Original Research Article

Spherical aberration and corneal asphericity in different grades of myopia

Anil Radhakrishnan[1*], Aswathy V M[2]

[1]Assistant Professor, [2]Cornea Consultant, Department of Ophthalmology, Amrita Institute of Medical Sciences, Amrita lane, Ponekkara, Kochi – 682041, Kerala, INDIA.
Email: anilradh@gmail.com

Abstract

Purpose: The objective of this study was to find any possible relationship between spherical aberration, corneal asphericity and degree of refractive error using Hartmann- Shack's aberrometry and Placido disc based corneal topography. **Materials and Methods:** 100 eyes of fifty healthy individuals aged between 18 and 34 years were recruited. We excluded all subjects with best corrected visual acuity less than 20/20, any systemic disease or any ocular pathology. All subjects underwent auto-refractometer measurement followed bysubjective refraction and acomprehensive ocular examination. Optical aberration and corneal asphericity of each subject were measured using Hartmann- Shack's aberrometry and Placido disc based corneal topography. Subjects were divided into three refractive error groups [1] mild myopes - Spherical Equivalent [SE] ≤ 3D [2] moderate myopes - SE between -3D to -6D and [3] high myopes SE ≥ -6D. Data were statistically evaluated using ANOVA. **Results:** There was a statistically significant negative correlation between spherical aberration and corneal asphericity (P value <0.01). The mean value of Spherical Aberration in mild myope was -0.190±.32 microns, moderate was -0.167±.19 microns and high myope was -0.107±.17 microns. There was a statistically significant increase in spherical aberration at moderate myopic group compared to mild myopic group (P value < 0.030). Mean value of Corneal Asphericity (Q Value) of mild myopic group was -0.416±.15, moderate myopic group was -0.336±.16 and High myopic group was -0.4313±.07 corneal asphericity for the high myopic group was significantly more than that of mild and moderate myopic groups (P value < 0.05). Mean value of higher order aberration in mild myopic group was 0.224±.14 moderate myopic group was 0.2286±.14 and for high myopic group was 0.302±.14. Higher order aberration was increased with degree of refractive error but it was not statistically significant. **Conclusion:** In this study, there was statistically significant negative correlation between spherical aberration and corneal asphericity, indicating that more prolate the cornea, less the amount of spherical aberration. The degree of corneal asphericity was seen to be higher in high myopes.

Key Words: Spherical aberration, Corneal asphericity.

[*]**Address for Correspondence:**
Dr. Anil Radhakrishnan, Assistant Professor, Department of Ophthalmology, Amrita Institute of Medical Sciences, Amrita lane, Ponekkara, Kochi – 682041, Kerala, INDIA.
Email: anilradh@gmail.com

Received Date: 13/08/2017 Revised Date: 24/09/2017 Accepted Date: 09/10/2017
DOI: https://doi.org/10.26611/1009411

Access this article online	
Quick Response Code:	Website: www.medpulse.in
	Accessed Date: 12 October 2017

INTRODUCTION

Optical aberrations are inevitable in any optical system and human eye is no exception[1,2,3,4]. Among the different higher order optical aberrations, spherical aberrations predominate. In a telescope or an operating microscope, where an array of lenses of lenses are required, aspheric lensesdeal with spherical aberration. The human cornea is also endowed with aspheric shape though inferior to an eagle's eye. The aim of our study was to find any possible relationship between spherical aberration, corneal asphericity and degree of refractive error in young Asian Indian population.

How to cite this article: Anil Radhakrishnan, Aswathy V M. Spherical aberration and corneal asphericity in different grades of myopia. *MedPulse International Journal of Ophthalmology*. October 2017; 4(1): 01-06. https://www.medpulse.in/Ophthlmology/

MATERIALS AND METHODS

Data of 100 eyes of 50 subjects were utilized for this cross-sectional study, which was done among students with myopic and myopic astigmatic refractive errors, from August 2016 to January 2017. The study conducted in Department Of Ophthalmology, Amrita Institute of Medical Sciences, Kochi after informed consent and ethical committee clearance. The inclusion criteria were[1] normal people aged between 18 and 35 years with myopia and myopic astigmatism,[2] Best corrected visual acuity (BCVA) greater than or equal to 20/20.The exclusion criteria were[1] best corrected visual acuity less than 20/20[2] any systemic disease, diabetes, hypertension, renal or cardiac disease, which possibly can impact visual parameters[3] any ocular pathology[4] any person who has undergone ocular surgery. All subjects underwent auto-refractometer measurement using NIDEK, followed by subjective acceptance using standard Snellen's visual acuity chart. A comprehensive ocular examination, including non-contact tonometry, slit lamp examination and retinal examination was done by anophthalmologist. Hartmann- Shack's aberrometry was then performed with WASCA analyzer. Three consecutive readings were taken from each eye under mesopicconditions and one representative reading was used for analysis. If there was a discrepancy in one reading, 5 or more readings were taken till 3 consistent consecutive values were obtained. After each measurement, a color map of both the total and higher-order wave front aberration, along with a numerical list showing the spherocylindrical refractive error to the nearest 0.01 D (corneal or spectacle plane plus- or minus-cylinder format), pupil size to the nearest 0.1mm, total and higher order root mean square wave front error, peak-to valley wave front errors, and Zernike coefficients were obtained. The RMS OPD HO [sum total of all higher order aberrations] as well as Z (4,0) [spherical aberration] were determined. Placido based corneal topography was done next with ATLAS topographer. Again 3 readings were taken from each eye. Q value computed by the topographer was used for analysis. For the purpose of analysis, subjects were divided into three refractive error groups[1] mild myopes- Spherical Equivalent [SE] ≤ 3D[2] moderate myopes- SE between -3D to -6D and[3] high myopes SE ≥ -6D. Data was tabulated using MS excel and analyzed using software IBM SPSS version 20. Data was analyzed using ANOVA [Analysis of variance].

RESULTS

Age and sex: Of the 100 eyes, 31(62%) were females and 19 (38%) males. The mean age of the patient was 24.80 ±. 46 years.

Degree of myopia - 50 eyes had mild myopia, 42 eyes had moderate myopia and 8 eyes had high myopia.

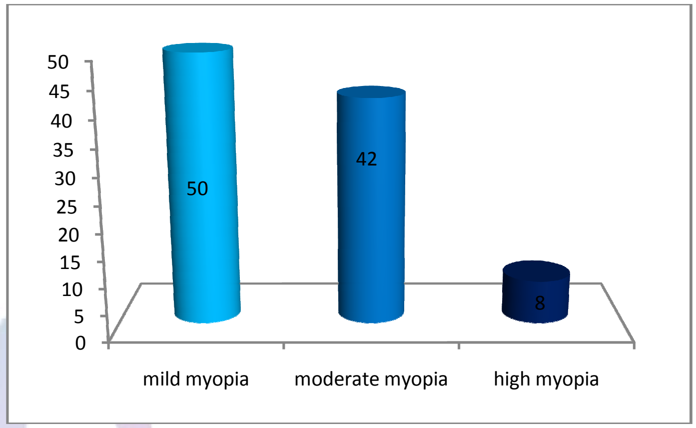

Figure 1:

Statistical Analysis: Data were expressed as mean ± standard deviation. Pearson correlation method was used to find the relation between RMSHO [sum of root mean square value of all higher order aberrations], Z (4, 0) [spherical aberration as measured by aberrometerby Zernike polynomials] and corneal asphericity [as measured by Q value]. A p value ≤ 0.05was considered to be statistically significant. The software IBM SPSS version 20 was used for statistical analysis.

Table 1: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age	50	18	34	24.80	4.669
Q value	100	-.900	.210	-.384	.162
RMS OPD HO	100	.040	.650	.232	.149
Z(4,0)	100	-.632	1.039	-.088	.276

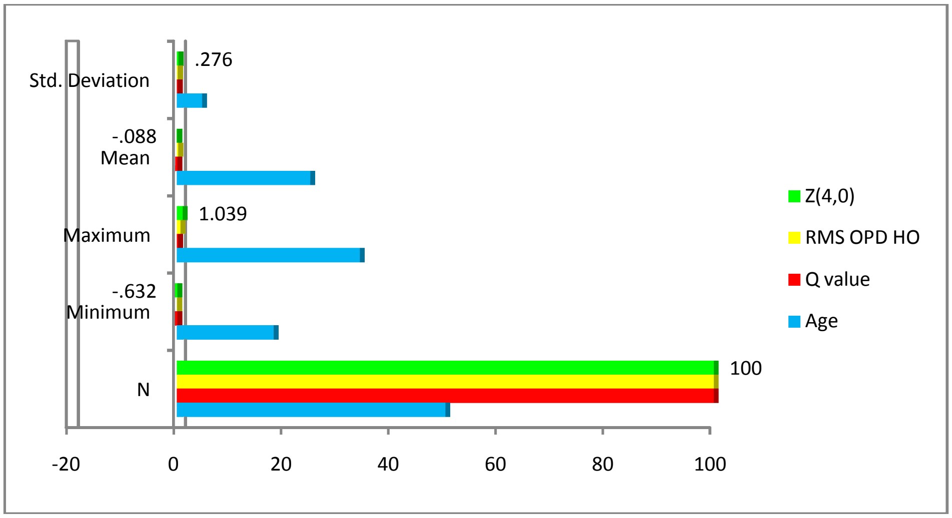

Figure 2:

Out of 100 myopic eyes, mean Q value was - 0.384 ±.162, while RMS OPD HO was 0.232 ±. 149 micrometers and Z(4,0) was -0.088 ±.276 micrometers.

Correlation between Spherical aberration (Z 4, 0) and corneal asphericity (Q value)

Table 3:

	Q value	Z(4,0
Pearson Correlation		
Sig. (2-tailed)	1	-.638**
N		
Pearson Correlation		
Sig. (2-tailed	-.638**	.000
N		

Correlation is significant at the 0.01 level (2-tailed) There was a statistically significant negative correlation between spherical aberration and corneal asphericity. (P value <0.001)

Table 4:

Variable	Q value		
	N	Pearson Correlation	p Value
Z(4,0)	100	-0.638	<0.001

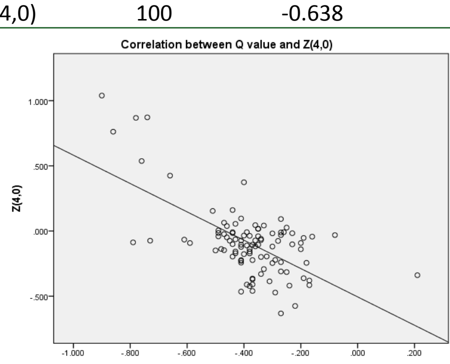

Figure 3:

Correlation between higher order aberration and corneal asphericity

Table 5:

	Q value		
	N	Pearson Correlation	p value
RMS OPD HO	100	-0.29	.003

We found no correlation between Higher order aberration and corneal asphericity.

Table 6:

Variables	Grades	N	Mean	SD	p Value
	Mild	50	-.4162	.1599	
Q value	Moderate	42	-.3360	.1661	.040
	High	8	-.4313	.0738	
	Mild	50	.2242	.1575	
RMS OPD HO	Moderate	42	.2286	.1406	.383
	High	8	.3025	.1410	
Z(4,0)	Mild	50	-.0190	.3262	.035

Group comparison: The mean Q value of mild myope category was -0.416 ±. 15, moderate myope was -0.336±.16 and high myope was -0.431±.07. Mean value of Spherical aberration in mild myopic was -0.190±.32, moderate was -0.167±.19 and high myopic was -0.107±.17. Mean value of Higher order aberration in mild myopic group was 0.224±.14 moderate myopic group was 0.2286±.14 and for high myopic group was 0.302±.14

Table 7:

Variables	Grades		p Value
Q value	Mild	Moderate	.050
		High	1.000
	Moderate	High	.364
Z(4,0)	Mild	Moderate	.030
		High	1.000
	Moderate	High	1.000

Correlation between degree of myopia And Higher order aberration (RMS OPDHO)

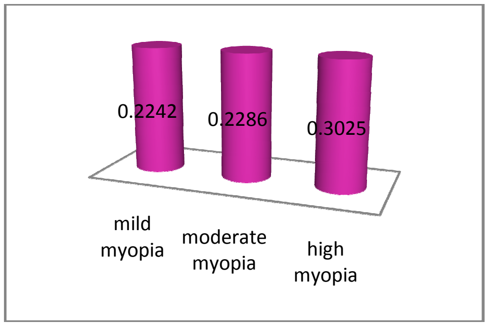

Figure 4:

RMS OPD HO of high myopic group was more than mild and moderate myopic group. There were no statistically significant correlation between RMS OPD HO and degree of myopia. (P Value > 0.05)

Correlation between degree of myopia and Spherical aberration (Z4, 0)

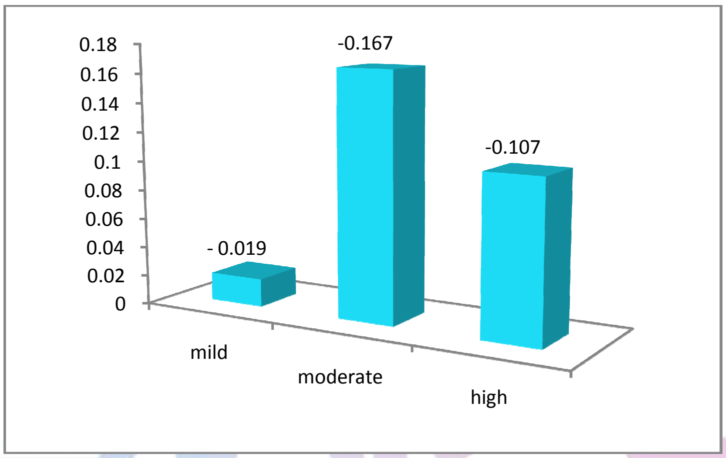

Figure 5:

When spherical aberration was compared with degree of myopia, there was a statistically significant (P value <0.03) increase in spherical aberration at moderate myopic group (-0.167 ±.19) compared to mild myopic group. (-0.019±.32).

Correlation between degree of myopia and corneal asphericity (Q value)

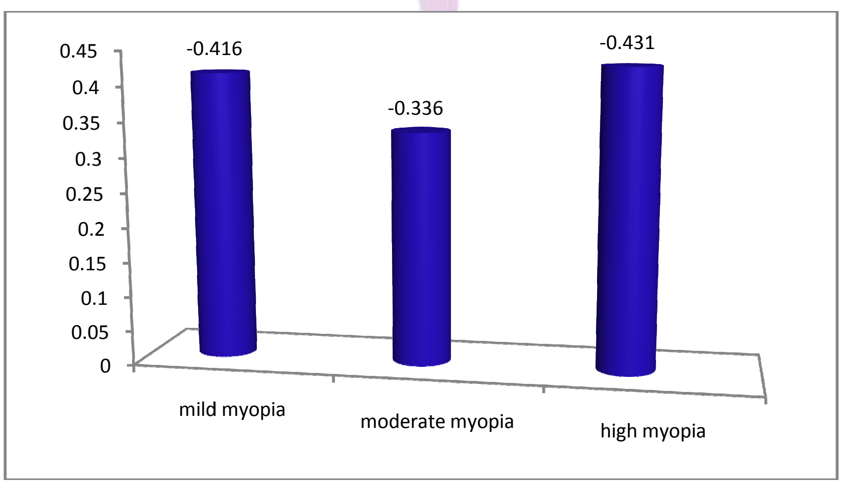

Figure 6:

Corneal asphericity for the high myopic group (-.431±0.73) was significantly more than that of mild myopic (-.416±.15) and moderate myopic group (-.336±.16).

DISCUSSION

Optical aberrations include tilt, myopia, hyperopia, astigmatism and higher order aberrations. The vast majority of them can easily be corrected by spectacles are termed lower order aberrations. Other optical aberrations, for instance coma, spherical aberration, trefoiletc which are not corrected by traditional spherocylinder lenses are called higher order aberrations. Correction of such optical aberrations improves the optical transfer function and increases the contrast and spatial detail of retinal image[1,2,3,4,11]. A variety of wave front-sensing or aberrometry devices are available to measure optical aberrations, which can be employed to guide laser ablation during customized refractive surgery [1,2,3,4]. The data derived are represented as normalized Zernicke polynomial, which represents total wave front error as a series of terms that describe surface shape components with respect to angular and radially arranged basis functions of different frequencies and orders. The 1st order includes vertical [Z1,-1] and horizontal tilt [Z1, 1] ; 2nd order includes defocus [plus or minus spherical power [Z 2,0], oblique astigmatism[Z2,-2] and ATR/WTR astigmatism [Z2,2]. The first and second order aberrations are called **lower order aberrations,** which are corrected by spectacles. Third order and above are termed **higher order aberrations**. The 3rd order aberrations are vertical coma [Z3,-1], horizontal coma [Z3,1], oblique trefoil [Z3,-3], horizontal trefoil[Z3,3] while 4th order includes Spherical aberration [Z4,0], Oblique quadrafoil [Z4, -4], Oblique 2nd order astigmatism[Z4,-2], WTR/ATR 2nd order astigmatism [Z4,2], Quadrafoil [Z4,4] In wave front guided refractive surgery or customized LASIK, excimer laser ablation is done based on the aberrometry data which is incorporated into the excimer laser system. This can offer better quality of vision, at least in patients with significant higher order aberrations[12,13]. However, in the normal eye higher order aberrations are relatively small, comprising 10 – 15 % of the aberrations of the eye[1,4,5]. Also, the limits of refractive surgery with the present technology make any attempt to address any aberration more than 4th order redundant. Recently, wave front technology is being incorporated into IOL designs. These aspheric lenses compensate for corneal spherical aberration and thereby improve contrast sensitivity.

Asphericity: The normal virgin human cornea is a prolate ellipsoid like a bullet[11,12,14]. It is steeper in the center and flatter in the periphery in order to reduce spherical aberrations. The curvature of an ellipsoid can be expressed through an asphericity quotient or Q value, which is expressed as the rate of change of corneal curvature. The Q value of a sphere is 0, while Q value of a prolate ellipsoid is negative and for an oblate ellipsoid positive. A perfect prolate ellipsoid [totally spherical aberration free] has a Q value of -0.52[8,9]. The average Q value of human cornea is -0.2 to - 0.3 and is half way between a perfect ellipsoid and a sphere. Myopic refractive surgery makes the cornea oblate, i.e. flatter in the center and steeper in the periphery with a positive Q value. It is seen that spherical aberration accounts for the major bulk of higher order aberrations [HOA] after refractive surgery and hence aspheric treatment alone may suffice in most patients. In aspheric treatment mode, excimer laser beam profile is designed in such a way to ablate more tissue in the periphery so that disturbance of Q value is less [7,13]. This study was conducted to find any possible correlation between HOA, spherical aberration in particular and corneal asphericity in different degrees of myopia. 100 eyes of 50 subjects were divided into three refractive error groups - mild myopes [spherical equivalent SE ≥ -3diopters], moderate myopes [SE -3 to -6 diopters] and high myopes [SE ≥ - 6 diopters]. Higher order aberrations [HOA] were measured using Hartmann-Shack's aberrometry and corneal asphericity measured using Placido based topography. Correlation coefficient [r] is used to describe relationship between variables. A positive value suggests a positive correlation and the reverse vice-versa. A 'r' value more than 0.5 indicates a strong correlation, 0.3 to 0.5 indicates a moderate correlation and 0.1 to 0.3 a weak one. We found a strong negative correlation [r = -0.638] between spherical aberration and corneal asphericity (P value <0.001), suggesting more prolate the cornea, less the amount of spherical aberration. But HOA and corneal asphericity showed only a weak correlation [r = -0.29]. Among the myopes, spherical aberration was more in moderate myopes. The mean value of spherical aberration in mild myopia was -0.190 ±.32, moderate myopia was -0.167 ±.19 and high myopia was -0.107 ±.17. There was a statistically significant increase in spherical aberration in the moderate myopic group compared to mild myopic group (P value < 0.030), but the value dipped again in the highly myopic group. Higher order aberrations [RMS HO] also increased with degree of refractive error but it did not reach the level of statistical significance. Mean value of higher order aberration in mild myopic group was 0.224±.14, moderate myopic group was 0.2286±.14 and for high myopic group was 0.302±.14. The mean value of Corneal asphericity (Q value) of mild myopic was-0.416± 0.15, moderate myopic was -0.336 ±.16 and high myopic was -0.4313 ±.07. Corneal asphericity for the high myopic group was significantly more than that of mild and moderate myopic groups (P value < 0.05). Carney L G *et al* compared corneal asphericity and spherical aberration of 113 myopic eyes using

Topographic modeling system TMS-1 (software version 1.1) and Nidek OPD-II Scan wave front aberrometer and found that Q value was more in high myopes compared to low myopes[13]. Also, the degree of spherical aberration increased with increasing myopia, similar to our study. Mean Q value of low myopes was -0.37±0.19, moderate myopes was -0.306 ± 0.25 and high myope was -0.199±0.24. They concluded that less negative Q value was associated with positive corneal spherical aberration[9]. ArbaMosquera S and de Ortueta D[12]studied the correlation between corneal spherical aberration and asphericity before and after LASIK in 146 eyes. They found that both corneal and ocular spherical aberrations correlated well with Q value in patients before and after LASIK for myopic astigmatism. The ocular spherical aberration was induced at a rate of half the induced corneal spherical aberration. The relationship between corneal asphericity and spherical aberration is applicable to clinical practice in excimer laser refractive surgery and cataract surgery. Excimer laser ablation with an aspheric treatment profile has greatly reduced the untoward visual effects of ablative refractive surgery like glare and haloes[3,7,10,12]. Similarly aspheric intraocular lenses have improved quality of vision postoperatively in patients.

REFERENCES

1. Thibos LN, Applegate RA, Schwiegerling JT, et al. Standards for reporting the optical aberrations of eyes. J Refract Surg2002, 18: S652-661.
2. Thibos LN, Hong X. Clinical applications of Shack-Hartmann aberrometer. Optom Vis Sci.1999, 76:817-825.
3. Panagopoulou SI, Pallikaris IG.Wavefront customized ablations with the WASCA Asclepion workstation. J Refract Surg 2001, 17:S608 – S612.
4. Mrochen M, Kaemmerer M, Mierdel P, Krinke HE, Seiler T. Principles of Tscherningaberrometry. J Refract Surg 2000, 16:S570-S571.
5. Smolek MK, Klyce SD, Sarver EJ. Inattention to non superimposable midline symmetry causes wavefront analysis error. Arch Ophthalmol 2002, 120:439-447.
6. Schwiegerling JT, Greivenkamp JE, Miller JM. Represenation of videokeratoscopic height data with Zernike polynomials.J Opt Soc Am A 1995, 12:2105-2113.
7. Buhren J, Kunhe C, Kohnen T. Influence of pupil and optic zone diameter on higher order aberrations in wave-front guided myopic LASIK. J Cataract Refract Surg 2005, 31:2272-2280.
8. Smith G, Cox MJ, Calver R, Garner LF.The spherical aberration of the crystalline lens of the human eye. Vision Res. 2001 Jan 15; 41(2):235-43.
9. Carney LG, Mainstone JC, Henderson BA.Corneal topography and myopia.A cross-sectional study. Invest Ophthalmol Vis Sci. 1997 Feb;38(2):311-20.
10. Manns F, Ho Arthur, Patel JM, Culbertson W. Ablation profiles for wave front guided correction of myopia and primary spherical aberration. J Cataract Refract Surg 2002, 28: 766 – 774.
11. Applegate RA, Thibos LN, Hilmantel G. Optics of aberrroscopy and super vision. J Cataract Refract Surg 2001; 27: 1093-1107.
12. ArbaMosquera S, de Ortueta D. Correlation among ocular spherical aberration, corneal spherical aberration, and corneal asphericity before and after LASIK for myopic astigmatism with the SCHWIND AMARIS platform.J Refract Surg. 2011 Jun; 27(6):434-43.
13. Manns F et al. Ablation profiles for wavefront guided correction of myopia and primary spherical aberration. J Cataract Refract Surg 2002; 28: 766 – 774.
14. Knapp S, Awwad ST, Ghali C, McCulley JP. Ocular aberrations measured by the Fourier-based WaveScan and Zernike-based LADARWave Hartmann-Shack aberrometers. J Refract Surg. 2009; 25:201-9.
15. Kretz FT, Tandogan T, Khoramnia R, Auffarth GU. High order aberration and straylight evaluation after cataract surgery with implantation of an aspheric, aberration correcting monofocal intraocular lens.Int J Ophthalmol. 2015 Aug 18; 8(4):736-41.
16. Xu ZQ, Song XH, Li WZ, Dou Y, Wu Q. Clinical study inpatient-reported outcomes after binocular implantation of aspheric intraocular lens of different negative spherical aberrations. Asian Pac J Trop Med. 2017 Jul;10(7):710-713

Source of Support: None Declared
Conflict of Interest: None Declared