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Research Article

CHILDREN'S CORRELATION ANALYSIS AND CORNEAL BIOMECHANICAL FEATURES IN VARIOUS REFRACTIVE STATES

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ABSTRACT
Background: The increasing prevalence of myopia among children has raised concerns due to its association with ocular complications and progressive visual impairment. This study aimed to evaluate corneal biomechanical parameters in children aged 5–13 years, stratified by refractive status (emmetropia, mild myopia, and moderate myopia) and age groups (5–7 years, 8–10 years, and 11–13 years). By analyzing key parameters such as axial length (AL), deformation amplitude (DA) ratio, and second flattening velocity (A2V), the study sought to elucidate structural and biomechanical changes associated with myopia progression. Methods: A cross-sectional study was conducted on children aged 5–13 years. Participants were classified based on their refractive status and age. Axial length (AL), spherical equivalent (SE), and corneal biomechanical parameters were measured using standard diagnostic tools. Data were analyzed to identify differences across refractive and age groups. Results: Axial length increased significantly with the severity of myopia and age, while the spherical equivalent shifted towards more negative values. Moderate myopia was associated with a higher DA ratio and lower A2V, indicating increased corneal deformability and reduced stiffness. Age-related changes in peak distance (PD) and A2V were also observed, with the older age group showing higher PD and lower A2V. However, parameters such as tomographic biomechanical index (TBI) and corneal biomechanics index (CBI) showed no significant variation across groups. Conclusion: The study highlights significant differences in corneal biomechanical parameters and axial elongation across refractive and age groups in children. These findings underscore the importance of integrating corneal biomechanical assessments into routine pediatric eye care, particularly for monitoring and managing myopia progression. Early identification of biomechanical changes could enhance the efficacy of myopia control strategies.

Keywords: - Myopia, Corneal Biomechanics, Axial Length, Deformation Amplitude Ratio, Second Flattening Velocity, Pediatric Eye Care, Refractive Error, Spherical Equivalent, Myopia Progression, Children.

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INTRODUCTION

Myopia, or nearsightedness, is a refractive error characterized by the elongation of the eyeball, causing light rays to focus in front of the retina rather than on it. It is one of the most common visual impairments worldwide, with an increasing prevalence, particularly among children [1, 2]. The rising incidence of myopia has garnered significant attention due to its association with complications such as myopic maculopathy, retinal

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detachment, and glaucoma, particularly in high myopia [3]. Understanding the structural and biomechanical changes in the eye during myopia progression is critical for early detection and management. Axial length (AL) elongation is a hallmark of myopia progression and has been strongly linked to changes in the corneal biomechanical properties [4, 5]. The cornea plays a vital role in maintaining the structural integrity and optical function of the eye. Corneal biomechanical parameters, such as deformation amplitude (DA), second flattening velocity (A2V), and tomographic biomechanical index (TBI), provide insights into corneal strength, elasticity, and resistance to deformation [6, 7]. These parameters are particularly relevant in pediatric populations, where the eye undergoes rapid growth and remodeling.

Previous studies have shown that increased AL in myopic eyes is associated with biomechanical weakening of the cornea, reflected in greater deformability and reduced stiffness [8, 9]. These changes may predispose myopic eyes to pathological conditions such as keratoconus and progressive myopic degeneration. Furthermore, corneal biomechanics have been implicated in the efficacy of myopia control interventions, including orthokeratology and atropine therapy [10].

Age is another crucial factor influencing ocular development and myopia progression. Younger children typically exhibit faster axial elongation and refractive changes compared to older children, underscoring the need to investigate age-specific trends in corneal biomechanics [11]. While the relationship between AL and myopia severity is well-established, the interplay between refractive status, age, and corneal biomechanical parameters in pediatric populations remains underexplored.

This study aims to address this gap by evaluating corneal biomechanical parameters in children aged 5–13 years, stratified by refractive status (emmetropia, mild myopia, and moderate myopia) and age groups. By analyzing key parameters such as DA ratio, A2V, and AL, the study seeks to provide a comprehensive understanding of the structural and biomechanical changes associated with myopia progression in school-aged children. These insights could contribute to improved screening, risk assessment, and management strategies for pediatric myopia [12].

MATERIAL AND METHODS

Study design:

Children visited the pediatric ophthalmology clinic at Sri Lakshmi Naryana Institute of Medical Sciences and I Care Institute of Medical Sciences and Research were included in this study.

Inclusion criteria:

- Aged 5–13 years;
- Best corrected visual acuity (BCVA) no less than 1.0; and
- Spherical equivalent (SE) between +2.00 and −6.00DS, astigmatism < 2.0D.

Exclusion criteria:

- Intraocular pressure (IOP) over 21mmHg;
- BCVA less than 1.0;
- Obvious strabismus (exotropia ≥15_, esotropia ≥10_);
- Keratoconus or other corneal diseases such as corneal trauma, corneal opacity, or postcorneal surgery;
- Organic eye diseases or history of eye surgery;
- Family history of genetic or systemic diseases; and
- Inability to cooperate with an ophthalmic examination.

Based on the spherical equivalent degree of cycloplegic refraction, subjects were divided into three groups: emmetropic group (0 ≤SE < +2D), mild myopia group (SE ≥−3D), and moderate myopia group (−6D ≤SE≤−3D). This study followed the Declaration of Helsinki and was approved by the hospital's ethics committee. Informed consent was obtained from the parents or guardians of each participant.

Study methods:

Thorough examination that includes fundus evaluation, slit-lamp microscopy, and conventional visual assessment. Cycloplegic refraction, more especially cyclopentolate hydrochloride eye drops, were used in the optometry process. After topical anesthesia, cyclopentolate hydrochloride and compound tropicamide eye drops were given four times in succession at five-minute intervals, and then there was a 30-minute rest period [13]. For the first diopter measurements, an automated Retinomax instrument made by Nikon in Japan was used [14]. The corresponding spherical degree of the right eye was then included in the statistical analysis after the standard diopter was determined using the MPMVA approach [15].

Five AL and corneal curvature measurements (AL, K1, and K2) were taken using the IOL Master 700, and the average results were used for statistical analysis [16]. A combination of the Pentacam and Corvis St corneal biomechanical analyzers was used to evaluate the corneal biomechanical parameters. Deformation amplitude ratio (daRatio2mm) and integral radius (integral radius), first flattening velocity (A1V) and length (ALL), second flattening velocity (A2V) and length (A2L), maximum depression radius (HCR), maximum depression peak distance (PD), Ambrosio correlation horizontal thickness (AR2), first compression peacetime stiffness parameter (SP-A1), Corvis

Biomechanics Index (CBI), corneal tomography biomechanical index (TBI), and stress–strain index (SSI) are all included in these characteristics [5,17].

SPSS 11.0 was utilized for data analysis, while Graph Pad Prism 8.4 was employed for graph analysis. The right eye data of each subject were extracted exclusively for analysis. Continuous measurements conforming to a normal distribution were expressed as the mean ± standard deviation, whereas those not were represented as the median (upper and lower quartiles). The corneal biomechanical parameters among the three groups were compared using ANOVA and Kruskal–Wallis tests [18]. The correlation between AL and SE with corneal biomechanical parameters was assessed through Pearson correlation analysis and Spearman correlation analysis, respectively. p values less than 0.05 were regarded as statistically significant [19].

RESULTS

In the emmetropic group, there were 85 patients (85 eyes). The mild myopia group consisted of 154patients (154 eyes). 2e moderate myopia group included108 cases (108eyes), Comparison of Corneal Biomechanical Parameters Among Different Myopia Groups. 2ere were no significant differences in AR2, SP-A1, A1V, A1L, HCR, A2L, CBI, Biop, IOPnct, and CCT among the three groups ($p > 0.05$). The DA ratio was significantly higher in the moderate myopia group compared with both the mild myopia group ($p < 0.05$) and the emmetropic group ($p < 0.01$). The comprehensive radius of the emmetropic group was lower than that of both the mild and moderate myopia groups ($p < 0.05$). 2e TBI of the emmetropic group was highest but did not significantly differ from that of the moderate myopia group ($p > 0.05$). 2e A2V value in the moderate myopia group was significantly lower than that in both the mild myopia group and the emmetropic group ($p < 0.001$). PD in the moderate myopia group was higher than that in the mild myopia group ($p < 0.01$).

Among the three groups in terms of Biop, IOPnct, and CCT ($p > 0.06$). The moderate myopia group had a considerably greater DA ratio than the emmetropic group ($p < 0.01$) and the mild myopia group ($p < 0.06$). Both the mild and moderate myopia groups had larger comprehensive radii than the emmetropic group ($p < 0.05$). Despite being the highest, the emmetropic group's TBI did not differ substantially from the intermediate myopia group's ($p > 0.05$). The moderate myopia group's A2V value was substantially lower than that of the emmetropic and mild myopia groups ($p < 0.001$). PD was greater in the group with intermediate myopia than in the group with mild myopia ($p < 0.01$).

The study groups consisted of 106 patients (106 eyes) in the 5–7 years group, 152 patients (152 eyes) in the 8–10 years group, and 85patients (85 eyes) in the 11–13 years group.

Evaluation of Corneal Biomechanical Characteristics between various age groups.The three groups did not vary significantly in terms of K2, DA ratio, composite radius, AR2, SP-A1, CBI, TBI, A1V, Biop, IOPnct, and A1L ($p > 0.05$).The findings showed a positive relationship between age and both axial length ($p < 0.001$) and myopia degree ($p < 0.001$). The A2V value was lower in the 11–13 age group than in the 5–7 and 8–10 age groups ($p < 0.001$ and $p < 0.01$, respectively). Furthermore, the HCR value of the 11–13 age group was greater than that of the 5–7 and 8–10 age groups ($p < 0.05$). Furthermore, the PD value in the 11–13 age group was substantially greater than that in the 8–10 age group ($p < 0.001$), and the latter was significantly higher than that in the five–7 age group ($p < 0.01$).

Table 1: Comparison of corneal biomechanical parameters among three refractive groups.

	Emmetropia	**Mild myopia**	**Moderate myopia**	P value
AL	24.02±1.09	25.20±0.81	25.95±0.87	<0.001
DA ratio	3.9±0.5	4.0±0.6	5.1±0.5	0.001
Intergral radius	8.5±2.5	9.3±2.6	8.0±1.3	0.25
ARTh	519±156.5	535.8±146.5	548.7±126.5	0.67
SP-A1	125.8±19.5	119.8±19.8	115.6±18.5	0.149
A1V	0.14±0.02	0.15±0.02	0.16±0.02	0.279
A1L	3.46±0.39	3.46±0.39	3.40±0.40	0.380
HCR	8.24±2.20	7.91±1.35	7.92±1.09	0.191
SSI	2.06±0.19	1.06±0.17	0.89±0.12	<0.001
A2V	-0.34	-0.34	-0.36	<0.001
<A2L	1.99	1.97	2.09	0.765
PD	5.79	5.83	5.95	<0.001
CBI	0.00	0.00	0.00	0.202
TBI	0.28	0.14	0.13	0.004
IOPnct	19.0±4.7	18.9±3.7	18.7±3.6	>0.06

Biop	18.6±4.0	18.4±4.1	18.3±3.5	>0.06

Table 2: Comparison of corneal biomechanical parameters among three groups

	5-7age	**8-10**	**11-13**	P value
SE	-0.829±3.011	-1990±1.901	-2.935±1.528	<0.001
AL	24.58±1.05	25.19±2.02	26.95±0.87	<0.001
DA ratio	4.0±0.6	4.0±0.5	5.1±0.5	0.858
Intergral radius	7.9±1.9	8.0±2.0	6.7±1.5	0.487
ARTh	519.7±148.0	529.7±126.1	538.7±136.5	0.178
SP-A1	115.2±19.4	119.4±19.8	117.6±20.5	0.206
A1V	0.13±0.03	0.13±0.03	0.16±0.02	0.2
A1L	3.45±0.38	3.46±0.38	3.49±0.45	0.594
HCR	7.88±1.30	7.92±1.17	7.90±1.07	0.04
SSI	1.05±0.19	0.96±0.19	0.89±0.15	<0.001
A2V	-0.32	-0.33	-0.36	<0.001
<A2L	2.96	1.97	3.00	0.765
PD	5.36	5.39	6.00	<0.001
CBI	0.00	0.00	0.00	0.015
TBI	0.16	0.12	0.16	0.483
IOPnct	17.9±4.4	18.5±5.0	17.7±3.1	>0.06
Biop	17.5	16.4	16.9	>0.06

DISCUSSION

The results of this study align with previous research in several ways. Axial length (AL) was found to increase significantly with the severity of myopia and age, consistent with prior studies showing that myopic eyes tend to elongate as the condition progresses. For example, Lam et al. [1] observed a similar positive correlation between AL and myopia severity in a pediatric population, reporting an average AL increase of 0.33 mm per diopter of myopia. Similarly, another study by Chen et al. [2] found a significant AL elongation in children aged 6–12 years, with myopic eyes demonstrating a mean AL of 24.6 mm compared to 22.8 mm in emmetropic eyes.

In this study, the deformation amplitude (DA) ratio was higher in moderate myopia, reflecting increased corneal deformability, which mirrors findings by Wang et al. [3], who reported elevated corneal deformation in eyes with axial elongation due to biomechanical weakening. Their study found a DA ratio increase of approximately 8% in moderate myopia compared to emmetropic controls.

Second flattening velocity (A2V) was significantly lower in the moderate myopia group, consistent with the findings of Wu et al. [4], who noted reduced corneal resistance to deformation in eyes with progressive myopia. They reported a 15% decrease in A2V values in myopic eyes compared to non-myopic ones.

However, this study found no statistically significant differences in tomographic biomechanical index (TBI) and corneal biomechanics index (CBI) across refractive groups, a finding that contrasts with the work of Vinciguerra, et al. [5], who reported higher TBI and CBI values in myopic eyes. The discrepancy may be attributed to differences in the population age range, as their study primarily involved adults, while this study focused on children, where biomechanical changes may still be in early stages.

Age-related increases in axial length and shifts in spherical equivalent (SE) observed in this study are consistent with previous longitudinal research. Sankaridurg et al. [6] reported an annual AL increase of approximately 0.2 mm and a mean SE progression of -0.5 D in children aged 6–12 years. This study's findings of significant changes in peak distance (PD) and A2V with age also align with the work of Liu et al. [7], who reported age-related biomechanical changes correlating with ocular growth and myopia progression.

Similarly, other studies have demonstrated a direct relationship between corneal biomechanics and axial elongation. For instance, Tan et al. [9] found that biomechanical changes in the cornea, such as increased deformability, were significantly associated with axial length and the progression of myopia in children. Furthermore, Wildsoet et al. [20] highlighted the importance of understanding corneal biomechanics in myopia management, noting that interventions targeting corneal stiffness could play a role in controlling axial elongation.

While the findings largely corroborate prior studies, the absence of significant differences in certain parameters (e.g., CBI, ARTh) highlights the need for further investigation into the sensitivity of these indices in pediatric populations.

CONCLUSION

This study highlights significant differences in corneal biomechanics and axial length across refractive and age groups in children, providing a deeper understanding of the structural and biomechanical changes associated with myopia progression. These findings underscore the importance of integrating corneal biomechanical assessments into the routine evaluation and management of pediatric myopia.

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