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A Comparison Between the Diagnostic Results of Short Wavelength Automated Perimetry and Standard Automated Perimetry in Glaucoma Patients: A Cross-Sectional Comparative Study

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Abstract: Background: The aim is to compare the diagnostic results of Short Wavelength Automated Blue on Yellow Perimetry (SWAP) with Standard Automated White on White Perimetry (W-W) in glaucoma-suspect and glaucomatous patients and to evaluate the role of SWAP in the early detection of glaucomatous visual field deficits as they are usually discovered, using W-W, only when they have reached an advanced stage. Material and methods: In this cross-sectional comparative study, held in Tishreen University Hospital – Ophthalmology Department from January 2021 to January 2022, 51 eyes of 31 subjects were enrolled. they underwent full ophthalmological examination including bio microscopy, Intraocular Pressure (IOP) measurement by means of Goldmann's applanation tonometry, and color vision testing using Ishihara's plates. The participants were divided into two groups: a Glaucoma- suspect group (31 eyes) and a Glaucomatous group (20 eyes). Informed consent was obtained from all subjects after the nature and possible consequences of the procedure had been fully explained to them. As all included subjects were familiar with SAP, we conducted two tests on each subject; first SAP (G pattern) then SWAP using (OCTOPUS 900) perimeter. The two testing sessions were separated by resting periods. The reliability parameters, test duration and visual field global indices were compared between W-W and SWAP. Results: In the Glaucoma- suspect group Mean Sensitivity (MS) was significantly higher in W-W than SWAP (P:0.0001). Both Mean Defect (MD) and Square Root of Loss of Variance (sLV) were significantly higher in SWAP (P:0.0001). Reliability Factor was greater in SWAP but not statistically significant (P:0.07). In the Glaucomatous group MS was significantly higher in W-W (P:0.0001). MD was significantly higher in SWAP (P:0.0001), as well as sLV (P:0.04). Reliability Factor was significantly greater in SWAP (P:0.02). And Test Time was significantly longer in SWAP in both Glaucoma-suspect and Glaucomatous groups (P:0.0001 & P:0.002) respectively. Conclusion: This study showed that SWAP is superior to W-W in identifying patients with early glaucoma, ocular hypertension, glaucoma suspects and patients with progressive optic disc cupping and may therefore be quite useful for determining early and progressive changes in glaucoma. However, in order to conclude that SWAP is an early indicator of glaucomatous damage, longer follow-up is required. And with the longer time needed to conduct SWAP, W-W remains the gold standard with SWAP being a valuable tool in the process.

Keywords: Short-Wavelength, Automated Perimetry, Glaucoma-Suspect, Glaucomatous, Visual Field Deficits, Octopus 900, Reliability Parameters, Global Indices

1. Introduction

Diagnosis of glaucoma requires a clinical triad; elevated intraocular pressure, structural alteration of the optic nerve head, and visual field defects [1, 2]. As a psychophysical test of optic nerve function, Visual field testing is an essential component of glaucoma assessment in terms of detection as well as in monitoring the progression of the disease [1, 3, 4]. For the past few decades, White on White Automated Perimetry (W-W) also known as Standard Automated Perimetry (SAP) has been considered the test of reference for glaucoma diagnosis and monitoring [1, 2]. Performed with a uniform white target projected on a homogenous white background, SAP detects glaucomatous changes only after extensive optic disc damage. This may occur because the W-W stimulus has broadband characteristics that activate the spectrum of retinal ganglion cells within the tested retina [4, 5]. Because the large overlap in the ganglion cell network results in considerable redundancy, glaucomatous losses may be masked if all types of ganglion cells are stimulated. In addition, it is very difficult to distinguish true progression of field loss on SAP from long-term variability [4]. And since demonstrable visual field deficits occur after structural changes in the optic disc [1, 6, 7], it is now considered subordinate to optic nerve head description [1, 2, 6].

Therefore, there is a general agreement on the need to improve early diagnosis of visual loss in patients suspected to have glaucoma and to improve the sensitivity of SAP to detect the progression of glaucomatous optic neuropathy [4, 5]. It is well accepted that there are similar limitations of SAP in the early detection of onset as well as progression of Glaucomatous Optic Neuropathy (GON) [4, 5].

Several studies have reported that foveal blue and blue-yellow color vision defects are present in patients with ocular hypertension and glaucoma and these deficits appear to be early indicators of glaucomatous damage [1, 2, 8-12]. In the studies of Drance, Lakowski et al it was demonstrated that patient with ocular hypertension who had blue and blue-yellow color deficiencies had a much higher incidence of glaucomatous visual field loss 5 years later, as compared with normal color vision results [1, 2, 12].

By using special techniques that selectively examine the sensitivity of short wavelength sensitive cones, it is possible to detect glaucomatous visual field deficits at an earlier stage. Several studies have shown that short wavelength automated perimetry (SWAP) was more sensitive than SAP in detecting early glaucomatous defects and it has shown greater progression of existing glaucomatous defects [1, 2, 8, 13, 14].

Which has generated considerable interest as a potential means for detecting the presence of visual field loss before that identified by conventional W-W perimetry and also for detecting progressive field loss in advance of W-W. SWAP has been studied in a variety of conditions, including glaucoma, diabetic macular edema, and neuro-ophthalmic disorders. SWAP is currently commercially available on the Humphrey Field Analyzer (HFA) models and as an option on the Octopus 900 perimeter [4, 8, 13, 15, 16].

SWAP utilizes a blue stimulus to preferentially stimulate the blue cones and a high luminance yellow background, Blue on Yellow Perimetry (B-Y), to adapt the green and red cones and to saturate, simultaneously, the activity of the rods. Compared with W-W perimetry, SWAP is limited clinically by the following: greater variability associated with the estimation of threshold; ocular media absorption; increased examination duration; and an additional learning effect [4].

The aim of this study is to compare the diagnostic results of SWAP; B-Y with SAP; W-W in glaucoma-suspect and glaucomatous patients and to evaluate the role of B-Y perimetry in the early detection of glaucomatous visual field deficits as they are usually discovered, using W-W, only when they have reached an advanced stage.

2. Patients, Materials, and Methods

In this cross-sectional comparative study, held in Tishreen University Hospital – Ophthalmology Department from January 2021 to January 2022, 51 eyes of 31 subjects (21 males and 10 females) were enrolled. The study was conducted in accordance with the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects after the nature and possible consequences of the procedure had been fully explained to them, and the Ethics Committee of the Faculty of Medicine in Tishreen University approved the study on December 15th 2020. The systemic and ocular history was taken. Then subjects underwent full ophthalmological examination by means of slit-lamp bio microscopy, gonioscopy, autorefraction, Best-Corrected Visual Acuity (BCVA) testing on Snellen's chart, fundus and optic nerve head examination using a +90 D non-contact lens, Intraocular Pressure (IOP) measurement by means of Goldmann's applanation tonometry, measurement of central corneal thickness (CCT) by ultrasonic pachymetry. The CCT-corrected IOP was taken for analysis. Color vision testing was done using Ishihara's plates, and motility test.

Inclusion Criteria: Age between 40- and 65-year-old, willing to fill the informed consent form. Previous experience with SAP, CCT-corrected IOP <30 mmHg in the suspected eye. To be classified as a glaucoma suspect in the given eye, one or more of the following inclusion criteria was met in addition to a normal or baseline W-W field: Primary Open Angle Glaucoma (POAG) in the fellow eye; a presenting IOP of 26 mm Hg and a vertical Cup to Disc (CD) ratio 0.6; a presenting IOP of 26 mm Hg and a positive family history for glaucoma; a presenting IOP of 21 mm Hg and a between eye asymmetry in CD ratio 0.2; a presenting IOP of 21 mm Hg and a CD ratio of 0.8; a presenting IOP of 21 mm Hg and the presence of any focal disc abnormality, notching or disc hemorrhage; or a presenting IOP of 30 mm Hg. In the POAG eyes, a repeatable, glaucomatous W-W visual field defect at baseline was required to coexist with an abnormal optic disc, also consistent with a diagnosis of glaucoma (including increase in cup size, increase in cup disc ratio, disc asymmetry, changes in the lamina cribrosa, loss of neuroretinal rim, pallor, evidence of peripapillary atrophy,

vessel changes, or disc margin hemorrhage).

Exclusion Criteria: BCVA less than 0.7, refractive error 5 D sphere or 2.5 D cylinder or more, patients with congenital color vision defects, gonioscopic evidence of anterior chamber abnormality or closed /narrow angles, congenital glaucoma, secondary glaucoma, chronic ocular surface disease or inflammation, ocular media opacities (significant cataract determined by slit-lamp examination with dilated pupils), patients who had retinal and neurological diseases (E.g. history of stroke or other CNS disorder) or other systemic disease that could influence the visual field, patients who had evidence of retinal pathology like retinitis pigmentosa, diabetic or hypersensitive retinopathy, age related macular degeneration, serious eye disease, eye trauma, amblyopia, history of any ocular surgery, optic nerve disorder not attributable to glaucoma, abnormal pupil, patients taking drugs like Antihistamines, antidepressants, oral contraceptive pill or other medication that could affect visual field, pregnancy, inability to undergo a visual field test, mentally retarded, illiterate subjects, patients with low IQ to understand the test, uncooperative for visual field analysis, or not willing to fill informed consent sheet.

The participant eyes were divided into two groups: a Glaucoma-suspect group (31 eyes) and a Glaucomatous group (20 eyes). As all included subjects were familiar with SAP before commencing the study, every patient was briefed and instructed on Octopus Perimeter. We conducted two tests on each subject; first SAP (G pattern) using Goldmann size III stimulus then SWAP with a Goldmann size V stimulus using OCTOPUS 900 perimeter. Extensive rest periods were given within and between tests to minimize fatigue effects, the two testing sessions were separated by a 15-minute resting period and no single visit lasted more than 90 min. The reliability parameters, test duration and visual field global indices were compared between SAP and SWAP. The reliability of each visual field test was assessed, as both positive and negative catch trials < 25%, Those with a reliability factor exceeding 15% were considered unqualified field and were excluded. The W-W and SWAP visual fields were reviewed by one researcher experienced in visual field interpretation.

All statistical analyses were performed using IBM SPSS statistics (version 20.0, SPSS Inc., Chicago, Illinois, USA).

3. Results

The mean age was 56.03±5.9-year-old.

Table 1. *Age descriptive data of the study population.*

Age (year old)	Number	Ratio
45-50	6	20.70%
50-55	6	20.70%
55≤	17	58.60%
Total	31	100%

In the Glaucoma- suspect group, Mean Sensitivity (MS) was significantly higher in W-W than SWAP (W-W: 22.96±2.8db, SWAP: 17.57±3.7db; P: 0.0001). Mean Defect (MD) was significantly higher in SWAP (W-W: 4.19±2.2db, SWAP: 6.1±2.5db; P: 0.0001). Square Root of Loss of Variance (sLV) was also significantly higher in SWAP (W-W: 2.90±1.3db, SWAP: 5.26±2.1db; P: 0.0001). Reliability Factor (RF) was greater in SWAP but not statistically significant (W-W: 1.85±2.6%, SWAP: 2.73±4.1%; P: 0.07). Diffused Defect (DD) was significantly greater in SWAP (W-W: 3.04±1.3db, SWAP: 3.95±1.4db; 0.0001). Positive Catch Trials were higher in SWAP but not statistically important (W-W: 0.29±0.9%, SWAP: 1.74±5.4%; P: 0.1). Negative Catch Trials were significantly higher in SWAP (W-W: 2.51±4.1%, SWAP: 3.58±6.1%; P: 0.03). And Test Time was significantly longer in SWAP (W-W: 5.37±1.1 m, SWAP: 7.51±3.2 m; P: 0.0001).

In the Glaucomatous group, MS was significantly higher in W-W than SWAP (W-W: 15.1±4.1db, SWAP: 7.95±3.4db; P: 0.0001). MD was significantly higher in SWAP (W-W: 11.58±4.9db, SWAP: 14.23±4.1db; P: 0.0001). sLV was also significantly higher in SWAP (W-W: 6.21±0.3db, SWAP: 6.80±1.2db; P:0.04). RF was significantly greater in SWAP (W-W: 7.33±5.6%, SWAP: 10.09±5.3%; P: 0.02). DD was significantly greater in SWAP (W-W: 7.41±4.1db, SWAP: 12.52±2.3db; 0.0001). Positive Catch Trials were higher in SWAP but not statistically important (W-W: 3.80±5.09%, SWAP: 4.50±5.1%; P: 0.6). Negative Catch Trials were significantly higher in SWAP (W-W: 6±5.8%, SWAP: 10.6±8.3%; P: 0.01). And Test Time was significantly longer in SWAP (W-W: 6.28±1.5 m, SWAP: 8.62±4.1 m; P: 0.002).

Table 2. *The IOP descriptive data of the study population.*

Sample	IOP (Mean ± SD)	P- value
Suspected Eye	15.12±4.1	0.0001
Glaucomatous Eye	20.86±4.4	

Table 3. *The CD ratio descriptive data of the study population.*

Sample	CD Ratio (Mean ± SD)	P- value
Suspected Eye	0.31±0.07	0.0001
Glaucomatous Eye	0.67±0.1	

Table 4. *Results and reliabilities of W-W and SWAP in Glaucoma-suspect group.*

Suspected Eye	W-W	SWAP	P- Value
MS (db)	22.96±2.8	17.57±3.7	0.0001
MD (db)	4.19±2.2	6.1±2.5	0.0001
sLV (db)	2.90±1.3	5.26±2.1	0.0001
RF (%)	1.85±2.6	2.73±4.1	0.07
DD (db)	3.04±1.3	3.95±1.4	0.0001
+ Catch Trials (%)	0.29±0.9	1.74±5.4	0.1
Catch Trials (%)-	2.51±4.1	3.58±6.1	0.03
Test Time (m)	5.37±1.1	7.51±3.2	0.0001

Table 5. *Results and reliabilities of W-W and SWAP in Glaucomatous group.*

Glaucomatous Eye	W-W	SWAP	P- Value
MS (db)	15.1±4.1	7.95±3.4	0.0001
MD (db)	11.58±4.9	14.23±4.1	0.0001
sLV (db)	6.21±0.3	6.80±1.2	0.04
RF (%)	7.33±5.6	10.09±5.3	0.02
DD (db)	7.41±4.1	12.52±2.3	0.0001
+ Catch Trials (%)	3.80±5.09	4.50±5.1	0.6
Catch Trials (%)-	6±5.8	10.6±8.3	0.01
Test Time (m)	6.28±1.5	8.62±4.1	0.002

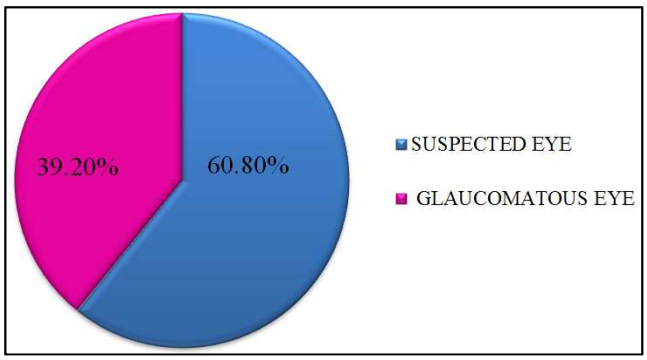

Figure 1. *Study population divided into two study groups.*

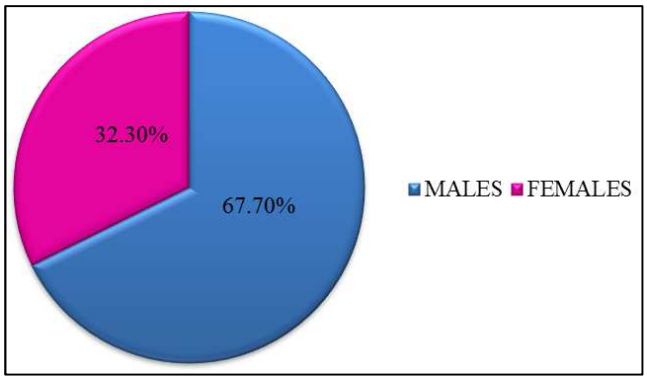

Figure 2. *The Male:Female prevalence of the study population.*

4. Discussion

For both Glaucoma-suspect group and Glaucomatous group, our data showed statistically significant differences in all visual field global indices between SWAP and SAP, in accordance with the studies of Su et al [1], Javed et al [2], Mohamed [4], and Balasubramanian [18]. Except for MS and DD which weren't included in those comparison studies as they used Humphrey Field Analyzer instead of Octopus 900 used in our study. Test time was longer in SWAP in both study groups, in accordance with Su et al [1] and Mohamed [4] studies. As for reliability parameters, we found statistically significant difference in Glaucomatous group, which disagrees with the studies of Su et al [1] and Javed et al [2]. That might be due to lack of experience in SWAP compared to SAP, in addition to the fact that, The prevalence of incorrect responses is modestly correlated with increasing severity of field loss rather that with increase in fatigue. We haven't found such difference in Glaucoma-suspect group because suspected eye was always tested second in the study, and this result goes in accordance with Su et al study [1], as well as, Javed et al study [2].

Patients with "seemingly normal" field on SAP, demonstrated new deficits using SWAP. And those with established deficits on SAP, showed deepening of these deficits with SWAP.

Some limitations of SWAP include the long time needed to conduct the test compared to SAP, ocular media absorption, and that it requires greater accommodation by patients. And with follow up we will experience greater variability and an additional learning effect.

5. Conclusion

SWAP is superior in detecting the early glaucomatous damage as compared to SAP. This applies to early glaucoma, ocular hypertension, glaucoma suspects and patients with progressive optic disc cupping and glaucomatous patients. In patient where SAP fields are normal in the presence in strong suspicion, we should proceed for SWAP, although this test needs greater cooperation from the patient.

SWAP is a valuable tool and a useful addition to an already available gold standard to detect glaucomatous damage in suspects without lens opacities and start the treatment to prevent irreversible vision loss [17, 18].

Further studies and longitudinal follow-ups are required to compare these two methods of perimetry with same stimulus size and intensity to support these findings and to confirm SWAP as an early indicator of glaucomatous damage.

Conflicts of Interest

There are no conflicts of interest.

Authors' Contributions

B. Bayerly did the literature review, gathered the study sample, conducted the tests, analyzed and interpreted the patients data, and studied the results. Then, wrote the manuscript. All this was done under the supervision of Y. Suleiman and K. Jalloul. All authors read and approved the final manuscript.

Registration

The study was conducted in accordance with the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects after the nature and possible consequences of the procedure had been fully explained to them, and the Ethics Committee of the Faculty of Medicine in Tishreen University approved the study on December 15th 2020.

List of Abbreviations

B-Y	Blue on Yellow Perimetry
CD	Cup to Disc Ratio
Db	Decibel
IOP	Intraocular Pressure
MD	Mean Defect
MS	Mean Sensitivity
GON	Glaucomatous Optic Neuropathy
POAG	Primary Open Angle Glaucoma
SAP	Standard Automated Perimetry
SWAP	Short Wavelength Automated Perimetry
W-W	White on White Perimetry

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