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ORIGINAL ARTICLE

Online circular contrast perimetry: Tablet validation study against desktop test and standard automated perimetry

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ABSTRACT

Purpose: To assess correlation, agreement and diagnostic accuracy of a new tablet-based 24-degree, 52-point online circular contrast perimetry application (OCCP), compared to computer-based OCCP and standard automated perimetry (SAP).

Methods: Seventy-five participants (26 controls, 49 glaucomatous) were tested via SAP using Humphrey field analyzer (Zeiss), then by computer OCCP on a 24-inch monitor, followed by two OCCP tests on a tablet (iPad Air 5th gen). Key outcome measures included pattern standard deviation (PSD), mean deviation (MD), mean sensitivity per point, and visual field index (VFI)/visual index (VI).

Results: Agreement and correlation of VFI, PSD, and MD between OCCP tablet and SAP were very strong, with spearman's ρ and intra-class correlation coefficients between 0.81–0.86 and 0.80–0.93, respectively. MD Bland–Altman bias was greater for OCCP tablet against SAP—0.53 to 0.68 dB—compared to OCCP computer against SAP at 0.05 dB. 95% limits of agreement were comparable for OCCP versus SAP. Point-by-point Bland–Altman bias demonstrated tighter agreements between OCCP tablet and OCCP personal computer (PC) compared to OCCP generally and SAP. Receiver–operating–characteristic curves were comparable across outcomes between all OCCP tests, SAP, and cirrus optical coherence tomography parameters with no significant differences. Test duration was longer for OCCP tablet than SAP, whereas OCCP PC was shorter than SAP ($p < 0.001$).

Conclusions: OCCP tablet has strong correlation, agreement, and similar area-under-curve in identifying glaucomatous eyes from controls to both SAP and OCCP computer, demonstrating prospect as a tool for glaucoma perimetry testing in low-resource settings, with further enhancements to reduce test duration.

INTRODUCTION

Glaucomatous disease forms one of the foremost causes of irreversible vision loss globally, characterized by progressively worsening and often imperceptible visual field deficits that significantly impair quality of life. By 2040, 111.8 million people will likely be affected by glaucoma, with a disproportionate impact on populations in Asia and Africa.[1] Perimetry is essential in the early screening, diagnosis, management, and follow-up of glaucoma.[1] Highly specialized calibrated machines such as the Humphrey field analyzer (HFA) (Zeiss, https://www.zeiss.com/

meditec/en/products/perimetry/humphrey-field-analyzer-3.html) are used for standard automated perimetry (SAP)—the clinical standard—which requires supervision and guidance from trained staff. SAP technology has inherent limitations, namely the costs associated with purchase and maintenance, the lack of portability and the need for patient supervision (often requiring travel). Present guidelines recommend glaucoma patients undergo perimetry monitoring a minimum of three times within 2 years of initial diagnosis.[2] This is inefficient for public ophthalmology practices with large patient volumes, causing longer wait times to access care. Additionally, SAP's inherent limitations restrict access to perimetry in developing and other low resource contexts.[3]

Recent advancements have led to research, development and popularization of more portable digital perimetry, including on computers, laptops, tablets, and virtual reality devices.[4–7] Investigators have found that these technologies are able to yield results that are comparable to those produced by HFA perimetry, suggesting that they are clinically useful.[8,9] These offer benefits of cost reduction to healthcare practices and patients, care extension to resource limited settings, and a capacity for increased monitoring frequency, which is a protective factor against debilitating disease progression.[10,11] Observational studies have demonstrated excellent uptake and short-term compliance when tablet technology is made available.[9] This was particularly evident during the COVID-19 pandemic, when tablet -based perimetry was particularly popular. However, this technology was found to be limited by the need for additional viewing-shield apparatus and headrests to maintain viewing distance.[12] An example of a promising digital perimetry application that does not require any additional apparatus is the novel online circular contrast perimetry (OCCP), a recently validated test that functions on any personal computer (PC) and is newly developed for tablets.[13,14]

During OCCP development, a normative cohort was used to establish an age-standardized dataset for both 24-2 and 10-2 modalities, based on consistent results from disease-free cohorts, in line with SAP and other digitized perimetry approaches, allowing calculation of global visual field indices.[15,16] These indices such as mean deviation (MD) and pattern standard deviation (PSD) were validated in a cohort study of 220 people, with OCCP showing similar sensitivity and specificity to SAP as well as good to excellent test-retest reliability in further studies.[17,18] Recently, the OCCP demonstrated similarity on desktop computer screens of different sizes without the need for standardization using screen photometry, a limitation of previous studies.[5,13,15] However, it has still not been tested on tablet devices which are less expensive, more portable and require less equipment (e.g., keyboard) than a desktop computer. Therefore, to increase portability of the OCCP and expand perimetry in low-resource environments, it is useful to assess whether the newly developed tablet version of the OCCP is comparable to the validated desktop version and to SAP, without the need for external calibration.

Significance

Tablet-based online circular contrast perimetry (OCCP) has strong correlation, agreement and similar area-under-curve in identifying glaucomatous eyes from controls to both standard automated perimetry and OCCP computer, with further enhancements required to reduce test duration. In its current state, it demonstrates potential as a glaucoma perimetry tool.

The aim of this study was to evaluate agreements, correlations, and glaucoma diagnostic capabilities of the tablet OCCP to both desktop computer OCCP and SAP.

METHODS

Ethics and study design

This single-center, prospective cross-sectional, and observational study gained ethical approval through the Royal Australian and New Zealand College of Ophthalmology Human Research and Ethics Committee (reference number 90.18). Written informed consent was obtained from all participants before participation. All aspects of the study were in line with the tenets specified in the Declaration of Helinski 2024, which was ensured through local site administration.

Participants

Seventy-five participants (26 control, 49 with glaucoma) were recruited from a specialist ophthalmology clinic in Melbourne, Victoria, Australia from April 2024 to June 2025 as part of their standard ophthalmological appointments.

The inclusion criteria required participants to be adults (>18 years) with either open or closed angle glaucoma and aged-matched controls, able to provide written informed consent to participate, able to read and understand English, have a best corrected binocular visual acuity of ≤0.7 logarithm of minimum angle of resolution as well as an acceptable optical coherence tomography (OCT) imaging.

Exclusion criteria included significant cognitive impairment, any ocular pathology that is not glaucoma and inadequate reliability—which made results indeterminate—in SAP and OCCP testing. Reliability was defined as <15% false positives (FP), <33% false negatives (FN), or <20% fixation losses (FL) as per the method established by Heijl and Krakau in 1975, consistent with other studies.[13,15,19]

Clinical parameter assessment

All clinical parameters in this study were assessed by principal investigator SS who applied the inclusion and exclusion criteria after the completion of a thorough ophthalmic assessment, representing a convenience sampling approach. The assessment involved collecting the following clinical elements from patients: Distance refractive correction and best-corrected visual acuity, central corneal thickness, OCT of the optic nerve head through Cirrus High Definition-OCT (https://www.zeiss.com/meditec/en/products/optical-coherence-tomography-devices.html), intraocular pressures as determined using Goldman applanation tonometers (https://haag-streit.com/en/products/categories/general-diagnostics/tonometers/goldmann-applanation-tonometer), and SAP using the HFA running SITA standard 24-2 testing algorithm (https://www.zeiss.com/meditec/en/products/perimetry/humphrey-field-analyzer-3.html). The SAP results collected here were used in the study if the participant was selected.

Control participants were defined as having normal intraocular pressure, usual appearance of the optic nerve head, normal SAP results, and no evidence of any ocular pathology as determined by the initial ophthalmic assessment. Glaucomatous participants were defined as having optic nerve damage with associated visual field deficits determined through SAP, consistent with the process of glaucoma diagnosis outlined by the American Academy of Ophthalmology.[20]

Overview of the OCCP test on desktop PC and tablet

The OCCP test assesses 52 loci across the visual field, spanning 24° from fixation with 6° spacing, consistent with the 24-2 HFA grid.[21] Users fixate on a 3.5° rotating star (Figure 1A) and respond to peripheral flickering stimuli (Figure 1B) via key, mouse, or touchscreen input. Valid or Invalid responses are indicated through different auditory feedback, with late or early responses tagged as FPs (Figure 1C). FNs are identified through randomly presented modified catch trials.[22] Random delays and adaptive response windows adjusted to prior reaction times, prevent rhythmic responses.

On computers, fixation begins on top to test the inferior hemifield, then shifts downward for the superior hemifield (Figure 1D). On tablets or small laptops, testing begins in a top corner (dependent on eye) and progresses through quadrants (Figure 1E), with both approaches producing consistent results.[5]

Stimuli are 3.5° counterphase flickering discs separated by 6°. To mimic SAP's bowl and account for physiological hill of vision, stimulus size increases with increasing eccentricity (Figure 1D,E). The stimulus alternates circular light and dark rings on flicker, which means light rings are replaced by dark rings and vice versa, so called 'counter-phase', for a total of 3 flicker cycles per loci, lasting 360 ms, or 8.3 Hz per cycle (Figure 1C). For the first and last 30 ms, contrast of the visual stimuli is increased and decreased linearly to reduce saccades and temporal transients.[17]

The visual stimuli used in OCCP resemble those used in Pulsar Perimetry with several key differences. In OCCP, ring luminance adjusts across devices, and circular design with consistent contrast across directions with a gradient rim to avoid orientation-selective ganglion cell activation, which can impact perimetry sensitivity.[5,17,21] The Pulsar perimetry targets are also larger.[17,23]

A key difference between the OCCP and frequency doubling perimetry is in luminance. In frequency doubling perimetry, dark and light rings alternate around an average background brightness—similar to mean-modulated flickers. This assumes that the background brightness represents the exact mean of the dark and light rings, an assumption that cannot be made in an application used on different device types such as the OCCP. To counter this, OCCP adjusts light rings to the devices background brightness, with dark rings fluctuating in strength depending on the required contrast, similar to luminance-pedestal flickers.[24] This approach ensures consistency across different display types as it accounts for display-to-display variability in gamma correction and greyscale.

In the absence of manual head fixation, OCCP employs: a screen-size–based viewing distance calibration; continuous 1 Hz facial tracking to halt testing if head deviation exceeds 15% in four planes, with voice prompts for repositioning; and blind spot identification using 0.5° high-contrast stimuli within a 4 × 10° grid. These methods reduce head-position error to <1%.[25] The blind spot is mapped by presenting a series of small visual stimuli measuring at 0.5° with maximum contrast to the user as test points within a 4 × 10° grid, until no response is provided (i.e., the blind spot is mapped). In the situation where the blind spot is too remote from the fixation point or too close, the OCCP test prompts the participant—via inbuilt verbal instruction—to move closer or further away from the screen, respectively. Later in the test, the blind spot location is re-assessed when the fixation point moves (Figure 1D,E) Mapping the blind spot enables subsequent fixation monitoring during the test, with each response to a blind spot stimulus counted as a FL, analogous to the Heijl–Krakau method for FL detection—this process is independent of the machine learning based facial tracking. When a FL is detected, the user is instructed to refocus on the fixation point.

Compared to the desktop OCCP test, the tablet OCCP assesses the visual field one quadrant at a time, and thus FL assessment can only occur when the superior and inferior temporal field quadrants are assessed—that is, the first and last quarters of the test duration. To make up for this shortfall, the frequency of FL assessments is

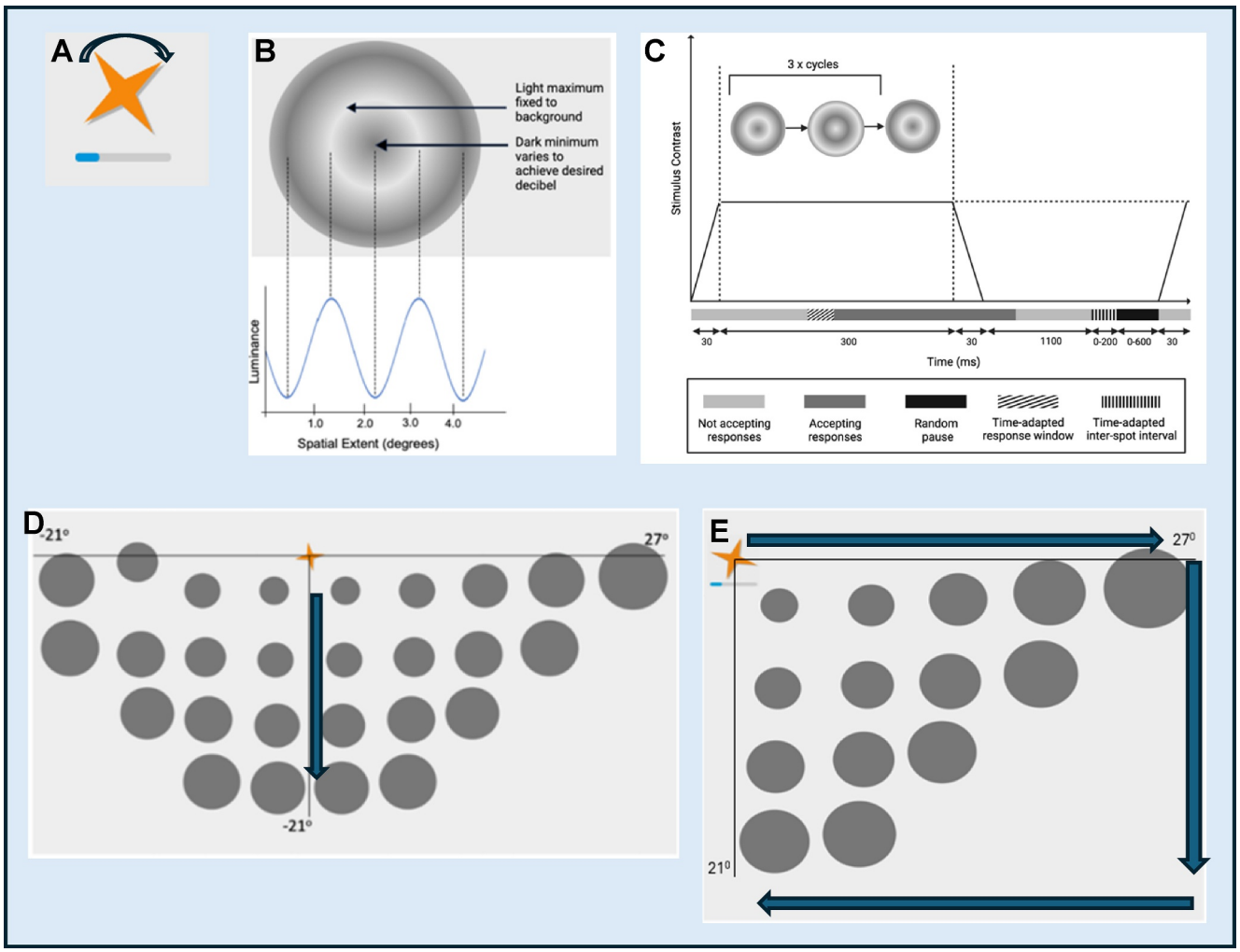

FIGURE 1 OCCP test details. (A) The fixation point, a rotating orange star with blue test progress bar underneath. (B) Flickering visual stimuli with associated luminance graph and size. (C) Cycle of stimulus presentation: stimulus presents for three flicker cycles—alternating light and dark rings per cycle—lasting 360 ms with grading of contrast at beginning and end of stimulus appearance. (D) 24-2 OCCP computer map demonstrating loci in inferior hemifield, arrow indicates movement of fixation point to test superior hemifield. (E) 24-2 OCCP tablet map demonstrating loci in inferior right quadrant, arrows indicate movement of fixation point to three other locations, testing those respective visual field quadrants. OCCP, online circular contrast perimetry.

doubled during testing of the temporal quadrants, resulting in a similar number of FL assessments.

In standardizing brightness, luminance (0%–100%) for greyscale values (0–255) is derived from Web Content Accessibility Guidelines. Testing employs a 220 cd/m^2 light-gray background, with instructions to set screen brightness ≥75%.

Results are converted to relative decibels (rdB) to enable SAP comparison. An rdB is a relative logarithmic measure of the minimum luminance that a patient can detect. It represents the degree to which the visual stimulus has been reduced from the instruments maximum brightness, making rdB an instrument dependent value. Clinically, it is used to express the dimmest visual stimulus that a patient can still see compared to the maximum brightness of the instrument.

The results are converted to rdB using the following method. Firstly, contrast of targets is calculated via the Michelson formula[26]:

$$\text{Contrast} = (\text{RLa} - \text{RLb})/(\text{RLa} + \text{RLb}),$$

where RLa and RLb are maximum and minimum amplitude of relative ring brightness, respectively. Contrast sensitivity is converted to rdB similar to frequency doubling perimetry rdB conversion[27]: rdB = −20 log (contrast sensitivity), resulting in a dynamic range of 0–38 rdB, consistent with HFA and other validated perimetry technology.[18]

An important distinction when comparing thresholds is that SAP uses Weber contrast which is not equivalent to Michelson. However, previous studies identified OCCP

thresholds are uniformly higher than SAP by around 1.02 log units (95% CI: 0.95–1.08), this factor needs to be applied for direct comparison.[13,28]

Testing procedure

As part of the patient's routine ophthalmic assessment, SAP was conducted via the SITA standard 24-2 algorithm on HFA with one eye chosen by randomization. This SAP modality was chosen given it provides accurate reports of visual field deficits and is widely regarded as the perimetric method of choice.[3,21] The order of initial perimetric testing (computer-based OCCP vs. SAP) was also randomized. Trained investigators obtained informed consent prior to testing and monitored participants throughout. Once selected, participants were comfortably positioned at a desk with a desktop PC (LG, https://www.lg.com) and directed to register for a participant account where patient details were stored securely. The monitoring investigator ensured optimal participant placement at the distance calculated by the OCCP application, with seating height adjusted as necessary. All lights were switched off, leaving the testing device as the brightest light source. All screens were wiped prior to testing and participants requiring refractive correction were instructed to wear their corrective lenses.

Following SAP and computer based OCCP testing, the OCCP was conducted twice on the tablet (iPad Air 5th gen, https://support.apple.com/en-us/111887) with another 5-min break offered in between. The tablet was placed on the desk, gently sloped to perpendicular.

Main outcome measures

The main outcome measures compared between the tablet OCCP, desktop PC OCCP and SAP were MD, PSD, mean sensitivity per point and visual index (VI)/visual field index (VFI) for OCCP and SAP, respectively. FP rate (%), FN rate (%), FL (number), time duration (min), OCT mean thickness of circumpupillary retinal nerve fiber layer (OCT cpRNFL), and ganglion cell complex inner plexiform layer (OCT GCC) were among the secondary outcome measures.

Statistical methods

Data were analyzed using SPSS (v30.0.0.0; https://www.ibm.com/products/spss-statistics) and Real Statistics in Excel 2016 (Microsoft 365; https://real-statistics.com/). Significance was set at $p < 0.05$, with Bonferroni adjustment for family-wise error. Sample size ($\alpha = 0.05$, $\beta = 0.10$) used 95% CI of test-retest agreement (0.51–0.98), yielding 36, increased to 75 for reliability.[29] Paired differences between control and glaucomatous eyes were assessed using Wilcoxon rank-sum or ANOVA, based on Shapiro–Wilk normality testing. Glaucomatous eyes were classified as mild (> −6 dB), moderate (−6 to −12 dB) and severe (< −12 dB) per Hodapp–Parrish–Anderson.[30] Categorical data were analyzed with chisquare.

Reliability indices (FP, FN, FL, time duration) were assessed with related sample Friedman's two-way ANOVA. Bland–Altman analysis evaluated mean bias and 95% limits of agreement (LoA) between outcome measures and pointwise sensitivities across 52 loci for SAP, tablet OCCP, and computer OCCP.

For SAP, sensitivity thresholds were converted to the logarithm of contrast sensitivity (logCS) = 1/(contrast threshold),[18] where contrast = (max luminance − background)/background. Decibels were reported as 25 + 10 logCS for 4 mm^2 Goldmann III stimuli.[27] For OCCP, logCS used the Michelson formula.[26]

Inter-test reliability of VFI/VI, PSD, and MD was measured with intra-class correlation coefficients (ICCs, poor <0.5; moderate 0.5 to <0.75; good 0.75 to <0.9; excellent ≥0.9).[31] Non-parametric tablet data used Spearman's rank with 95% CI (excellent $\rho \geq 0.8$; good 0.6 to <0.8; moderate 0.4 to <0.6).[32] Diagnostic capacity was evaluated via receiver-operator-characteristic curves and area-under-curve (AUC), and the AUCs were compared using the Delong method, similar to previous papers comparing SAP with various other technologies.[33–36] Missing data (3 SAP, 5 OCCP-computer, and 7 tablet retests) were excluded pairwise.

RESULTS

Table 1 summarizes clinical and perimetric attributes by glaucoma severity. Seventy-six participants were enrolled; one was excluded for not meeting inclusion criteria. Mean age was 65.95 ± 12.62 years, with no significant age differences between glaucoma subgroups and controls.

Figure 2 demonstrates key reliability parameters; OCCP tablet tests had significantly lower FP ($F_{2,62} = 18.01$, $p < 0.001$) and FN ($F_{2,62} = 10.91$, $p = 0.004$) means than SAP. For FL, OCCP computer was significantly lower than SAP ($W = 2.20$, $p = 0.028$), while OCCP tablets were not ($F_{2,57} = 3.74$, $p = 0.15$). For time duration, both tablet tests were significantly higher than SAP ($F_{2,62} = 6.41$, $p = 0.041$) and OCCP computer ($F_{2,59} = 87.76$, $p < 0.001$).

Table B1 shows Spearman's ρ, ICC, Bland–Altman bias and 95% LoA across MD, PSD, and VI/VFI. Without stratification, OCCP tablet tests showed excellent correlation to SAP and OCCP computer. ICCs were excellent except PSD, which showed good agreement. MD bias was 0.68 and 0.67 (tablet test 1 vs. SAP), 0.02 (tablet test 1 vs. tablet test 2), and 0.05 (computer vs. SAP). LoA were narrower between tablets than tablet versus SAP. Glaucoma

TABLE 1 Participant clinical and perimetry attributes with glaucoma severity stratification.

Variables	Mild glaucoma	Moderate glaucoma	Severe glaucoma	Total glaucoma	Controls	*p*-value
Total	23	11	15	49	26	-
Gender (F/M)	10/13	7/4	7/8	24/25	12/14	0.73
Eyes tested (OD/OS)	13/10	9/2	7/8	29/20	15/11	0.34
Abnormal ONH (% eyes)	100	100	100	100	0	-
Age (year)	65.8 (12.6)	68.6 (12.0)	71.1 (12.6)	68.1 (12.4)	61.9 (12.2)	0.066
logMAR visual acuity	0.02 (0.06)	0.17 (0.11)	0.22 (0.20)	0.12 (0.16)	−0.01 (0.06)	<0.001
Corrected IOP (mmHg)	14.8 (5.4)	14.6 (6.3)	12.0 (4.4)	13.9 (5.4)	16.7 (5.7)	0.12
CCT (μm)	550.4 (37.2)	542.5 (32.2)	543.6 (40.1)	546.5 (36.5)	563.6 (64.8)	0.80
Spherical equivalent (D)	−2.18 (3.64)	−1.82 (2.75)	−0.57 (1.54)	−1.61 (2.97)	0.05 (2.09)	0.013
OCT cpRNFL MT	72.52 (11.24)	61.00 (7.73)	57.43 (10.07)	65.48 (12.17)	89.36 (9.66)	<0.001
OCT cpRNFL ST	73.65 (11.71)	59.57 (13.57)	61.02 (10.41)	66.74 (13.36)	90.50 (9.64)	<0.001
OCT cpRNFL IT	71.69 (13.34)	62.54 (5.97)	54.08 (12.92)	64.45 (13.98)	88.18 (12.91)	<0.001
OCT cpGCC MT	68.13 (8.13)	63.00 (10.62)	52.36 (14.01)	62.35 (12.47)	76.80 (8.18)	<0.001
OCT cpGCC ST	69.65 (8.83)	65.73 (17.11)	50.64 (16.66)	63.21 (15.63)	76.72 (8.63)	<0.001
OCT cpGCC IT	63.39 (11.72)	57.00 (14.87)	52.43 (17.22)	58.73 (14.72)	74.88 (8.63)	<0.001
SAP MD	−2.40 (1.63)	−7.78 (1.70)	−18.20 (4.85)	−8.44 (7.49)	−0.58 (1.79)	<0.001
OCCP comp MD	−3.23 (2.06)	−5.98 (3.73)	−15.71 (7.26)	−7.26 (6.86)	−1.76 (1.38)	<0.001
OCCP tablet 1 MD	−2.78 (1.68)	−5.19 (2.87)	−15.44 (6.77)	−7.20 (6.92)	−1.09 (1.00)	<0.001
OCCP tablet 2 MD	−2.56 (1.80)	−5.04 (2.17)	−16.16 (6.92)	−7.04 (7.11)	−1.16 (0.71)	<0.001
SAP PSD	3.71 (2.20)	7.24 (2.61)	10.83 (2.25)	6.68 (3.85)	2.22 (1.15)	<0.001
OCCP comp PSD	3.24 (1.73)	4.60 (1.99)	7.61 (2.64)	4.74 (2.74)	1.62 (1.07)	<0.001
OCCP tablet 1 PSD	3.35 (1.77)	5.19 (2.24)	8.04 (2.54)	5.20 (2.92)	1.61 (1.33)	<0.001
OCCP tablet 2 PSD	3.10 (1.84)	4.99 (1.76)	7.98 (2.20)	4.95 (2.81)	1.53 (0.91)	<0.001
SAP VFI/VI	93.77 (5.63)	81.45 (11.06)	45.33 (16.70)	75.81 (24.05)	97.86 (2.46)	<0.001
OCCP comp VI	91.59 (7.58)	83.70 (14.51)	50.33 (25.51)	78.55 (23.54)	97.00 (3.27)	<0.001
OCCP tablet 1 VI	93.09 (5.98)	85.18 (10.00)	52.80 (24.13)	78.98 (22.92)	98.58 (2.42)	<0.001
OCCP tablet 2 VI	93.45 (6.88)	85.60 (11.45)	49.08 (24.22)	78.90 (24.14)	98.44 (1.73)	<0.001
SAP T.D (min)	5.95 (1.73)	6.78 (0.84)	7.76 (2.24)	6.69 (1.90)	5.03 (1.01)	<0.001
OCCP comp T.D (min)	4.41 (1.23)	5.06 (1.34)	6.29 (1.10)	5.07 (1.44)	3.63 (1.17)	<0.001
OCCP tablet 1 T.D (min)	7.00 (2.13)	8.64 (2.82)	10.19 (2.34)	8.34 (2.70)	5.12 (1.50)	<0.001
OCCP tablet 2 T.D (min)	6.86 (2.28)	7.90 (2.21)	10.29 (2.21)	8.09 (2.64)	5.28 (1.59)	<0.001

Note: Data is represented as mean (standard deviation).

Abbreviations: CCT, central corneal thickness; cpRNFL, circumpapillary retinal nerve fiber layer; GCC, ganglion cell complex inner plexiform layer; IOP, intraocular pressure; IT, inferior thickness; logMAR, logarithm of minimum angle resolution; MD, mean deviation; MT, mean thickness; OCCP, online circular contrast perimetry; OCT, optical coherence tomography; OD, oculus dexter (right eye); ONH, optic nerve head; OS, oculus sinister (left eye); PSD, pattern standard deviation; SAP, standard automated perimetry; ST, superior thickness; T.D, time duration.

stratification reduced correlations to moderate-good; moderate glaucoma showed poor, insignificant agreement, while mild and severe groups showed good-excellent significant agreement.

Figures A1–A3 show Bland–Altman plots for MD, PSD and VFI/VI across test comparisons. The comparisons between OCCP and SAP were consistent with previous studies; the comparisons among different OCCP delivery methods were tighter than between OCCP and SAP.

Figure 3 shows mean sensitivity per point agreement: OCCP versus SAP had negative bias in the temporo-inferior field (underreporting), whereas OCCP tests compared to each other showed minimal bias.

Figure 4 shows receiver-operating-characteristic curves: OCCP tablet, OCCP computer, and SAP had

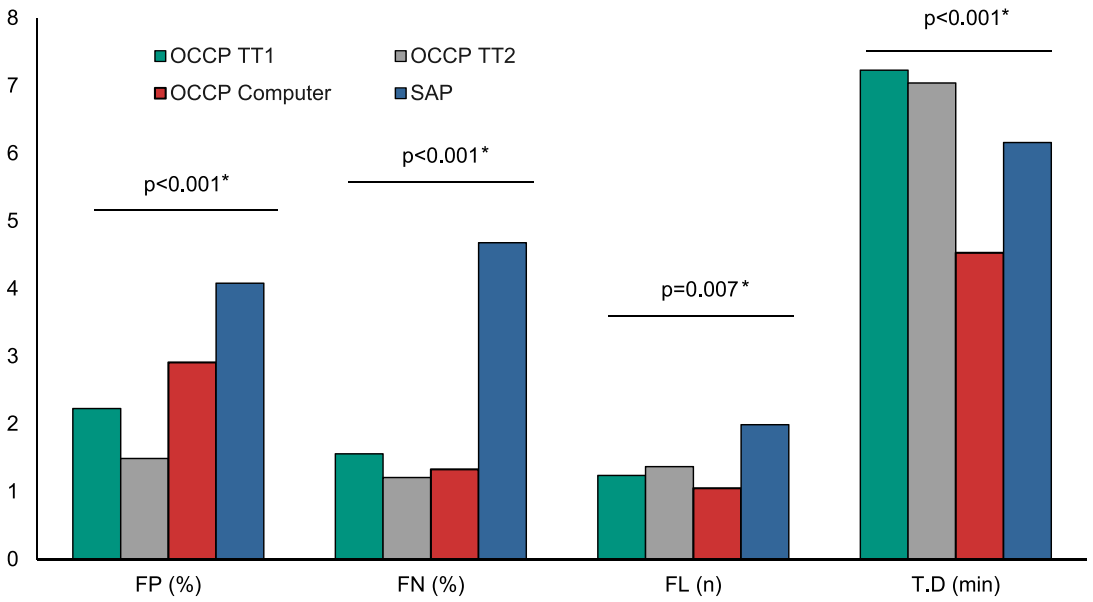

FIGURE 2 Mean reliability parameters of each OCCP test, compared to SAP; FL, instances of fixation loss; FN (%), false-negative; FP, false-positive (%); N.S, not significant; T.D (min), time duration in minutes. Significance (*) was determined through related-sample Friedman's two-way analysis of variance by ranks, adjusted by Bonferroni correction for pair-wise analysis. OCCP, online circular contrast perimetry; SAP, standard automated perimetry.

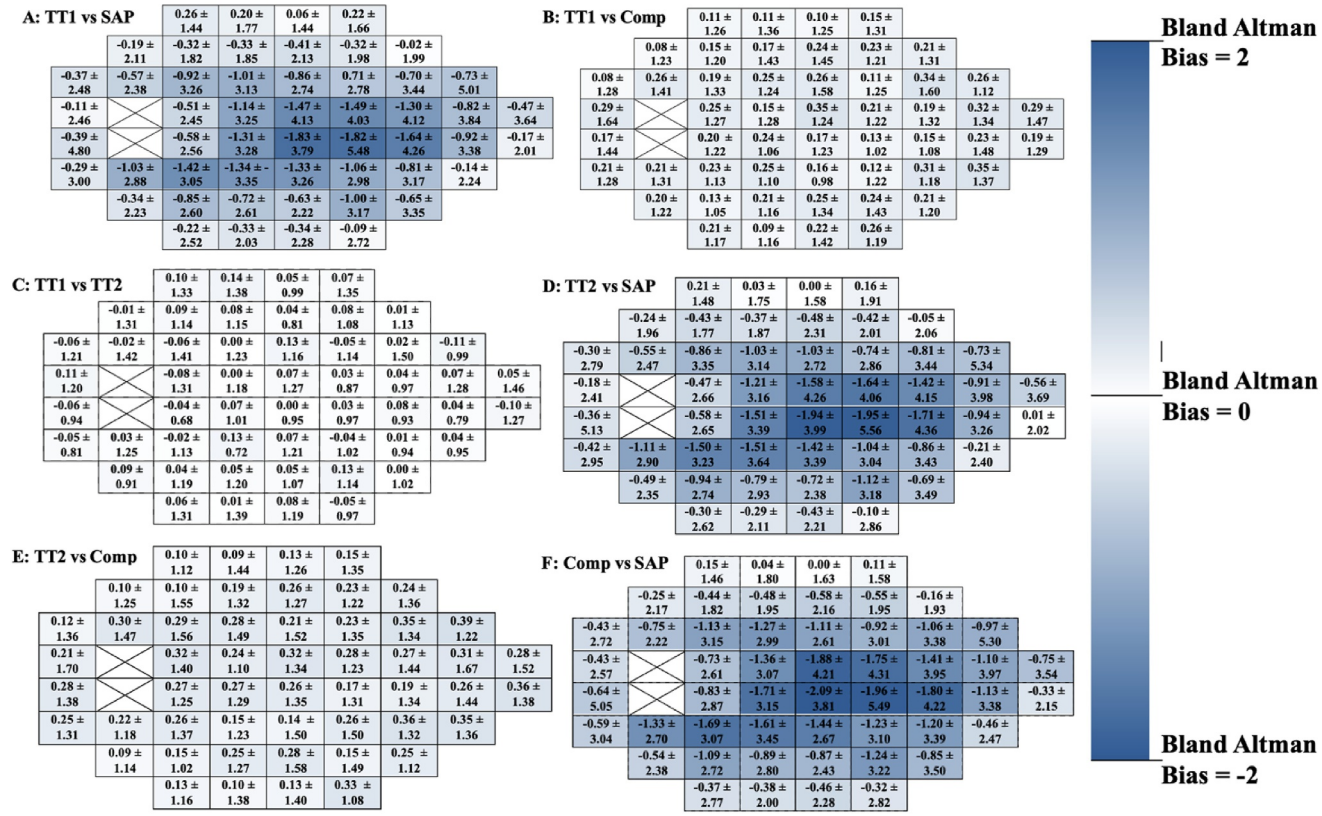

FIGURE 3 (A–F) Left eye orientation heatmaps demonstrating point-by-point sensitivity Bland–Altman bias with 95% limits of agreement at all 52 testing points for OCCP computer and tablet tests compared to SAP. Darker shades represent greater bias. Figure style adapted from Gong et al. (A) represents OCCP tablet test 1 versus SAP. (B) Represents OCCP tablet test 2 versus OCCP computer. (C) Represents OCCP tablet test 1 versus OCCP tablet test 2. (D) Represents OCCP tablet test 2 versus SAP. (E) Represents OCCP tablet test 2 versus OCCP computer. (F) Represents OCCP computer versus SAP. Point-by-point sensitivities are represented as bias ± 1.96 × standard deviation. OCCP, online circular contrast perimetry; SAP, standard automated perimetry.

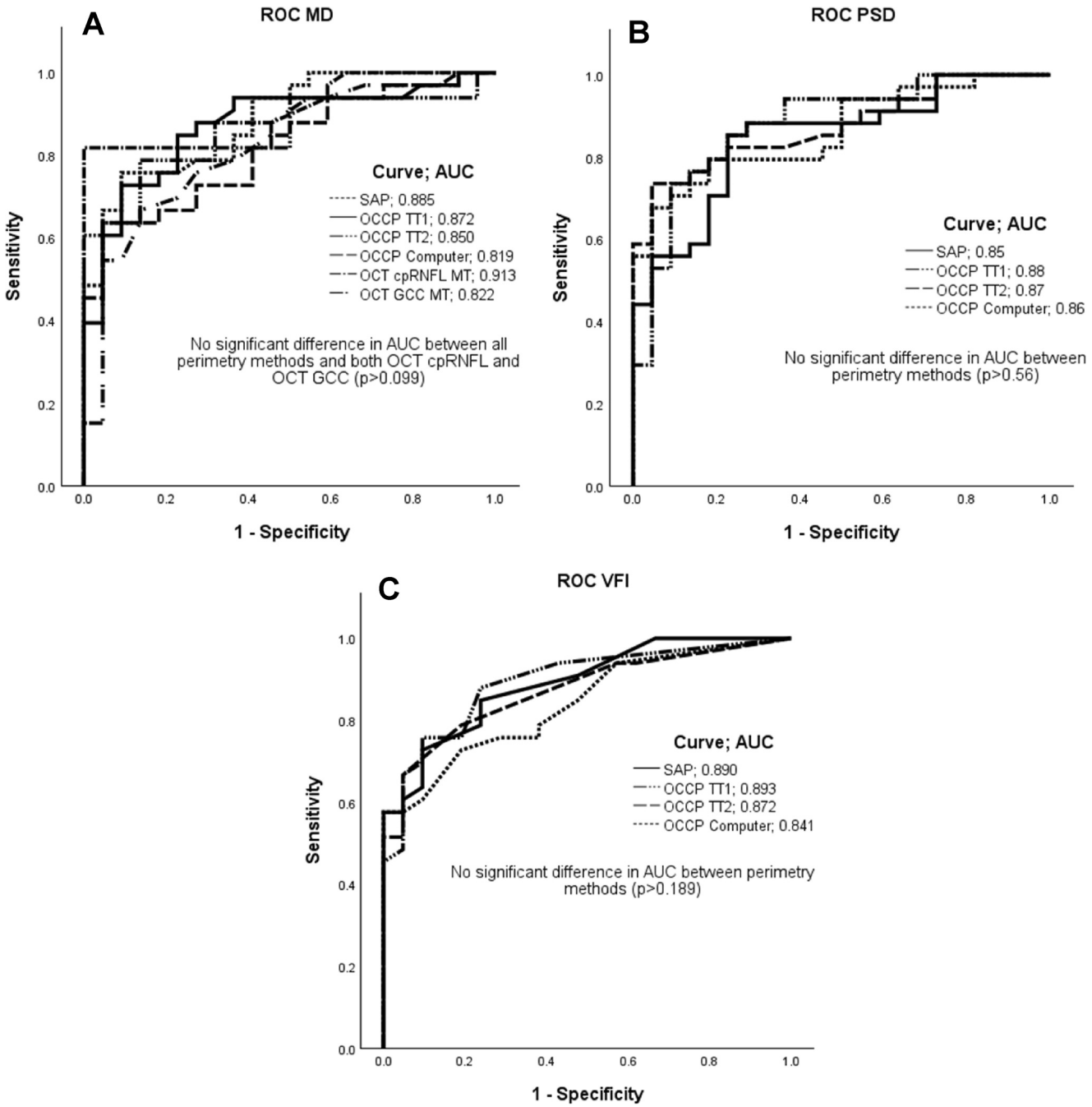

FIGURE 4 (A–C) ROC and associated AUC for SAP, OCCP tablet tests and OCCP computer across the global indices MD, PSD and VFI. (A) Represents ROC for MD across all perimetry types and for mean thickness of OCT circumpapillary retinal nerve fiber layer and OCT ganglion cell complex inner plexiform later. (B) Represents ROC for PSD across all perimetry types. (C) Represents ROC for VFI across all perimetry types. AUC and comparative *p*-values were computed based on the Delong method (1988). AUC, area under the curve; MD, mean deviation; OCCP, online circular contrast perimetry; OCT, optical coherence tomography; PSD, pattern standard deviation; ROC, receiver operator characteristic curves; SAP, standard automated perimetry; VFI, visual field index.

similar AUCs across MD, PSD, and VFI. OCT cpRNFL MT, OCCP TT1 VI, and SAP VI best identified glaucoma, with all inter-AUC comparisons non-significant as shown in Table B2 and Figure 4.

Table 2 presents AUC values with optimal cutoffs and associated sensitivity and specificity values.

DISCUSSION

Tablet devices are promising tools for screen-based perimetry given portability, processing power, and affordability compared to desktop computers and current SAP devices like HFA. Their limitations include smaller screen

TABLE 2 Area under ROC with optimal cutoffs and associated sensitivity and specificity.

Instrument	Variable	AUC (SE)	*p*-value	Optimal cutoff[a]	Sens/spec (%) at optimal cutoff
SAP	MD	0.89 (0.04)	<0.0001	−2.38	76/91
	PSD	0.85 (0.05)	<0.0001	2.3	85/77
	VI	0.89 (0.04)	<0.0001	95.5	73/91
OCCP TT1	MD	0.87 (0.05)	<0.0001	−2.13	73/91
	PSD	0.88 (0.05)	<0.0001	2.5	74/91
	VFI	0.89 (0.04)	<0.0001	96.5	76/91
OCCP TT2	MD	0.85 (0.05)	<0.0001	−1.77	79/86
	PSD	0.87 (0.05)	<0.0001	2.68	74/96
	VFI	0.87 (0.05)	<0.0001	96.5	67/95
OCCP computer	MD	0.82 (0.06)	<0.0001	−3.65	64/96
	PSD	0.86 (0.05)	<0.0001	3.26	68/96
	VFI	0.84 (0.05)	<0.0001	89.5	58/100
OCT cpRNFL MT		0.91 (0.04)	<0.0001	74.5	82/100
OCT GCC MT		0.82 (0.06)	<0.0001	69.5	67/86

Abbreviations: AUC, area-under-curve; cpRNFL, circumpapillary retinal nerve fiber layer; GCC, ganglion cell complex inner plexiform layer; MD, mean deviation; MT, mean thickness; OCCP, online circular contrast perimetry; OCT, optical coherence tomography; PSD, pattern standard deviation; ROC, receiver operator characteristic curves; SAP, standard automated perimetry; SE, standard error; TT1, tablet test 1; TT2, tablet test 2; VFI, visual field index; VI, visual index.

[a]As determined via Youden's index. AUC was computed based on the Hanley–McNeil method (1982) and *p*-values were calculated through asymptotic *z*-test for area under the ROC curve.

size and inconsistent positioning, but these are mitigated in OCCP through software innovations such as machine-learning facial tracking, repeated FL assessment and viewing distance optimization.

Reliability in perimetry is commonly assessed using FP, FN, and FL.[22] Tablet OCCP performed well across these measures, showing lower values than SAP, likely reflecting its optimized design. Prior OCCP studies generally showed similar or better reliability indices compared to SAP.[5,13,14,37,38] However, FP and FN comparisons between devices need caution given test-specific factors such as FP calculation, response timing and stimulus presentation intervals.[22] Greater patient engagement may factor in, with earlier studies noting preference for OCCP over SAP for comfort, albeit on desktop versions.[39]

Both tablet tests were significantly longer than SAP and computer OCCP, possibly due to requiring three fixation-point movements versus one on computer OCCP (Figure 1). As the tablet remains a prototype, development is focused on reducing test duration while maintaining diagnostic accuracy.

Tablet OCCP showed very strong correlation with SAP and computer OCCP (Table 2). ICC and Bland–Altman analyses indicated close agreement across MD, VFI/VI and PSD, similar to other tablet perimetry studies.[6,18] Tablet OCCP exhibited slightly higher Bland–Altman biases (<1.4 dB) when compared to SAP and computer OCCP, which had negligible bias between them. This likely reflects device and algorithm differences requiring further investigation and optimization. Importantly, comparison between the OCCP tablet tests demonstrated almost no bias (0.02) and narrow LoA (−3.01, 3.05), supporting excellent inter-test reliability.

Upon stratification by glaucoma severity, correlations decreased, particularly in the moderate subgroup ($n = 11$) where some results were statistically insignificant. This is likely due to the reduction in value range as a result of stratification. OCCP tablet appeared comparable to SAP in mild and severe glaucoma but less so in moderate disease, where OCCP computer showed greater agreement. This discrepancy may partly reflect subgroup size differences (mild $n = 23$, severe $n = 15$).

Mean sensitivity per point Bland–Altman analysis (Figure 3A,D,F) showed OCCP underestimated temporo-inferior sensitivities while aligning with SAP in more peripheral areas. This may reflect OCCP's magnification factor and fixed normal threshold, unlike SAP which measures the physiological hill of vision. Adjusting OCCP's magnification formula or upper sensitivity limits may address this. These findings are consistent with prior OCCP-SAP comparisons using different monitors,[5] suggesting algorithmic consistency and repeatable differences with SAP.

Diagnostic performance was comparable across SAP, tablet OCCP, and computer OCCP, with no significant differences in AUC for receiver operator characteristic curves of MD, PSD and VFI (Figure 4). Tablet OCCP also showed no significant differences in MD AUC compared to OCT cpRNFL or OCT GCC mean thickness, supporting its utility in glaucoma detection. At optimal cutoffs, tablet OCCP demonstrated sensitivity and specificity comparable to SAP.

OCCP has previously had preference over SAP due to free head movement, usage ease, accessible interface, and audio cues.[14,37–39] These features extend to the tablet format, which also offers portability, easier mounting, and instant-on functionality. Patient appraisal of tablet perimetry remains to be explored, and future work should include preference surveys comparing tablet, computer and SAP, as in prior OCCP studies.[15,38,39]

These findings highlight tablet OCCP's potential in glaucoma identification and monitoring, particularly in low-resource settings. Unlike computers requiring accessories and SAP requiring specialized equipment and staff, tablet OCCP only needs a webcam-enabled tablet and internet connection. This aligns with the broader movement toward AI and telemedicine in diagnostics. Portable perimetry also supports in-home use: OCCP home-monitoring studies in developing settings found comparable clinic and home results over 3–6 months,[38] whereas tablet perimetry in developed settings showed good concordance between home and clinic visual fields.[40] Future work should investigate adherence to home-based OCCP testing schedules.

Limitations of this study include recruitment from a single center, limiting external validity; potential learning effects given participants were experienced in perimetry; and possible fatigue from multiple successive tests, especially considering the OCCP test takes longer than a 24-2 SITA standard. However, ICC values (Table 2) do not suggest fatigue or learning effects.

Although the initial OCCP parameters were based on a small normative database (comprised of <200 eyes), subsequently over 40,000 tests have since been run with 13 research publications. Such larger data have allowed the normative database to expand to include many hundreds of high-quality normal results and appropriate age-stratification within these normative cohorts.

Features of the OCCP technology compared to the clinical standard include the need for participants to change fixation position during the test (otherwise the user would have to sit uncomfortably close to the screen with unwanted presbyopic and prismatic effects); the use of a larger target rather than a small stimulus increment; and the OCCP background luminance being over 20 times higher than that of the HFA. One could argue that these are inferior to features of SAP; alternatively, one could consider these as specializations of OCCP required for the adaptation to device-naïve perimetry that is easy for patients and clinicians to use and calibrate for. For instance, the bright screen allows consistency between monitors and useable perimetry without a hood blocking out stray light; as the computer is the brightest light source in the testing room.[5] Several studies have demonstrated that despite using very different physiological parameters to SAP, OCCP results in accurate and repeatable perimetry measurements, with the convenience of being hardware naïve.[5,15,16,28,29,37–39]

Unlike conventional perimetry machines, OCCP does not currently provide gaze tracking, although ongoing work to improve the system's AI to include gaze tracking is underway. Although gaze tracking is ideal, it is difficult to achieve precision with computer webcams (compared to inbuilt infrared cameras on many machines). However, to make up for this, OCCP has functionality that overlaps this, including FL monitoring. Furthermore, OCCP employs methods of fixation stability beyond which is offered by conventional perimetry machines. For instance, a FL is simply counted on a perimetry machine. On OCCP, it is not only counted but results in an immediate verbal prompt to the test-taker 'look at the star'; that is, there is immediate corrective action to refocus the patient and let them know they are being actively monitored. Secondly, if FL persist, then the blind spot is recalibrated—that is, the position redetected, and this occurs especially after the star moves from the superior to inferior screen. Because of the nature of testing by quadrant, FL assessment is only occurring when the first and last quadrants are assessed. The inherent assumption then is that the FL rate averaged over quarters two and three will be approximately equal to the average of quarters one and four. Given the timing of these quadrants that assumption is likely to be reasonable; for instance, if the FL had been assessed only in the first two quarters of the test, for example, then this assumption may not be reasonable.

Tests were supervised, restricting findings to supervised settings. Only one tablet type (10.9″ iPad Air 5th Gen) was tested, limiting generalizability. Future research can involve multi-center comparisons, unsupervised testing, and assessing different tablet models.

CONCLUSIONS

In summary, OCCP tablet demonstrates strong correlation, agreement, and diagnostic accuracy compared to SAP and OCCP computer, holding promise as a perimetric tool in screening, identification, and monitoring glaucoma in resource-limited settings. This is especially important given the rise of glaucoma worldwide resulting in the growing need for perimetry approaches that are user-friendly, portable, cost-effective, and therefore accessible.

AUTHOR CONTRIBUTIONS

Rahman Abdul: Data curation; formal analysis; investigation; methodology; writing—original draft; writing—review and editing. **Abdul A. Khoder**: Data curation; investigation; writing—original draft. **Angela Gong**: Formal analysis; visualization. **Lazar Busija**: Data curation; software. **Simon E. Skalicky**: Conceptualization; Data curation; investigation; methodology; supervision; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

A/Prof Simon E. Skalicky is a director of Eyeonic Pty Ltd which owns patent WO2021051162A1 regarding online circular contrast perimetry. He participated in planning the study design in conjunction with the other authors, and provided input on the draft of the manuscript (spell check and explanation of how the test functions in the methods section) but did not participate in the analysis or interpretation of the data. The remaining authors have nothing to disclose. This study was not funded.

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REFERENCES

1. Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. *Ophthalmology*. 2014;121:2081–90. https://doi.org/10.1016/j.ophtha.2014.05.013
2. Spaeth GL. European glaucoma society terminology and guidelines for glaucoma, 5th edition. *Br J Ophthalmol* 2021;105:1–169. https://doi.org/10.1136/bjophthalmol-2021-egsguidelines
3. Rai B, Sabeti F, Carle C, Maddess T. Visual field tests: a narrative review of different perimetric methods. *J Clin Med*. 2024;13:2458. https://doi.org/10.3390/jcm13092458
4. Khizer MA, Khan TA, Ijaz U, Khan S, Rehmatullah AK, Zahid I, et al. Personal computer-based visual field testing as an alternative to standard automated perimetry. *Cureus*. 2022;14:e32094. https://doi.org/10.7759/cureus.32094
5. Gong A, Busija L, Skalicky S. Evaluating the consistency of online circular contrast perimetry across different computer monitors: a cross-sectional study. *J Curr Glaucoma Pract*. 2025;19:15–27. https://doi.org/10.5005/jp-journals-10078-1468
6. Kang J, De Arrigunaga S, Freeman SE, Zhao Y, Lin M, Liebman DL, et al. Comparison of perimetric outcomes from a tablet perimeter, smart visual function analyzer, and Humphrey field analyzer. *Ophthalmol Glaucoma*. 2023;6:509–20. https://doi.org/10.1016/j.ogla.2023.03.001
7. Selvan K, Mina M, Abdelmeguid H, Gulsha M, Vincent A, Sarhan A. Virtual reality headsets for perimetry testing: a systematic review. *Eye*. 2024;38:1041–64. https://doi.org/10.1038/s41433-023-02843-y
8. Tsapakis S, Papaconstantinou D, Diagourtas A, Droutsas K, Andreanos K, Moschos MM, et al. Visual field examination method using virtual reality glasses compared with the Humphrey perimeter. *Clin Ophthalmol*. 2017;11:1431–43. https://doi.org/10.2147/opth.s131160
9. Prea SM, Kong GYX, Guymer RH, Vingrys AJ. Uptake, persistence, and performance of weekly home monitoring of visual field in a large cohort of patients with glaucoma. *Am J Ophthalmol*. 2021;223:286–95. https://doi.org/10.1016/j.ajo.2020.10.023
10. Gardiner SK, Crabb DP. Frequency of testing for detecting visual field progression. *Br J Ophthalmol*. 2002;86:560–4. https://doi.org/10.1136/bjo.86.5.560
11. Boodhna T, Crabb DP. More frequent, more costly? Health economic modelling aspects of monitoring glaucoma patients in England. *BMC Health Serv Res*. 2016;16:611. https://doi.org/10.1186/s12913-016-1849-9
12. Kumar H, Thulasidas M. Comparison of perimetric outcomes from Melbourne rapid fields tablet perimeter software and Humphrey field analyzer in glaucoma patients. *J Ophthalmol*. 2020;2020:8384509. https://doi.org/10.1155/2020/8384509
13. Meyerov J, Deng Y, Busija L, Bigirimana D, Skalicky SE. Online circular contrast perimetry: a comparison to standard automated perimetry. *Asia Pac J Ophthalmol*. 2023;12:4–15. https://doi.org/10.1097/apo.0000000000000589
14. Skalicky S, Meyerov J, Deng L, Bigirimana D. Online perimetry: validation, comparison with standard automated perimetry and patient appraisal. *Invest Ophthalmol Vis Sci*. 2023;64:5484. https://iovs.arvojournals.org/article.aspx?articleid=2789471
15. Skalicky SE, Bigirimana D, Busija L. Online circular contrast perimetry via a web-application: optimising parameters and establishing a normative database. *Eye*. 2023;37:1184–90. https://doi.org/10.1038/s41433-022-02085-4
16. Chen YX, Meyerov J, Skalicky SE. Online circular contrast perimetry via a web-application: establishing a normative database for central 10-degree perimetry. *Clin Ophthalmol*. 2024;18:201–13. https://doi.org/10.2147/opth.s440964
17. Gonzalez-Hernandez M, Garcia-Feijo J, Mendez MS, de la Rosa MG. Combined spatial, contrast, and temporal functions perimetry in mild glaucoma and ocular hypertension. *Eur J Ophthalmol*. 2004;14:514–22. https://doi.org/10.1177/112067210401400611
18. Kong YX, He M, Crowston JG, Vingrys AJ. A comparison of perimetric results from a tablet perimeter and Humphrey field analyzer in glaucoma patients. *Transl Vis Sci Technol*. 2016;5:2. https://doi.org/10.1167/tvst.5.6.2
19. Heijl A, Krakau CE. An automatic static perimeter, design and pilot study. *Acta Ophthalmol*. 1975;53:293–310. https://doi.org/10.1111/j.1755-3768.1975.tb01161.x
20. Gedde SJ, Vinod K, Wright MM, Muir KW, Lind JT, Chen PP, et al. Primary open-angle glaucoma preferred practice pattern®. *Ophthalmology*. 2021;128:P71p150. https://doi.org/10.1016/j.ophtha.2020.10.022
21. Vesti E. Essential perimetry. The field analyzer primer. *Acta Ophthalmol*. 2003;81:98. https://doi.org/10.1034/j.1600-0420.2003.00011.x
22. Yohannan J, Wang J, Brown J, Chauhan BC, Boland MV, Friedman DS, et al. Evidence-based criteria for assessment of visual field reliability. *Ophthalmology*. 2017;124:1612–20. https://doi.org/10.1016/j.ophtha.2017.04.035
23. Zeppieri M, Brusini P, Parisi L, Johnson CA, Sampaolesi R, Salvetat ML. Pulsar perimetry in the diagnosis of early glaucoma. *Am J Ophthalmol*. 2010;149:102–12. https://doi.org/10.1016/j.ajo.2009.07.020
24. Anderson AJ, Vingrys AJ. Interactions between flicker thresholds and luminance pedestals. *Vision Res*. 2000;40:2579–88. https://doi.org/10.1016/s0042-6989(00)00121-8
25. External Data: Australian Therapeutics Goods Association. Conformity assessment 41JA 465431. https://www.tga.gov.au/resources/resource/forms/medicaldevice-conformity-assessment-application (2024). Accessed June 10, 2024.
26. Campbell FW, Green DG. Optical and retinal factors affecting visual resolution. *J Physiol*. 1965;181:576–93. https://doi.org/10.1113/jphysiol.1965.sp007784
27. Swanson WH, Horner DG, Dul MW, Malinovsky VE. Choice of stimulus range and size can reduce test-retest variability in glaucomatous visual field defects. *Transl Vis Sci Technol*. 2014;3:6. https://doi.org/10.1167/tvst.3.5.6
28. Chen YX, Corbett J, Gale J, Meyerov J, Gong A, Cheng J, et al. Online circular contrast perimetry: validity and repeatability of home performance. *J Glaucoma*. 2025;34:853–68. https://doi.org/10.1097/ijg.0000000000002635
29. Meyerov J, Chen Y, Busija L, Green C, Skalicky SE. Repeatability of online circular contrast perimetry compared to standard automated perimetry. *J Glaucoma*. 2024;33:505–15. https://doi.org/10.1097/ijg.0000000000002384
30. Hodapp E, Parrish RK, Anderson DR. *Clinical decisions in glaucoma*. St. Louis: Mosby; 1993.
31. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med*. 2016;15:155–63. https://doi.org/10.1016/j.jcm.2016.02.012
32. Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. *Anesth Analg*. 2018;126:1763–8. https://doi.org/10.1213/ane.0000000000002864
33. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics*. 1988;44:837–45. https://doi.org/10.2307/2531595

34. Monsalve B, Ferreras A, Calvo P, Urcola JA, Figus M, Monsalve J, et al. Diagnostic ability of Humphrey perimetry, octopus perimetry, and optical coherence tomography for glaucomatous optic neuropathy. *Eye*. 2017;31:443–51. https://doi.org/10.1038/eye.2016.251
35. Nishijima E, Hosaka D, Ogawa S, Itoh Y, Noro T, Okude S, et al. Comparison of glaucoma detection performance of binocular perimetry screening program using imo perimetry with frequency doubling technology. *Transl Vis Sci Technol*. 2024;13:9. https://doi.org/10.1167/tvst.13.8.9
36. Najjar RP, Rukmini AV, Finkelstein MT, Nusinovici S, Mani B, Nongpiur ME, et al. Handheld chromatic pupillometry can accurately and rapidly reveal functional loss in glaucoma. *Br J Ophthalmol*. 2023;107:663–70. https://doi.org/10.1136/bjophthalmol-2021-319938
37. Hoang TT, Mai TQ, Pham DT, Nguyen X, Nguyen DA, Vu D, et al. Glaucoma clinic monitoring over 6 months using online circular contrast perimetry in comparison with standard automatic perimetry: the developing-world setting. *Clin Ophthalmol*. 2024;18:3767–80. https://doi.org/10.2147/opth.s496728
38. Hoang TT, Mai TQ, Pham DT, Nguyen X, Nguyen DA, Vu D, et al. Glaucoma home monitoring using online circular contrast perimetry over 6 months: performance and patient attitudes in the developing world setting. *Clin Ophthalmol*. 2025;19:1263–76. https://doi.org/10.2147/opth.s519093
39. Meyerov J, Deng Y, Busija L, Skalicky SE. Circular contrast perimetry via web application: a patient appraisal and comparison to standard automated perimetry. *Ophthalmol Sci*. 2022;2:100172. https://doi.org/10.1016/j.xops.2022.100172
40. Jones PR, Campbell P, Callaghan T, Jones L, Asfaw DS, Edgar DF, et al. Glaucoma home monitoring using a tablet-based visual field test (eyecatcher): an assessment of accuracy and adherence over 6 months. *Am J Ophthalmol*. 2021;223:42–52. https://doi.org/10.1016/j.ajo.2020.08.039

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APPENDIX A

FIGURES

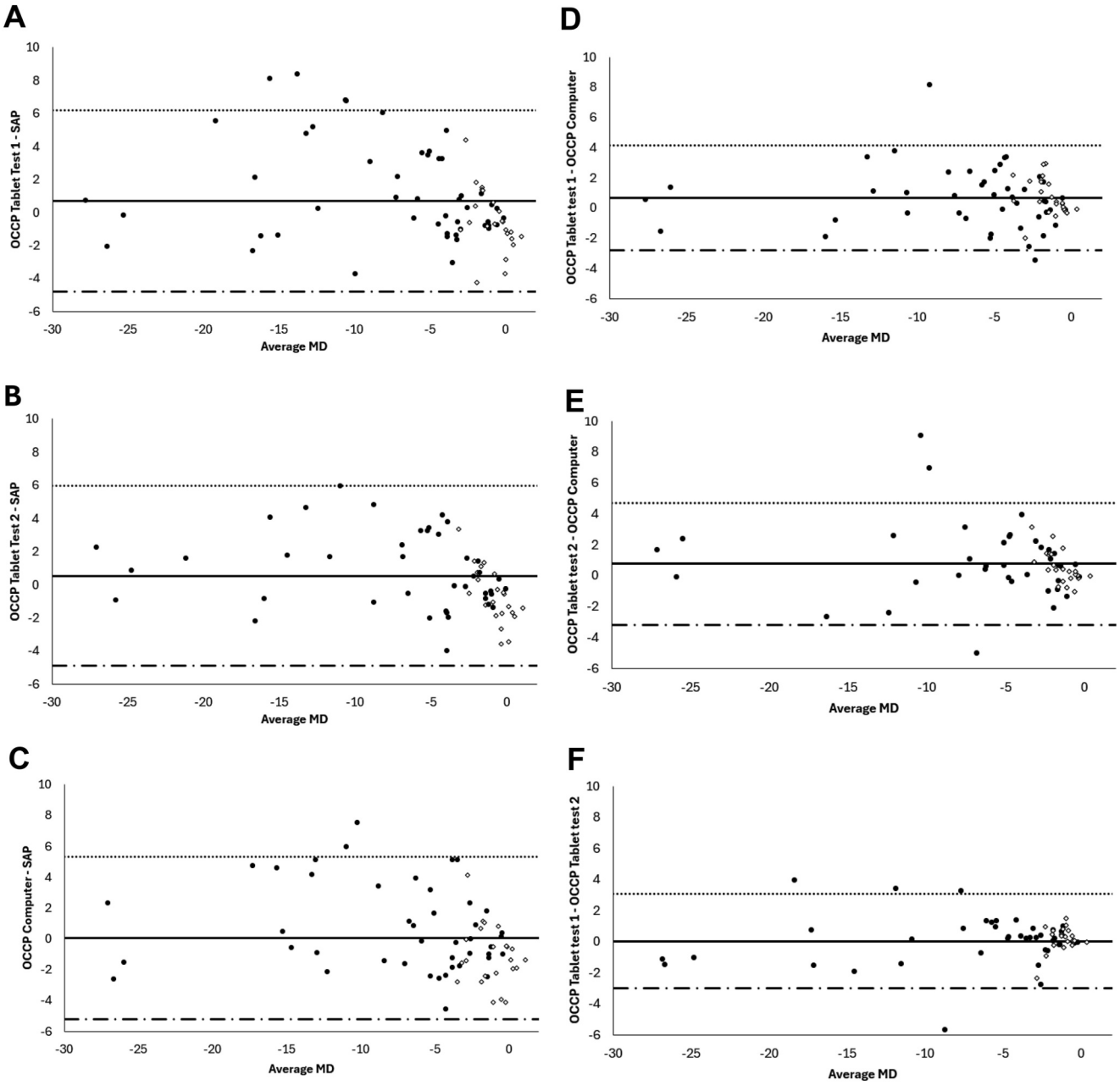

FIGURE A1 (A–F) Mean deviation Bland–Altman plots between different forms of OCCP and SAP. For the following, black dots represent glaucoma patients and white diamonds represent control patients. (A) Represents plot for the first OCCP tablet test and SAP. (B) Represents plot for the second OCCP tablet test and SAP. (C) Represents plot for the computer OCCP and SAP. (D) Represents plot for the first OCCP tablet test and the computer OCCP. (E) Represents plot for the second OCCP tablet test and computer OCCP. (F) Represents plot for the first and second OCCP tablet tests. The black horizontal line on each plot is the Bland–Altman bias (mean of the difference) between the two tests. The dashed horizontal lines are the 95% upper and lower LoA calculated as $1.96 \times \text{SD} \pm \text{mean}$, where SD is the standard deviation of the mean difference. LoA, limits of agreement; OCCP, online circular contrast perimetry; SAP, standard automated perimetry.

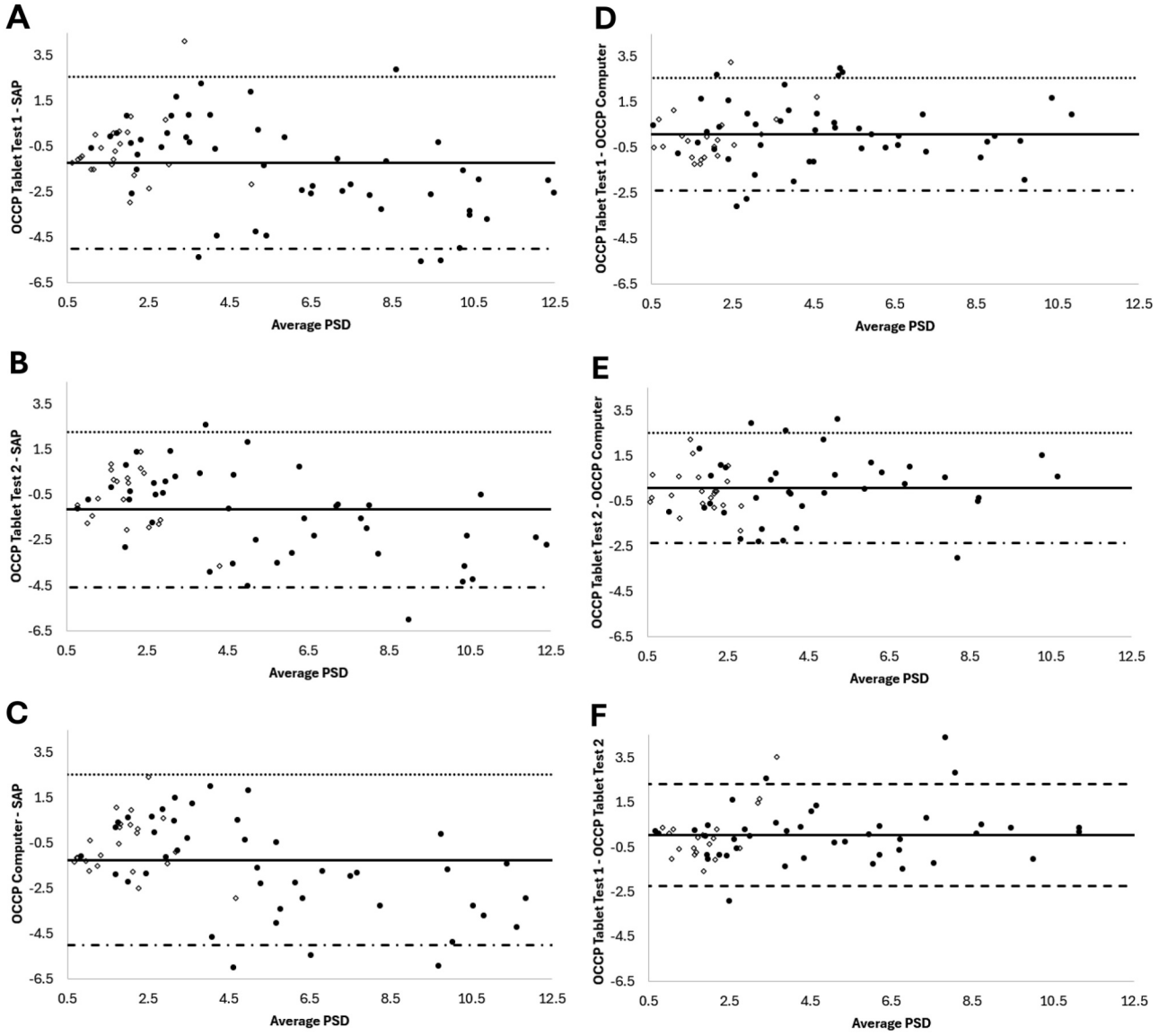

FIGURE A2 (A–F) Pattern standard deviation Bland–Altman plots between different forms of OCCP and SAP. For the following, black dots represent glaucoma patients and white diamonds represent control patients. (A) Represents plot for the first OCCP tablet test and SAP. (B) Represents plot for the second OCCP tablet test and SAP. (C) Represents plot for the computer OCCP and SAP. (D) Represents plot for the first OCCP tablet test and the computer OCCP. (E) Represents plot for the second OCCP tablet test and computer OCCP. (F) Represents plot for the first and second OCCP tablet tests. The black horizontal line on each plot is the Bland–Altman bias (mean of the difference) between the two tests. The dashed horizontal lines are the 95% upper and lower LoA calculated as 1.96 $\times$ SD $\pm$ mean, where SD is the standard deviation of the mean difference. LoA, limits of agreement; OCCP, online circular contrast perimetry; SAP, standard automated perimetry.

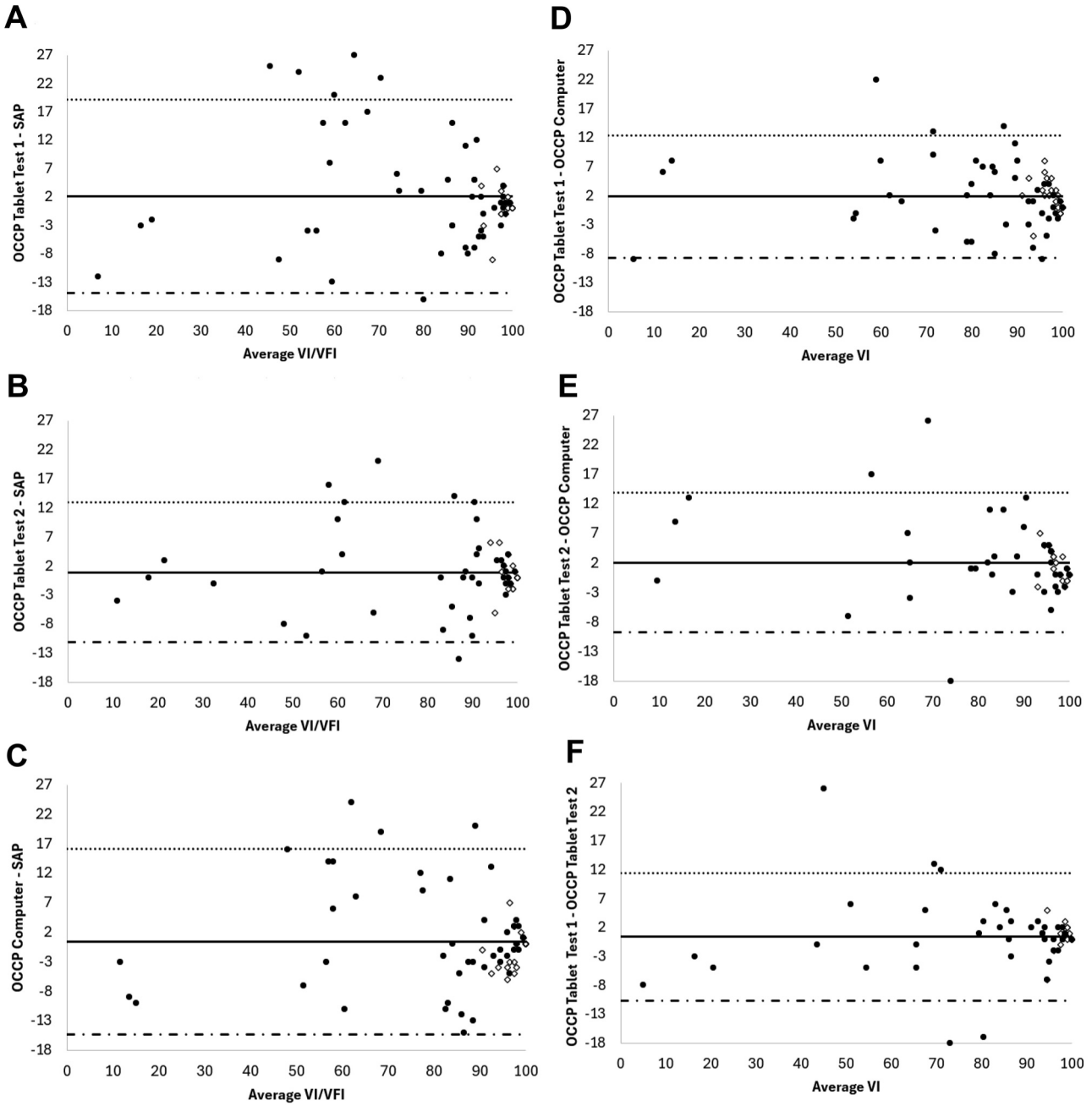

FIGURE A3 (A–F) Visual field index (SAP)/visual index (OCCP) Bland–Altman plots between different forms of OCCP and SAP. For the following, black dots represent glaucoma patients and white diamonds represent control patients. (A) Represents plot for the first OCCP tablet test and SAP. (B) Represents plot for the second OCCP tablet test and SAP. (C) Represents plot for the computer OCCP and SAP. (D) Represents plot for the first OCCP tablet test and the computer OCCP. (E) Represents plot for the second OCCP tablet test and computer OCCP. (F) Represents plot for the first and second OCCP tablet tests. The black horizontal line on each plot is the Bland–Altman bias (mean of the difference) between the two tests. The dashed horizontal lines are the 95% upper and lower LoA calculated as 1.96 × SD ± mean, where SD is the standard deviation of the mean difference. LoA, limits of agreement; OCCP, online circular contrast perimetry; SAP, standard automated perimetry.

APPENDIX B

TABLES

TABLE B1 Correlation and agreement parameters between OCCP computer test, OCCP tablet tests, and SAP, with MD stratified by glaucoma subgroup.

Variable	Spearman's rho [95% CI]	*p*-value (rho)	ICC [95% CI]	*p*-value (ICC)	Bland–Altman bias	Bland–Altman 95% LoA
MD (dB)						
OCCP TT1 versus SAP	0.86 [0.78–0.91]	<0.001	0.91 [0.86–0.93]	<0.001	0.68	[−4.81, 6.17]
OCCP TT1 versus computer	0.84 [0.75–0.90]	<0.001	0.95 [0.91–0.97]	<0.001	0.67	[−2.83, 4.16]
OCCP TT1 versus TT2	0.92 [0.87–0.95]	<0.001	0.97 [0.95–0.98]	<0.001	0.02	[−3.01, 3.05]
OCCP TT2 versus SAP	0.85 [0.76–0.91]	<0.001	0.92 [0.87–0.95]	<0.001	0.53	[−4.90, 5.96]
OCCP TT2 versus computer	0.86 [0.77–0.92]	<0.001	0.94 [0.89–0.96]	<0.001	0.75	[−3.22, 4.71]
OCCP computer versus SAP	0.79 [0.67–0.87]	<0.001	0.92 [0.87–0.95]	<0.001	0.05	[−5.23, 5.33]
PSD (dB)						
OCCP TT1 versus SAP	0.81 [0.72–0.88]	<0.001	0.80 [0.54–0.90]	<0.001	−1.24	[−5.01, 2.54]
OCCP TT1 versus computer	0.84 [0.74–0.90]	<0.001	0.90 [0.84–0.93]	<0.001	0.1	[−2.38, 2.58]
OCCP TT1 versus TT2	0.89 [0.83–0.93]	<0.001	0.92 [0.88–0.95]	<0.001	0.04	[−2.24, 2.32]
OCCP TT2 versus SAP	0.82 [0.72–0.89]	<0.001	0.81 [0.55–0.91]	<0.001	−1.16	[−4.58, 2.26]
OCCP TT2 versus computer	0.80 [0.68–0.88]	<0.001	0.89 [0.82–0.93]	<0.001	0.06	[−2.38, 2.51]
OCCP computer versus SAP	0.79 [0.67–0.87]	<0.001	0.74 [0.44–0.87]	<0.001	−1.36	[−5.46, 2.73]
VFI/VI (%)						
OCCP TT1 versus SAP	0.86 [0.79–0.89]	<0.001	0.92 [0.87–0.95]	<0.001	2.13	[−14.93, 19.18]
OCCP TT1 versus computer	0.86 [0.78–0.91]	<0.001	0.96 [0.93–0.98]	<0.001	1.87	[−8.69, 12.43]
OCCP TT1 versus TT2	0.93 [0.88–0.96]	<0.001	0.97 [0.94–0.98]	<0.001	0.4	[−10.66, 11.47]
OCCP TT2 versus SAP	0.86 [0.78–0.92]	<0.001	0.93 [0.89–0.96]	<0.001	1.6	[−14.14, 17.34]
OCCP TT2 versus computer	0.89 [0.81–0.93]	<0.001	0.95 [0.92–0.97]	<0.001	2.08	[−9.72, 13.88]
OCCP computer versus SAP	0.82 [0.72–0.89]	<0.001	0.93 [0.89–0.96]	<0.001	0.45	[−15.25, 16.14]
MD (dB)—Total glaucoma ($N = 49$)						
OCCP TT1 versus SAP	0.88 [0.80–0.94]	<0.001*	0.90 [0.81–0.95]	<0.001*	2.13	[−14.93, 19.18]
OCCP TT1 versus computer	0.87 [0.77–0.93]	<0.001*	0.95 [0.91–0.97]	<0.001*	1.87	[−8.69, 12.43]
OCCP TT1 versus TT2	0.93 [0.88–0.97]	<0.001*	0.97 [0.94–0.98]	<0.001*	0.4	[−10.66, 11.47]
OCCP TT2 versus SAP	0.89 [0.80–0.94]	<0.001*	0.91 [0.82–0.95]	<0.001*	1.6	[−14.14, 17.34]
OCCP TT2 versus computer	0.88 [0.78–0.94]	<0.001*	0.93 [0.86–0.97]	<0.001*	2.08	[−9.72, 13.88]
OCCP computer versus SAP	0.83 [0.71–0.91]	<0.001*	0.92 [0.85–0.95]	<0.001*	0.45	[−15.25, 16.14]
MD (dB)—Mild glaucoma ($N = 23$)						
OCCP TT1 versus SAP	0.72 [0.43–0.88]	<0.001*	0.71 [0.44–0.87]	<0.001*	−0.38	[−2.80, 2.04]
OCCP TT1 versus computer	0.59 [0.21–0.82]	0.004*	0.57 [0.20–0.79]	0.003*	0.36	[−3.05, 3.77]
OCCP TT1 versus TT2	0.80 [0.54–0.92]	<0.001*	0.84 [0.64–0.93]	<0.001*	0.08	[−1.81, 1.98]
OCCP TT2 versus SAP	0.70 [0.37–0.88]	<0.001*	0.51 [0.12–0.77]	<0.001*	−0.41	[−3.61, 2.79]
OCCP TT2 versus computer	0.80 [0.53–0.92]	<0.001*	0.73 [0.36–0.90]	<0.001*	0.8	[−1.71, 3.31]
OCCP computer versus SAP	0.61 [0.24–0.82]	0.003*	0.57 [0.21–0.80]	<0.001*	−0.78	[−4.00, 2.45]

TABLE B1 (Continued)

Variable	Spearman's rho [95% CI]	*p*-value (rho)	ICC [95% CI]	*p*-value (ICC)	Bland–Altman bias	Bland–Altman 95% LoA
MD (dB)—Moderate glaucoma ($N = 11$)						
OCCP TT1 versus SAP	0.67 [0.10–0.91]	0.023*	0.26 [−0.15 to 0.68]	0.102	2.59	[−2.49, 7.66]
OCCP TT1 versus computer	0.70 [0.10–0.93]	0.025*	0.47 [−0.10 to 0.83]	0.057	1.45	[−4.35, 7.25]
OCCP TT1 versus TT2	0.81 [0.34–0.95]	0.005*	0.58 [−0.08 to 0.88]	0.037*	0.07	[−4.67, 4.82]
OCCP TT2 versus SAP	0.60 [−0.07 to 0.90]	0.067	0.26 [−0.14 to 0.70]	0.072	2.46	[−1.31, 6.23]
OCCP TT2 versus computer	0.65 [−0.05 to 0.92]	0.058	0.44 [−0.27 to 0.84]	0.107	0.89	[−5.84, 7.61]
OCCP computer versus SAP	0.60 [−0.07 to 0.90]	0.067	0.48 [−0.07 to 0.83]	0.042*	1.76	[−3.71, 7.23]
MD (dB)—Severe glaucoma ($N = 15$)						
OCCP TT1 versus SAP	0.66 [0.22–0.88]	0.007*	0.71 [0.24–0.90]	<0.001*	2.76	[−4.90, 10.43]
OCCP TT1 versus computer	0.94 [0.78–0.98]	<0.001*	0.97 [0.91–0.99]	<0.001*	0.57	[−2.91, 4.04]
OCCP TT1 versus TT2	0.85 [0.53–0.96]	<0.001*	0.94 [0.80–0.98]	<0.001*	−0.43	[−5.41, 4.55]
OCCP TT2 versus SAP	0.70 [0.19–0.91]	0.011*	0.71 [0.22–0.91]	<0.001*	2.73	[−5.53, 10.98]
OCCP TT2 versus computer	0.77 [0.19–0.95]	0.016*	0.90 [0.64–0.98]	<0.001*	1.12	[−5.76, 8.01]
OCCP computer versus SAP	0.69 [0.17–0.91]	0.014*	0.81 [0.36–0.95]	<0.001*	2.44	[−4.12, 9.00]

Note: *p*-values for all Spearman's rho calculated through two-tailed *t*-tests, whereas *p*-values for all ICC's calculated through *F*-test.

Abbreviations: CI, confidence interval; dB, decibels; ICC, intraclass correlation coefficients; LoA, limits of agreement; MD, mean deviation; *N*, sample size; OCCP TT1, first OCCP tablet test; OCCP TT2, second OCCP tablet test; OCCP, online circular contrast perimetry; PSD, pattern standard deviation; SAP, standard automated perimetry; VFI, visual field index; VI, visual index.

*Represents statistical significance at $\alpha = 0.05$.

TABLE B2 Comparisons of AUC between all tests across MD, PSD, and VFI/VI.

Comparison pair	MD AUC difference (SE)	MD *p*-Value	PSD AUC difference (SE)	PSD *p*-value	VFI/VI AUC difference (SE)	VFI/VI *p*-Value
OCCP TT1 versus SAP	−0.013 (0.3)	0.79	0.032 (0.312)	0.56	0.004 (0.293)	0.94
OCCP TT1 versus computer	0.53 (0.318)	0.23	0.016 (0.303)	0.66	0.054 (0.307)	0.19
OCCP TT1 versus TT2	0.022 (0.312)	0.53	0.005 (0.301)	0.895	0.022 (0.297)	0.53
OCCP TT1 versus OCT cpRNFL MT	−0.041 (0.292)	0.37	-	-	−0.025 (0.283)	0.56
OCCP TT1 versus OCT GCC MT	0.05 (0.324)	0.44	-	-	0.034 (0.304)	0.53
OCCP TT2 versus SAP	−0.035 (0.305)	0.44	0.027 (0.310)	0.61	−0.019 (0.297)	0.69
OCCP TT2 versus computer	0.031 (0.323)	0.51	0.011 (0.303)	0.823	0.032 (0.312)	0.41
OCCP TT2 versus OCT cpRNFL MT	−0.063 (0.297)	0.14	-	-	−0.047 (0.288)	0.25
OCCP TT2 versus OCT GCC MT	0.028 (0.329)	0.64	-	-	0.012 (0.308)	0.80
OCCP computer versus SAP	−0.066 (0.311)	0.21	0.016 (0.312)	0.754	−0.051 (0.307)	0.30
OCCP computer versus OCT cpRNFL MT	−0.094 (0.304)	0.10	-	-	−0.079 (0.300)	0.15
OCCP computer versus OCT GCC MT	−0.003 (0.333)	0.96	-	-	−0.02 (0.318)	0.72
SAP versus OCT cpRNFL MT	−0.028 (0.283)	0.54	-	-	−0.028 (0.282)	0.49
SAP versus OCT GCC MT	0.063 (0.315)	0.26	-	-	0.031 (0.302)	0.55
OCT cpRNFL MT versus OCT GCC MT	0.091 (0.307)	0.10	-	-	0.059 (0.294)	0.23

Note: AUC comparisons were computed based on the Delong method (1988).[33]

Abbreviations: AUC, area under the curve; cpRNFL, circumpapillary retinal nerve fiber layer; GCC, ganglion cell complex inner plexiform layer; MD, mean deviation; MT, mean thickness; OCCP TT1, first OCCP tablet test; OCCP TT2, second OCCP tablet test; OCCP, online circular contrast perimetry; OCT, optical coherence tomography; PSD, pattern standard deviation; SAP, standard automated perimetry; SE, standard error; VFI, visual field index; VI, visual index.