IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Special Issue-18, May 2019 E-ISSN: 2347-2693

Matlab mapping of full field peripheral refraction profile with multifocal contact lenses in myopes

K Mitra[1*], V Ramasubramanian[2]

[1] Department of Health Science, Bachelor in Optometry, Pailan College of Management & Technology, Kolkata, India
[2] The College of Optometry, University of Houston, Houston, Texas

Corresponding Author: gkriti105@gmail.com

Available online at: www.ijcseonline.org

Abstract— *Purpose*: MFCLs have been a better choice for myopia control followed by Ortho K lenses presumably by inducing a relative peripheral myopia. The study was done in emmetropes and myopes to assess the peripheral refraction (PR) profile at all possible eccentricities to have a better understanding of myopia control with the help of MATLAB.
Methods: 5 emmetropes and 18 myopic adults of age 18-30 years with -0.50 to -6.00 D spherical component and less than 1.00 D astigmatism were fitted with commercially available center near multifocal soft contact lenses with low and high add. Center and peripheral refraction were measured under cyclopleigia at all possible eccentricities ranging from 0-180, 90-270, 30-210, 60-240, 120-300, 150-330 under four conditions: baseline (No lens wear); single vision spherical(SVCL); MFCL low add and MFCL high add by using Grand-Seiko WAM 5500 autorefractor with the help of MATLAB programming. Measurements are taken in Single Click Mode and High Speed Mode. Results are interpreted as a change in relative PR profile as refractive power vector components; M, J_0 and J_{45} and analysed using a separate MATLAB program.
Results: The results show statistically significant differences ($p<0.05$) between each condition for means of High speed mode and M value in each meridian. MFH showed a myopic defocus nasally but temporally there was hyperopic defocus.
Conclusion: In comparison to high add, center near multifocal low add showed a more myopic periphery both temporally and nasally in young myopes.

Keywords*:* Peripheral refraction, Relative peripheral defocus, Myopia control, Multifocal contact lens

I. INTRODUCTION

Studies done on animal models shows that peripheral optical errors has amajor role inthe development of myopia.Evidence for emmetropization in animals with severed optic nerves suggests that emmetropization is primarily controlled at the retinal level. But the higher levels of the visual system play a significant role in refining the process though there is no similar study done in humans.[1-5]Prolate retinal shape is considered to be one of the major cause of myopia progression.In recent years, optical factors, such as relative peripheral hyperopic defocus and the greater accommodative lag found in myopic eyes, have been linked to axial growth of the eye and, thus, myopia development.Atchinson et al. observed that peripheral refraction is more hyperopic in myopes than emmetropes in the horizontal meridian.[6-8]
Peripheral refraction can be measured by BHVI Eye Mapper, Shin-Nippon open view autorefractor and an open field WAM-5500 auto refractometer. BHVI Eye Mapper based on Hartmann Shack principle is known for its great speed for measuring peripheral refraction. Refraction data can be calculated from wavefront aberrations and quantified using the three refractive power vectors:

- M (spherical equivalent),
- J180 (with-/ against-the-rule astigmatism)
- J45 (oblique astigmatism).

SE= Spherical +Cylinder/2J 180= -(Cyl)/2 *Cos 2(Axis)
J 45 = -(Cyl)/2 * Sin 2(Axis)[25]

The Grand Seiko WAM-5500 autorefractometer can be used as a screening method of over-refraction in the clinical fitting of contact lenses and it is also used extensively for measuring peripheral refraction. In the same way measurements can be quantified using the three refractive power vectors.[26]

II. OBJECTIVES

The main objective of the study is to determine the effect of full field peripheral refraction with multifocal contact lenses in myopes.

III. REVIEW OF LITERATURE

In recent years, optical factors, such as relative peripheral hyperopic defocus and the greater accommodative lag found in myopic eyes, have been linked to axial growth of the eye and, thus, myopia development.Atchinson et al. observed that peripheral refraction is more hyperopic in myopes than emmetropes in the horizontal meridian.[6-8]

A study was done to compare the peripheral optical effect of single vision and center distance multifocal contact lenses (MFCLs). It measured peripheral refraction of MFCLs in the horizontal meridian for low and moderate myopes. Peripheral refraction was relatively hyperopic compared with center at 30 and 35 degrees in the temporal visual field (VF) in low myopes, and at 30 and 35 degrees in the temporal VF, and 10, 30, and 35 degrees in the nasal VF in moderate myopes.MFCL correction resulted in a relative myopic shift in peripheral refraction compared with SVCL correction which explained recent reports of reduced myopia progression rates with MFCL correction.[22]

A study measured changes in peripheral refractive error and axial length followed for 1 year in young adults. Higher myopes showed a relatively peripheral hyperopic shift which increased with increasing myopia though there was no significant axial length changes. The study probably reconfirmed presence of a relative hyperopic shift at the periphery for myopes.[24]

Contact lenses are an ideal way to deliver myopic defocus 360° in the periphery because the lens stays relatively centered with eye movements. A study was done to find the potential of commercial center distance multifocal contact lenses in controlling myopia by using Grand-Seiko WAM 5500 auto-refractometer. It concluded that commercially available dominant design MFCLs induced a significant change in relative peripheral refractive error (RPRE). Higher add MFCLs (+3.00D) showed a greater effect than lower add ones (+2.00D) although an increase in 1D of power did not correspond to the same amount of change in RPRE.[28 29]

The growing incidence of pediatric myopia worldwide has generated strong scientific interest in understanding factors leading to myopia development and progression. Overall, orthokeratology and soft multifocal CLs have shown the most consistent performance for myopia control with the least side effects.[30]

A peer reviewed article showed that Orthokeratology, multifocal soft CL, and custom designed RGP CL were able to generate a significant relative peripheral myopia in myopic eyes. Conversely, standard and experimental soft CL were not able to induce significant peripheral myopic and astigmatic defocus values.[31]

A network meta-analysis study intervened refractive error changes and changes in axial length followed for 1 year for 16 different interventions to control myopia progression. The results showed the leading intervention being high dose atropine to moderate dose atropine followed by low dose markedly slowed myopia progression. Pirenzipine, orthokeratology, and peripheral defocus modifying contact lenses showed moderate effects.[32]

A study intervened 6 different conditions, two designs of multifocal contact lenses(center distance and center near) with high add and low add, one monofocal contact lens. Peripheral refraction was measured in +-40 degree horizontal meridian in four subjects. The results showed that center distance multifocal soft contact lenses gave a very small peripheral myopic shift in these four subjects. It concluded that they would need a larger optical zone and a more controlled depth of field to explain a possible treatment effect on myopia progression.[32]

Lot of peripheral refraction studies has been done to explore the horizontal meridian, very few the vertical meridian as well, but always the oblique meridians are spared. Thus, we wanted to intervene all possible eccentricities, the aim of the study being to plot a full field peripheral refraction profile in myopes so that we can probably have a clear understanding about the effect at different eccentricities which might help in understanding myopia control in future

IV. METHODOLOGY

A cross sectional study was conducted for 1 year in Lotus College of Optometry and Eye Hospital, Juhu Mumbai
on 18 to 30 years old young adults having mild to moderate myopia with minimal astigmatism who are compatible to wear contact lenses and does not have any ocular or lid anomalies.
The study was done in Grand Seiko WAM -5500 open field auto refractor

A target of LED lights consisting of 69 lights was used
A similar protocol was followed for all the subjects; emmetropes and myopes. A detailed history of systemic illness, allergy to any ocular drugs was noted. Subjects having allergy to cyclopentolate drops are excluded. The subject is then well explained about the whole procedure and his/her right eye is chosen.

An informed written consent (see appendix) was signed by the patient. One drop of Cyclopentolate Hydrochloride 1% was instilled in the right eye. The subject was asked to close his eyes for few minutes. A second drop was administered after 15 minutes and the subject was asked to keep eye closed for few minutes again. A total of 45 minutes was the waiting time after the instillation of the first drop before starting the experiment.

The subject's pupil reactions were seen to check for complete mydriasis. If no reaction was observed and the subject is unable to read N6 target in the Near Vision test chart at about 40 cm, then the experiment is started. Otherwise, a further drop was instilled and pupillary reaction was checked again after 10 minutes.
The subject was then made to sit in a position where the target was set up for measuring peripheral refraction. The target consists of 1 central point of fixation and 68 peripheral points.

Construction of the Target
A graphical representation of the target was made before actual construction. Six different meridians were taken 0-180, 30-210, 60-240, 90-270, 120-300, and 150-330 with a difference in eccentricity being 2.5 to 5 degree. The fixation points were distributed in a symmetrical pattern in all the six meridians. The points were spread such that they would cover most of the periphery with no large spaces without a data point. Some data points near the center were eliminated to avoid crowding of data points. The spacing from the center point was calculated as follows -

Tan (ø) x 150 cm = z(cm), where ø = eccentricity(°) and z = distance from center

Table 1

Eccentricity	Distance from center in cm
0.00	0
2.5	6.55
5.0	13.13
7.5	19.76
10.0	26.46
12.5	33.27
15	40.21
17.5	47.32
20.0	54.62
22.5	62.16
25.0	69.98
27.5	78.12
30.0	86.64

The target was constructed on a Hard Board measuring 6ft by 4ft.Then all the points were marked on the hard board as per the measured eccentricities in all the 6 meridians. The measurements were rechecked for error and then a 0.5cm holes were drilled at each point. Next, black cloth was stuck on the boards with glue to maintain a uniform black background on the target. Then a sequence of light emitting diodes (LED) connected in series was pushed in from behind the 0.5cm holes and glued. After this the board was mounted with hooks and rope on the wall and an electricity source was arranged.

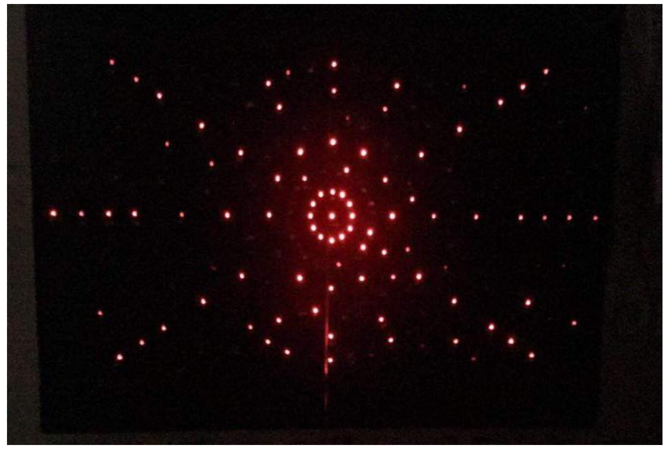


Fig.1. Target LED

The target appeared as shown in Figure 1 when all the sequences are lit up at the same time. Total 69 points were there. All the LEDs were covered with black tape.
Each LED was given a unique 6 digit code to be able to identify it. The code was formed as such – the first 3 digits of the six digits was the amount of eccentricity and the next three digits were the axis on which the point lies. For example, if the point was numbered '150030' then 150 would mean 15.0 degree eccentric and 030 would mean the 30° axis. The points were labelled with their unique numbers according to the six digit code.

- *Subjects, contact lens and measurements*
  Peripheral Refraction in Myopes
  Multifocal soft contact lenses, centre near design (Clariti multifocal) are chosen according to the spherical equivalent of the subjective refraction of the patient's right eye.
  The contact lenses have a centre thickness of 0.07mm, a low modulus of 0.5 and a Dk/t of 86.
  Two add powers are chosen, high add and low add.
  The patient's right eye is cyclopleiged with a cyclopleiging eye drop. There are 4 conditions of measurement –
- Baseline or No Lens wear
- Spherical soft contact lens
- Multifocal Low Add
- Multifocal High Add
  Peripheral refraction is measured with no lens wear. Choice of contact lens selection is done with the help of research randomizer to avoid bias. According to research randomizer, contact lens is chosen and put on patient's right eye. Contact lens fitting assessment is done in slit

lamp biomicroscope. After adequate adaptive time, measurement of peripheral refraction is taken with Grand Seiko WAM 5500 autorefractometer. The same way measurement is taken with all other soft contact lenses on the same day.

Peripheral Refraction in Emmetropes

Measurement is taken as baseline No lens wear, and separately with multifocal high add and multifocal low add contact lenses in a similar way.

- *Alignment of the subjects to WAM*

The height (vertical) and the horizontal placement of the WAM was adjusted such that the small infra-red ring of light from WAM exactly surrounds the central illuminated LED. The extreme LED in the 4 directions 2 horizontally and 2 vertically are visible through the machines binocular open view window. Once the machine has been adjusted according to the subject and the subject is seated comfortably with the head on head rest and the chin on chin rest, the head is fixed into the place with a head strap that restricts the subjects head movements and allows only for eye movements for different fixation.

Working of MATLAB program

Two types of readings 1) High Speed Mode (spherical equivalent readings for 5secs for each point) and 2) Single click mode (sphere, cylinder and axis values a minimum of 3 readings for each point). The subject fixates on one LED at a time. All the data would get saved as matlab files (.mat)

The two types of readings are taken and saved on the laptop. The subject is allowed to take one break after each condition. Contact lens fit is evaluated in Slit lamp.

Post which the alignment procedure is repeated to make sure the centration remain the same.

At the end of the procedure, when all the 69 points data is collected for each of the conditions all the data is checked and the experiment is concluded.

The information collected is later used to plot full field peripheral refraction profile of the patient.

At each point of fixation there is a small 5mm red light emitting diode (LED) which glows when the subject is asked to fixate. The distance between the subject's eye and the point of fixation was 1.50 meters. As all LED's are covered with black tape except for the one that the subject is asked to fixate. It causes no distraction for the subject while fixating. The program used for data collection and saving of data was written using Matlab codes.

The program featured a graphic user interface (GUI) that is semi-automated

Table 2 Patients' Demographic Data

Subjects	**Age (years)**	**MSE (D)**	**Astigmatism (D)**
Emmetropia (n = 5)	20.5 ± 0.90 Range: 20 to 24	-0.08 ± 0.12 Range: -0.25 to 0.00	-0.05 ± 0.16 Range: -0.50 to 0.00
Myopia (n = 18)	20.33 ±1.78 Range: 18 to 24	-2.35 ±6.34 Range: -5.50 to -0.50	-0.65 ± 0.63 Range: -1.00 to 0.00

Data collection

MATLAB Programming

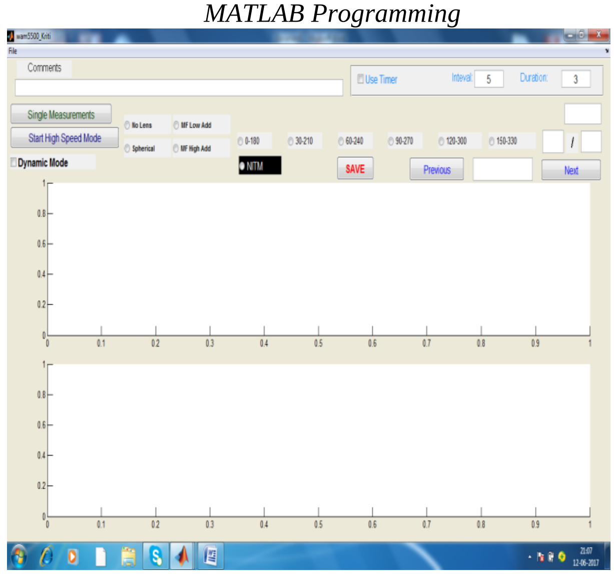


Fig. 2. Matlab measurement template

Measurements are taken in 2 modes –

1. High Speed Mode: It is the spherical equivalent of spherical and cylindrical component which runs continuous at a stretch for 5 seconds. Data gets saved in mat. files.
2. Single-click Mode: It takes measurement separately in spherical, cylinder and axis and power vectors J45 (sin component) and J180 (cos component).

Measurement Template

- Matlab measurement template consists of 4 conditions which can be selected separately
- After selecting a particular condition, the particular meridian needs to be selected

- Measurement begins automatically once we click on Start High Speed Mode button
- High speed mode runs continuously for 5 seconds and takes measurement of peripheral refraction on each point of eccentricity
- After high speed mode, single click measurements are taken for the same point
- Data gets saved automatically in mat. files
- Measurement is taken for all eccentricities in each meridian
- The same procedure is repeated for all four conditions; NOL(No lens wear), MFL(Multifocal low add), MFH(Multifocal high add) and SPH(Spherical lens)

Data Extraction

- Data extraction from matlab is done by a separate matlab program
- Data from each meridian (0-180, 30-210, 60-240, 90-270, 120-300, 150-330)separately for each conditions is extracted in excel of each myope
- Data in matlab comes upto 15 decimal points

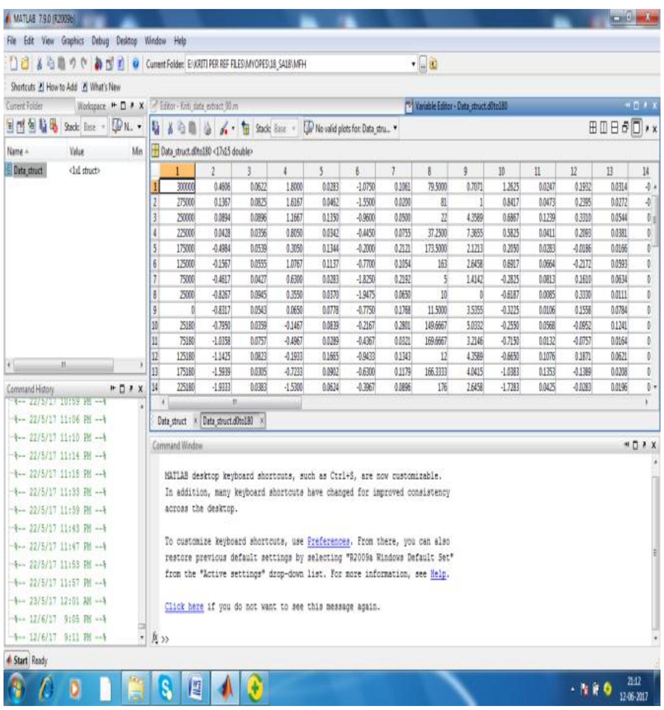
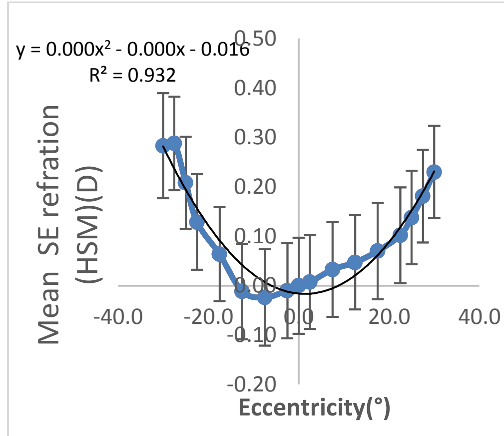


Fig. 3. *Extracted data from matlab for 0-180 meridian for 1 myope*

Observations

Profile of multifocal high add and low add in myopes



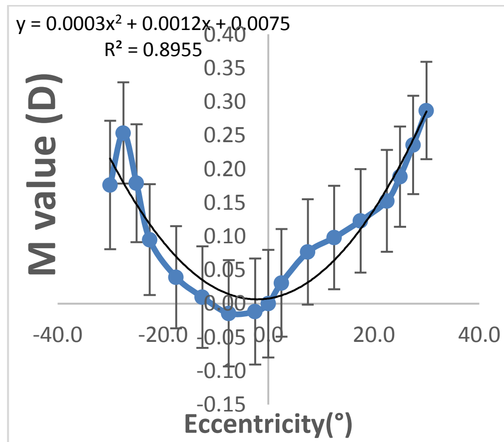
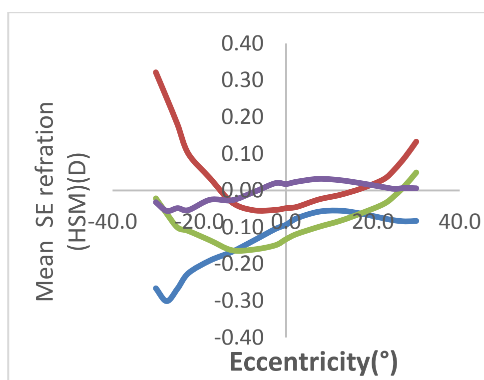
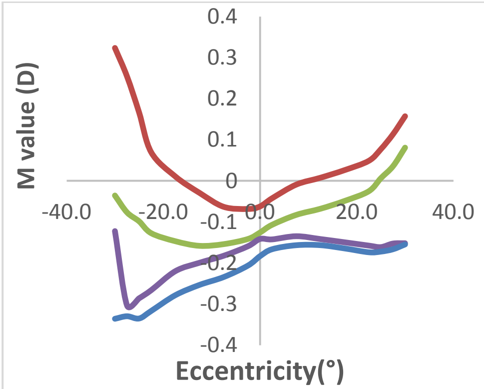


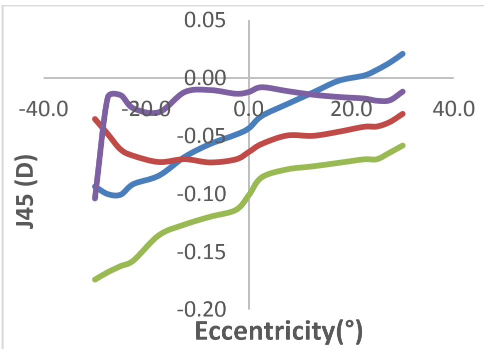
Table 2: Average Mean SE refraction of HSM, M value, J45, and J180 in horizontal meridian of Multifocal Low Add soft lenses of all myopes

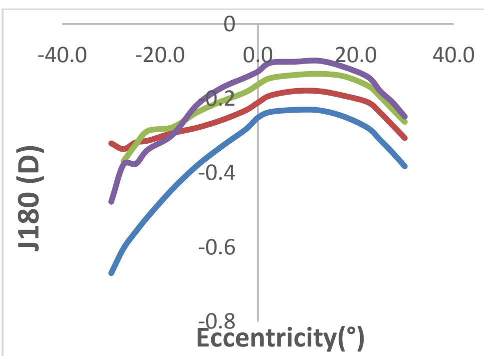
Peripheral Refraction meridian-wise in Myopes

0 – 180



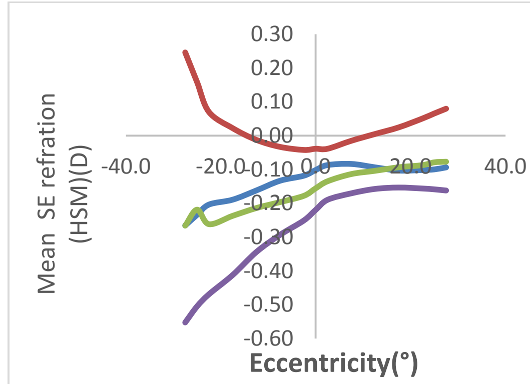


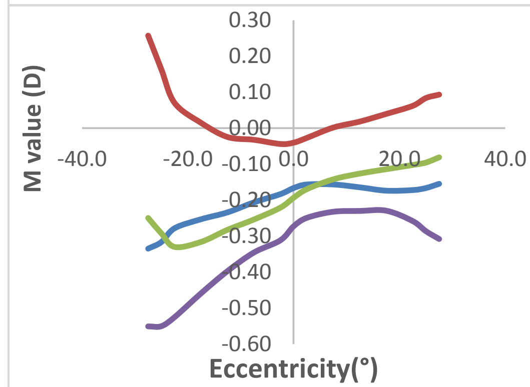


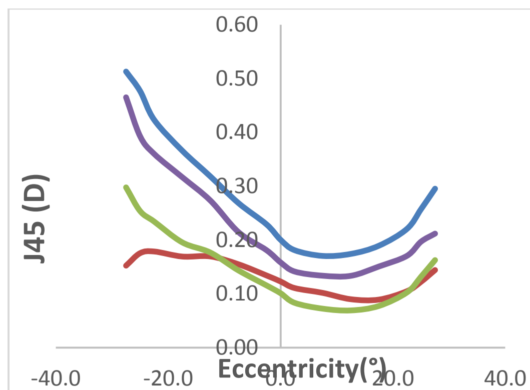


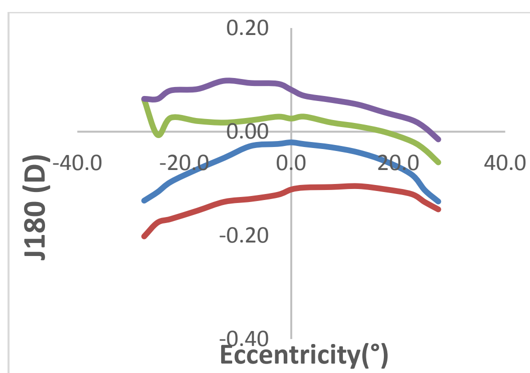
- MFL shows a myopic shift both nasally and temporally as compared to MFH as well as from baseline and other modalities
- MFH shows a complete hyperopic shift in the nasal meridian as compared to HSM Mean and M value of all other modalities.

30 – 210



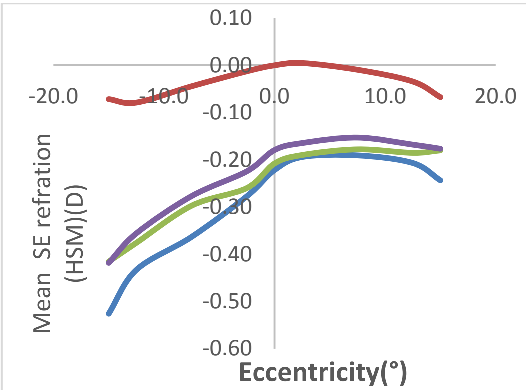


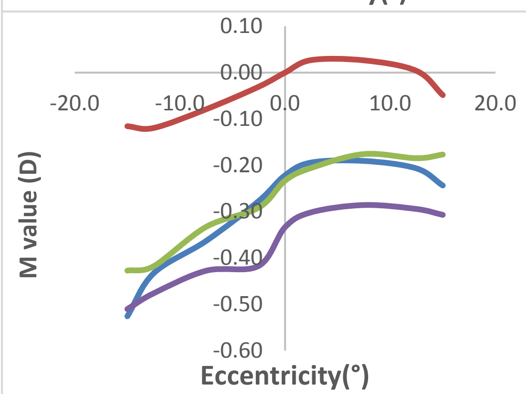


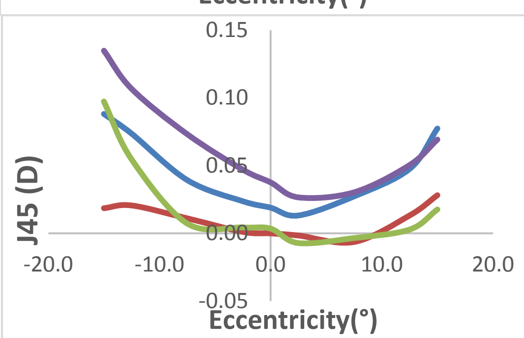


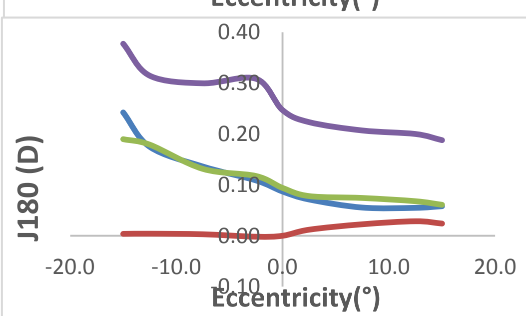
- HSM Mean and M value shows a myopic shift for MFL as compared to MFH. Nasally more hyperopic shift for MFH lenses.
- J45 shows a mild myopic shift for both MFH and MFL lenses and J180shows a myopic shift for MFH lenses both nasally and temporally

60 – 240



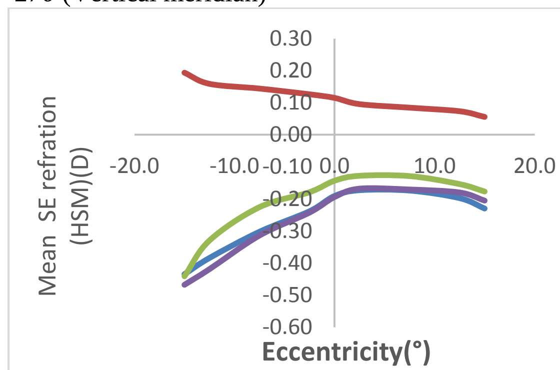


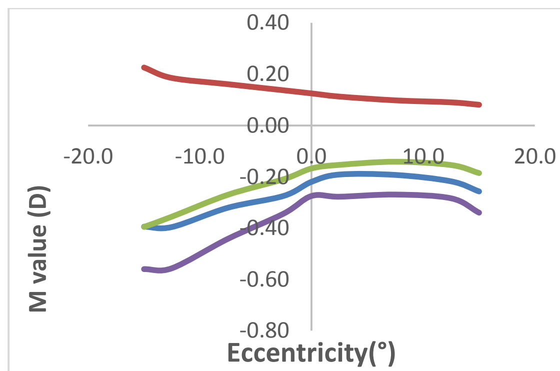


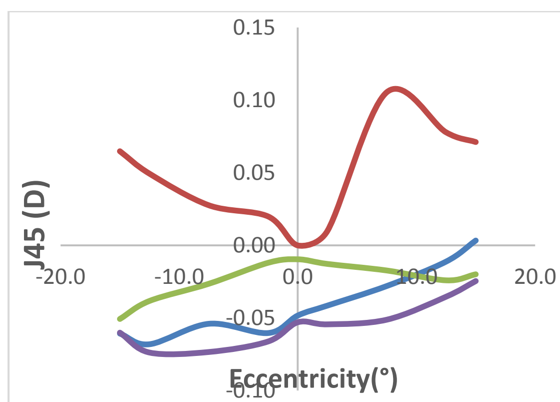


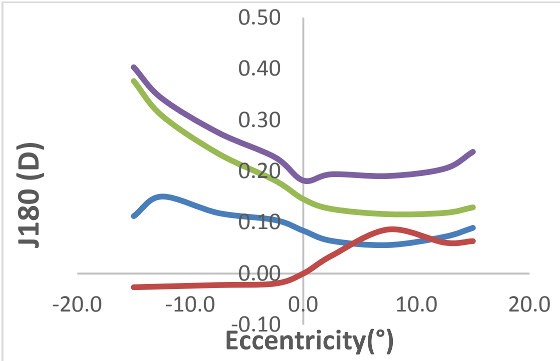
- HSM Mean and M value shows an abrupt hyperopic shift for MFH both nasally and temporally.
- J180 shows more myopic shift for MFH compared to MFL, J45 shows almost similar pattern for both MFH and MFL, more myopic than other modalities.

90 – 270 (Vertical meridian)



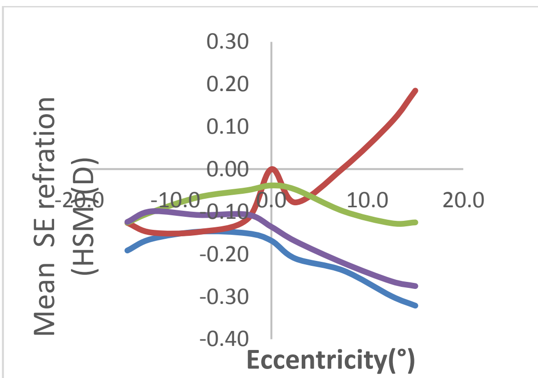


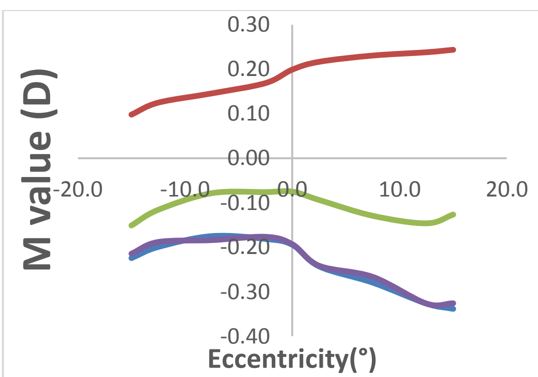


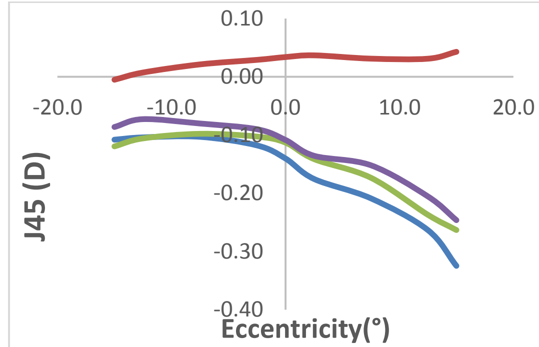


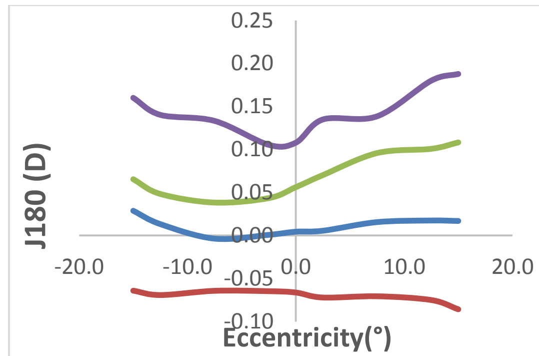
- HSM Mean and M value shows an abrupt hyperopic shift for MFH both nasally and temporally
  - J180 shows a decent myopic shift for MFH whereas J45 shows hyperopic shift in MFH.

120 – 300



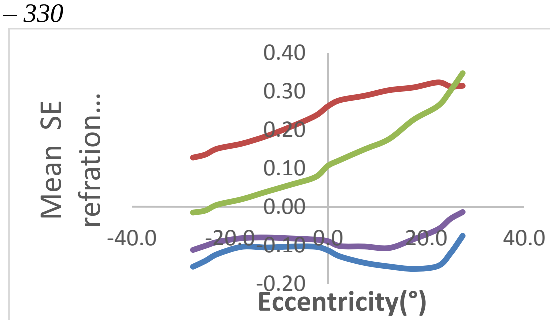


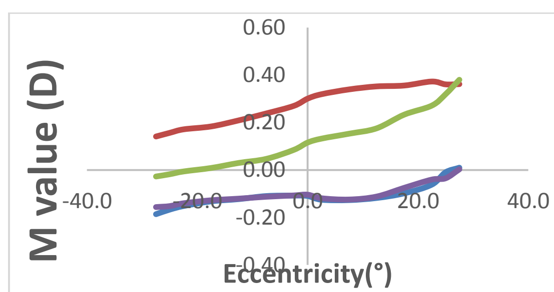


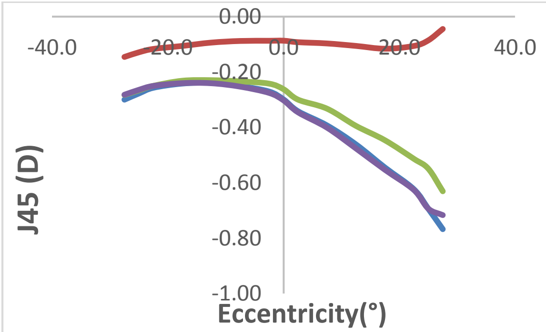


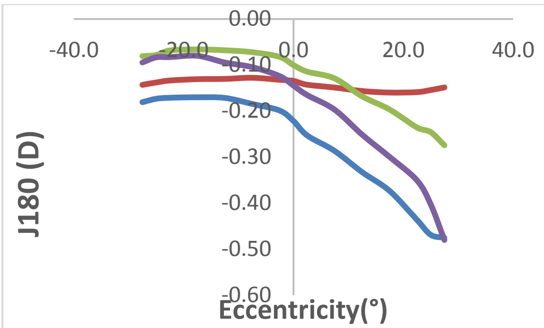
- Mean HSM and M value both show hyperopic shift for MFH
- J180 shows a more myopic shift for MFH but hyperopic shift in J45.

150 – 330







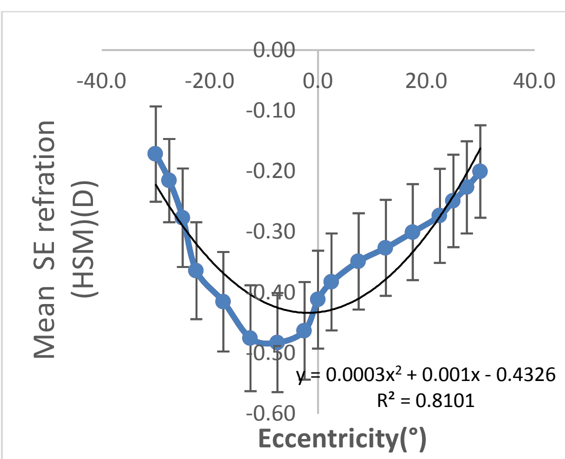


Mean HSM and M value shows a hyperopic shift for MFH and MFL but comparatively MFH shows a greater hyperopic shift.

- J45 shows a hyperopic shift for MFH.

Profile of multifocal high add and low add in emmetropes
Table: 3. Average Mean SE refraction of HSM, M value, J45, and J180 in horizontal meridian (0-180) of

Multifocal High Add soft lenses of all emmetropes



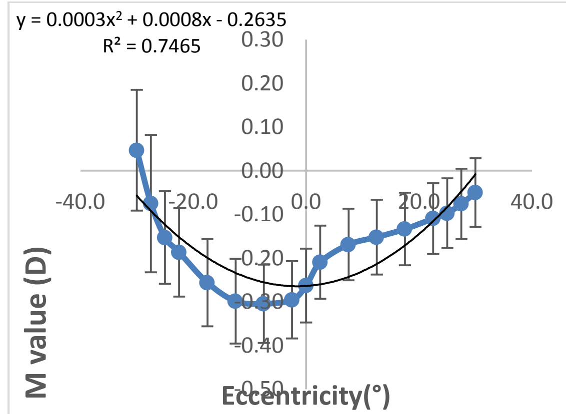
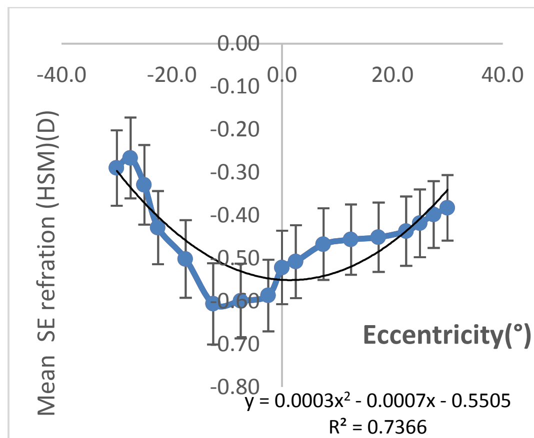
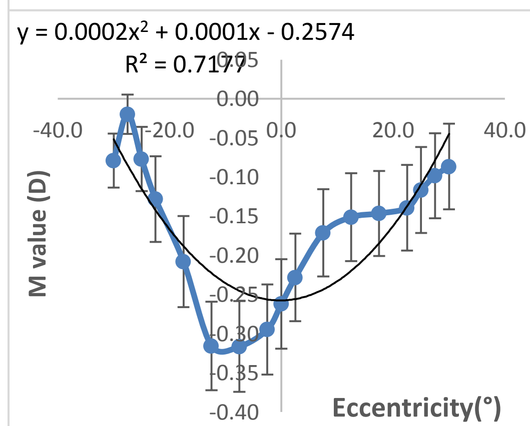
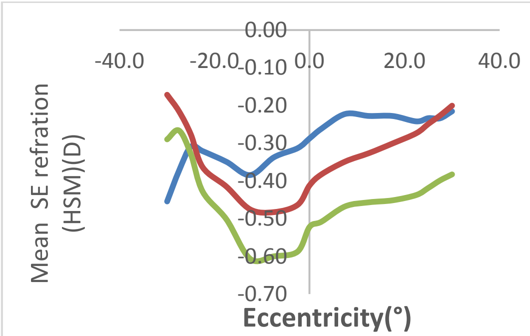


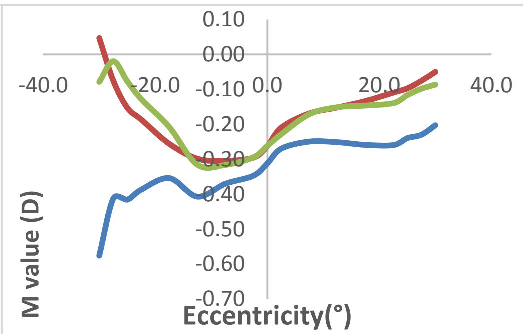
Table: 4. Average Mean SE refraction of HSM, M value, J45, and J180 in horizontal meridian (0-180) of Multifocal Low Add soft lenses of all emmetropes





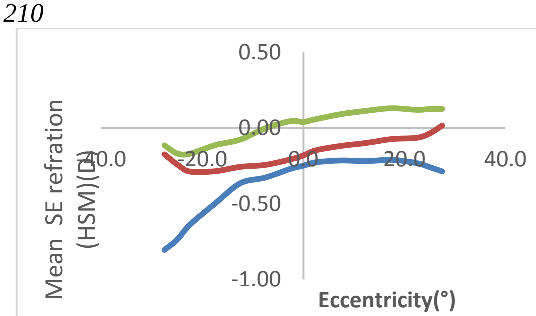
Comparison of means in meridian wise in emmetropes
0 – 180 (Horizontal meridian)

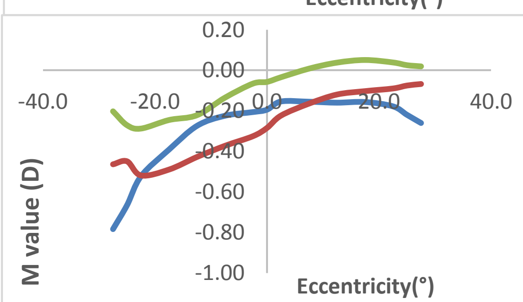




- HSM Mean shows most myopic shift for MFL lenses as compared to baseline(NOL) and MFH

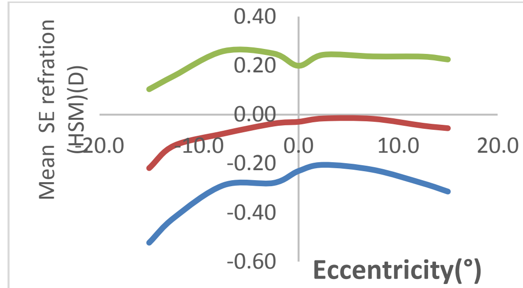
30 – 210

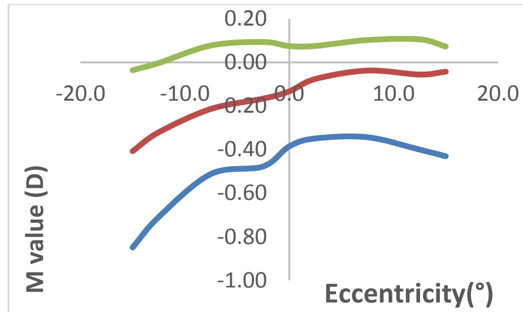




- Hyperopic shift of MFL in HSM Mean and M value. Myopic shift of MFH in M value

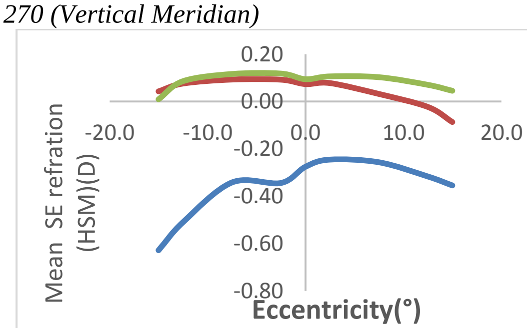
60 – 240

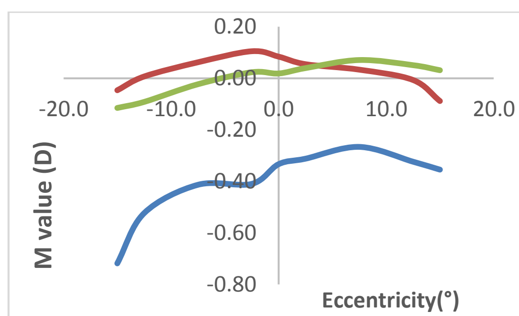




- Hyperopic shift of MFL and MFH in HSM Mean and M value as compared with baseline(NOL)

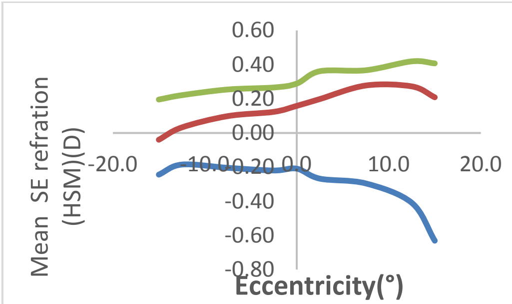
90 – 270 (Vertical Meridian)

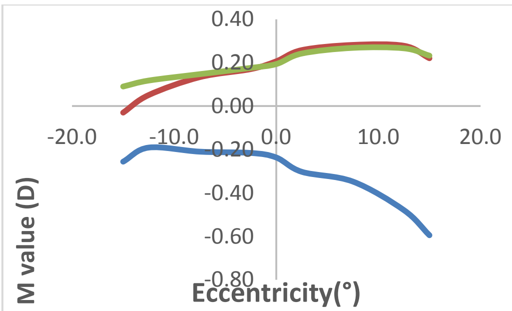




- Hyperopic shift of both MFH and MFL in the vertical meridian

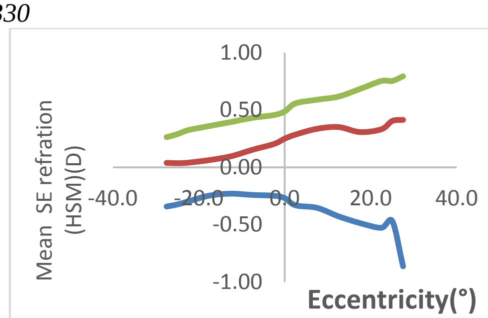
120 – 300

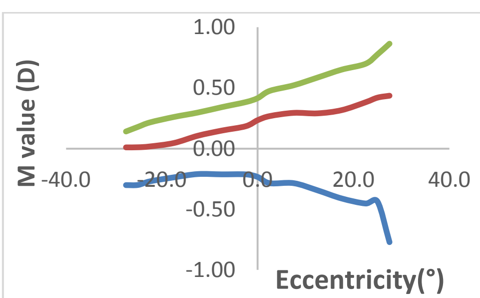




- Temporally more hyperopic shift noted almost similar pattern in MFH and MFL as compared to baseline(NOL)

150 – 330

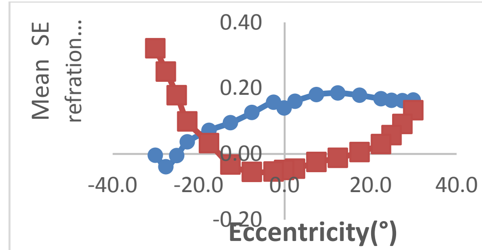


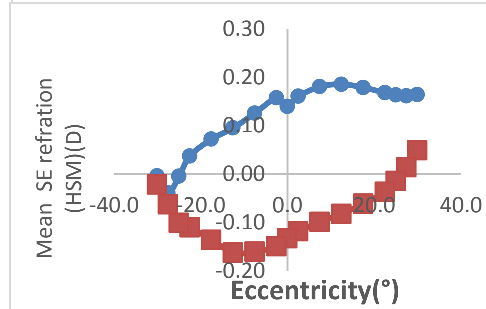


- Temporally more hyperopic shift noted almost similarly in MFH and MFL as compared to baseline(NOL)

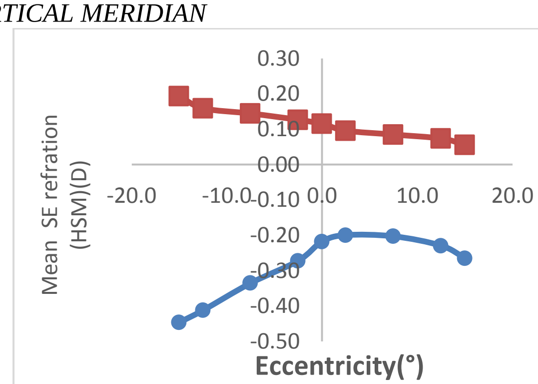
RPR of MFH and MFL compared with baseline (NOL) in horizontal and vertical meridian in Myopes

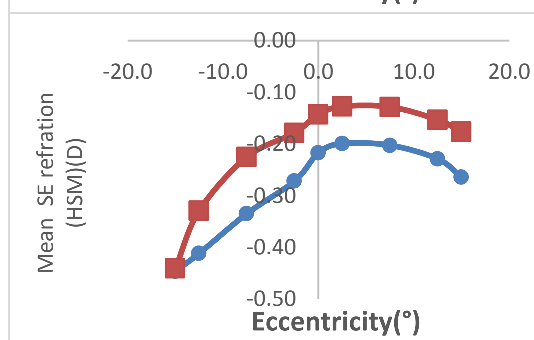
HORIZONTAL MERIDIAN





VERTICAL MERIDIAN





- In the horizontal meridian MFL showed a more myopic shift as compared to MFH
- Abrupt hyperopic shift of MFH in the nasal side in contrary to MFL in horizontal meridian
- MFL shows myopic shift both horizontally and temporally in horizontal meridian
- In the vertical meridian, MFL shows more myopic shift compared to MFH
- Uniform myopic shift of MFL increasing inferiorly

V. RESULTS AND DISCUSSION

The average means of High speed mode, M value, J45 and J180 were compared between each of the conditions; No lens wear(NOL), Multifocal low add(MFL), Multifocal high add(MFH) and spherical(SPH) soft contact lenses at each meridian. One way ANOVA was done to compare the results between groups and within groups. In post hoc tests, Tukey HSD and Bonferroni showed significant differences. Test of homogeinity of variances was statistically significant.

The results show statistically significant differences ($p<0.05$) between each conditions for means of High speed mode and M value in each meridian.

At *0–180* meridian; in comparing means of high speed mode(HSM) and M ValueTukey HSD and Bonferroni showed greatest difference between NOL and MFL (p value=0.000). Difference between MFL and MFH was also significant (p value=0.000). M value showed statistically significant difference between NOL and MFH (p value=0.000), NOL and MFL (p value=0.000), MFL and MFH (p value=0.000). NOL and SPH was insignificant (p value=0.007). At *30-210* meridian; Mean HSM and M Value showed statistically significant differences between NOL and MFL (p value=0.000), NOL and MFH (p value=0.000), MFL and MFH (p value=0.000). NOL and SPH was insignificant (p value=0.970). At *60-240* meridian; Mean HSM showed statistically significant differences between NOL and MFH (p value=0.000), MFL and MFH (p value=0.000). NOL and MFL was insignificant (p value=0.714). M value showed statistically significant difference between NOL and MFH (p value=0.000), MFL and MFH (p value=0.000). At *90-270* meridian; Mean HSM showed statistically insignificant differences. M value showed statistically significant difference between NOL and MFH (p value=0.002). MFL and MFH (p value=0.055), NOL and MFL (p value=0.518) andalso NOL and SPH was insignificant (p value=0.405).

At *120-300* meridian; Mean HSM showed statistically significant differences between NOL and MFH (p value=0.000), MFL and MFH (p value=0.002). NOL and SPH (p value=0.453) was insignificant. M value showed statistically significant difference between NOL and MFH (p value=0.017), rest others was insignificant. At *150-330* meridian; Mean HSM showed statistically significant differences between NOL and MFL (p value=0.000), MFL and MFH (p value=0.00), NOL and SPH (p value=0.025). M value showed statistically significant difference between NOL and MFH (p value=0.000), NOL and SPH (p value=0.024).

VI. CONCLUSION

Center near multifocal low add contact lenses has shown an overall relative myopic peripheral refraction profile both nasally and temporally as compared to baseline no lens wear in young myopes. On the contrary, peripheral refraction profile of center near multifocal high add lenses has shown a relative hyperopic periphery nasally though temporally it is better. Thus, keeping in mind about quality of vision, contrast and all other factors, center near multifocal contact lenses can be a better option as a prescribed modality for myopia control.

VII. ACKNOWLEDGMENT

We greatly acknowledge the support of the Students of Lotus College of Optometry who participated in the study and also Cooper Vision for arranging trial Multifocal Contact Lenses

VIII. FUNDING

This research received no funding from external source

IX. CONFLICTS OF INTEREST

The authors declare no conflicts of interest

REFERENCES

[1]. Benavente-Pérez A, Nour A, Troilo D. Axial eye growth and refractive error development can be modified by exposing the peripheral retina to relative myopic or hyperopic defocus. Invest Ophthalmol Vis Sci 2014 Sep 4 [cited 2017 Jan 6];55(10):6765–73

[2]. Aldossari H, Suheimat M, Atchison DA, Schmid KL. Effect of Accommodation on Peripheral Eye Lengths of Emmetropes and Myopes. Optom Vis Sci 2017 Jan 3 [cited 2017 Jan 7]

[3]. Verkicharla PK, Suheimat M, Schmid KL, Atchison DA. Peripheral Refraction, Peripheral Eye Length, and Retinal Shape in Myopia. Optom Vis Sci 2016 Sep [cited 2017 Jan 8];93(9):1072–8.

[4]. Sheppard A, Davies L. Clinical evaluation of the Grand Seiko Auto Ref/Keratometer WAM-5500. Opthalmic Physiol Dept. 2010; 30(2):143-51.

[5]. Smith E III, Ramamirthan R, Qiao-Grider Y, Hung L, Huang J, Kee C, Coats D, Paysee E. Effects of foveal ablation on emmetropization and form-deprivation myopia. Invest Ophthalmolol Vis. Sci. 2007; 48:3914-22.

[6]. Atchison DA, Rosén R. The Possible Role of Peripheral Refraction in Development of Myopia. Optom Vis Sci 2016 Sep [cited 2017 Jan 6];93(9):1042–4.

[7]. Calver R, Radhakrishnan H, Osuobeni E, Leary OÕ. Peripheral refraction for distance and near vision in emmetropes and myopes. 2007;584–93.

[8]. Charman WN, Radhakrishnan H. Peripheral refraction and the development of refractive error : a review. 2010;321–38.

[9]. Wu P-C, Huang H-M, Yu H-J, Fang P-C, Chen C-T. Epidemiology of Myopia. Asia-Pacific J Ophthalmol (Philadelphia, Pa) Jan [cited 2017 Jan 7];5(6):386–93

[10]. Ehsaei A, Mallen EAH, Chisholm CM, Pacey IE. Visual Psychophysics and Physiological Optics Cross-sectional Sample of Peripheral Refraction in Four Meridians in Myopes and Emmetropes. 2011;7574–85.

[11]. Fedtke C, Ehrmann K, Holden BA. A Review of Peripheral Refraction Techniques. 2009;86(5):429–46.

[12]. Fedtke C, Ehrmann K, Falk D, Bakaraju RC, Holden BA. The BHVI-EyeMapper: peripheral refraction and aberration profiles. Optom Vis Sci 2014 Oct [cited 2017 Jan 6];91(10):1199–207

[13]. Hartwig A, Charman WN, Radhakrishnan H. Baseline peripheral refractive error and changes in axial refraction during one year in a young adult population. J Optom Jan [cited 2017 Jan 6];9(1):32–9
[14]. Giner A, Aldaba M, Arjona M, Vilaseca M, Pujol J. Assessment of multifocal contact lens over-refraction using an infrared, open-field autorefractor: A preliminary study. Cont Lens Anterior Eye [Internet]. 2015 Oct [cited 2017 Jan 7];38(5):322–6
[15]. Berntsen DA, Kramer CE. Peripheral defocus with spherical and multifocal soft contact lenses. Optom Vis Sci [Internet]. 2013 Nov [cited 2017 Jan 7];90(11):1215–24
[16]. Daniela Lopes-Ferreira et al. Peripheral refraction with dominant design multifocal contact lenses in young myopes.Journal of Optometry(2013) 6, 85-94
[17]. Gifford P, Gifford KL. The Future of Myopia Control Contact Lenses. Optom Vis Sci 2016 Apr [cited 2017 Jan 7];93(4):336–43
[18]. Queirós A, Lopes-Ferreira D, González-Méijome JM. Astigmatic Peripheral Defocus with Different Contact Lenses: Review and Meta-Analysis. Curr Eye Res [Internet]. 2016 Aug [cited 2017 Jan 9];41(8):1005–15
[19]. Huang J, Wen D, Wang Q, McAlinden C, Flitcroft I, Chen H, et al. Efficacy Comparison of 16 Interventions for Myopia Control in Children: A Network Meta-analysis. Ophthalmology 2016 Apr [cited 2016 Nov 21];123(4):697–708
Robert Rose, Bart Jaeken, Anna Lindskoog Petterson, Pablo Artal, Peter Unsbo,
[20]. Evaluating the peripheral optical effect of multifocal contact lenses. Ophthalmic Physiol Opt 2012. doi: 10.1111/j.1475-1313.2012.00937
[21]. Bullimore M, Fusaro R, Adams C. The repeatability of automated and clinical refraction. Optom Vis Sci. 1998; 75:617-22
[22]. Davies L, Mallen E, Wolffsohn J, Gilmartin B. Clinical evaluation of the Shin-Nippon NVision-K 5001/Grand Seiko WR-5100K autorefractor. Optom Vis Sci. 2003; 80:320-4
[23]. Choi M et al., Clinical and kindergarten test of a new eccentric infrared photorefractor(Power Refractor). Optom Vis Sci.2000; 77:537-48
[24]. Unsbo P, Off-axis wavefront measurement for optical correction in eccentric viewing. J Biomed Opt. 2005; 10:034002
[25]. Fedtke C, Ehrmann K, Falk D, Bakaraju RC, Holden BA. The BHVI-EyeMapper: peripheral refraction and aberration profiles. Optom Vis Sci 2014 Oct [cited 2017 Jan 6];91(10):1199–207
[26]. Hartwig A, Charman WN, Radhakrishnan H. Baseline peripheral refractive error and changes in axial refraction during one year in a young adult population. J Optom Jan [cited 2017 Jan 6];9(1):32–9
[27]. Giner A, Aldaba M, Arjona M, Vilaseca M, Pujol J. Assessment of multifocal contact lens over-refraction using an infrared, open-field autorefractor: A preliminary study. Cont Lens Anterior Eye [Internet]. 2015 Oct [cited 2017 Jan 7];38(5):322–6
[28]. Berntsen DA, Kramer CE. Peripheral defocus with spherical and multifocal soft contact lenses. Optom Vis Sci [Internet]. 2013 Nov [cited 2017 Jan 7];90(11):1215–24
[29]. Daniela Lopes-Ferreira et al. Peripheral refraction with dominant design multifocal contact lenses in young myopes.Journalof Optometry(2013) 6, 85-94
[30]. Gifford P, Gifford KL. The Future of Myopia Control Contact Lenses. Optom Vis Sci 2016 Apr [cited 2017 Jan 7];93(4):336–43
[31]. Queirós A, Lopes-Ferreira D, González-Méijome JM. Astigmatic Peripheral Defocus with Different Contact Lenses: Review and Meta-Analysis. Curr Eye Res [Internet]. 2016 Aug [cited 2017 Jan 9];41(8):1005–15
[32]. Huang J, Wen D, Wang Q, McAlinden C, Flitcroft I, Chen H, et al. Efficacy Comparison of 16 Interventions for Myopia Control in Children: A Network Meta-analysis. Ophthalmology 2016 Apr [cited 2016 Nov 21];123(4):697–708

