The value of static perimetry in the diagnosis and follow-up of negative dysphotopsia

Rozendal, L.R.W.; Vught, L. van; Luyten, G.P.M.; Beenakker, J.W.M.

The Value of Static Perimetry in the Diagnosis and Follow-up of Negative Dysphotopsia

Lisa R. W. Rozendal, MD,[1]* Luc van Vught, BSc,[1,2] Gregorius P. M. Luyten, MD, PhD,[1] and Jan-Willem M. Beenakker, PhD, MSc[1,2]

SIGNIFICANCE: There is a clinical need for a quantitative test to objectively diagnose negative dysphotopsia, especially because the diagnosis is generally assessed using patients' subjective descriptions. In the search of a clinical test to objectify the shadow experienced in negative dysphotopsia, this study excludes static perimetry as suitable evaluation method.

PURPOSE: This study aimed to evaluate the value of static perimetry in the objective assessment and follow-up of negative dysphotopsia.

METHODS: Peripheral 60-4 full-threshold visual field tests were performed in 27 patients with negative dysphotopsia and 33 pseudophakic controls. In addition, 11 patients with negative dysphotopsia repeated the test after an intraocular lens exchange. Both the total peripheral visual field and the averaged peripheral visual field from 50 to 60° eccentricity were compared between patients and controls, and pre-operatively and post-operatively in patients who had an intraocular lens exchange.

RESULTS: The peripheral visual fields from 30 to 60° did not show significant differences between patients with negative dysphotopsia and pseudophakic controls. Analysis of the peripheral visual field from 50 to 60° showed a median [Q1, Q3] of 20.0 [17.1, 22.5] dB in the negative dysphotopsia group compared with 20.1 [15.5, 21.3] dB in the control group ($P = .43$). Although 82% of patients treated with an intraocular lens exchange subjectively reported improvement of their negative dysphotopsia complaints post-operatively, there were no significant differences in their total peripheral visual field or averaged peripheral visual field from 50 to 60° ($P = .92$).

CONCLUSIONS: Full-threshold static perimetry with a Goldmann size III stimulus up to 60° eccentricity does not show significant differences between patients with negative dysphotopsia and pseudophakic controls or between measurements before and after intraocular lens exchange. Therefore, this type of static perimetry cannot be used as a quantitative objective test for diagnosis or follow-up of patients with negative dysphotopsia.

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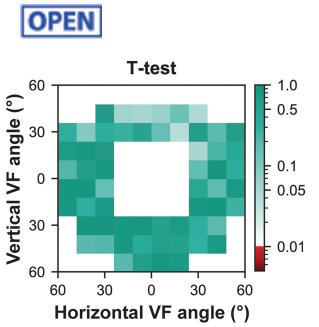

Author Affiliations:
[1]Department of Ophthalmology, Leiden University Medical Center, Leiden, the Netherlands
[2]Department of Radiology, C. J. Gorter Center for High Field MRI, Leiden University Medical Center, Leiden, the Netherlands
*L.R.W.Rozendal@lumc.nl

Cataract surgery is a safe procedure with, in general, excellent outcomes. It is performed 4000 to 10,000 times per million people per year in economically developed countries.[1] Nevertheless, a subset of these patients is affected by complaints of pseudophakic dysphotopsia, which is reported to have a significant negative effect on the satisfaction of visual quality in pseudophakic patients after an otherwise uneventful cataract surgery.[2] These dysphotopsia can be divided into positive dysphotopsia, including glare and halos, and the less understood negative dysphotopsia.

Negative dysphotopsia is generally described as a dark shadow or crescent in the temporal peripheral visual field, which is present directly after intraocular lens implantation.[3,4] Incidences up to 19% directly after surgery have been reported when patients are actively asked about these complaints.[5,6] One year post-operatively, 3.2% of pseudophakic patients still report negative dysphotopsia.[6,7] Although many potential factors of influence have been identified,[4,6,8–11] the exact origin of negative dysphotopsia is still not fully understood. Various treatment options have been proposed for negative dysphotopsia, including intraocular lens exchange, piggyback intraocular lens implantation, and reverse optic capture, but none of these treatments have shown to be successful in all cases.[6,12,13] To improve these treatment results, a standardized and objective method to evaluate the experienced loss of peripheral vision is essential. However, limited clinical tests are available to provide an objective measurement of the quality of the patients' peripheral visual field. As a result, the diagnosis and characterization of negative dysphotopsia rely on the subjective descriptions of patients, which limits both the accurate quantification of the severity of the complaint and the evaluation of the therapy success.

Makhotkina et al.[14] evaluated Goldmann kinetic perimetry as an objective measurement in pseudophakic patients with negative dysphotopsia. They found a significantly smaller extension of the inferior temporal and inferior nasal visual field quadrants in patients with negative dysphotopsia when compared with pseudophakic controls. In addition, they identified a shadow in the superior temporal and inferior temporal quadrants that correlated with the patients' subjective description of negative dysphotopsia in 30% of the patients.

Kinetic perimetry is particularly useful to identify patterns of visual field loss and, depending on the experience of the examiner, is able to assess high eccentricities, but it has difficulties with accurately measuring a diffuse visual field loss and with quantification of the depth of a scotoma, which might explain its inability to quantify shadows in some negative dysphotopsia patients.[15,16] The fully automated static perimetry has the advantages that it can both differentiate smaller changes in retinal sensitivity and provide a more detailed measure of the depth of a scotoma compared with kinetic perimetry.[16,17] Although the central visual field up to 30° eccentricity is commonly tested with the static perimetry Swedish Interactive Threshold Algorithm acquisition strategy, in which test duration is limited because of the threshold algorithm and therewith retest variability, such implementation is not available for the peripheral visual field from 50 to 60° where the negative dysphotopsia complaints are located. With the static perimetry full-threshold strategy, the retinal sensitivity of the visual field can be measured up to 60° eccentricity using a stair-tapping technique to determine threshold sensitivity. To date, it has not been systematically studied if the shadow experienced in patients with negative dysphotopsia can be identified in the peripheral visual field from 50 to 60° using the full-threshold strategy. Therefore, we performed a systematic evaluation of the ability of full-threshold static perimetry to provide an objective evaluation of negative dysphotopsia.

METHODS

Patients with negative dysphotopsia and pseudophakic controls were prospectively evaluated in the ESCRS vRESPOND study (CCMO registry no. NL58358.058.16) at Leiden University Medical Center. The study was performed in conformance with the tenets of the Declaration of Helsinki, and ethical approval was granted by the Medical Ethics Committee of Leiden University Medical Center. Written informed consent was obtained from each subject before participation in the study.

Patients with negative dysphotopsia were referred to the Department of Ophthalmology of Leiden University Medical Center by local ophthalmologists and were invited for participation in the study. The diagnosis of negative dysphotopsia was made when patients reported a shadow or dark region in the temporal peripheral visual field in absence of other evident causes of this visual complaint and no clear abnormalities of the intraocular lens or intraocular lens positioning upon biomicroscopy. The pseudophakic controls were invited for the study after uneventful cataract surgery in Leiden University Medical Center or two local hospitals and were evaluated within 3 months after surgery. All patients with negative dysphotopsia had a general biomicroscopy of the retina and the optic nerve before invitation for participation in the study. Invitation of participants in the control group was based on the pre-operative screening, including full biomicroscopy, before cataract surgery. Participants in both the negative dysphotopsia and the control group who were previously diagnosed with or suspect for ocular pathology that could be expected to affect the peripheral vision, such as retinal diseases or glaucoma, were excluded from participation. In total, 27 patients with negative dysphotopsia and 33 pseudophakic controls were included between January 2017 and October 2019, referred from 19 local hospitals in the Netherlands. However, four pseudophakic controls reported symptoms of negative dysphotopsia during the study evaluations and were therefore excluded from the study. A subgroup of 11 patients of the negative dysphotopsia group was treated with an intraocular lens exchange.

Study Measurements

To evaluate the use of static perimetry for the diagnosis of negative dysphotopsia, peripheral 60-4 full-threshold tests with a size III white-to-white stimulus (Humphrey Field Analyzer II-I; Carl Zeiss Meditec, Jena, Germany) were performed in the negative dysphotopsia group and the control group. In the subgroup of negative dysphotopsia patients with an intraocular lens exchange, a second 60-4 full-threshold test was performed approximately 3 months after the intraocular lens exchange procedure to assess if static perimetry can be used to assess treatment efficacy. Because full-threshold strategy tests are relatively long tests of approximately 15 minutes per eye, the reliability of each test was monitored using the device-reported amount of fixation losses, false-positive errors, and false-negative errors. Tests were considered unreliable and, subsequently, excluded, when the number of fixation losses was ≥20%, the number of false-positive errors was ≥33%, or the number of false-negative errors was ≥33%.[17] The Humphrey Field Analyzer outputs were automatically digitalized by an in-house–developed software based on the PyTesseract package (version 0.3.0) using Python (version 3.7; Python Software Foundation, Wilmington, DE) and Tesseract OCR (GitHub, San Francisco, CA).[18] This piece of software is made publicly available at https://doi.org/10.5281/zenodo.6380011.

All digitalized Humphrey Field Analyzer printouts were manually checked. The distribution at each test point from 30 to 60° eccentricity was evaluated. To analyze the total peripheral visual field, the mean of each individual Humphrey Field Analyzer test point was compared between groups. In addition, the four test points measured between 50 and 60° eccentricity in the temporal visual field were averaged as a measure of the total peripheral temporal visual field from 50 to 60° and compared between groups.

Statistical Analysis

Baseline parameters including age, date of surgery, type of intraocular lens and intraocular lens power, Snellen visual acuity,[19] and axial length were compared between the negative dysphotopsia

TABLE 1. Characteristics of the negative dysphotopsia group and the control group

Parameter	Negative dysphotopsia group	Control group	*P*
	Mean ± SD		
Sex (% male)	11.5	46.4	.005
Age (y)	66.0 ± 8.7	69.3 ± 8.2	.16
Intraocular lens power (D)	22.4 ± 2.2	19.7 ± 3.8	.003
Snellen VA	1.0 ± 0.2	1.1 ± 0.2	.15
Axial length (mm)	23.1 ± 1.0	24.3 ± 1.7	.006
	Median [Q1, Q3]		
Time after surgery (mo)	7.5 [3.0, 11.5]	2.0 [2.0, 2.75]	<.001

Data were not available for all subjects. Of four patients, the cataract surgery date was unknown, and in one of these patients, the intraocular lens power was also unknown. Snellen visual acuity and axial length were measured at the first visit after inclusion in the study, except in two participants in whom only their visual field test was included in the analyses. VA = visual acuity.

TABLE 2. Overview of intraocular lenses placed during primary cataract surgery and intraocular lens exchange surgery

				Amount of intraocular lenses per group (percentage)		
				Negative dysphotopsia		
Intraocular lens	Type	Spheric/aspheric	Material	Primary cataract surgery	Intraocular lens exchange	Control
Tecnis ZCB00 (J&J Vision)	Monofocal	Aspheric	Hydrophobic acrylic	12 (46.2)	—	23 (82.1)
Quadrimax PC 545 (Ophtec)	Monofocal	Aspheric	Hydrophilic acrylic	4 (15.4)	—	5 (17.9)
AcrySof IQ SN60WF (Alcon)	Monofocal	Aspheric	Acrylate/methacrylate copolymer	2 (7.8)	—	—
AcrySof IQ SA60AT (Alcon)	Monofocal	Spheric	Acrylate/methacrylate copolymer	1 (3.8)	—	—
iSert 251 (HOYA)	Monofocal	Aspheric	Hydrophobic acrylic	2 (7.8)	—	—
CT LUCIA 621P/PY (Zeiss)	Monofocal	Aspheric	Hydrophobic acrylic	1 (3.8)	—	—
Vivinex (HOYA)	Monofocal	Aspheric	Hydrophobic acrylic	1 (3.8)	—	—
FineVision Trifocal (Bausch)	Trifocal	Aspheric	Hydrophilic acrylic	1 (3.8)	—	—
enVista MX60T (Bausch+Lomb)	Toric	Aspheric	Hydrophobic acrylic	1 (3.8)	—	—
Lentis MPlus X (Oculentis)	Multifocal	Aspheric	Hydrophilic acrylic	1 (3.8)	—	—
Tecnis ZA9003 (J&J Vision)	Monofocal	Aspheric	Hydrophobic acrylic	—	9 (81.8)	—
Artisan Afakia (Ophtec)	Monofocal	Aspheric	Hydrophobic acrylic	—	2 (18.2)	—

group and the control group with either an unpaired two-sample *t* test or Mann-Whitney *U* test. Statistical tests were performed with SciPy and SPSS (version 25; IBM Corporation, Armonk, NY). The averages of the total peripheral visual field and of the four test points representing the peripheral temporal visual field from 50 to 60° were compared between patients and controls using a Mann-Whitney *U* test. The comparison between pre-operative and post-operative measurements was performed with the Wilcoxon test. An α of 0.05 was used as threshold for statistical significance, except for the total peripheral visual field analysis where an α of 0.01 was used to partly compensate for the high number of tested points.

RESULTS

Analysis of the baseline parameters showed no significant differences between the patients with negative dysphotopsia and the pseudophakic controls in age and visual acuity (Table 1). The negative dysphotopsia group had significantly more females and a significantly longer time after surgery than the control group. In addition, the intraocular lens power and the axial length differed significantly between both groups. In the majority of participants, a monofocal aspherical intraocular lens was placed during primary cataract surgery (Table 2). The subgroups of negative dysphotopsia patients with and without intraocular lens exchange were comparable at baseline, except for the time after surgery, which was 11.0 [6.0, 14.0] months (median [Q1, Q3]) in patients with negative dysphotopsia and intraocular lens exchange and 3.0 [2.0, 9.3] months in patients with negative dysphotopsia without intraocular lens exchange ($P = .03$). During intraocular lens exchange surgery, mostly the Tecnis ZA9003 IOL (Johnson & Johnson Vision, New Brunswick, NJ) was implanted (Table 2).

Twenty patients with negative dysphotopsia and 22 pseudophakic controls successfully completed the peripheral 60-4 full-threshold test. Two participants, one in each group, did not complete the test. Twelve subjects, six of whom were from the negative dysphotopsia group, were excluded from further analysis because of a higher percentage of fixation losses, false-negative errors, or false-positive errors than the pre-determined cutoff values (Figs. 1, 2). Included subjects in both groups had comparable perimetry reliability values (Table 3).

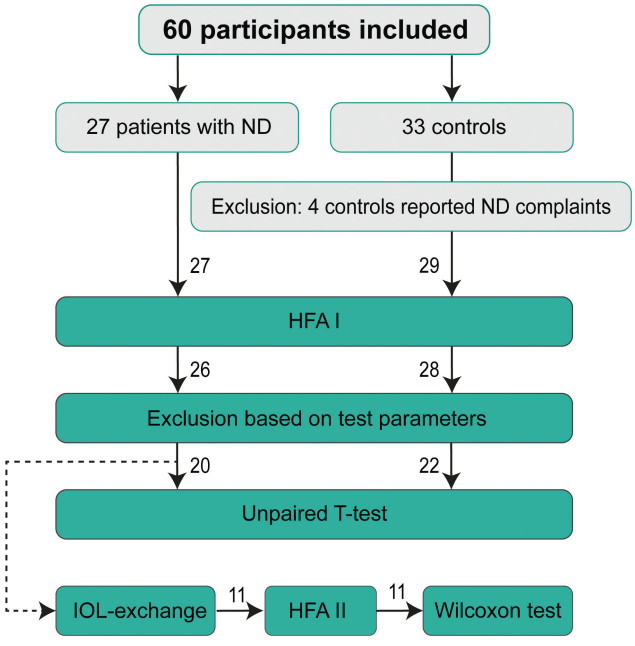

FIGURE 1. Representation of exclusion process of participants. Flowchart of exclusion of participants after inclusion in the study. After the second Humphrey Field Analyzer II-I visual field test (Carl Zeiss Meditec, Jena, Germany), no patients were excluded based on test parameters. HFA = Humphrey Field Analyzer; ND = negative dysphotopsia.

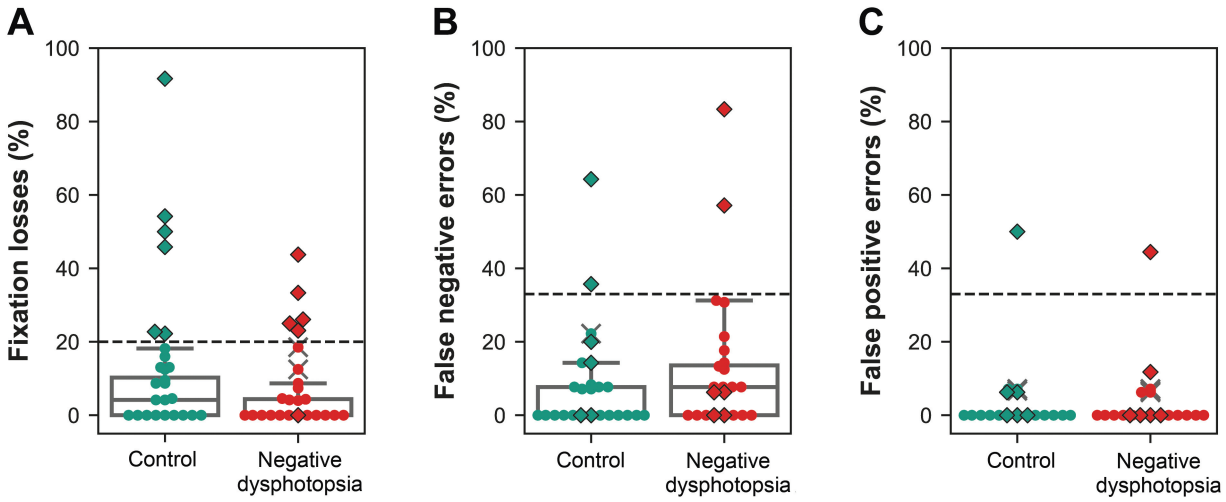

FIGURE 2. Representation of participants excluded based on test parameters. Exclusion of participants based on (A) amount of fixation losses ≥20% (black dotted line), (B) amount of false-negative errors ≥33% (black dotted line), and (C) amount of false positive errors ≥33% (black dotted line). In total, 12 patients were excluded from analyses. The box plots represent the median, 25th percentile, and 75th percentile from the included participants only. The diamonds indicate participants who were excluded. ND = negative dysphotopsia.

On average, the entire peripheral visual field showed similar values at each test point in patients with negative dysphotopsia and pseudophakic controls (Fig. 3A), without significant differences at any of these points ($P > .04$, Fig. 3B). The combined measure of the peripheral temporal visual field from 50 to 60°, 20.0 [17.1, 22.5] dB in the negative dysphotopsia group and 20.1 [15.5, 21.3] dB in the control group showed no significant differences ($P = .43$) (Fig. 4A).

Of the 11 patients with negative dysphotopsia who received an intraocular lens exchange, 9 (82%) reported an improvement of the complaint after surgery. The visual fields of each of these patients (Fig. 5A) did not show any statistical differences ($P > .01$, Fig. 5B). In addition, the combined evaluation of the peripheral temporal visual field from 50 to 60° was very similar, 19.5 ± 3.0 dB (mean ± SD) pre-operatively and 19.8 ± 2.2 dB post-operatively ($P = .92$) (Fig. 4B).

DISCUSSION

The aim of this study was to evaluate if static perimetry can be used as a quantitative test in the assessment and follow-up of patients with negative dysphotopsia. This study showed that both the individual test points and the combined measurement of the peripheral temporal visual field from 50 to 60° were not significantly different between patients with negative dysphotopsia and pseudophakic controls. As a result, the static perimetry full-threshold test measuring up to 60° eccentricity with a Goldmann size III stimulus was not able to objectively detect the shadow experienced by patients with negative dysphotopsia.

Although Makhotkina et al.[14] did identify a shadow in 30% of patients with negative dysphotopsia using Goldmann kinetic perimetry, we were not able to quantify the experienced shadow with static perimetry. This is likely caused by the maximal extent of 60° to which the visual field can be assessed with static perimetry, whereas the temporal peripheral visual field extends to at least 90°. Makhotkina et al.[14] were able to measure up to the maximal 90° with kinetic perimetry and thereby identified a shadow between 50 and 90° in the temporal visual field. Despite the limited range of the static perimetry test, the reported shadows between 50 and 60° visual field eccentricity should be within the measurement range. However, we assessed monocular visual field testing, whereas Masket et al.[20] suggest that the scotoma might be larger in binocular vision. The experienced shadow in patients with negative dysphotopsia could thus be located outside the range of the static perimetry peripheral 60-4 test.

Similarly, no changes were observed with static perimetry after intraocular lens exchange, although symptoms were alleviated in 82% of patients. However, this is in line with the earlier observations, as the complaint could not be objectified with static perimetry. Because this subjective improvement of the complaint was not visible in the results of the 60-4 full-threshold test, this test is not suitable for assessing treatment success in negative dysphotopsia patients.

This study has some limitations that need to be acknowledged. The full-threshold strategy is a time-consuming test with an approximately three times longer test duration than more modern clinical perimetry strategies, which requires a significant concentration of the patient. Although the full-threshold test has an advantage that it determines the sensitivity for each point independently, this prolonged testing may result in fatigued participants, leading to inaccurate results. The clinical relevance of perimetric testing of the peripheral visual field is shown by Wall et al.[21] in patients with

TABLE 3. Overview of reliability indices for the included patients from the negative dysphotopsia group and the control group

	Negative dysphotopsia group	Control group	
Reliability indices	**Median [Q1, Q3]**		***P***
Fixation losses (%)	0 [0, 4.5]	4.2 [0, 11.8]	.20
False-negative errors (%)	7.7 [0, 14.1]	0 [0, 7.7]	.14
False-positive errors (%)	0 [0, 0]	0 [0, 0]	.68

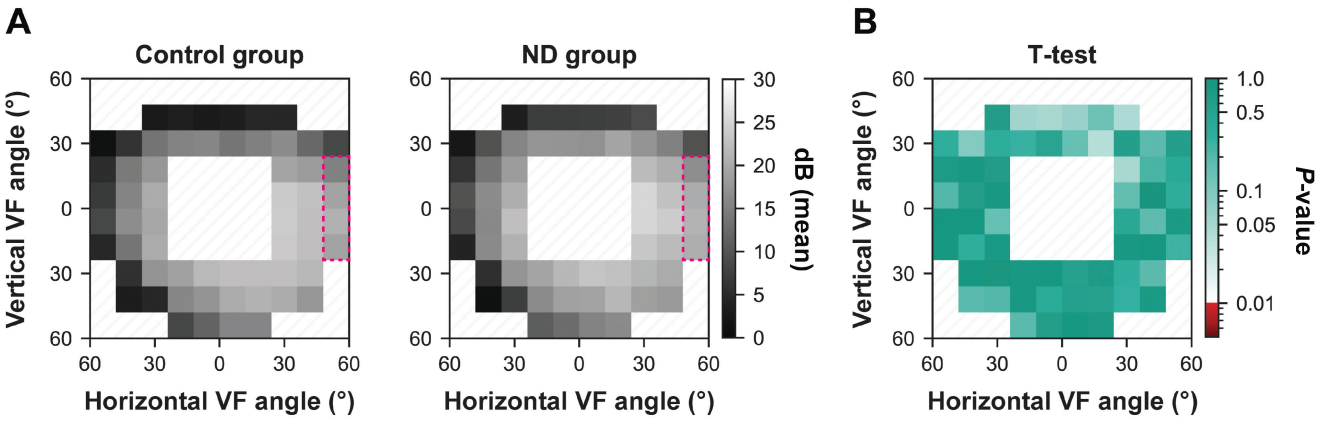

FIGURE 3. Grouped visual field test results of the control group and the negative dysphotopsia group. (A) Mean decibel values of each point in the control group and the negative dysphotopsia group. The pink dotted square indicates the four test points used to assess the combined peripheral temporal visual field from 50 to 60°. The upper and nasal fields show lower sensitivities due to blockage by the eyebrows or nose. (B) *P* values of the *t* test between both groups, showing no significance for all points ($P > .04$). The hatched area indicates the areas that have not been tested.

intracranial hypertension suspected for peripheral visual field loss. Although we used one stimulus (size III) to test the sensitivity of the visual field, a larger stimulus (size V) is probably easier to detect in the peripheral visual field. Wall et al., however, showed no differences in the detection of visual field loss between different sizes of stimulus, although they did identify a higher retest variability with a size III stimulus in the peripheral visual field.[22,23] Also, the floor effect, in which very low sensitivities of the dynamic range are unable to detect, is less pronounced with a larger size V stimulus than with a size III stimulus.[24,25] We expect that this would not affect the detection of the peripheral shadow, as this is described as a relatively large scotoma where little to no light is reported. In addition, a selection bias may have arisen because we excluded participants with a high percentage of fixation losses, false-negative errors, and false-positive errors. However, in both groups, a comparable number of participants were excluded (Fig. 2). The sample size of the negative dysphotopsia group with intraocular lens exchange and a second peripheral 60-4 full-threshold test was relatively small but was expected to match the subjectively reported treatment success of 82%. The effect of intraocular lens exchange in a larger group of patients including these cases will be expounded in future research.

Our study showed overall lower mean sensitivities at the combined measure of the peripheral temporal visual field from 50 to 60° compared with the study by Brenton and Phelps.[26] This is presumably due to the selection of subjects, as we studied pseudophakic subjects. Furthermore, generally lower sensitivities are found with full-threshold strategy than with other test strategies.[27,28] Earlier

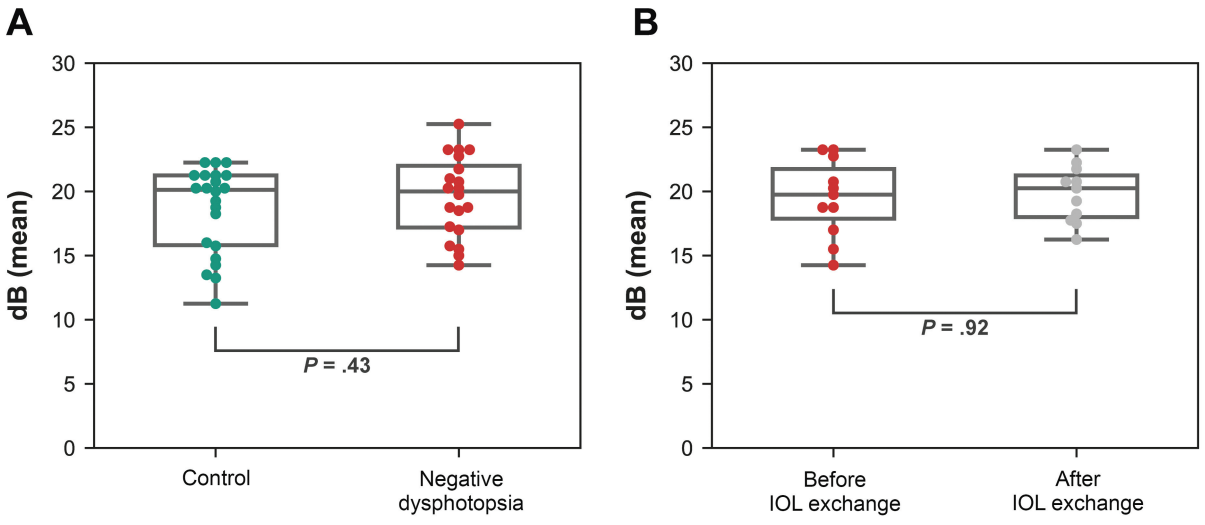

FIGURE 4. Grouped mean decibel values of each participant. (A) Mean decibel values of the combined test points representing the peripheral temporal visual field from 50 to 60° from each subject of the negative dysphotopsia group and the control group, and (B) of the negative dysphotopsia group before and after lens exchange. No significant difference was found in both analyses ($P > .43$). The box plots represent the median, 25th percentile, and 75th percentile.

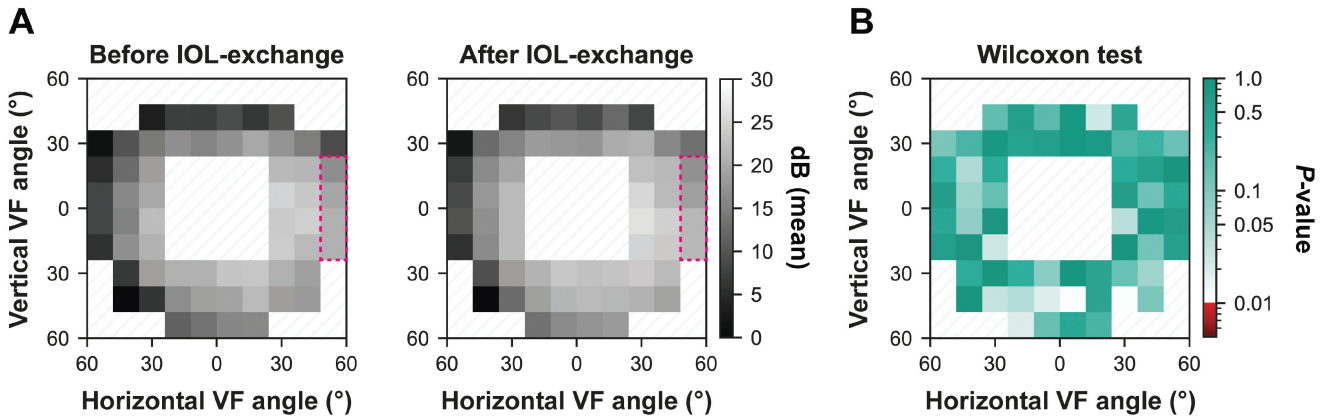

FIGURE 5. Grouped visual field test results of the negative dysphotopsia group with intraocular lens exchange. (A) Mean decibel values of each point in the negative dysphotopsia group before and after lens exchange. The pink dotted square indicates the four test points used to assess the combined peripheral temporal visual field from 50 to 60°. (B) *P* values of the *t* test between both groups, showing no significance for all points ($P > .01$). The hatched area indicates the areas that have not been tested.

studies have shown peripheral aberrations after intraocular lens implantation, which lead to a decreased peripheral image quality.[29] Also, presbyopia correction intraocular lenses could have an effect on the peripheral sensitivity.[30,31] Because the majority of our subjects in both groups had a monofocal aspherical intraocular lens, and only a few patients in the negative dysphotopsia group had a multifocal or spherical intraocular lens, we do not expect significant influence on the peripheral visual sensitivity. It can be speculated that there is no absolute change in contrast sensitivity to detect because there is no damage in the visual pathway in patients with negative dysphotopsia.[31] However, some studies did detect negative dysphotopsia with Goldmann kinetic perimetry.[14,20] The visual field loss established in the peripheral nasal and superior quadrant can likely be explained by anatomical obstruction from the eyelid, eyebrow, or nose.

In conclusion, comparison between the results of full-threshold static perimetry measuring up to 60° eccentricity with a Goldmann size III stimulus in patients with negative dysphotopsia and pseudophakic controls, as well as in patients with negative dysphotopsia before and after intraocular lens exchange, showed no relevant differences in the quantified temporal peripheral visual field. Therefore, this type of full-threshold static perimetry is not suitable for either the diagnosis or the follow-up of patients with negative dysphotopsia.

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