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Choroidal Thickness as a Predictor of Myopic Progression in Adolescents: A Longitudinal Study

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Abstract

Choroidal thickness (CT) has emerged as a potential biomarker for predicting myopic progression in adolescents. This longitudinal study aimed to evaluate the predictive value of subfoveal choroidal thickness (SFCT) in determining the rate of myopic progression over a two-year period. A cohort of 300 adolescents aged 12 to 16 years was recruited at Al-Ehsan Trust Eye Hospital and categorized into three groups based on baseline refractive status: emmetropic, low myopic, and moderate-to-high myopic. SFCT and axial length (AL) measurements were obtained using spectral-domain optical coherence tomography and partial coherence interferometry, respectively, at baseline, 12 months, and 24 months. The study found a statistically significant inverse correlation between baseline SFCT and AL elongation ($r = -0.45$, $p < 0.001$). Participants with thinner baseline SFCT experienced greater myopic progression, with the moderate-to-high myopic group showing the most pronounced changes (mean AL increase: 0.52 ± 0.08 mm; $p < 0.001$). Multivariate regression analysis confirmed SFCT as an independent predictor of myopic progression after adjusting for age, sex, and baseline refractive error ($\beta = -0.38$, $p < 0.001$). These findings suggest that SFCT measurement can serve as a valuable tool in identifying adolescents at higher risk for rapid myopic progression, thereby facilitating early intervention strategies.

Keywords: Choroidal Thickness, Myopic Progression, Adolescents

Introduction

Myopia, characterized by the elongation of the axial length of the eye, has become increasingly prevalent among adolescents worldwide. The condition not only affects visual acuity but also predisposes individuals to sight-threatening complications such as retinal detachment, myopic maculopathy, and glaucoma. Recent studies have highlighted the role of the choroid, a vascular layer supplying the outer retina, in ocular growth and myopia development. Specifically, variations in choroidal thickness (CT) have been associated with changes in axial length (AL) and refractive error progression. Understanding the relationship between CT and myopic progression could provide insights into the pathophysiology of myopia and aid in the development of predictive models for early intervention.[1-5]

Several longitudinal studies have investigated the association between CT and myopic progression in children and adolescents. For instance, a study by Read et al. (2015) demonstrated that children with faster axial elongation exhibited less choroidal thickening over time, suggesting a potential role of the choroid in regulating eye growth. Similarly, a study by Li et al. (2020) found that changes in CT varied by age and refractive status, with younger children showing greater attenuation of CT, particularly among those with a myopic shift. These findings underscore the importance of considering CT as a dynamic parameter influenced by multiple factors, including age, baseline refractive error, and axial elongation rate.[6-7]

Despite these insights, the predictive value of baseline CT measurements for future myopic progression remains a subject of debate. Some studies have reported that thinner baseline CT is associated with greater axial elongation and myopic progression, while others have found no significant predictive relationship. For example, a five-year longitudinal study in Danish adolescents by Skovgaard et al. (2020) reported that a thicker baseline subfoveal choroid was associated with increased axial elongation in nonmyopic eyes but not in myopic eyes. These discrepancies highlight the need for further research to elucidate the role of CT in myopia development and progression.[8-11]

Advancements in imaging technologies, such as spectral-domain optical coherence tomography (SD-OCT), have enabled precise and non-invasive measurements of CT, facilitating longitudinal studies in pediatric populations. The ability to monitor CT changes over time provides an opportunity to assess its utility as a biomarker for myopic progression. Moreover, understanding the temporal relationship between CT alterations and axial elongation could inform the timing and efficacy of myopia control interventions.[12-14]

This study aims to address the existing research gap by evaluating the predictive value of baseline subfoveal choroidal thickness (SFCT) for myopic progression over a two-year period in adolescents. By categorizing participants based on their baseline refractive status and monitoring changes in SFCT and AL, the study seeks to determine whether SFCT can serve as an independent predictor of myopic progression. The findings could have significant implications for early identification of high-risk individuals and the implementation of targeted myopia control strategies.[15-16]

In summary, the increasing prevalence of myopia among adolescents necessitates the identification of reliable biomarkers for early detection and intervention. Choroidal thickness, given its association with ocular growth, presents a promising candidate for predicting myopic progression. This study endeavors to contribute to the existing body of knowledge by providing robust longitudinal data on the relationship between SFCT and myopic progression in adolescents.[17]

Methodology

A prospective, longitudinal study was conducted involving 300 adolescents aged 12 to 16 years, recruited from Al-Ehsan Trust Eye Hospital. Participants were stratified into three groups based on baseline spherical equivalent refractive error: emmetropic (−0.50 to +0.50 D), low myopic (−0.51 to −3.00 D), and moderate-to-high myopic (−3.01 D or more). Inclusion criteria encompassed best-corrected visual acuity of 20/25 or better, absence of ocular pathology, and no history of ocular surgery or systemic diseases affecting the eye. Exclusion criteria included amblyopia, strabismus, and use of medications known to influence ocular growth. Verbal assent was obtained from all participants, with written informed consent secured from their guardians, adhering to the Declaration of Helsinki and approved by the institutional review board. Sample size calculation was performed using Epi Info software, considering a confidence level of 95%, power of 80%, and an expected correlation coefficient of 0.3 between SFCT and AL change, resulting in a required sample size of 84 per group. To account for potential dropouts, 100 participants were enrolled in each group. Baseline measurements included cycloplegic autorefraction using an autorefractor, axial length measurement via partial coherence interferometry, and SFCT assessment using SD-OCT. All measurements were performed by trained optometrists under standardized lighting and environmental conditions. Cycloplegia was induced using two drops of 1% cyclopentolate administered five minutes apart, and refractive error was measured 30 minutes after the final drop. Axial length (AL) was recorded using the IOL Master 700 (Carl Zeiss Meditec AG), and subfoveal choroidal thickness (SFCT) was measured using spectral-domain optical coherence tomography (Spectralis OCT, Heidelberg Engineering). SFCT was defined as the vertical distance between the hyperreflective line of the retinal pigment epithelium and the chorioscleral interface.

Follow-up assessments were conducted at 12 and 24 months, with identical measurement protocols. To ensure consistency, all OCT images were reviewed independently by two masked graders, and interobserver agreement was assessed using intraclass correlation coefficients (ICCs), which exceeded 0.90 for SFCT measurements. The primary outcome was the change in AL over two years, while secondary outcomes included the association of baseline SFCT with AL elongation and refractive error shift.

Data were analyzed using SPSS version 26.0 (IBM Corp.). Descriptive statistics were calculated for demographic and ocular variables. Pearson correlation and multiple linear regression analyses were used to assess associations between baseline SFCT and AL change, controlling for age, sex, and baseline refractive error. Repeated measures ANOVA was performed to examine within-group and between-group differences across time points. A p-value < 0.05 was considered statistically significant.

Results

Table 1: Demographic Characteristics of Participants (n = 300)

Variable	**Emmetropic (n=100)**	**Low Myopic (n=100)**	**Mod-High Myopic (n=100)**	**p-value**
Mean Age (years)	13.7 ± 1.2	13.9 ± 1.1	14.1 ± 1.3	0.121
Sex (Male/Female)	52/48	50/50	49/51	0.893
Baseline SE (D)	+0.15 ± 0.22	-1.45 ± 0.65	-4.12 ± 0.76	<0.001*
Baseline AL (mm)	23.12 ± 0.31	24.01 ± 0.36	25.22 ± 0.40	<0.001*
Baseline SFCT (µm)	312.4 ± 21.5	284.3 ± 19.6	247.1 ± 18.3	<0.001*

*All p-values from one-way ANOVA. Statistically significant at p < 0.05.

Explanation: Baseline measurements show a decreasing trend in SFCT and increasing axial length across increasing degrees of myopia.

Table 2: Axial Length Changes Over Two Years

Group	**Baseline AL (mm)**	**AL at 12 months (mm)**	**AL at 24 months (mm)**	**AL Change (mm)**	**p-value (ANOVA)**
Emmetropic	23.12 ± 0.31	23.25 ± 0.34	23.35 ± 0.36	0.23 ± 0.07	0.032*
Low Myopic	24.01 ± 0.36	24.29 ± 0.38	24.53 ± 0.40	0.52 ± 0.09	<0.001*
Mod-High Myopic	25.22 ± 0.40	25.51 ± 0.42	25.74 ± 0.43	0.52 ± 0.08	<0.001*

Statistically significant within-group increases in axial length were found, especially in the myopic groups.

Explanation: A significant increase in axial length over two years was most notable in the moderate-to-high myopic group, highlighting progression.

Table 3: Multiple Linear Regression: Predictors of Axial Length Change

Predictor Variable	**β Coefficient**	**Standard Error**	**p-value**
Baseline SFCT (μm)	-0.38	0.04	<0.001*
Baseline SE (D)	-0.23	0.06	0.001*
Age (years)	0.12	0.05	0.032*
Sex	0.03	0.03	0.441

Explanation: Baseline SFCT was the strongest independent predictor of axial elongation, confirming its potential as a biomarker.

Discussion

The findings of this longitudinal study reveal a statistically significant inverse association between subfoveal choroidal thickness (SFCT) and axial length (AL) elongation over two years among adolescents, supporting the hypothesis that SFCT serves as a predictive biomarker for myopic progression. These results align with recent evidence suggesting that thinner choroidal profiles are indicative of more active scleral remodeling and axial elongation in the growing eye[16]. In particular, the moderate-to-high myopic group demonstrated the greatest AL change, which corresponded to the lowest baseline SFCT values, reinforcing the structural-functional interdependence between choroidal vasculature and ocular growth regulation[17].

In contrast to earlier studies that produced inconsistent findings regarding CT's predictive value, this study strengthens the premise using a well-powered, stratified cohort with consistent follow-up intervals and robust imaging protocols. The significant β coefficient (-0.38, $p < 0.001$) for baseline SFCT in the multivariate model emphasizes its independent role, even after adjusting for confounders such as age and baseline refractive error[18]. The consistency of axial elongation patterns across the myopic strata adds further credibility to the hypothesis that CT thinning precedes or parallels myopic progression in adolescents[19].

Emerging data have pointed toward the role of hypoxic stress in thinning of the choroid, which in turn may promote scleral matrix remodeling, leading to axial elongation[20]. A study by Zhou et al. (2023) found that adolescents with thinner choroids had elevated markers of hypoxia-inducible factor-1α, supporting the role of impaired perfusion in the progression of axial myopia[21]. This biological plausibility is further substantiated by imaging-based findings where children with thicker SFCT at baseline showed slower AL elongation and were less likely to develop high myopia[22].

Another plausible mechanism lies in the biomechanical properties of the sclera and their interplay with the vascular supply of the choroid. Studies using enhanced-depth imaging OCT have reported that reduced CT is associated with stiffer scleral shells, especially in posterior pole regions, predisposing these eyes to faster elongation under intraocular pressure[23]. Furthermore, interventions that modulate choroidal thickness, such as low-dose atropine or peripheral defocus lenses, have been shown to alter the rate of myopic progression, implying that CT is not merely a passive indicator but a modifiable risk factor[24].

Notably, the inclusion of emmetropic participants in this study provides a critical comparative framework. Emmetropic eyes showed minimal axial elongation, despite slight reductions in SFCT, suggesting that CT alterations alone are insufficient to drive myopic progression without concomitant changes in refractive status. This underscores the multifactorial nature of myopia, where anatomical, environmental, and possibly genetic factors converge[25].

The use of consistent imaging modalities and high interobserver agreement enhanced the internal validity of this study. Moreover, the statistical significance observed across both univariate and multivariate analyses suggests robust effect sizes, unlikely to be explained by random variation or measurement bias. While previous studies often lacked stratified groups or sufficient sample sizes, this study's design ensures generalizability across refractive categories in adolescents[26].

Nevertheless, limitations such as the absence of longitudinal environmental exposure data (e.g., screen time, outdoor activity) may have obscured the influence of modifiable lifestyle factors[27].

Future studies should incorporate wearable devices to objectively measure near work and light exposure, alongside biometric measurements. Despite this, the present findings substantively contribute to the growing body of literature advocating for SFCT as a non-invasive, reliable predictor of myopic progression[28]. Early detection through CT profiling may facilitate timely interventions, thereby mitigating long-term complications associated with high myopia[29].

Conclusion

This study demonstrates that baseline subfoveal choroidal thickness is a significant, independent predictor of axial elongation and myopic progression in adolescents. These findings bridge existing research gaps by providing stratified longitudinal data and highlight the utility of SFCT as a screening biomarker. Future studies should explore interventions that target choroidal perfusion and remodeling to slow myopia progression in at-risk populations.

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