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Association of Sub-Choroidal Thickness with Refractive Error and Axial Length in Myopia and Emmetropia: An OCT Scan Study

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Abstract

Aim: *To find out the correlation of choroidal thickness (CHT) with refractive error (RE) & axial length (AL) in North-Indian population of age group of 18-35 years having myopia or emmetropia using A-scan and Oct imaging.*

Objective *is to check for a relationship of CHT with AL & RE in myopic – emmetropic individuals with help of A-scan and Oct imaging.*

Methods *this study is an observation- analysis based cross sectional study which involved 200 eyes of individuals presented at outpatient department of Eye care solution consisting 50 beings with ≥4 D Myopia & 50 other Emmetropic presenting for ailments other than refractive error taken as Control group. The criteria for selection of subjects were done on basis of selective age 18-35 years, degree of refractive error and clear ocular media. However, subjects with history of any intraocular pathology, surgery, inflammation or any associated systemic disorder such or vascular diseases were excluded another thing where in person with OCT scan less signal strength, motion artifact & focal signal loss were too excluded. A written-informed consent was taken from all subjects prior to enrolment.*

Results: *This study investigated the structural characteristics of the eye across three groups of myopic individuals and a control group. Myopia Group I (with myopia ranging from -3.00 D to -4.75 D) showed an average axial length of 24.78 mm, macular thickness of 100.08 µm, and choroidal thickness of 309.54 µm. Myopia Group II (with myopia between -5.00 D and -6.75 D) exhibited a greater axial length of 25.83 mm, a macular thickness of 112.34 µm, and a choroidal thickness of 289.47 µm. Myopia Group III (with myopia of -7.00 D and above) had the longest axial length at 26.10 mm, a macular thickness of 110.38 µm, and the thinnest choroidal thickness at 255.38 µm. In comparison, the control group, consisting of emmetropic individuals, had an average axial length of 23.26 mm, macular thickness of 322.24 µm, and a significantly thicker choroid (242.23 µm) across both Sattler's and Haller's layers. These findings highlight the progressive structural changes—particularly axial elongation and choroidal thinning—associated with increasing myopia severity.*

Conclusion: *The results of this study reveal a definite link between the degree of myopia and anatomical variations in the eye. Axial length increases in tandem with myopia, and the choroid significantly thins, especially in the deeper layers (Sattler's and Haller's). According to these results, axial elongation and choroidal thinning are progressive features of myopia, with alterations becoming more noticeable as refractive error increases. Gaining knowledge of these structural changes may help direct future treatment approaches and offer significant understanding into the pathophysiology of myopia*

INTRODUCTION

Myopia, also known as short-sightedness, is a type of refractive error wherein light rays coming from far comes to focus in front of retina [2]. The 1st definition of this condition was given by Kepler in 1611, then 1632 Plumpiest examined 1st myopic eye & stated involvement of posterior segment elongation. In 1866 Donders explained the pathological and clinical basis [1]. Plotting the prevalence of myopia in adults and children (1999 to 2020) versus

age served as the baseline, and helped to characterize the generational effect on myopia prevalence over the next three decades. As a result from 4.44% in 1999 to 21.15% in 2019, the percentage of urban children aged 5 to 15 who have myopia increased. Our estimates for the prevalence of myopia based on a slope of 0.8% year (4.05% every 5 years) show that it will reach 31.89% in 2030, 40.01% in 2040, and 48.14% in 2050. All age groups will see an overall increase in myopia prevalence of 10.53% in the next years due to the generational effect, which is brought on by the nature of the condition lasting a lifetime once formed [23]. In majority of cases myopia is due to axial that is due to increase in antero-posterior diameter of eyeball. Curvature myopia is associated with increased curvature of lens, cornea or both (1mm increased curvature causes 6 dioptres of myopia, in this the cornea is flatter than normal whereas lenticular curvature is rare condition but can cause marked myopia as curvature changes of lens occurs when ligaments get relaxed produced during spasm of accommodation. However, Index myopia is produced by increased refractive index of lens. Fewer conditions wherein index gets increased are also evidenced in cases of Incipient cataract and by reduction in index may lead Diabetic myopia [1-4].

On basis of clinical variants myopia is further classified into simple, physiological or pathological myopia. Simple myopia is a condition of limited progression whereas pathological type also known as degenerative myopia may rise to such extent that it might a require medical intervention. In physiological myopia the ocular contents are within normal limits with no retinae changes however, in severe dioptric error temporal globe enlargement, myopia crescent or traction can be seen [3]. During dilated retinae examination several findings can be observed such as retinal atrophy, choroidal atrophy, myopic crescent at optic disc, macular changes, posterior staphyloma, cystoid degeneration & weiss's reflex presence [1]. Talking about choroid its positioned between the sclera and the retinae in the posterior segment of eye [6], this highly vascular structure choroid forms most part of uveal structure comprising maximum vasculature of eye. Structurally, it's made up of five layers, of which blood vessels form the major part, it performs functions like providing nourishment & oxygen supply to the outer retina (photoreceptor cell layer and retinal thermoregulation) absorbs excess light and prevents internal reflection of light due to presence of melanocytes and also regulates intraocular pressure (IOP) by regulating the ocular blood flow [5]. The choroid also plays a critical role in regulating eye growth and in development of refractive error such as myopia [6]. Evidences are there of choroids role in managing eye growth and refractive error, emerged from studies in the 1990s that demonstrated that the thickness of the choroid changed rapidly and predictably in response to changing focus of retinal image, with the magnitude and direction of these changes appearing to correlate with the sign and degree of defocus. When developing eyes were exposed to myopic defocus a rapid thickening of the choroid was observed [7,8,6]. Thinning of choroid may lead to insufficient retinal nourishment, retinal pigment epithelium (RPE) degeneration and photoreceptor cell loss. Therefore, information about choroidal thickness (CHT) could be useful in many clinical situations for diagnosis, management, and monitoring of disease progression, thus its very relevant to keep normative data CHT [6].

Prior to the development of OCTA, an intravenous (IV) dye for fluorescein angiography (FA) or indocyanine green angiography (ICGA) was needed in order to visualize the retinal or choroidal microvasculature. Even However, there are certain benefits to using classic angiography methods, like the capacity to identify leaks, etc. [21]. This clinical evaluation of choroid can be done with different techniques, primarily Indocyanine angiography (ICG) modality was used but it was an invasive procedure nor it provided information of CHT or any structural information [6,9,10]. Other modality such as Ultrasonography is useful in the diagnosis and management of various vitreoretinal pathologies even in opaque media, it can detect & characterize tumors, CHT but due to low resolution of images made it difficult to evaluate CHT [11]. Similar outcome was evidenced when tried with magnetic resonance imaging (MRI) the resolution of images was not fine to produce an outcome [6]. Prior to the development of OCTA, an intravenous (IV) dye for fluorescein angiography (FA) or indocyanine green angiography (ICGA) was needed in order to visualize the retinal or choroidal microvasculature. Even However, there are certain benefits to using classic angiography methods, like the capacity to identify leaks, etc. [12,13]. However, with the introduction of enhanced depth imaging Optical coherence tomography (EDI-OCT) by Spaide et al [14] choroidal visualization was possible. OCT is an imaging technique based on laser interferometry that provides cross-sectional images of ocular tissues within 10_{um} with high resolution using near infrared light [15]. The development of newer OCT methods allows scanning 100 times faster than earlier OCT techniques, providing higher resolution with improved signal strength, that opened up the possibility of more reliable visualization and measurement of the choroid in vivo [16]. As we all know, in high myopic eyes the earliest changes begin in the choroid [17]; recent interest has focused on the choroid as an important structure involved in the pathophysiology of high myopia [18]. Choroidal thickness is an important, accurate, safe and simple parameter in studying the pathogenesis of high myopia it was found that CHT thinner than normal eyes [19]. Swept-source

OCT (SS-OCT; DRI-OCT) [20] is the latest milestone in retinal and choroidal imaging it uses light of longer wavelength & provides a better resolution of choroidal layers and its thickness. Due to several advantages offered by SS-OCT over SD-OCT better resolution, imaging of vitreous, retina and choroid, longer OCT scans, and penetration into hazy media many surgeons are using SD-OCT. Though the choroidal thickness profile for Indian population has been reported using SD-OCT for collecting normative data of CHT [21,22]. The enhanced retinal coverage provided by the scan procedures is another benefit of SD-OCT. The SD-OCT machines' standard scan protocol generates 21 B-scan images in 1.4 seconds, which is equivalent to the time needed for a single Stratus OCT image and covers the retina's 6 mm x 6 mm surface. Whereas the 1.6 mm spacing on the Stratus OCT macular mapping procedure, the vertical space between consecutive images in the raster is 300 μ, which can be as low as 50 μ in some of the SD-OCT machines. A higher scan density may be able to identify subtle focal changes in the parafoveal region that the typical TD-OCT imaging methodology is unable to identify [23].

METHODOLOGY

This is an observation- analysis based cross sectional study which involved 200 eyes of individuals presented at outpatient department of Sangam Netralaya Mohali Punjab. approval and informed consent was taken from all subjects prior to enrolment. The optimal sample size for proposed study is calculated on the basis of anticipated OCT for groups. On the basis of mean and standard deviation of 2 groups; myopes and emmetropes (control group). On the basis of 95% coefficient and 80% power of test sample size comes to be 100 people to be divided into 2 groups of 50 each. The study population consisted of 50 beings with ≥4 dioptres of Myopia divided into groups & 50 other individuals with Emmetropia presenting for ailments other than refractive error taken as Control group. The criteria for selection of subjects were done on basis of selective age 18-35 years, degree of refractive error and clear ocular media. However, subjects with history of any intraocular pathology, surgery, inflammation or any associated systemic disorder such or vascular diseases were excluded another thing wherein person with OCT scan less signal strength, motion artifact & focal signal loss were too excluded.

Patient were examined in outpatient department of Ophthalmology in Sangam Netralaya Mohali. A detailed history will be taken in all cases such as current symptoms, health problems, medications, and ocular co-morbidities will also be documented. All patients included in the study will undergo a detailed ocular examination. It consists of visual acuity assessment on Snellen's visual acuity chart; uncorrected - best corrected visual acuity will be noted followed by Slit lamp examination of the anterior posterior segment, measurement of IOP with applanation tonometer, A.L measurement with A-scan and at last measurement of retinal thickness and choroidal thickness using Spectral Domain OCT (Cirrus HD 500, Carl Zeiss) with EDI (enhance depth imaging) technique high definition (HD) radial-line foveal scan for each participant for better visualization of structures. The scans performed were Macular cube 512 x 128 scan (gets macular thickness & 3d image data through a 6mm square grid acquires series of 128 horizontal lines comprising 512 a-scan and central horizontal HD b-scan) & HD radial scan (generates 12 high-definition radial scan lines at depth of 2 mm with 8 b-scans and each b-scan composed of 1024 a-scans, these scans have adjustable line of 3-6mm). There were 2 layers of choroid Haller & Sattler's which were particularly examined so to investigate the relation of CHT with AL & RE in myopes & emmetropes. The findings were recorded in the proforma attached. For analysis, the subjects were divided into the following 2 groups: group A - Myopic eyes Further divided into 3, group B – control eyes.

Data analysis

Quantitative parameters will be described using mean and standard deviation. Normality of test will be tested by using Kolmogorov–Smirnov test. Student–t–tests will be used for comparison of mean for the 2 groups and significance of OCT will be tested as shown in **figure 1** and in case of non-normal distribution Mann-Whitney U test will be used for comparison. Chi-square test will be used for testing significance between outcome parameters and patient characteristic. Data analysis will be carried out by using SPSS (statistical package for the social sciences) 25.0 software. Where radial ocular coherence tomography radial scan is shown in **figure 2**.

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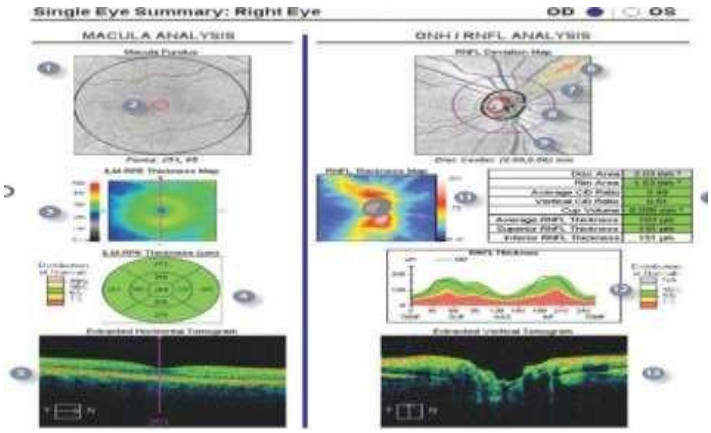

Figure1. OCT scan showing the scan of macula of Myopic patient

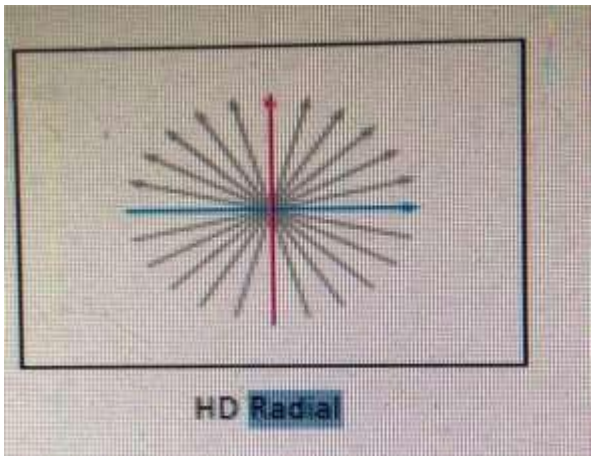

Figure2. Optical coherence tomography showing HD radial scan

RESULT:

Myopia groups	Spherical Power	Cylindrical Power	Average axial length	Average Macular Thickness	Average choroidal thickness	Average Sattler's Value	Average Haller's	BCVA
I	-3.00 D - -4.75 D	-0.25 - -2.00Dcyl	24.78mm	100.08um	309.54 um	113.31 um	175.34 um	6/6
II	-5D TO -6.75 DS	-0.25 TO -2.00	25.83 mm	112.34 um	289.47um	111.06 um	157.74um	6/6
III	-7D And Above	-0.25 TO -2.00	26.10 mm	110.38 um	255.38um	111.88um	162.67	6/6

Table 1. Showing myopias group indicating average values of axial length, Macular thickness, choroidal thickness, Haller's and Sattler's

.

Myopia Group I comprises individuals with myopia ranging from -3.00 diopters (D) to -4.75 D, with cylinder power between -0.25 D and -2.00 D. All participants in this group exhibit a best-corrected visual acuity (BCVA) of 6/6. The average axial length in this group is measured at 24.78 mm, which is relatively typical for individuals with moderate myopia. The macular thickness averages at 100.08 µm, and the choroidal thickness is approximately 309.54 µm, reflecting a moderate degree of thinning as compared to normal values. For the Sattler's and Haller's layers, the average thicknesses are 113.31 µm and 175.34 µm, respectively, indicating some variation in the structural dimensions of the choroid across different layers as shown in **table 1**.

Myopia Group II includes individuals with myopia in the range of -5.00 D to -6.75 D, and cylinder power between -0.25 D and -2.00 D. Similar to Group I, all participants maintain a BCVA of 6/6. In this group, the average axial length increases to 25.83 mm, reflecting a greater degree of axial elongation commonly associated with higher degrees of myopia. The average macular thickness is slightly higher than in Group I, with an average of 112.34 µm, possibly indicating a compensatory mechanism in the retinal structure. The average choroidal

thickness is 289.47 μm, which is thinner compared to Group I, reflecting the relationship between axial length and choroidal thinning in higher myopia. The average thickness of Sattler's layer is 111.06 μm, and the average thickness of Haller's layer is 157.74 μm, both of which show some reduction in thickness compared to the control group, reflecting the progressive changes seen with increasing myopia as shown in **table 1.**

Myopia Group III consists of individuals with high myopia, defined as refractive error greater than -7.00 D, and cylinder power between -0.25 D and -2.00 D. As with the other myopia groups, all individuals in this group exhibit a BCVA of 6/6. The average axial length in Group III is 26.10 mm, which is significantly greater than in the less myopic groups, and is consistent with the higher degree of axial elongation observed in severe myopia. The average macular thickness is 110.38 μm, which is slightly less than in Group II, suggesting ongoing structural changes in the retina due to the increased axial length. The average choroidal thickness in this group is 255.38 μm, representing further thinning of the choroid compared to Group II, which is a typical finding in high myopia. The average thickness of Sattler's layer is 111.88 μm, while Haller's layer has an average thickness of 162.67 μm, both of which show a further reduction in thickness as myopia becomes more severe as shown in **table 1.**

The control group consisting of individuals without myopia, serves as a baseline for comparison. The average axial length in this group is 23.26 mm, which is within the normal range for individuals with emmetropia. The average choroidal thickness is 322.24 μm, which is higher than in the myopic groups, reflecting the typical choroidal thickness found in individuals with no refractive error. The average Sattler's layer thickness is 113.55 μm, and the average Haller's layer thickness is 242.23 μm, both of which are greater than the corresponding values in the myopic groups, highlighting the structural differences in the choroidal layers between emmetropes and myopic individuals as shown in **table 1.**

These findings provide valuable insights into the structural alterations associated with varying degrees of myopia, particularly in relation to axial length, macular thickness, and choroidal thickness. As myopia severity increases, axial elongation and choroidal thinning become more pronounced, reflecting the adaptive and degenerative changes that occur in the eye in response to increasing refractive error.

DISCUSSION:

The current study offers strong evidence of association between axial elongation and sub-choroidal thinning with severity of myopia in the population of North-Indian adults aged 18–35 years. These results concur with the current concept of myopic progression, whereby axial length elongation is coupled with structural changes in the posterior segment, particularly in the choroid (Read et al., 2013; Ikuno, 2013) [26].

Progressive elongation in axial length was seen with the increase from 24.78 mm in mild myopia to 26.10 mm in high myopia, whereas choroidal thickness decreased from 309.54 μm to 255.38 μm over the same range. This inverse relation highlights the contribution of elongation in the axis towards mechanical stretching and thinning of the choroid. These findings are in accordance with the work done previously where similar choroidal thinning has been reported in extremely myopic eyes (Flores-Moreno et al., 2013; Fujiwara et al., 2009).[27] One explanation for the thinning would be mechanical stretching of the globe with resulting vascular compression and diminished perfusion of the choroidal vasculature (Spaide, 2009).[28]Notably, emmetropic subjects in this population showed a considerably thicker choroid (mean 322.24 μm), as previously seen in normative data reported in previous population-based works (Li et al., 2011).[29] The sub-choroidal layers, i.e., Sattler's and Haller's layers, seem especially vulnerable to these changes. The vascular layers' degeneration could impair retinal pigment epithelium (RPE) function and outer retina metabolism, which may contribute to photoreceptor damage in high myopia (Ohno-Matsui, 2016).[30] The clinical applications of the measurement of choroidal thickness are broad. Choroidal thinning has been suggested as a marker for not just myopia-associated complications diagnosis but also disease monitoring (Margolis and Spaide, 2009).[31] Enhanced Depth Imaging Optical Coherence Tomography (EDI-OCT) and Swept Source OCT (SS-OCT) have become reproducible modalities to quantify these delicate in vivo changes with high reproducibility (Spaide et al., 2008; Imamura et al., 2010).[32] This technical development allows for the early identification of at-risk patients and can potentially inform myopia management strategies. The merit of this study is in its clearly defined age stratum and strict exclusion criteria, which reduce confounding influences such as ocular surgery or systemic disease. In addition, segmental analysis of sub-choroidal layers brings novelty and accuracy to the results. Some restrictions do need to be considered, however. In the first place, cross-sectional design restricts causality. Longitudinal studies would provide more insight into the development of choroidal thinning over time. In the second place, the effect of environmental and genetic aspects on choroidal thickness was not evaluated. Finally, diurnal variations in choroidal thickness that can affect OCT measurements were not controlled for in imaging (Tan et al., 2012) [33]. In summary, the

study enforces the correlation between rising myopic refractive error, axial elongation, and choroidal thinning. Since the prevalence of myopia is on the rise, particularly in urban India, these structural parameters may become critical in the identification of at-risk individuals for myopic maculopathy and management strategies. Additional studies are necessary to determine threshold degrees of choroidal thinning that can predict pathological myopia and its associated complications.

FUTURE PROSPECTIVE:

Can evaluate the elongation process of eyeball which give rise to progressive/degenerative myopia and can study about the intra ocular implants for myopia control. Future research should focus on longitudinal studies to track choroidal changes over time and assess their role in predicting myopia progression and complications. Integrating genetic, environmental, and lifestyle factors could further enhance understanding. Advancements in OCT technology may also allow for more precise, layer-specific analysis, aiding early diagnosis and personalized interventions for myopic patients.

CONCLUSION:

This research sets up a statistically significant and clear relationship between sub-choroidal thickness, axial length, and refractive error in subjects with differing levels of myopia versus emmetropic controls. The results verify the increase in myopia severity with elongation of axial length and increasing thinning of the choroid—especially of the Sattler's and Haller's layers. These changes in anatomy are indeed key indicators of ocular remodelling in myopic eyes and underscore the significance of early identification and follow-up with sophisticated imaging modalities such as EDI-OCT. By establishing normative and comparative measurements within the 18–35 age group of the North Indian population, this study lends important insights towards the pathophysiological comprehension of myopia. These findings substantiate the ability of choroidal thickness as a biomarker for myopic change and associated complications. Early detection of these structural alterations might help clinicians in personalizing preventive measures and therapeutic interventions to control and potentially retard the advancement of myopia.

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