods

A cross-sectional observational study was conducted among patients who previously underwent bilateral cataract surgery (sequential) with monofocal IOL implantation in a tertiary care teaching hospital in Sao Paulo, Brazil from April 2018 to August 2021. The study was conducted as per the guidelines of Declaration of Helsinki and was approved by Ethics Committee for Analysis of Research Projects of Faculty of Medicine of University of Sao Paulo (Process 91953018.40000.0068). The study was explained to every participant, and patients' written informed consent was obtained before their enrolment.

After assessment, all patients were submitted to a complete ophthalmologic examination with VA recording with best correction (BCVA) for near and far vision, evaluation of extrinsic ocular motility (cover/uncover test), test with striated Bagolini lenses, refractometric examination (retinoscopy and Greens refractor), slit-lamp biomicroscopy (Haag-Streit AT® 900), tonometry (AT 900, Medvision), and direct (Pocket Junior®, Welch Allyn) and indirect (ODS® 6.0, Eyetec) fundoscopy. The patients were again submitted to optical biometrics by partial coherence interferometry (PCI; IOLMaster®, Carl Zeiss Meditec, Jena, Germany), calibrated according to the manufacturer's recommendation. Keratometry and axial length were also measured in both eyes.

Inclusion criteria: Patients of both sexes, aged between 50 - 70 years, undergoing a sequential cataract surgery without complications, at least 12 ± 3 weeks of second eye surgery who presented with BCVA > 0.7 in both eyes, centered IOLs (surgery performed without complications), intraocular pressure (IOP) < 20 mm Hg without medication, present sensory fusion as evaluated by Bagolini striated lenses, excavation of the optic nerve < 0.7 and normal fundoscopy.

Exclusion criteria: Patients with BCVA < 0.7; cataract surgery with complications; the presence of posterior capsule opacity; decentered IOL; and carriers of other pre-existing eye diseases that could alter BCVA (moderate or intense dry eye, uveitis, glaucoma, and degenerative retinal disease).

Group criteria: Patients were divided into two groups: control group (n = 69) with an interocular post-surgical refraction difference in Spherical Equivalent (SE) < 1.00 D and anisometropia group (n = 42) with an interocular post-surgical refraction difference in SE > 1.00 D.

Study procedure: Cataract surgeries were performed with the following standard surgical technique in the described order: topical anesthesia with 1% lidocaine without preservatives; 2.2-mm incision in clear corneal autosealant in the most curved meridian; use of dispersive and cohesive viscoelastic; continuous circular capsulorhexis; hydrodissection and use of Infinity® Vision System OZIL® *Intelligent Phaco* (Alcon Laboratories, Fort Worth, TX, USA). A folding unifocal IOL was implanted with an appropriate injector inside the capsular bag. After viscoelastic removal, the implanted IOL was centralized with the patient looking at the direct illumination of the surgical microscope, and the surgery was completed with hydration of the incisions with a balanced saline solution. Patients were in-

structed to use 0.3% gatifloxacin eye drops for 10 days four times a day and 0.1% dexamethasone eye drops four times a day initially with instillations regression over 30 days.

Aniseikonia measurement: The measurement was performed with the patient using optical correction from far, the addition of +2.50 D, and green and red filters to dissociate the images of the two eyes. The patient was positioned 40 cm in front of the computer monitor with the software of Aniseikonia Inspector Version 3 (AI3). The green filter use in the right eye was standardized. The test began with the patient pointing at the computer screen to show which of the two rectangular boxes presented was wider and taller at the time. If the images looked the same for the patient, the examiner would select the "E" button for the same. The aniseikonia measurement results were obtained in magnification/minification percentage; in the vertical and horizontal meridians, together with a consistency value that allowed considering the results reliable or inconsistent. In this research, we used the media of the measures taken in horizontal and vertical directions in the 8˚ visual fields.

Stereopsis measurement: Stereoacuity was measured with TNO stereotest (Stereo Optical Company, INC) under best refractive correction from far, the addition of +2.50 D, and Polaroid glasses at 40 cm distance. Patients were asked to identify the circle, which was different from other circles, in a group of four circles. During stereoacuity determination, if the patient could not identify the correct circle for two consecutive times, then the previous result was considered the examinee's stereoacuity. For analysis purposes, seconds of arc were transformed into units of logarithm at the base of 10. Each doubling of the stereoacuity threshold, for example, 100 to 200 seconds of arc, corresponds to a change of 0.3 from log10 of the transformed value.

Aniseikonia symptoms: The quantitative evaluation of aniseikonia symptoms was performed using a modified questionnaire of Bannon and Triller [19]. Ten symptoms (headaches, asthenopia. photophobia, reading difficulty, nausea, motility, nervousness, vertigo and dizziness, general fatigue, and distorted space perception) were evaluated on a quantitative scale of 1 - 5. The patient reported the presence of each symptom as 1 (never), 2 (little), 3 (sometimes), 4 (often) and 5 (always).

Sample size: The calculation to identify stereoacuity differences of 0.30 units of log10 seconds of arc with a 90% statistical power and a significance level of 0.05 between groups was 39 patients.

Statistical analysis: Variables including age, BCVA, SE, corneal astigmatism, axial length, IOL power, and symptoms were expressed in mean ± standard deviation, minimum and maximum values. For the statistical analysis, R 3.6 software (R Core Team, Vienna, Austria) was used. Comparison of sex distribution between Control and Anisometropia Groups was done with the Chi-Square test. Comparison of age, biometric parameters, aniseikonia, stereoacuity, and aniseikonia symptoms distributions between Control and Anisometropia Groups was done with the non-parametric unpaired Mann-Whitney U-test. Pearson correlation ana-

lysis was calculated between aniseikonia and anisometropia, stereopsis and anisometropia, aniseikonia and associated symptoms, stereopsis and associated symptoms, and stereopsis and aniseikonia. Multivariate analysis was used to obtain an equation to predict the dependent variable (stereopsis), based on the independent variables (aniseikonia, SE; IOL power and axial length) in the Anisometropia Group. Dispersion diagram of real values of stereopsis (Y-axis) versus predicted values of independent variables (X-axis) was done in Anisometropia Group. The null hypothesis was rejected at the 0.5 level of significance.

3. Results

Age and gender details are depicted in Table 1.

The age and sex distributions did not significantly differ between the two groups. The biometric parameters distributions between the two groups are depicted in Table 2.

The comparison of refractive error (SE) and IOL power between the groups revealed a statistically significant difference with $p < 0.0001$ and $p = 0.039$, respectively.

Values of mean aniseikonia and mean stereoacuity are depicted in Table 3.

There was no significant difference between the groups regarding aniseikonia; however, the difference in stereopsis between the groups was statistically significant ($p < 0.0001$).

Table 1. Comparison of age and sex distributions between control and anisometropia groups.

Groups	Control	Anisometropia	P values
Participants	69	42	
Sex (male:female)	21:48	13:29	1.0[a]
Age[b]	60.81 ± 8.73 (50 - 70)	59.71 ± 7.87 (53 - 70)	0.255[c]

Age values in ± standard deviation and range; [a]from the Chi-square test, [b]Years of age, and [c]from the non-parametric unpaired Mann-Whitney U-test.

Table 2. Comparison of biometric parameters distributions between control and anisometropia groups.

Groups	Control	Anisometropia	P value[a]
Participants	69	42	
logMAR BCVA RE	0.09 ± 0.07 (0 - 0.2)	0.10 ± 0.05 (0 - 0.20)	0.619
logMAR BCVA LE	0.09 ± 0.06 (0 - 0.2)	0.09 ± 0.05 (0 - 0.2)	0.751
Diff. LogMAR BCVA	0.03 ± 0.05 (0 - 0.2)	0.02 ± 0.04 (0 - 0.1)	0.649
Diff. Refractive error (SE)[b]	0.38 ± 0.26 (0 - 0.8)	1.80 ± 0.86 (1.1 - 3.0)	<0.0001
Diff.Corneal astigmatism (D)[c]	0.48 ± 0.47 (0 - 0.8)	0.49 ± 0.64 (1 - 5.0)	0.644
Diff. Axial length (mm)[d]	0.20 ± 0.7 (0 - 1.5)	0.49 ± 1.09 (0 - 2.4)	0.529
Diff. IOL power (D)[c]	0.83 ± 1.05 (0 - 7)	1.86 ± 3.33 (0 - 7)	0.039

Values in ± standard deviation and range; [a]from the non-parametric unpaired Mann-Whitney U-test, [b]SE = Spherical Equivalent, [c]D = diopter, [d]mm = millimeter.

Table 3. Comparison on the level of aniseikonia (%) and stereoacuity (units Log10 seconds of arc) between control and anisometropia groups.

Groups	Control	Anisometropia	P value[a]
Participants	69	42	
Aniseikonia [(H + V)/2][b]	0.64 ± 1.41 (−3.5 - 5.5)	0.62 ± 1.76 (−4.5; 5)	0.766
Stereoacuity	1.95 ± 0.17 (1.5 - 2.3)	2.12 ± 0.22 (1.7 - 2.6)	<0.0001

Values in ± standard deviation and range; [a]from the non-parametric unpaired Mann-Whitney U-test, [b]percentage of interocular images magnification/minification of horizontal and vertical directions in the 8˚ visual fields

The aniseikonia symptoms distributions between the two groups are depicted in Table 4.

There was no difference between the two groups considering each or the mean of the ten symptoms related to aniseikonia.

In control group, there was no significant relationship between aniseikonia and anisometropia (r = −0.23 and p = 0.061), stereopsis and anisometropia (r = 0.17 and p = 0.17), aniseikonia and associated symptoms (r = 0.076 and p = 0.53), stereopsis and associated symptoms (r = −0.14 and p = 0.24), and stereopsis and aniseikonia (r = −0.098 and p = 0.42) by Pearson correlation analysis. Also, in anisometropia group, there was no significant relationship between aniseikonia and anisometropia (r = 0.055 and p = 0.73), stereopsis and anisometropia (r = 0.27 and p = 0.087), aniseikonia and associated symptoms (r = −0.16 and p = 0.32), stereopsis and associated symptoms (r = 0.043 and p = 0.79), and stereopsis and aniseikonia (r = −0.12 and p = 0.44) by Pearson correlation analysis.

The linear regression model and correlation constructed with anisometropia group data allowed obtaining an equation to predict the dependent variable (stereopsis), based on the independent variables (aniseikonia, anisometropia, IOL power, and axial length).

$$\begin{aligned}&\text{stereoacuity units log10 seconds arc}\\&= 2.024626603 - 0.122464059 \times \text{axial length}\\&+0.001163012 \times \text{IOL power} + 0.113751496\\&\times \text{SE anisometropia} - 0.006254317 \times \text{aniseiconia}\end{aligned}$$

The dispersion diagram of real values of stereoacuity versus predicted values independent variables contribution to aniseikonia is depicted in Figure 1.

In anisometropia group, the contribution of each independent variable in stereopsis was as follows: axial length 18.06%, anisometropia 44.53%, aniseikonia 25.71%, and IOL power 11.71%.

4. Discussion

Currently, most cataract surgeries produce excellent visual outcomes with significant improvement in the patients' quality of life [20] [21]. After cataract surgery, significant damage to binocular vision rarely occurs, since the majority

Table 4. Comparison on the level of aniseikonia symptoms (scale 1 - 5) between control and anisometropia groups

Groups	Control	Anisometropia	P value[a]
Participants	69	42	
Headaches	1.30 ± 0.93	1.38 ± 0.96	0.210
Asthenopia	1.41 ± 0.96	1.74 ± 1.34	0.205
Photophobia	2.20 ± 1.63	2.57 ± 1.61	0.115
Reading Difficulty	1.78 ± 1.34	1.67 ± 1.14	1.000
Nausea	1.00	1.00	-
Motility	1.14 ± 0.60	1.02 ± 0.15	0.267
Nervousness	1.22 ± 0.77	1,19 ± 0.97	0.782
Vertigo and Dizziness	1.12 ± 0.58	1.21 ± 0.81	0.525
General Fatigue	1.33 ± 0.80	1.31 ± 0.92	0.512
Distorced Space Perception	1.39 ± 1.11	1.29 ± 0.83	0.817
Symptoms (mean)	1.39 ± 0.46	1.44 ± 0.44	0.461

[a]from the non-parametric unpaired Mann-Whitney U-test.

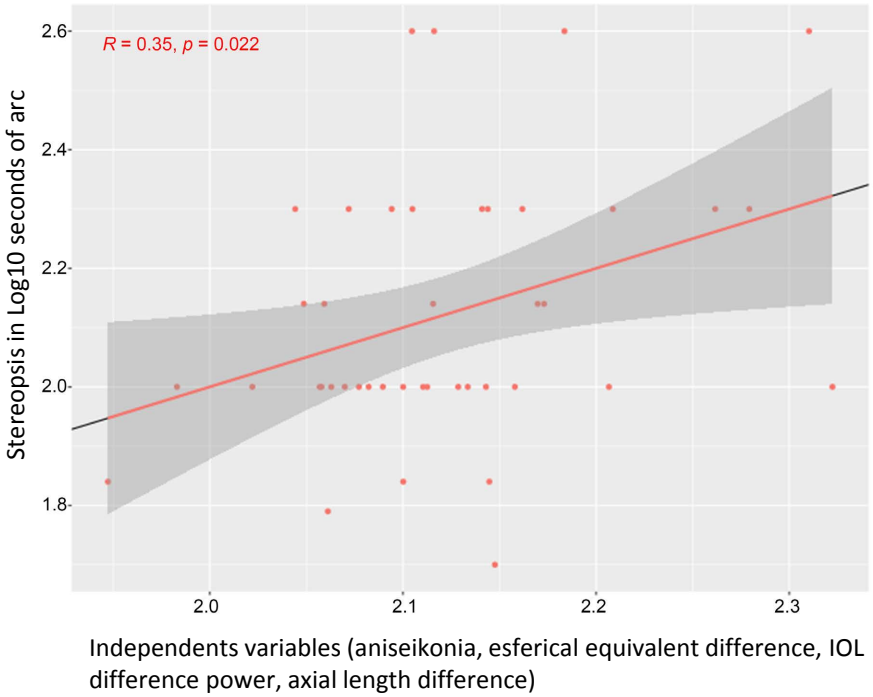

Figure 1. The dispersion diagram of real values of stereoacuity versus predicted values of the contribution of anisometropia, aniseikonia, IOL power and axial length. Anisometropia group: Pearson correlation coefficient r = 0.35; p < 0.022.

(72.7%) of biometric prediction errors are within ± 0.50 D of power scheduled IOL [22]. However, problems with binocular vision due to post-surgical anisometropia may occur due to "refractive surprise" which occurs, as reported by Lundstrom *et al.* [3] in 3555 out of 282,811 operated cataract cases, are defined by the

authors as post-surgical refractive error greater than ±2.00 D. In this study, bilateral pseudophakia with an interocular post-surgical refraction difference in SE < 1.00 D comprised control group (n = 69), and those interocular post-surgical refractive differences in SE > 1.00 D comprised anisometropia group (n = 42). There was no significant difference between the groups regarding age and gender (Table 1).

Table 2 shows that there was no significant difference in the comparison of right eye BCVA with the left-eye BCVA and BCVA interocular difference between the groups (p = 0.649). However, there was a significant difference in interocular refraction (SE), since this parameter defined the composition of the groups. The refractive difference in SE was 0.38 ± 0.26 D in the control group and 1.80 ± 0.86 D in the anisometropia group (p < 0.0001).

Gobin *et al.* [23] proposed a comprehensive classification of anisometropia, considering four pure types: corneal anisometropia, lenticular, by a correction with ophthalmic lenses (glasses), and mixed. The authors defined corneal anisometropia by the interocular main corneal meridians' power difference. In this study, the interocular differences between the groups concerning corneal astigmatisms were 0.48 ± 0.47 D and 0.49 ± 0.64 D and not significant (p = 0.644) (Table 2). They characterized axial anisometropia by the interocular axial powers difference. Axial power was estimated by measuring axial length by optical biometer and using the following formula: Axial power = n/L-IPP, in which L is the axial length (mm); n = 1.336 is the vitreous humor refraction index, and IPP = 1.6 mm, which corresponds to the estimated image position in the main plane of Gulstrand's eye model. In this study, the differences concerning axial length were 0.20 ± 0.27 mm and 0.49 ± 1.09 mm between the groups and were insignificant (p = 0.529) (Table 2). They defined lenticular anisometropia by the interocular IOL powers difference. The IOL power was calculated using biometric formulas. In this study, the interocular differences in the IOL power were 0.83 ± 1.05 D and 1.86 ± 3.33 D between the groups, representing significant difference (p = 0.039) (Table 2). They characterized anisometropia by optical correction due to the interocular difference in ophthalmic lenses SE. In this study, the interocular difference in SE was 0.38 ± 0.26 D and 1.80 ± 0.86 D in the control and anisometropia groups, respectively, since the cut-off belonging to one of the groups was defined by the difference in SE (Table 2).

Rustein *et al.* [9] measured aniseikonia before and after cataract surgery. They selected patients with anisometropia of 2.00 D or more. In the pre-surgical evaluation, anisometropia of 1.05 ± 0.29 D, aniseikonia of 1.85% ± 0.70%, and 29% of them with stereoacuity of 60 arc seconds or better were documented. They verified 4 ± 1 weeks after cataract surgery in the first eye, anisometropia of 3.69 ± 0.59 D, aniseikonia of 6.03% ± 1.30%, and only 6% with stereoacuity of 60 seconds of arc or better. The aniseikonia increment occurred with the increase of anisometropia, resulting in a reduction in stereopsis. After 4 ± 1 weeks after the second eye surgery, anisometropia of 0.68 ± 19 D, aniseikonia of 1.53% ± 0.36%, and 50% with stereoacuity of 60 seconds of arc or better were documented. The

authors also verified that aniseikonia showed considerable variation, and therefore, could not be predicted by the amount of induced anisometropia. In this study, 12 ± 3 weeks after second eye surgery, the aniseikonia induced in the control group was 0.64% ± 1.41% for a SE difference of 0.38 ± 0.26 D and in the anisometropia group of 0.62% ± 1.76% for the difference in SE of 1.80 ± 0.86 D (**Table 2** and **Table 3**).

Cataract surgery performed in anisometropia was studied by Gobin *et al.* [14]. They found 7.6% anisometropia in 263 consecutive patients selected for cataract surgery. Pre-surgical aniseikonia values of 2% and 4% were found in 3.0% and 7.5% of patients, respectively, depending on a refractive error. The authors concluded that cataract surgery in anisometropia could induce aniseikonia of 4% or more if the IOL power choice was scheduled for emmetropia. Krzizok *et al.* [24] reported that cataract surgery for unilateral high myopia correction with IOL scheduled for emmetropia could result in high aniseikonia with many visual complaints. The authors reported the case of a patient with symmetric myopia of −4.00 D who presented diplopia with asthenopia, combined with moderate aniseikonia and anisophoria, after surgery on the first eye. The authors pointed out that the individual tolerance for vertical anisophoria was very poor.

In this study, the aniseikonia was 0.64 ± 1.41 (control group) and 0.62% ± 1.76% (anisometropia group), without significant difference (p = 0.766) (**Table 3**). Katsumi *et al.* [25] reported that a difference of up to 3.0% in the size of retinal interocular images could be well tolerated binocularly. Oguchi and Mashima [26] demonstrated that with aniseikonia being in the range of 3% - 5%, binocular summation and stereopsis are possible. In the daily ophthalmic practice, it is verified that differences in SE of ±3.00 D corrected with ophthalmic lenses (glasses) are tolerable for most patients [27]. However, it should be emphasized that the anisophoria induced by reading using bifocal and/or multifocal lenses can cause discomfort and even diplopia in performing close visual tasks. Considering that the vergence amplitude is commonly insufficient to compensate for vertical anisophoria above ±2.00 D, it may be necessary to lower the optical zone center of the unifocal lenses in glasses for reading or the incorporation into bifocal or *multifocal of slab-off* prism to minimize this prismatic effect [27]. None of the patients in this study required prescribing a *slab-off* prism or lower decentering of the optical center in their glasses for reading.

All ten symptoms associated with aniseikonia did not show significant differences between the groups. Also, there was no difference in the comparison of their means between the two groups (p = 0.461) (**Table 4**). In general, it can be considered that the participants were little symptomatic in this study.

Aniseikonia tolerance was defined as the total amount of optic aniseikonia that a patient can endure without harming the stereopsis threshold. It can be measured with iseikonic afocal lenses and stereopsis tests. Krarup *et al.* [28] induced aniseikonia with iseikonic afocal lenses, measured stereopsis using Randot® and TNO stereotest, and found that the tolerance to IOL power difference-induced aniseikonia was around 3 D, representing approximately 3% - 5% of aniseikonia

when glasses are used. These values of aniseikonia are much higher than those found in our study.

Theoretically, anisometropia has been described to correlate linearly 1:1 with optical aniseikonia. Krarup *et al.* [28] did not find the correlation of 1:1 between anisometropia and aniseikonia, as in this study. In the control group, a difference in SE of 0.38 ± 0.26 D corresponded to aniseikonia of 0.64% ± 1.41%, while in the anisometropia group, a difference in SE of 1.80 ± 0.86 D corresponded to aniseikonia of 0.62% ± 1.76% (**Table 2** and **Table 3**). Other studies have also described difficulty in finding a significant correlation between anisometropia and perceived aniseikonia [9] [29] [30]. This difficulty may be due to an adaptation of the visual system. Burian [31] [32] described an adaptation of 1.5% - 6% after 3 - 4 days in afocal iseikonic lenses-induced aniseikonia. Adaptation to aniseikonia could explain the findings of previous electrophysiological and psychophysical studies [33] [34] [35] in which there was a significant adaptation of short-term stereopsis in 3% aniseikonia induced by afocal iseikonic lenses. Similarly, there are reports of patients undergoing cataract surgery who maintained good stereopsis despite manifesting iatrogenic aniseikonia of up to 20% [6] [9] [36] [37].

Most cataract surgeons hesitate to schedule unilateral emmetropia in patients with myopia and hyperopia greater than 2 - 3 D due to the risk of anisometropic IOL-induced aniseikonia. Kramer *et al.* [12] showed that the percentages of patients with IOL-induced aniseikonia and clinically relevant symptoms in patients with up to 3 D of anisometropia may be lower than the previously reported. In this study, there was no significant relationship between anisometropia and aniseikonia, anisometropia and stereopsis, aniseikonia and associated symptoms, stereopsis and the symptoms, and stereopsis and aniseikonia by Pearson correlation analysis. According to Kramer *et al.* [12], many patients may develop neural adaptation and become asymptomatic. This neural plasticity and visual reinterpretation have been demonstrated in several recent studies [38] [39] [40]. Our results corroborate the findings of Krarup *et al.* [28] and suggest that most bilateral pseudophakic patients tolerate aniseikonia well due to optical correction of up to 3 D of anisometropia.

In this study, the stereopsis measured by Randot stereotest was 1.95 ± 0.17 units log10 seconds of arc in the control group and 2.12 ± 0.22 units log10 seconds of arc in the anisometropia group, showing a significant difference ($p < 0.0001$) (**Table 3**). These values correspond to approximately 90 seconds of arc (control group) and 130 seconds of arc (anisometropia group). There have been no clear definitions of normal stereoacuity that stands for bifixation. Forty to 60 seconds of arc is usually accepted as normal stereopsis [8] [25] [35] [36]. The range of 60 - 100 seconds of arc is considered normal, and 100 - 400 seconds of arc are considered subnormal binocularity [41]. Some studies have shown a slight decline in stereopsis with age, testing stereopsis in people aged between 17 and 83 years with TNO stereotest, attributing this decline more to the failure of fusional capacity than a deficiency of stereopsis at cortical level [12]. The evalua-

tion of other visual function aspects should include contrast sensitivity, and the degree of astigmatism may have been useful [13].

Concerning the anisometropia group, the correlation plot between stereopsis and dependent variables is depicted in **Figure 1**. Contributions from each independent variable in stereopsis were as follows: axial length: 18.06%, anisometropia: 44.53%, aniseikonia: 25.71%, and IOL power 11.71%, It is emphasized that the joint contribution of axial length and anisometropia to stereopsis was 70.24%.

There are limitations to this study. Anisometropia group could have been scaled with a larger number of bilateral pseudophakic eyes presenting post-surgical differences in SE > ±2.00 D, which would certainly allow a better evaluation of induced aniseikonia and its repercussions on stereopsis and the triggering of associated symptoms. Another limitation was that we did not consider pre-surgical refractive states of pseudophakic eyes. Another limitation was that the assessments of the aniseikonia symptoms were based on the outcomes reported by the participants, although the use of Bannon and Triller [19] symptoms questionnaire provided a systematic and simplified way of numerically quantifying the symptoms associated with aniseikonia. Despite the above limitations, our findings represent an important contribution to the literature, as they suggest that stereopsis, aniseikonia, and associated symptoms did not represent a substantial problem for the visual comfort of bilateral pseudophakic patients with post-surgical anisometropia of less than 3 D.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Nogaj, S., Dubas, K., Michalski, A. and Stopa, M. (2021) Spectacle Correction of Anisometropia Following Cataract Surgery. *Klinika Oczna*, **123**, 39-42. https://doi.org/10.5114/ko.2021.102117

[2] Brannan, S., Dewar, C., Sen, J., Clarke, D., Marshall, T. and Murray, P.I. (2003) A Prospective Study of the Rate of Falls before and after Cataract Surgery. *British Journal of Ophthalmology*, **87**, 560-562. https://doi.org/10.1136/bjo.87.5.560

[3] Lundstrom, M., Dickman, M., Henry, Y., Manning, S., Rosen, P., Tassignon, M.J., *et al.* (2018) Risk Factors for Refractive Error after Cataract Surgery: Analysis of 282 811 Cataract Extractions Reported to the European Registry of Quality Outcomes for Cataract and Refractive Surgery. *Journal of Cataract & Refractive Surgery*, **44**, 447-452. https://doi.org/10.1016/j.jcrs.2018.01.031

[4] Romano, P.E. (1999) Aniseikonia? YECH! [Editorial]. *Binocular Vision & Strabismus Quarterly*, **14**, 173-176.

[5] Lubkin, V. (1999) Aniseikonia at Millenium [Editorial]. *Binocular Vision & Strabismus Quarterly*, **14**, 179-182.

[6] Highman, V.N. (1977) Stereopsis and Aniseikonia in Uniocular Aphakia. *British Journal of Ophthalmology*, **61**, 30-33. https://doi.org/10.1136/bjo.61.1.30

[7] Katsumi, O., Miyajima, H., Ogawa, T. and Hirose, T. (1992) Aniseikonia and Stereo-

acuity in Pseudophakic Patients: Unilateral and Bilateral Cases. *Ophthalmology*, **99**, 1270-1277. https://doi.org/10.1016/S0161-6420(92)31813-5

[8] Jimenez, J.R., Ponce, A., Del Barco, L.J., Diaz, J.A. and Pérez-Ocón, F. (2002) Impact of Induced Aniseikonia on Stereopsis with Random-Dot Stereogram. *Optometry and Vision Science*, **79**, 121-125. https://doi.org/10.1097/00006324-200202000-00014

[9] Rutstein, R.P., Fullard, R.J., Wilson, J.A. and Gordon, A. (2015) Aniseikonia Induced by Cataract Surgery and Its Effect on Binocular Vision. *Optometry and Vision Science*, **92**, 201-207. https://doi.org/10.1097/OPX.0000000000000491

[10] Lubkin, V., Linksz, A. and Chamby, G. (1969) Stereopsis with Spectacles in Monocular Aphakia. A Progress Report. *American Journal of Ophthalmology*, **67**, 547-553. https://doi.org/10.1016/0002-9394(69)94262-7

[11] Lubkin, V. and Linksz, A. (1977) A Ten-Year Study of Binocular Fusion with Spectacles in Monocular Aphakia. *American Journal of Ophthalmology*, **84**, 700-707. https://doi.org/10.1016/0002-9394(77)90387-7

[12] Kramer, P.W., Lubkin, V., Pavlica, M. and Covin, R. (1999) Symptomatic Aniseikonia in Unilateral and Bilateral Pseudophakia. A Projection Space Eikonometer Study. *Binocular Vision & Strabismus Quarterly*, **14**, 183-190.

[13] Undrakonda, V., Sahiti, T.K., Vennesh, P.S. and Kamath, Y.S. (2019) A Comparative Study of Stereoacuity in Patients with Various Grades of Cataract and Bilateral Pseudophakia. *Indian Journal of Ophthalmology*, **67**, 1834-1837. https://doi.org/10.4103/ijo.IJO_401_19

[14] Lee, S.Y. and Koo, N.K. (2005) Change of Stereoacuity with Aging in Normal Eyes. *Korean Journal of Ophthalmology*, **19**, 136-139. https://doi.org/10.3341/kjo.2005.19.2.136

[15] Wright, L.A. and Wormald, R.P.L. (1992) Stereopsis and Ageing. *Eye*, **6**, 473-476. https://doi.org/10.1038/eye.1992.100

[16] McKee, S.P. (1983) The Spatial Requirements for Fine Stereoacuity. *Vision Research*, **23**, 191-198. https://doi.org/10.1016/0042-6989(83)90142-6

[17] Allison, R.S., Gillam, B.J. and Palmisano, S.A. (2010) Binocular Slant Discrimination beyond Interaction Space. *Journal of Vision*, **8**, 536-536. https://doi.org/10.1167/8.6.536

[18] Smith, C.E., Allison, R.S., Wilkinson, F. and Wilcox, L.M. (2019) Monovision: Consequences for Depth Perception from Large Disparities. *Experimental Eye Research*, **18**, 62-67. https://doi.org/10.1016/j.exer.2018.09.005

[19] Bannon, R.E. and Triller, W. (1944) Aniseikonia—A Clinical Report Covering a Ten-Year Period. *American Journal of Ophthalmology*, **21**, 171-182. https://doi.org/10.1097/00006324-194405000-00001

[20] Lundstrom, M., Stenevi, U. and Thorburn, W. (2001) Quality of Life after First- and Second-Eye Cataract Surgery: Five-Year Data Collected by the Swedish National Cataract Register. *Journal of Cataract & Refractive Surgery*, **27**, 1553-1559. https://doi.org/10.1016/S0886-3350(01)00984-1

[21] Schuster, A.K., Pfeiffer, N., Schulz, A., Nickels, S., Hohn, R., Wild, P.S., *et al.* (2017) The Impact of Pseudophakia on Vision-Related Quality of Life in the General Population—The Gutenberg Health Study. *Aging* (*Albany, NY*), **9**, 1030-1040. https://doi.org/10.18632/aging.101208

[22] Nayak, H., Kersey, J.P., Oystreck, D.T., Cline, R.A. and Lyons, C.J. (2008) Diplopia Following Cataract Surgery: A Review of 150 Patients. *Eye* (*London*), **22**, 1057-1064.

https://doi.org/10.1038/sj.eye.6702847

[23] Gobin, L., Rozema, J.J. and Tassignon, M.J. (2008) Predicting Refractive Aniseikonia after Cataract Surgery in Anisometropia. *Journal of Cataract & Refractive Surgery*, **34**, 1353-1361. https://doi.org/10.1016/j.jcrs.2008.04.023

[24] Krzizok, T., Kaufmann, H. and Schwerdtfeger, G. (1996) Binocular Problems Caused by Aniseikonia and Anisophoria after Cataract Operation. *Klinische Monatsblätter für Augenheilkunde*, **6**, 477-480. https://doi.org/10.1055/s-2008-1035267

[25] Katsumi, O., Tanino, T. and Hirose, T. (1986) Effect of Aniseikonia on Binocular Function. *Investigative Ophthalmology & Visual Science*, **27**, 601-604.

[26] Oguchi, Y. and Mashima, Y. (1989) The Influence of Aniseikonia on the VEP by Random-Dot Stereogram. *Acta Ophthalmologica* (*Copenh*), **67**, 127-130. https://doi.org/10.1111/j.1755-3768.1989.tb00740.x

[27] Alves, A.A. (2008) Anisometropia. In: Alves, A., Ed., *Refração*, 5th Edition, Guanabara Koogan Cultura Médica, Rio de Janeiro, 92-117.

[28] Krarup, T.G., Nisted, I., Christensen, U. and Kiilgaard, J. (2020) The Tolerance of Anisometropia. *Acta Ophthalmologica*, **98**, 418-426. https://doi.org/10.1111/aos.14310

[29] Miyake, S., Awaya, S. and Miyake, K. (1981) Aniseikonia in Patients with a Unilateral Artificial Lens, Measured with Aulhorn's Phase Difference Haploscope. *American Intra-Ocular Implant Society Journal*, **7**, 36-39. https://doi.org/10.1016/S0146-2776(81)80095-X

[30] Hillman, J.S. and Hawkswell, A. (1985) The Control of Aniseikonia after Intraocular Lens Implantation. *Transactions of the Ophthalmological Societies of the United Kingdom*, **104**, 582-585.

[31] Burian, H.M. (1943) Clinical Significance of Aniseikonia. *Archives of Ophthalmology*, **29**, 116-133. https://doi.org/10.1001/archopht.1943.00880130136010

[32] Burian, H.M. (1943) Influence of Prolonged Wearing of Meridional Size Lenses on Spatial Localization. *Archives of Ophthalmology*, **30**, 645-666. https://doi.org/10.1001/archopht.1943.00880230077009

[33] Crone, R.A. and Leuridan, O.M. (1975) Unilateral Aphakia and Tolerance of Aniseikonia. *Ophthalmologica*, **171**, 258-263. https://doi.org/10.1159/000307521

[34] Stewart, C. and Whittle, J. (1996) Optical Correction of Aniseikonia in Anisometropia Can Enhance Stereoacuity. *Binocular Vision & Strabismus Quarterly*, **12**, 31-34.

[35] Campos, E.C. and Enoch, J.M. (1980) Amount of Aniseikonia Compatible with Fine Binocular Vision: Some Old and New Concepts. *Journal of Pediatric Ophthalmology & Strabismus*, **17**, 44-47. https://doi.org/10.3928/0191-3913-19800101-11

[36] Lubkin, V., Stollerman, H. and Linksz, A. (1966) Stereopsis in Monocular Aphakia with Spectacle Correction. *American Journal of Ophthalmology*, **61**, 273-276. https://doi.org/10.1016/0002-9394(66)90282-0

[37] Isomura, Y. and Awaya, S. (1980) Studies on Aniseikonia and Binocular Fusion with Special Reference to Stereoacuity. *Nippon Ganka Gakkai Zasshi*, **84**, 1619-1628.

[38] Dilks, D.D., Serences, J.T., Rosenau, B.J., Yantis, S. and McCloskey, M. (2007) Human Adult Cortical Reorganization and Consequent Visual Distortion. *Journal of Neuroscience*, **27**, 9585-9594. https://doi.org/10.1523/JNEUROSCI.2650-07.2007

[39] Bex, P.J. (2010) (In)sensitivity to Spatial Distortion in Natural Scenes. *Journal of Vision*, **10**, 2310-2315. https://doi.org/10.1167/10.2.23

[40] Chen, N., Shin, K., Millin, R., Song, Y., Kwon, M. and Tjan, B.S. (2019) Cortical Reorganization of Peripheral Vision Induced by Simulated Central Vision Loss. *Journal of Neuroscience*, **39**, 3529-3536. https://doi.org/10.1523/JNEUROSCI.2126-18.2019

[41] Lee, J.Y., Seo, J.Y. and Baek, S.U. (2013) The Effects of Glasses for Anisometropia on Stereopsis. *American Journal of Ophthalmology*, **156**, 1261-1266. https://doi.org/10.1016/j.ajo.2013.07.016