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Original Article

Impact of Chronic Smoking on Choroidal Thickness: A Comparative Analysis Using Optical Coherence Tomography

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Abstract

Background: Chronic smoking has systemic vascular effects, including alterations in ocular blood flow and choroidal thickness, impacting visual health.

Objective: To compare choroidal thickness (CT) in chronic smokers and nonsmokers using optical coherence tomography and to evaluate the effect of smoking duration on CT based on pack-year quartiles (PYQ).

Methods: This was a case-control study conducted at the Regional Institute of Ophthalmology, Medical College, Kolkata, India between January 2023 and June 2024. Choroidal thickness was assessed in 120 cases (60 smokers and 60 nonsmokers) over a period of 18 months. Choroidal thickness was measured using Enhanced Depth Imaging Spectral-Domain Optical Coherence Tomography (EDI SD-OCT) at the sub foveal region and 1.5 mm away in the superior, inferior, nasal, and temporal directions. CT between smokers and nonsmokers was compared. Statistical analysis was performed using the SPSS 23.0 software and a p-value of less than 0.05 was taken as statistically significant.

Results: The study analyzed age distribution, ocular parameters, and choroidal thickness in 60 smokers and 60 nonsmokers. The mean age in smokers and nonsmokers was found to be 43.1 ± 7.2 and 40.8 ± 11.4 years respectively. Smokers were found to have a significantly lower sub foveal CT compared to nonsmokers (272.42 ± 13.57 µm vs. 284.94 ± 14.15 µm, $p<0.05$). Increased smoking exposure significantly correlated with progressive choroidal thinning ($p<0.05$). Other ocular parameters, such as intraocular pressure ($p=0.235$) and axial length ($p=1.0$), were found to be comparable in both groups ($p>0.05$).

Conclusion: There significant choroidal thinning in chronic smokers as compared to nonsmokers with a dose-dependent effect linked to higher smoking exposure. These findings suggest a smoking-induced vascular compromise in the choroid.

Keywords: Choroidal thickness, smoking, optical coherence tomography, vascular compromise

Introduction

The choroid is a highly vascularized ocular structure located between the retina and the sclera, essential for maintaining retinal function by supplying oxygen and nutrients to the outer retinal layers. Anatomically, the choroid is composed of multiple layers, including Bruch's membrane, the choriocapillaris, Sattler's layer (medium-sized vessels) and Haller's layer

(large-caliber vessels). The choriocapillaris is a specialized network which is responsible for metabolic exchange between the retinal pigment epithelium and systemic circulation. On the other hand, Larger vessels regulate choroidal blood flow. The choroid is highly susceptible to systemic and ocular pathologies and its thickness is an important parameter for assessing ocular and systemic health. Conditions like hypertension, diabetes, and dyslipidemia may affect choroidal thickness.[1]

Choroidal thickness varies between individuals and is influenced by several physiological and demographic factors. In healthy adults, the sub foveal choroidal thickness (SFCT) generally ranges from 250 to 350 microns, though this can fluctuate based on age, axial length, refractive status, and diurnal variation. The choroid is typically thickest at the sub foveal region and gradually tapers toward the periphery. Age-related decline in choroidal thickness is a well-known phenomenon and progressive vascular atrophy is known to contribute to reduced choroidal perfusion. Myopia, hypermetropia, hydration status, systemic blood pressure, intraocular pressure and environmental conditions such as altitude and temperature are known to influence choroidal thickness.[2]

Many systemic and ocular conditions can lead to changes in choroidal thickness. Hypertension diabetes mellitus, Autoimmune diseases (systemic lupus erythematosus and rheumatoid arthritis) and endocrine disorders (hypothyroidism and hyperthyroidism) may impact CT as well as choroidal circulation. Ocular conditions like central serous chorioretinopathy are characterized by choroidal hyperpermeability and increased thickness. In contrast, the atrophic form of age-related macular degeneration leads to significant choroidal thinning due to the progressive degeneration of the choriocapillaris.[3]

Substance abuse, including alcohol consumption, illicit drug use and tobacco smoking significantly affect choroidal circulation and thickness. Chronic alcohol intake is associated with retinal and choroidal microvascular alterations leading to fluctuating choroidal thickness due to dehydration and vasodilatory effects. Cannabis is known to influence intraocular pressure and blood flow. Stimulants such as cocaine and amphetamines cause acute vasoconstriction thereby reducing choroidal perfusion and leading to transient thinning. Among these substances, tobacco smoking has the most extensively studied effects on choroidal thickness.[4] Chronic smoking introduces thousands of toxic chemicals into the bloodstream, including nicotine, carbon monoxide, and reactive oxygen species (ROS). These substances collectively contribute to endothelial dysfunction and microvascular damage..[5]

Assessing choroidal thickness in chronic smokers is important for assessment of smoking-induced ocular damage and systemic microvascular dysfunction. CT may serve as an early biomarker for various ocular pathologies.[6] Optical coherence tomography provides a non-invasive and highly sensitive method to evaluate these changes allowing for risk stratification and potential early interventions.[7] This study aims to perform a comparative analysis of choroidal thickness in chronic smokers versus nonsmokers using OCT and to assess the impact of smoking duration based on pack-year quartiles (PYQ).

Methods

This case-control study was conducted at the Regional Institute of Ophthalmology, Medical College, Kolkata, India, over an 18-month period from January 2023 to June 2024. Approval was obtained from the Institutional Ethics Committee, and informed written consent was secured from all participants prior to inclusion. Based on the findings of a previous study Sigler where a difference of 33 micrometers in the mean sub foveal thickness was found, keeping Alpha at 0.05 and Beta at 0.20, a sample size of 60 subjects in each group was calculated.

The study included male participants aged 25–50 years with best-corrected visual acuity of 6/6 (±2.0 diopters), near vision of N6, and normal intraocular pressure in both eyes. Cases comprised of chronic smokers with a history of smoking at least one pack (20 cigarettes) per day for 10 or more years, while controls included nonsmokers who met the same ocular criteria. Subjects with any ocular disease, previous eye surgery, or a history of drug intake known to affect ocular structures, particularly the choroid, retina, and retinal nerve fibers, were excluded from both groups.

The smokers (cases) were selected from the friends and relatives of out-patients. The nonsmokers were recruited from the in-patients and staff of the institution. All the subjects were counselled and an informed consent was taken. A personal interview was conducted and a detailed history was done

before going to ocular examination of both eyes and general check-up. Visual acuity of each eye with and without correction was taken. Refraction was carried out manually using Streak retinoscope followed by subjective correction.

Slit-lamp examination detailed examination was done to note the status of cornea, conjunctiva, anterior chamber, iris and the lens. Tonometry the cornea was anaesthetized using 0.5% proparacaine eye drop. The tear film was stained with sodium fluorescein 2% and intra ocular pressure was then measured using an Applanation Tonometer (Goldman).Fundus Examination- Optic disc was examined after dilating each pupil with one drop of a mixture of tropicamide 0.8% and phenylephrine 5%. A +90D lens (VOLK) was used at the slit-lamp for fundus examination.

All the subjects underwent EDI SD-OCT using the Spectralis Heidelberg apparatus. In each subject, two horizontal and vertical OCT EDI B –scans averaged 100 times, were taken centering on the fovea. In the horizontal and vertical scans, measurement of choroidal thickness was performed manually using the calipers provided by the Spectralis Heidelberg software on the center of fovea and 1.5 mm away from the fovea in the cardinal directions (superior, inferior, nasal and temporal). Choroidal thickness was measured from the outer limit of the retinal pigment epithelium to the choroidal-scleral junction. Comparison of choroidal thickness was done between smokers (cases) and nonsmokers (controls). Also, comparison of CT within smokers was done on the basis of pack-year quartiles (PYQ).

Statistical analyses were conducted using SPSS version 23.0. Foveal thickness, as measured using Enhanced Depth Imaging Spectral-Domain Optical Coherence Tomography (EDI SD-OCT), was analyzed as a continuous variable and presented as mean ± standard deviation (SD). Categorical data, including the proportion of subjects with reduced foveal thickness among smokers and nonsmokers, were expressed as frequency and percentage. The Chi-square test was used to evaluate associations between categorical variables. A p-value of less than 0.05 was considered statistically significant.

Results

The age distribution analysis revealed that the most common age group among smokers was 35–39 years (23.3%), followed by 30–34 years (20.0%). Among nonsmokers, the highest proportion also fell within the 35–39 years range (21.7%), followed by 30–34 years (18.3%) (Table 1).

All participants in both the smoker and nonsmoker groups were male (p=1.00). The mean pack-years among smokers was 20.2 ± 11.8, while it was 0 in the control group, and this difference was statistically significant ($p<0.05$). The intraocular pressure (IOP) was slightly lower in smokers (17.8 ±3.5 mmHg) compared to controls (18.5 ±2.9 mmHg), but this difference was not statistically significant (p=0.38). Similarly, the axial length (AL) was nearly identical between the two groups, with smokers having a mean AL of 22.9 ± 0.8 mm and controls at 22.9±1.0 mm (p=1.0) (p=1.0) (Table 2).

The comparison of choroidal thickness between smokers and nonsmokers showed significant thinning in several regions among smokers. In the sub foveal region, smokers had lower thickness in both the right eye (272.42 ± 13.57 µm vs. 284.94 ± 14.15 µm, $p<0.05$) and left eye (271.47 ± 15.27 µm vs. 285.38 ± 13.25 µm, $p<0.05$). Similarly, the superior parafoveal and nasal parafoveal regions showed significantly reduced thickness in smokers in both eyes ($p<0.05$). Overall smokers exhibited

Table 1 Age Distribution of Studied Subjects

Age Group (years)	Smokers (n=60)	Nonsmokers (n=60)	p-Value
25 to 29	8 (13.3%)	10 (16.7%)	
30 to 34	12 (20.0%)	11 (18.3%)	
35 to 39	14 (23.3%)	13 (21.7%)	
40 to 44	10 (16.7%)	9 (15.0%)	0.1890 (Not Significant)
45 to 49	9 (15.0%)	8 (13.3%)	
50	7 (11.7%)	9 (15.0%)	
Mean Age ± SD	43.1±7.2	40.8±11.4	

Table 2 Comparison of Clinical and Ocular Parameters Between Smokers and Controls

Variable	Smokers (n=60)	Controls (n=60)	p-Value
Age (years, mean ± SD)	43.1 ± 7.2	40.8 ± 11.4	0.18
Males (n)	60	60	1.00
Pack-years*	20.2 ± 11.8	0	<0.05
Intraocular Pressure (mmHg)	17.8 ± 3.5	18.5 ± 2.9	0.235
Axial Length (mm)	22.9 ± 0.8	22.9 ± 1.0	1.0

notable choroidal thinning particularly in the sub foveal and superior parafoveal regions (Table 3).

The distribution of smokers based on pack-year quartiles (PYQ) revealed that the Q3 (16-25 pack-years) had the highest number of cases, comprising 18 individuals (30%). The Q1 (1-5 pack-years) and Q4 (>25 pack-years) each included 15 individuals (25%), while the Q2 (6-15 pack-years) had the lowest proportion, with 12 individuals (20%). The analysis of retinal thickness across quartiles of PY (pack-years) showed a decreasing trend in most regions of both eyes. In the right eye, sub foveal thickness was highest in the 1st quartile (283.00 ± 11.78) and progressively declined to the 4th quartile (261.00 ± 7.58). A similar trend was observed in the superior parafoveal (276.00 ± 14.04 to 252.93 ± 8.97) and inferior parafoveal regions (269.53 ± 12.48 to 249.80 ± 8.94). The left eye also demonstrated a reduction in sub foveal thickness from 280.13 ± 16.29 in the 1st quartile to 265.73 ± 12.65 in the 4th quartile, with a comparable decline in superior parafoveal (276.33 ± 17.24 to 261.80 ± 12.53) and inferior parafoveal thickness (268.53 ± 15.95 to 257.40 ± 12.57) (Table 4).

The analysis of choroidal thickness across different pack-year quartiles (PYQ) demonstrated a significant decrease in thickness with increasing smoking exposure ($p<0.05$) in all choroidal regions. Both sub foveal and superior parafoveal regions showed a consistent decline in thickness in both eyes ($p<0.05$). Similarly, the nasal and temporal parafoveal regions exhibited a significant

Table 3 Comparison of Choroidal Thickness (CT) in Smokers vs Nonsmokers

Choroidal Thickness (in µm)	Variable	Smokers (n=60)	Nonsmokers (n=60)	p-Value
Right Eye	Sub foveal	272.42 ± 13.57	284.94 ± 14.15	<0.05
	Superior Parafoveal	264.78 ± 14.58	276.17 ± 14.68	<0.05
	Inferior Parafoveal	260.57 ± 14.14	271.82 ± 14.33	<0.05
	Nasal Parafoveal	264.53 ± 13.22	277.02 ± 13.59	<0.05
	Temporal Parafoveal	262.90 ± 13.32	277.87 ± 13.67	<0.05
Left Eye	Sub foveal	271.47 ± 15.27	285.38 ± 13.25	<0.05
	Superior Parafoveal	264.16 ± 15.16	276.10 ± 14.45	<0.05
	Inferior Parafoveal	261.78 ± 13.91	272.73 ± 14.07	<0.05
	Nasal Parafoveal	264.88 ± 14.87	277.87 ± 13.67	<0.05
	Temporal Parafoveal	261.18 ± 15.03	274.82 ± 14.71	<0.05

Table 4 Comparison of Choroidal Thickness in Individuals with Different Pack-Year Quartiles (PYQ)

Eye	Region	Q1 (1-5 pack-years) (n=15)	Q2 (6-15 pack-years) (n=12)	Q3 (16-25 pack-years) (n=18)	Q4 (>25 pack-years) (n=15)
Right Eye	Sub foveal	283.00 ± 11.78	277.17 ± 11.05	266.33 ± 11.81	261.00 ± 7.58
	Superior Parafoveal	276.00 ± 14.04	269.33 ± 11.79	258.75 ± 11.66	252.93 ± 8.97
	Inferior Parafoveal	269.53 ± 12.48	266.56 ± 12.57	253.83 ± 12.39	249.80 ± 8.94
	Nasal Parafoveal	275.53 ± 10.98	266.83 ± 11.67	258.42 ± 10.74	255.67 ± 10.37
	Temporal Parafoveal	272.53 ± 11.76	266.22 ± 12.45	255.00 ± 10.38	255.60 ± 10.61
Left Eye	Sub foveal	280.13 ± 16.29	275.22 ± 15.56	262.17 ± 8.45	265.73 ± 12.65
	Superior Parafoveal	276.33 ± 17.24	267.83 ± 14.57	257.08 ± 8.08	261.80 ± 12.53
	Inferior Parafoveal	268.53 ± 15.95	265.22 ± 13.05	253.67 ± 8.38	257.40 ± 12.57
	Nasal Parafoveal	275.80 ± 13.40	269.22 ± 13.91	255.17 ± 9.28	256.53 ± 11.98
	Temporal Parafoveal	272.07 ± 12.45	263.72 ± 14.75	251.58 ± 12.33	254.93 ± 12.55

Table 5 Correlation Between Choroidal Thickness and Pack-Year Quartiles (PYQ)

Choroidal Region	Finding
Sub foveal (Right & Left)	Significant decrease in thickness with increasing PYQ ($p<0.05$)
Inferior Parafoveal (Right & Left)	Significant decrease in thickness with increasing PYQ ($p<0.05$), except left inferior region (NS)
Superior Parafoveal (Right & Left)	Significant decrease in thickness with increasing PYQ ($p<0.05$)
Nasal Parafoveal (Right & Left)	Significant decrease in thickness with increasing PYQ ($p<0.05$)
Temporal Parafoveal (Right & Left)	Significant decrease in thickness with increasing PYQ ($p<0.05$)

reduction in thickness with increasing PYQ ($p<0.05$). These findings support a dose-dependent effect of chronic smoking on choroidal thinning, with certain regions being more vulnerable than others (Table 5).

Discussion

The choroid is a vital vascular structure that plays an essential role in ocular physiology by supplying oxygen and nutrients to the retinal pigment epithelium and photoreceptors. Choroidal thickness is an essential parameter that reflects choroidal vascular health and it can be affected by various ocular and systemic conditions.[8] A decrease in choroidal thickness has been implicated in the pathogenesis of retinal diseases such as age-related macular degeneration (AMD), diabetic retinopathy, and central serous chorioretinopathy (CSCR).[9] Studies using enhanced depth imaging optical coherence tomography (EDI-OCT) have demonstrated that choroidal thinning is an early marker of systemic vascular dysfunction and could predict the progression of ischemic and degenerative conditions.[10] Various Researchers including Abouammoh MA reported a significant reduction in

choroidal thickness in patients with chronic CSCR.[11] Similarly Gattoussi S demonstrated a strong correlation between reduced choroidal thickness and AMD.[12] Since choroid predominantly vascular in nature any systemic factor that alters vascular tone and perfusion may contribute to choroidal thinning and subsequent visual impairment.

The cause of reduced choroidal thickness in individuals having history of chronic smoking is multifactorial and includes factors such as vasoconstriction and oxidative stress. Nicotine present in tobacco is known to cause release of catecholamines which cause vasoconstriction of the choroidal vasculature. This vasoconstriction is responsible for reducing perfusion and nutrient delivery.[13] In a study by Teberik *et al.*[14] smokers were found to have significantly reduced sub foveal choroidal thickness as compared to nonsmokers.Additionally oxidative stress from smoking is known to cause endothelial dysfunction by reducing nitric oxide (NO) bioavailability, Reduced NO bioavailability leads to impaired vasodilation and promoting vascular inflammation.[15] This mechanism was supported by the findings of El-Mahdy *et al.*[16] who reported that chronic exposure to cigarette smoke resulted in increased oxidative damage to the choroidal endothelium.

In this study, smokers demonstrated significantly decreased sub foveal and parafoveal choroidal thickness as compared to nonsmokers. This finding is consistent with previous research. Quiroz-Reyes, M.A found that chronic smokers had reduced sub foveal choroidal thickness as compared to healthy controls thereby suggesting a direct relationship between smoking and choroidal thinning.[17] Furthermore, Yuan *et al.*[18] observed a reduction in choroidal thickness even in children exposed to second hand smoke.These findings align with this study where smokers exhibited a notable decrease in choroidal thickness particularly in the sub foveal and superior parafoveal regions. The regional differences in choroid thinning may be attributed to variations in choroidal vascular density and susceptibility to nicotine-induced vasoconstriction.

The relationship between smoking duration and choroidal thinning is another important area of investigation. This study demonstrated a progressive decrease in choroidal thickness with increasing pack-years of smoking which suggests that a there is a cumulative effect of smoking on choroidal vasculature. This finding is also supported by Moschos *et al.*[19] who reported that smokers with more than 20 pack-years had significantly thinner choroids compared to those with lower cumulative exposure. The dose-dependent association between smoking and choroidal thinning highlights the importance of early smoking cessation to preserve choroidal and retinal health. Given that choroidal atrophy is associated with retinal degenerative diseases the reduction in choroidal thickness seen in chronic smokers can be used as a biomarker for early vascular dysfunction as well as susceptibility to visual impairment.[20]

The limitations of this study included a relatively small sample size which may limit the applicability of findings of this study to a broader population. Additionally smoking history was assessed on the basis of self-reported pack-years making the data collection susceptible to recall bias. Lastly vascular risk factors such as hypertension, diabetes and lipid profile which could introduce confounding effects and influence the observed results, were not extensively analyzed. These were the major limitations of this study.

This study found a significantly reduced choroidal thickness among chronic smokers as compared to nonsmokers. Moreover, there was a dose-dependent relationship between smoking and choroidal thinning and increased smoking exposure (higher pack-year quartiles) was associated with progressive choroidal thinning. These structural changes suggest a possible smoking-induced vascular compromise in the choroid.

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