ONLINE CIRCULAR CONTRAST PERIMETRY: THE NORMATIVE DATABASE OF AN ASIAN POPULATION

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This study compared results of online circular contrast perimetry (OCCP) versus standard automated perimetry (SAP) in clinic, as well as clinic OCCP versus home OCCP in a normal Asian population. Healthy participants underwent a comprehensive ocular examination, retinal nerve fiber layer optical coherence tomography scan, and visual field tests performed in clinic, using OCCP and SAP. Within a week, participants were asked to repeat OCCP field test at home. 58 eyes of 29 healthy volunteers were selected. At the clinic, no difference between testing duration and fixation loss of SAP and OCCP was detected. False Positive (FP) rate of OCCP (3.57%) was significantly higher than SAP (1.07%, p < 0.001) while False Negative (FN) of SAP (1.64%) was significantly higher than those of OCCP (0.48%, p = 0.0225). In clinic OCCP compared to SAP revealed no significant difference in Mean Deviation (MD) (-0.29dB, p = 0.0825), and small differences in Pattern Standard Deviation (PSD) (-0.60dB, p = 0.0001) and Visual Index (VI)/Visual Field Index (VFI) (1.26%, p = 0.0199). Among 29 healthy participants, 15 people with 30 eyes completed home OCCP tests. Comparing in clinic and at-home OCCP, no significant difference between test duration, FP, FN, FL of was found. Small but significant improvements in OCCP MD (0.79dB, p = 0.0008), VI (1.63%, p = 0.0043), but not PSD (-0.45dB, p = 0.1609) were detected. Comparable outcomes between OCCP and SAP in clinic as well as between OCCP in clinic and OCCP at home were found in a normal Asian population.

Keywords: Online circular contrast perimetry, normal, healthy.

I. INTRODUCTION

Visual field testing plays a key role in glaucoma diagnosis and management. Referencing a normal population database not only improves diagnostic accuracy for detecting pathologic deviations in visual field testing but also make diagnostic modalities outstanding from others. Skalicky et al carried out a study to create the normative database for Online Contrast Circular Perimetry (OCCP) referenced from a Caucasian population in Australia.[1] However the applicability of normal ranges in perimetry thresholds cannot be assumed to apply from one ethnicity subgroup to another. There are differences in visual sensitivity parameters between different ethnic groups.[2] Normal sensitivity for contrast based frequency doubling perimetry (FDP) is different between Asian and Caucasian individuals.[3] These differences might explain the lower glaucoma detection rates and more advanced disease

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stage on presentation for Black, Asian and Hispanic patients compared to White patients.[4] It might also explain why longitudinal visual field monitoring in Black individuals are more variable than in White individuals (and hence visual field loss progression harder to identify).[5] This might also help explain why apparently similar levels of visual field loss result in different levels of perceived reduction in vision specific quality of life among different ethnic groups.[6] The data from an East Asian normal cohort will reinforce the normal population metrics for OCCP among East Asian populations, and improve the test's diagnostic accuracy in East Asia. Furthermore, evaluation of the accuracy and usability of OCCP performed by patients at home will determine the future of home-monitoring for glaucoma. Therefore, this study was conducted to compare the outcomes of OCCP with standard automated perimetry (SAP) in clinic as well as OCCP in clinic with OCCP at home in a healthy Asian population.

II. MATERIALS AND METHODS

Hanoi Medical University has granted ethical approval for our research, which adhered closely to the principles of the Declaration of Helsinki (IRB-VN01001). Participants provided signed consent papers.

1. Study population

At Hanoi Medical University Hospital, this observational study was conducted on volunteer patients in 2023 who met the study's eligibility requirements. Healthy participants without any additional ocular diseases and with normal IOP, optic nerve head, and RNFL were included. Best corrected visual acuity (BCVA) 20/20, reliable visual field indices on SAP, prior computer and internet-based web browser experience, and access to a laptop/ personal computer with internet connection were among the inclusion criteria. Any ocular or visual disease such as glaucoma, non-glaucomatous optic neuropathy, maculopathy, cataracts grade II or above), ocular hypertension, occludable angles, spherical refraction errors ≥ ±5 diopter, non-glaucomatous disc anomalies, cerebral disorders, drugs altering visual field (pilocarpine, vigabatrin, and chloroquine), vitreoretinal surgery, were among the exclusion criteria, as were and unreliable .visual field tests on SAP.

Eligible participants were enrolled consecutively. Data from both eyes from each patient was included in the analysis.

2. Clinical evaluation

A thorough clinical evaluation process was carried out on the participants, including a baseline structural optical coherence tomography (OCT, Cirrus, Zeiss) test and visual field testing. Patients conducted visual field testing in the clinic utilizing OCCP Eyeonic (Eyeonic Pty Ltd, Australia) and SAP (Carl Zeiss Meditec Inc, Dublin, California, USA) 24 - 2 test SITA Standard (Swedish Interactive Threshold Algorithm Standard) in randomized order once for each eye. Tests were considered unreliable based on the following traditional parameters, false negatives (FN) > 33%; false positives (FP) > 15%; fixation losses (FL) > 20% (based on the Heij-Krakau method). OCT scans were acquired. OCT reports with signal strength of less than seven out of ten were not accepted. Within 1 week, patients used their personal computers or laptops to retake the OCCP exam at home. Phone instruction and distance surveillance through video call were provided by the research team and available on request by the participant.

Online Circular Contrast Perimetry

Several recent studies have described the OCCP technology.[1,7-10] In essence, OCCP provides perimetry via a web browser, and can operate on any computer or tablet.

Testing condition

The testing was conducted in a controlled clinical setting with uniform ambient lighting, temperature, and background noise levels. SAP was conducted in a dedicated, quiet, and low-light environment. OCCP testing was performed in one location using standard, fully functional laptops in a quiet, unoccupied clinical setting. The main source of lighting was the computer monitor, which was adjusted to have at least 75% brightness. Each computer had its own mouse, webcam, volume control, and internet access. Each computer was of similar size, and required the user be seated at a viewing distance of 50cm from the monitor.

All optometrists were highly experienced in perimetry operations and had undergone further training in controlling OCCP in order to ensure the consistency of research protocols. Participants were positioned at the correct viewing distance (50cm) prior to the test beginning. A patch was on the non-tested eye. A skilled optometrist supervised the examination and corrected the subject's height and head posture.

Major outcomes

For SAP, mean deviation (MD), pattern standard deviation (PSD) and visual field index (VFI) were recorded as primary outcome measures. Calculation of the following similar outcome measures for OCCP was based on data obtained from an established normative dataset and determined in accordance with methods utilised in SAP: MD, PSD and Visual Index (VI); VI is calculated on a weighed mean system similar to visual field index (VFI).[1] The data from this study will be used to optimize the normative database for future OCCP use in East Asia.

In addition perimetric test duration and reliability criteria (FP, FN, FL rates), and age, gender, visual acuity, IOP, refraction, RNFL, CCT, and length of perimetric test were among the secondary outcome measures.

Statistical analysis

Descriptive and inferential statistical analyses were performed. Frequency, percentage (qualitative measures) and mean, standard deviation (quantitative measures) were descriptive statistics. Bland-Altman plots, linear regression, and paired sign-rank tests were used for statistical comparison testing. A statistical significance threshold of $p < 0.05$ was utilized. Stata and SPSS 23 were used to analyze the data.

III. RESULTS

1. Study population

Table 1. Demographic and clinical characteristics of study participants

	Non-Glaucoma
n (eyes)	29 (58)
n (eyes) performing home OCCP	15 (30)
Age	31.3 (11.1)
Gender (Male/ Female)	5/24
Best corrected visual acuity (Mean, SD)	0.0 (0.0)
Intraocular pressure (Mean, SD)	15.5 (2.8)
Spherical Equivalence (Mean, SD)	-3.1 (3.1)

	Non-Glaucoma
Central corneal thickness (Mean, SD)	530.5 (24.3)
Retinal Nerve Fiber Layer Average (Mean, SD)	104.1 (14.5)
Retinal Nerve Fiber Layer Superior (Mean, SD)	123.3 (16.5)
Retinal Nerve Fiber Layer Inferior (Mean, SD)	127.9 (20.4)

In total, 58 eyes of 29 healthy volunteer people were selected. Demographic and clinical characteristics are outlined in Table 1. Average age of the study population was under 35. All parameters of participants were within normal limit. Among 29 healthy participants, 15 people with 30 eyes completed home OCCP tests.

2. Clinic OCCP vs SAP

Table 2. Comparison between SAP and OCCP at clinic for test duration and reliability indices

	SAP	OCCP	p-value
Testing duration (minutes)			0.3874
Mean (SD)	5.02 (0.60)	5.05 (1.52)	
Median (IQR)	5.05 (0.80)	4.95 (1.00)	
Min-Max	3.90, 6.90	3.20, 11.90	
False Positive (%)			*< 0.001*
Mean (SD)	1.07 (1.59)	3.57 (3.19)	
Median (IQR)	0.00 (1.00)	3.00 (4.00)	
Min-Max	0.00, 6.00	0.00, 18.00	
False Negative (%)			*0.0225*
Mean (SD)	1.64 (2.98)	0.48 (0.78)	
Median (IQR)	0.00 (2.00)	0.00 (1.00)	
Min-Max	0.00, 16.00	0.00, 3.00	
Fixation Loss			0.3205
Mean (SD)	0.90 (1.00)	1.37 (1.59)	
Median (IQR)	1.00 (1.00)	1.00 (2.00)	
Min-Max	0.00, 3.00	0.00, 6.00	

There were no significant difference between SAP and clinic OCCP for testing duration and FL (Table 2). FP rate of clinic OCCP (3.57%) was significantly higher than that of SAP (1.07%, $p < 0.001$) while FN rate of SAP (1.64%) was significantly higher than those of clinic OCCP (0.48%, $p = 0.0225$).

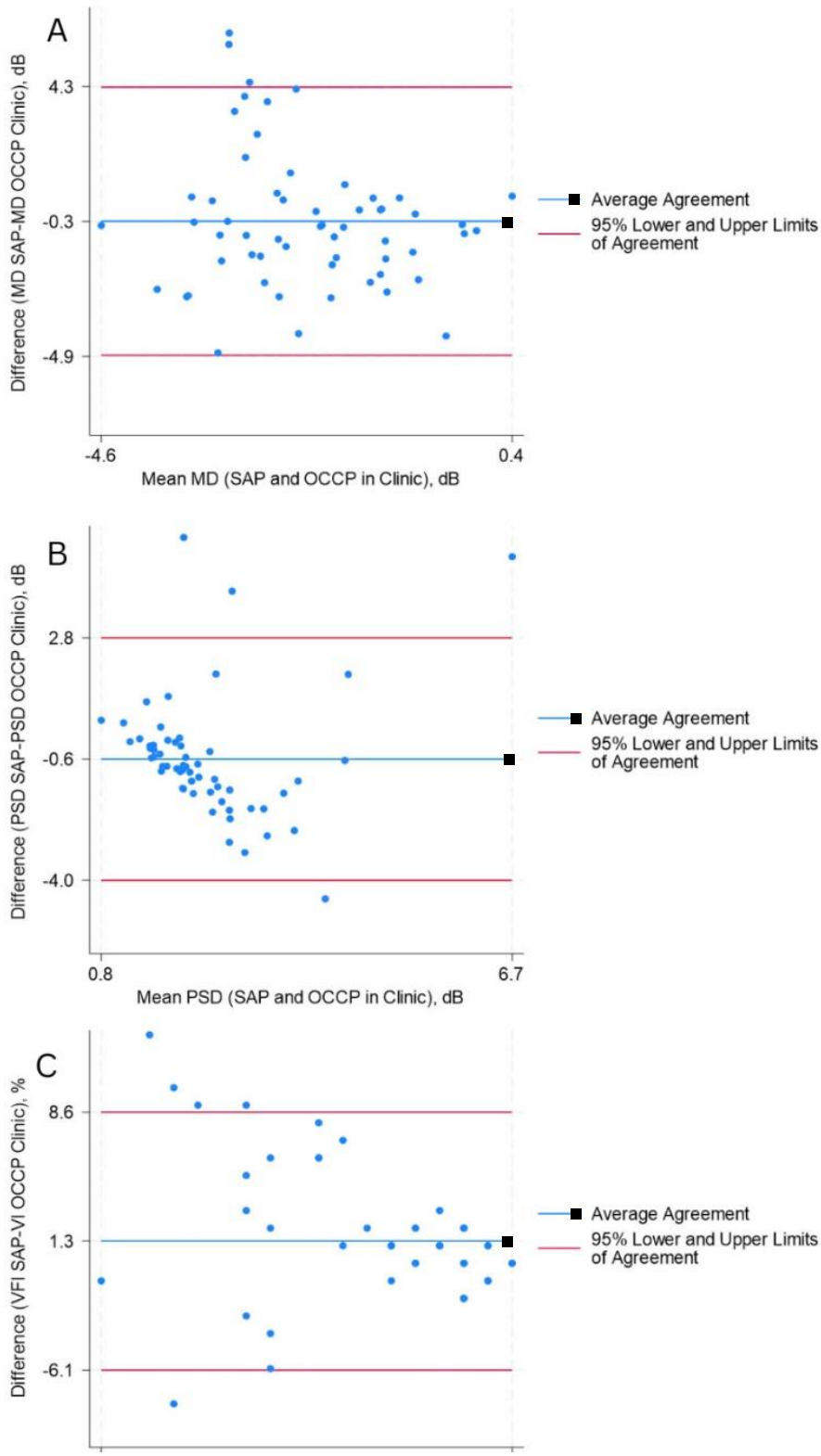

Chart 1. Agreement between SAP and OCCP parameters using Bland-Altman plots

Bland-Altman plots (Chart **1**) demonstrated strong agreement between clinic OCCP and SAP MD, with no significant bias (-0.29dB, p = 0.0825 Lower Limit of Agreement (LoA) -4.85dB, Upper LoA 4.28dB). A small but significant difference in PSD (Bias -0.60 dB, p = 0.0001, Lower LoA -4.01dB, Upper LoA 2.80dB) and VI/VFI (Bias 1.26%, p = 0.0199, Lower LoA -6.09%, Upper LoA 8.61%) was detected. MD for both perimetric tests had a similar linear decline with age according to the following equations with respective R^2 and p values.

MD SAP = -0.18 x age + 0.97 (R^2 = 10.58%, p < 0.001)

MD OCCP = -0.11x age – 0.56 (R^2 = 6.44%, p < 0.001)

3. Home OCCP vs Clinic OCCP

Table 3. Comparison between OCCP in clinic and OCCP at home for test duration and reliability indices

	OCCP Clinic	OCCP Home	p-value
Testing duration (minutes)			
Mean (SD)	4.46 (0.80)	4.19 (0.90)	0.0705
Median (IQR)	4.55 (1.50)	3.90 (0.70)	
Min-Max	3.20, 6.10	2.90, 6.80	
False Positive (%)			
Mean (SD)	2.93 (2.57)	4.30 (4.22)	0.15
Median (IQR)	3.00 (3.00)	3.00 (3.00)	
Min-Max	0.00, 9.00	0.00, 18.00	
False Negative (%)			
Mean (SD)	1.52 (1.73)	0.07 (0.25)	0.0625
Median (IQR)	1.00 (3.00)	0.00 (0.00)	
Min-Max	0.00, 6.00	0.00, 1.00	
Fixation Loss			
Mean (SD)	0.30 (0.53)	1.52 (1.71)	0.8695
Median (IQR)	0.00 (1.00)	1.00 (2.00)	
Min-Max	0.00, 2.00	0.00, 7.00	

Table 3 demonstrates no significant difference between test duration, FP, FN, FL for clinic and home OCCP.

There was overall good agreement between OCCP in clinic and at home, as demonstrated by Bland Altman plots in Chart 2. Compared to in-clinic testing, a small but significant improvement for at-home testing occurred for MD (bias 0.79dB, p = 0.0008, Lower LoA -2.41dB, Upper LoA 4.00dB) and VI (bias 1.63%, p = 0.0043, Lower LoA -5.76%, Upper LoA 9.03%). There was no significant change in PSD (bias -0.45, p = 0.1609, upper LoA 2.27dB, lower LoA -3.18dB).

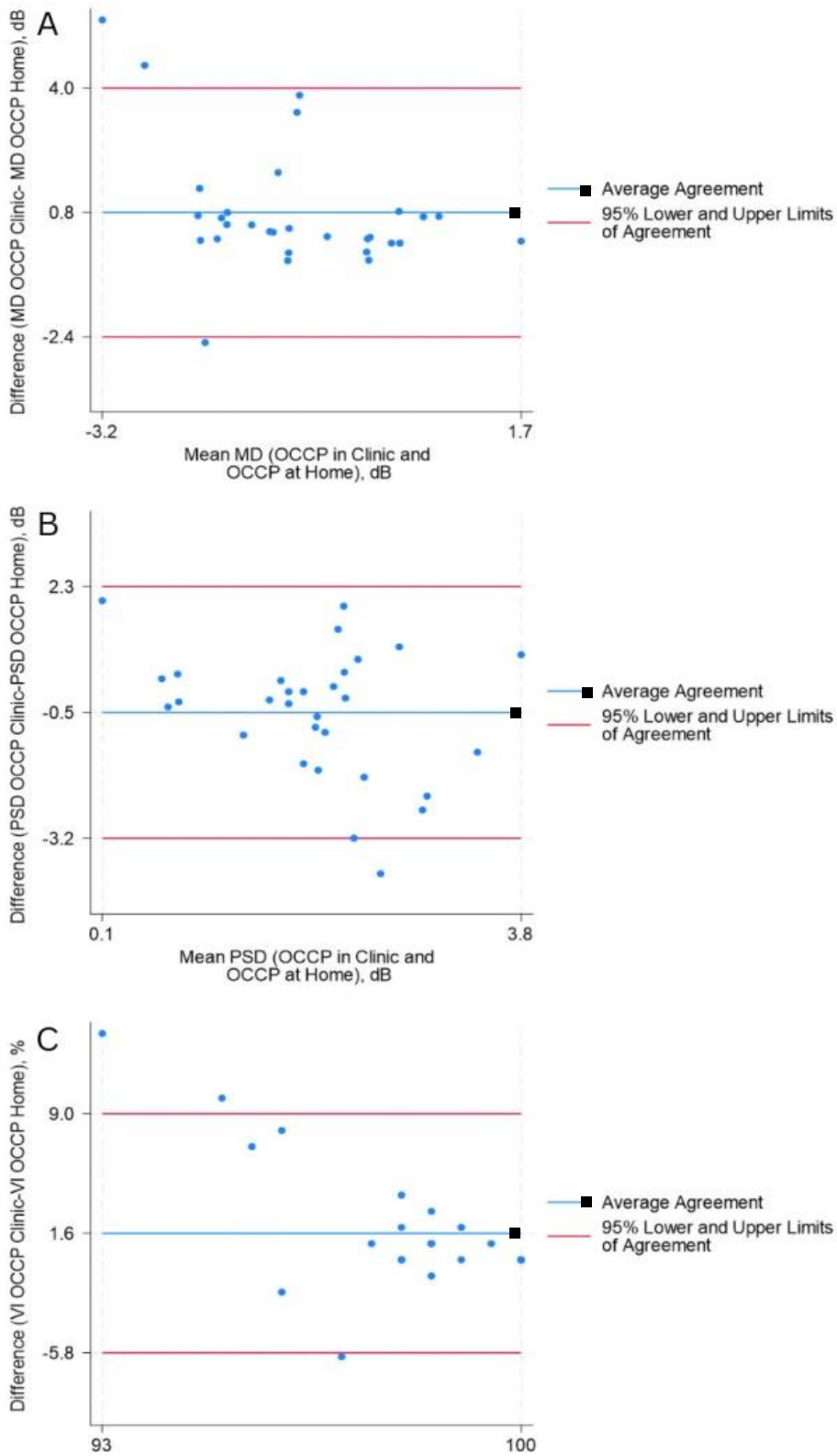

Chart 2. Agreement between OCCP clinic and OCCP home parameters

IV. DISCUSSION

The current study demonstrates the development of a normative database of OCCP in a normal Asian population. There is strong agreement between SAP and OCCP in the clinic setting, which is consistent with the previous study of Skalicky et al.[1] This is also the first such normal data for OCCP at home, showing a small but significant improvement in perimetric parameters compared to in clinic. While previous OCCP data was collected in Australia, this data was collected in an Asian country with an emerging economy.

No difference was detected between testing duration and FL of SAP and OCCP. Nonetheless, there was a significant difference between SAP and OCCP for false positives (FP) and false negatives (FN). Target presentation duration and inter-trial interval are two perimetric parameters that affect FP, whereas the brightness difference between the test target and the calculated threshold and the proximity to a scotoma influence FN.[11]

Mean threshold of both SAP and OCCP decreased with age at an approximate rate of 1 decibel per decade (R^2 = 10.58, $p < 0.001$ and R^2 = 6.44, $p < 0.001$). This finding was consistent with that of Skalicky et al.[1]

Our mean OCCP testing time in clinic was 5.05 minutes while that of the study from Skalicky et al was roughly 6 minutes. Bland-Altman plots of the current study demonstrated that MD Bias was -0.29dB while Skalicky et al revealed that MD Bias was 4dB. These findings indicate the evolution of OCCP technology.[1]

Future studies evaluating the accuracy and usability of online perimetry with OCCP in children would be of interest. Groth et al and Wang et al applied VisuALL, a virtual reality game-based automated perimetry, in normal pediatric participants or patients with childhood glaucoma.[12,13] Owning similar characteristics to a computer game, OCCP is expected to be suitable for any child suspected with or suffering from glaucoma.

The current study is the first to demonstrate data from OCCP performed at home. We found no significant difference between test duration, FP, FN, FL of OCCP in clinic and OCCP at home. Bland-Altman plots revealed a small but significant improvement in global indices when performed at home vs in clinic. This could be due to a variety of factors - extra familiarity with the test, extra comfort when setting up the device at home, different devices used at home vs in clinic. We note that these parameters were calculated based on the normative Caucasian dataset while in the future such parameters will be calculated with data from the Asian normative dataset. Similar to previous studies, a normative dataset not correctly calibrated to the particular ethnicity can lead to increased variation.[5] With ongoing enhancements and learnings from the use of OCCP in clinic vs at home, continued improvement to achieve consistency between different monitor types, improved patient cues and pre-test education, and the application of artificial intelligence to the testing and data analysis, further refinement of outcomes will achieve more consistency in testing over time which will lead to ongoing improvements in glaucoma diagnostic sensitivity. It is noted that these differences between in clinic and at home are small. This study demonstrates that home-based OCCP tests could be obtained with acceptable reliability and accuracy compared to the clinic-based version, and represents a milestone in the ability for perimetry to be successfully performed at home on a patient's own device. It is also important to note that any variability in home-based testing can be offset by the increased testing frequency such

opportunities offer.[14]

Glaucoma progression will be detected through many tests after years. If only one test is performed a year, it would take up to 6 years to pick up 1dB progression each year.[15] Glaucoma deterioration could be found earlier within 2 years if patient has 3 tests annually. It is recommended that 6 tests should be performed within the first 2 years after definitive diagnosis to not to miss any worsening sign of glaucoma visual field.[15] However, most healthcare systems cannot achieve this capacity for all glaucoma patients due to funding, personnel and equipment restraints, including in some developed economies.[16]

There is evidence to suggest that more regular home visual field tests could detect damage at an earlier stage. Anderson et al carried out a study on 43 patients who either had glaucoma, ocular hypertension or were glaucoma suspects. Sensitivity of detecting -2dB MD loss every year is 80% after 2.5 years of visual field testing performed every 6 months in clinic. Anderson et al (2017) found that a similar 80% sensitivity could be achieved with weekly home field test only after 0.9 years even when the compliance was 63%. These data highlighted the importance of regular field checks in reducing time of finding visual field progression.[17]

More than 50% of our participants (15/29) performed OCCP tests at home on their own devices. However, a significant proportion did not complete the home testing. Potential barriers include lacking the time or inclination to perform testing, or not appreciating the importance of home testing. More work is required to better understand these demotivating factors and how to better motivate individuals to perform regular home perimetry tests when requested to do so. Despite this, this study's home-monitoring OCCP data showed the potential of a new approach for glaucoma surveillance at home.

The current study has some limitations. A possible shortcoming is the selection of individuals from a single practice, but this is compensated by several studies of OCCP from across the globe. Despite the challenges of home-monitoring nature and additionally recruiting for studies in a developing-world setting, we were able to recruit a study population similar in size to other home-monitoring studies (Jones et al, 20 participants; Chia et al, 20 subjects, Tsapakis et at, 10 patients) with acceptable timeframe to generate the very first normative database in Asian people for OCCP.[14,18,19]

V. CONCLUSION

In the normal Asian population, comparable results were observed between OCCP and SAP in the clinic and between OCCP in the clinic and OCCP at home. OCCP may be a novel method for glaucoma screening in clinical settings and glaucoma home monitoring.

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