www.jmscr.igmpublication.org
Impact Factor (SJIF): 6.379
Index Copernicus Value: 79.54
ISSN (e)-2347-176x ISSN (p) 2455-0450
crossrefDOI: https://dx.doi.org/10.18535/jmscr/v6i9.112

IGM Publication
Journal Of Medical Science And Clinical Research
An Official Publication Of IGM Publication

A Novel Method of measuring metamorphopsia in macular diseases using computerised D charts

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Abstract
Purpose: *This study examines the ability of the computerised D chart to detect and quantify metamorphosis in different macular disorders and compare the results with other clinical measurements such as visual acuity, Amsler chart and Optical Coherence Tomography (OCT).*
Methodology: *A software version of D charts uses octagonal grids with varying eccentricities from 0.5 to 12 degrees from fixation. Subjects do fixation by focussing at the centre of the D-charts and locate the area of distortion by touching the screen. The sector was highlighted by a blue line and later the software determines MScore, Mtotal, Marea for each ring. D Chart measures were undertaken on 30 subjects and the results were compared to LogMAR visual acuity, Amsler chart and OCT.*
Results: *Computerised D-Chart is easy to use and there was no correlation between MScore and VA, MScore and CSF ($p>0.05$). There was a correlation between MScore and Amsler. ($r=0.806$ $p=0.000163$). Both cases showed similarities in the structural and functional details of metamorphopsia.*
Conclusion: *D charts allowed quantification of metamorphopsia in macular disease patients with variable visual acuities. It is one of the most important diagnostic tools to map distortion and central field loss and may be helpful in assessing ongoing macular diseases.*

Introduction

Ugarte et al defines metamorphopsia is a visual disturbance in which straight lines appear distorted due to the displacement of photoreceptors and/or visual cortex reorganisation and perceptual adjustment following disruption of sensory input from the retina in macular diseases.

Wiecek et al mentions that distortion results due to structural changes in the retina which leads to displacement of the retinal layers and leads to spatial distortion. Different types of maculopathy have different types of metamorphopsia such as micropsia, macropsia, diffuse and translucid scotoma. Amsler literature also has emphasised the importance of metamorphopsia and central translucid scotoma as hallmark functional symptoms in patients with macular diseases. Due to this, in everyday life, patients find difficulties with reading, cooking, watching television and driving, which signifies that this is an extremely disabling condition apart from vision-related quality of life issues such as walking difficulties, social distress and inconvenience of daily living.

It is very essential to measure metamorphopsia because a visual acuity of 6/6 does not mean that there is no visual pathology. The qualitative disturbance of vision may escape quantitative measurements. Furthermore, a distortion or a central vision loss precedes an evident organic lesion and the functional disturbances caused are

usually reversible. For any macular pathology, it serves as a sensitive guide. Traditionally it has been argued that there are different methods for measurements of metamorphopsia, eg. M charts, PHP, etc, both qualitative and quantitative, but these measurements both have their own flaws. (Fig. 1)

The present research was done to identify the qualitative changes in metamorphosia and central vision loss and thereby help patients across the globe apart from giving emphasis to metamorphopsia studies. Thus, this study will aim to work on the limitations identified in previous literatures. Moreover, the aim of our study is to quantify metamorphopsia in macular diseases using the software version of D charts. As computerised D charts are simple, straightforward and economical method of detecting and monitoring changes in central visual fields.

In our study, we did quantify metamorphopsia in a group of patients with retinal diseases using computerised D charts and compare the results with other clinical measurements such as visual acuity, Amsler Chart and OCT. We hypothesize, Mscore is correlated with VA, Amsler and OCT. Alternatively, Mscore is not correlated with aforesaid variables. Furthermore, in our study, we did structural and functional correlation too.

Method

This was a prospective pilot study done on variety of macular diseases patients attending clinics in Glasgow and Mumbai Reina Centre by using standard examination technique (Video 2) and patients were fully corrected for 40 cm viewing. Further tests comprising of history, visual acuity (Log MAR) and full ocular refraction was measured monocular with EDTRS Chart. Amsler chart was recorded monocular in all subjects (Fully corrected) at 40 cm. In the Amsler chart, test subjects were asked to draw the area of distortion and scotomas and was later calculated in percentage. Fundus assessment using direct and indirect Ophthalmoscope, FFA and OCT examinations were carried out.

Eight subjects (70-90 years) from GCU eye clinic with macular disease were tested using both by Amsler chart and computerised D Charts apart from detail ophthalmic examinations. The patients all had visual acuity of LogMAR < 0.0. Amsler scoring was calculated in percentage of total area and had to be verified to have metamorphopsia.

In Experiment 1 eyes of 24 macular diseases patients (11 women, mean age, 57 +/- SD 17.18 years; range, 20-76) and 17 men, mean age 57 +/- SD 17.18 years; range (20-76) were studied.

Table 1: Data sheet of patients from Mumbai Retina Centre.

VA(LogMar)		Amslers		M score		Wt M Score	Wt M Score	CSF (um)	CSF (um)
OD	OS	OD	OS	OD	OS	OD	OS	OD	OS
1	1	(-)	+	4.8	7.2	4.8	7.2	252	
0	1	(-)	+	0	22.5	0	5.523	333	253
		+	+	0	41.6	0	21.144	254	575
0.2	1	(-)	+	6.4	0	3.064	0	223	
0.3	0	(-)	+					360/468	
		+	+	4	0	26	0	487	348
0	0.3	(-)	+	0	0	0	0	386	335
		+	+					301	
0.2	0			0	0	0	0	49	
0.5	0			0	14.4	0	11.88		
1	2.00P			8	1.2	0.216	0.616		
0.2	0.4	(-)	+					308	290
0	0			1.5	0	0.77	0		
0.2	0.3	(-)	+	0	7.2	0	5.511	254	325
0.2	0.3	(-)	+	0	0	0	0	263	
0	2.00 P	+	+	0	1.2	0	1.06		
0.5	0.3	+	+	0	0	0	0		
		+	+	3	0	1.35	0	440	
		+	+	11.4	0	4.702	0		
0.5	3.00			2.6	6.3	2.2920001	2.463	255	
				0	0	0	0	230	240
0.3	0.3	(+)	+	0	0	4.8	0	326	265
0.3	0.3	+	+	6	0	6	0		
0	2.00P	+	+	0	7	0	2.503		
0.33333	0.34666657								
0.33255	0.36813559			17.00447					
OD:Average/Mean	0.3+/-0.3logMAR			57					
OS:0.4+/-0.4logMAR				17.7799					

Table 1 shows the clinical details of total 24 patients (Number of eyes: 24, Male/Female: 12/12, Age (years): 57+/-17.80 (20- 76), Log MAR BCVA: 0.54+/-0.59, Metamorphopsia score: 3.01 +/-5.05, CSF (µm): 303.04+/-102.59) presented with complaints of distortion to Mumbai Retina Clinic. All the patients completed software version of D test and underwent aforesaid tests. The OCT enhanced resolution with the intraretinal architectural morphology details were viewed (Kroyer et al., 2008).

With SPSS version 22 software (IBM, Armonk, New York, USA) statistical analysis were performed. The comparison of mean scores and calculation of SD for each parameter of the visual function and OCT measurements BCVA, measured using the LogMAR Chart, Kolmogorov - Smirnov and Shapiro-Wilk test for MScore – VA, MScore-Amslers and MScore-CSF was done for checking normality. For all the test significance level was 0.05. All tests of association were considered statistically significant if p less than 0.05. As the asumptions of Sperman's correlation was fulfilled in all the experiments so the nonparametric statistics were applied where key outcomes were found not to demonstrate a normal distribution. The association between the severity of metamorphopsia Log MAR BCVA, Amsler and OCT parameter were examined by the Spearman's rank correlation analysis (Okamoto et al, 2012; Lund Research Ltd, 2015). For the correlation between aforesaid variables best way to view the data is by scatter plots whereby to get an insight into a possible relationship amongst variables. Significance of Correlation Coefficient was performed using VassarStats.

Results

1 Experiment 1 Comparison of M Score with Visual Acuity (LogMAR)

D Chart results were compared to Log MAR visual acuity measured at 6m using standard clinical techniques (image 2).

2 Experiment 2 Comparisons of M Score with Amsler Chart

Eight subjects (70-90) years with macular disease were tested using both Amsler chart and computerised D Charts. The patients all had visual acuity of logMAR < 0.00. Amsler scoring was calculated in percentage of total area (image 3).

3 Experiment 3 Comparison of MScore with CSF

Patients from Mumbai were tested using both CSF macular map OCT scan and computerized D charts (image 4).

The research also corroborate the idea of Bae et al of using different methods of quantification of metamorphopsia which was reflected by a change in Mscore value and change in 2D map. From our OCT and D chart case report's findings of RE CNVM and BE DMO patients it was obvious to notice some short of structural and functional correlations amongst two (image 5).

In our aforesaid cases, these findings were depicted in the macular grid of OCT as thickness changes in the central, inner and outer rings calculated in terms of degrees. The compute-rised D chart showed an area of 2 D heat maps in rings in degrees. These two findings showed an approximate association (image/6).

Figure- 1 Different methods of metamorphopsia

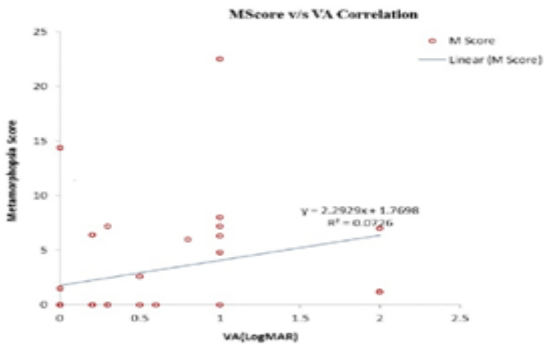

Figure – 2 A Spearman's rank order correlation showed the relationship to be monotonic. No correlation (r =0.270, p = 0.135, Spearman's rank

coefficient). The linear regression line is y = 2.2929x +1.7698 (r2=0.0726, P=0.135). So we accept the null hypothesis.

Video-2

http://www.journalonweb.com/tempaccess/45297.02.IJO_811_18I42620.mp4

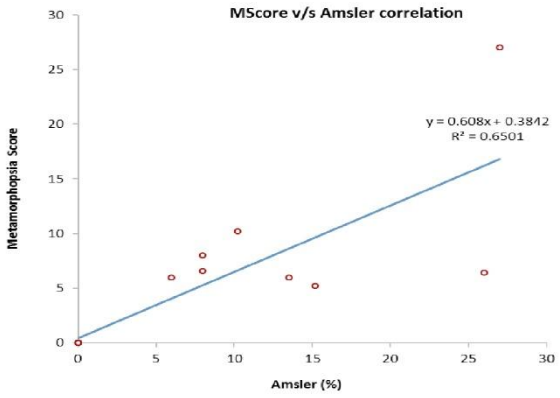

Figure- 3 A Spearman's rank order correlation showed the relationship to be monotonic. Our statistical analysis revealed that there was some extent correlation (t = 5.095, N = 16, r = 0.806, df = 14, p = 0.000169). (open circle). The linear regression line is y = 0.608x+0.3842 (r2=0.6501, P = 0.000169).

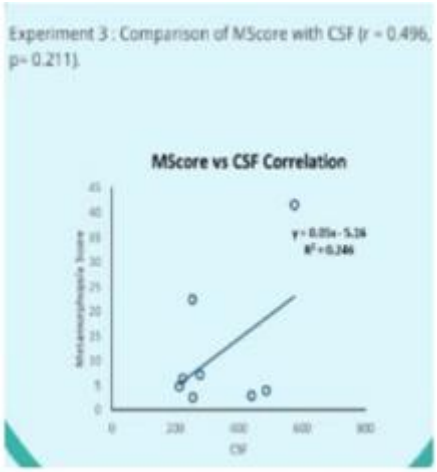

Figure-4 A Spearman's rank order correlation showed the relationship to be monotonic. Our statistical analysis revealed that there was no correlation (r = 0.496, p= 0.211, Spearman's rank coefficient) The linear regression line is y = 0.049x – 5.1652 (r2=0.2458, P=0.211, Spearman's rank coefficient).

Figure 5 : Comparison of OCT findings and D Chart results in a patient of Choroidal Neovascular Membrane. (a) 5-line raster line scan show The presence of an irregularly shaped PED with adjacent subretinal fluid, circular or basal laminar drusen, abnormal neovascular tissue underneath the RPE (b) The OD macular grid, CSF =281 which less than 288 µm. The inner inferior region shows thickness abnormality i.e. 349 µm (Normal: 288 µm) i.e. as per normative data, this is abnormal distribution and inner, middle and outer rings corresponds to 2.6, 7.8,15 degrees (c) : D chart of CNVM patient taken post anti VEGF and Eylea treatment. A software version of D chart measurement of a bilateral CNVM patient is shown in Figure 22 where the (RE) M-score was 2.6 (weighted score 29.25) with a small amount of residual distortion at inferior 7-12 degrees.

Figure-5 From our OCT and D chart case report's findings of RE CNVM patients it was obvious to notice some short of structural and functional correlations amongst two. These findings were depicted in the macular grid of OCT as thickness changes in the central, inner and outer rings calculated in terms of degrees. The computerised D chart showed an area of 2 D heat maps in rings in degrees. These two findings showed an approximate association.

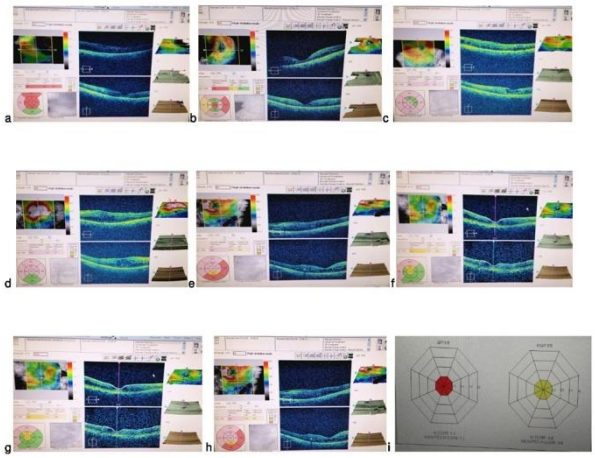

Figure 3 : Metamorphopsia in a patient of Diabetic Macular Oedema (a) OD OCT of DMO patient on 1st follow up b) OS OCT of DMO on 1st follow up (c)OD OCT on 2nd follow up (d)OS OCT on 2nd follow up (e)OD OCT on 3rd follow up (f) OS OCT on 3rd follow up (g) OD OCT on follow up (h) OS OCT on follow up (i)OU Computerised D chart of DMO and plots reflect the distortion and field loss i.e (RE) M-score was 4.8 (weighted score 4.8) with a central foveal fields distortion at 0-1.5 degrees. The (LE) M-score was 7.2 (weighted score 7.2) with foveal fields distortion at 0 -1.5 degrees. Further to this, the D Chart provided additional information about the magnitude of foveal and parafoveal fields loss.

Figure-6 OCT and D chart case reports findings of BE DMO patients it was obvious to notice some short of structural and functional correlations amongst two.

Discussion

In our first experiment, the D chart results and VA do not correlate very well because VA is for resolution and not for distortion whereas Mscore is for metamorphopsia and metamorphopsia seems to be independent of VA. The vast majority of MScore values were not following the trend line. There were lots of people with MScore 0

and 2 outliers. According to researchers the probable speculation being tractional force damaging and stretching INL, leads to damage to cellular components such as horizontal, bipolar, amacrine and muller cells which in turn leads to disturbances in N-M junction transmission and lowering of photoreceptors sensitivity. Moreover, the fact of VA and Mscore being not fully correlated is, VA is a measure of central vision whereas the D Chart can score in areas across the retina. Bae and Chae studies did show that M charts could detect metamorphopsia, could be used for screening metamorphopsia in CSC patients. However, even their research could not detect any relationship between MScore and BCVA.

In our second experiment, the D Chart results correlate a bit better with Amsler but it is not a perfect correlation because R2= 0.650 which indicates a good strong positive correlation. Both the tests measure metamorphopsia, D charts in degrees and Amslers in percentile forms. Mscore values were better predictor at lower values of Amsler percentage. As, Mscore values increase there was more variability in Amsler percentage. Strang studies have shown D charts is a quantitative test which detects not only metamorphopsia but the magnitude of metamorphopsia whereas Amslers is a qualitative test with low specificity and can detect only metamorphopsia and other clinical tests have got limitations and do not always provide reliable and accurate mappings of visual distortion within the central visual field. Further, the sample size was small and there were outliers too. Looking qualitatively, they fall the same eccentricity. The Amsler is only recorded as the % area affected, whereas D Chart also takes into account the density of the meta/field loss in each area.

In our third experiment, there was no correlation between D-Charts and CSF probably R2 value was not great (0.246). It appears that there was a correlation between 2 variables but statistically not significant due to small sample size apart from the presence of outliers. The variables were directly proportional i.e as CSF increases MScore value also increases. The clinical cases on (RE) CNVM and (BE) DMO showed the thicknesses in the macular grid of OCT in degrees (Structural change) were corresponding with the software version of D chart rings in degrees (Functional change) which were later calculated as MScore. Thus, there is a structural and functional correlation.

The various pathophysiological mechanism for metamorphopsia is deformation of the foveal pit or uneven focal retinal thickening.

There are previous reports by Mc Gowan et al on metamorphopsia scores with D chart of patients showing D charts are the simple, fast, easy and cheap examination for the quantification of metamorphopsia, magnitude of central field loss in macular diseases patients, for monitoring the changes following treatment. It also assists Ophthalmologist with additional information about the impact of vision loss on patients. Our literature search revealed a very limited & little information on a novel test of computerised D chart for quantification of metamorphopsia. Thus, the present study for the very first time designed in search of our research question on Asian patients.

The experiment 1 results further support the idea of Yorston et al and confirm no association between VA and MScore. It is also in line with previous studies done such as the research conducted by Strang who aimed at utilisation of D charts for quantification of the metamorphopsia in macular diseases patients.

In our 2nd experiment, we found a strong correlation between Amsler and MScore . A very little was found in the literature except in Yorston et al on the question of correlation between Amsler and Mscore ($r = 0.805$, $p= 0.000169$). i.e there was a good correlation but not perfect. owever, D chart provided additional information about the magnitude of distortion in different areas of the central visual field which was synonymous with our correlational analysis. These results are in agreement with Strang

findings, but differing from Matsumoto study possibly, m e tamorphopsia is not a symptom but it has numerous types of modules. Further in metamorphopsia, there are a number of frequency components of distortion. Its detection and measurements involve a top down information in addition to knowledge pertaining to the scene and to the cortical reorganization. These findings may be somewhat limited due to a specificity of Amsler testing method. This observation may support the hypothesis that there is a correlation between Mscore and Amslers. The D chart test was successful as it was able to identify our research question.

Our study's the third research question was to rule out whether there is any association between CSF thickness and Mscore and found no correlation.

Ooto et al and other reports have shown the structural abnormalities could be better appreciated with O C T. It also supports the previous research done by Bae et al and Dell'Omo and Mura, and an idea of Nowomiejska et al and Krasnicki et al study revealed no relationship between the degree of metamorphopsia and CRT, except for VA in patients with macular diseases. However, our study is similar to Watanabe et al and this is the first ever study done to rule out a correlation between CSF with Mscore using computerised D charts.

It can be argued that the reliable results in our study were because of use of computerised D chart by an expert Ophthalmologist. These findings might help us to understand (CSF & Mscore) foveal thickness in retinal diseases which is responsible for the quality of vision i.e solve the problem of metamorphopsia, micropsia and macropsia symptoms which were experienced by patients even following medical or surgical treatment. This, in turn, helps Ophthalmologist to solve the patient problem of vision due to a functional loss i.e vision-related quality of life. It provided further support for our hypothesis and the aim of our research. This has got an important implication for ruling out subtle abnormalities occurring in cases of unexplained metamorphopsia in eyes of patients not showing any gross OCT abnormalities / in the macula after treatment. To our knowledge, the test was successful at it was able to quantify metamorphopsia and rule out structural changes by using OCT and functional loss by using D chart. Thus it is an important issue for future research, and despite these promising results, questions remain.

Thus, computerised D chart is easy, quick, functional test which keeps the record of patients' real complaints i.e. metamorphopsia etc. the vision-related quality of life, monitor if changes following the treatment plan and still do the better management of patients whereas OCT findings explain only structural changes whereby Ophthalmologist can do good diagnosis and able to manage patients too.

During our study, we did encounter limitations namely small sample size, a very short period of study, ethnic population.

In my opinion, a further research which takes these variables into account, quantifying metamorphopsia in macular diseases of developing countries especially Asian countries patients, by using the retinal display iPad D chart on larger data is a need of an hour.

Conclusion

The present D chart study will be of great benefit to patients in order to gain &/or stabilise vision, both qualitatively and quantitatively.

It can be concluded that quantitative evaluation of metamorphopsia seems as an essential step in quantifying visual function in patients with macular disorders.

In this first ever research project on Indian and European patients using computerised D charts we were able to investigate not only quantification of metamorhopsia but also area and magnitude of metamorphopsia in order to early diagnose and prevent the rising epidemics of macular diseases in developing countries in

addition to increased prevalence of such diseases in affluent countries.

Our research findings do make several contributions to the several literatures of metamorphopsia showing limitations in earlier studies of Yorston et al, Strang, Rossetti et al, Van et al, Manabe et al, and able to confirm the findings reported by Gowan et al in their studies. As the idea is new and evolving, it would be worthwhile to compare experiences of researchers from developed countries. Additionally, the further early evaluation of metamorphopsia by using iPad with the retina display will be added benefit

For the same, unless the government adopts this concept of research, the goal of V2020 will not be attained and the problem of blindness will not be prevented.

Thus ensuring appropriate systems, services and support for the implementation of computerised D charts in clinical practice should be a top priority.

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