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Editorial Board Member of World Journal of Clinical Cases, Prashanth Panta, MDS, Reader (Associate Professor), Department of Oral Medicine and Radiology, Malla Reddy Institute of Dental Sciences, Suraram 500055, Telangana, India. maithreya.prashanth@gmail.com

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Correlation of myopia onset and progression with corneal biomechanical parameters in children

Li-Li Lu, Xiao-Juan Hu, Yan Yang, Shen Xu, Shi-Yong Yang, Cui-Yu Zhang, Qing-Ya Zhao

ORCID number: Li-Li Lu 0000-0003-2713-1150; Xiao-Juan Hu 0000-0003-0562-8908; Yan Yang 0000-0002-4315-8275; Shen Xu 0000-0002-4650-6125; Shi-Yong Yang 0000-0001-5687-2818; Cui-Yu Zhang 0000-0001-5278-5629; Qing-Ya Zhao 0000-0003-0743-9430.

Author contributions: Lu LL contributed to study conception, design, and writing of the article; Hu XJ, Yang Y contributed to collection of clinical data; Xu S, Yang SY contributed to data acquisition, data analysis, and interpretation; Zhang CY, Zhao QY contributed to editing, reviewing, and final approval of the article.

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STROBE statement: The authors

Abstract

BACKGROUND
Recent epidemiological studies have shown that general eye measurement parameters and corneal biomechanical properties can predict the speed of myopic progression in children.

AIM
To investigate the correlation between the onset and progression of myopia and corneal biomechanical parameters in children.

METHODS
The study included 102 cases in the emmetropia group, 207 cases in the myopic group, and 109 cases in the hyperopic group. The correlation between the change in corneal biomechanical indexes and the change in general ocular measurement parameters was analyzed. A one-way ANOVA test compared general ocular measurement and corneal biomechanical parameters. Pearson’s correlation coefficient was analyzed to correlate corneal biomechanical and general ocular measurement parameters.

RESULTS
The general ophthalmometric parameters: Spherical equivalent (SE), intraocular pressure (IOP), and axial length (AL), differed significantly among subjects in myopia, emmetropia, and hyperopic groups. Children’s SE positively correlated with corneal biomechanical parameters: Second velocity of applanation (A2V), peak distance (PD), and deformation amplitude (DA) \((P < 0.05)\), and second applanation length (A2L) \((P < 0.05)\). But it was negatively correlated with PD, DA and integral radius (IR) \((P < 0.05)\). Also, IOP was negatively correlated with A2L and IR \((P < 0.05)\). AL positively correlated with A2V and negatively correlated with second applanation time (A2T), highest concavity, and PD. Central corneal thickness positively correlated with first applanation length, first applanation
The study included elementary school students aged 9–11 years who visited our hospital from November 2019 to April 2020, were enrolled for myopia study. We found a correlation between myopia development and various corneal biomechanical parameters in children. These findings may allow clinicians to take preventive measures to minimize a further increase in axial length.
hospital from November 2019 to April 2020. Our hospital ethics committee approved the study, and all enrolled subjects provided informed consent. Inclusion criteria: (1) best-corrected vision acuity ≥ 0.5 (LogMAR); and (2) no history of wearing special glasses, such as keratoplasty lenses. Exclusion criteria: (1) other eye diseases, such as amblyopia, strabismus, cone cornea, and lid entropion; (2) history of previous ophthalmic surgery, such as retinal, congenital cataract, and ptosis surgery; and (3) systemic diseases affecting the eye, such as diabetes mellitus. We grouped the subjects according to their spherical equivalent lens degree: (1) myopic group: SE < -0.50 D; (2) emmetropia group: -0.50 D ≤ SE ≤ +0.50 D; and (3) hyperopic group: SE > +0.50 D. There were 207 cases in the myopic group, including 142 males and 65 females, with a mean age of 10.23 ± 0.58 years. There were 102 cases in the emmetropia group, including 61 males and 41 females, with a mean age of 10.04 ± 0.64 years. There were 109 cases in the hyperopic group, including 59 males and 50 females, with a mean age of 10.19 ± 0.84 years. We followed up on patients in the myopia group every 3 mo, recording the axial measurement, medical optometry, and corneal biomechanical parameters. After 1 year of follow-up, we compared changes in corneal biomechanical indexes and other clinical characteristics.

Methods
After enrollment, all subjects underwent routine ophthalmic examinations, including naked eye visual acuity, best-corrected visual acuity, anterior segment, fundus, medical optometry, and other ophthalmic examinations. Subjects’ intraocular pressure (IOP), anterior chamber depth, corneal curvature, spherical equivalent (SE), flat-axis corneal curvature, and steep-axis corneal curvature were recorded. IOLMaster measured axial length (AL). Corvis ST measured corneal biomechanical parameters and biological parameters, including the first velocity of applanation (A1V), first applanation length (A1L), first applanation time (A1T), first applanation deformation amplitude (A1DA), the second velocity of applanation (A2V), second applanation length (A2L), second applanation time (A2T), second applanation deformation amplitude (A2DA), time from the start until the highest concavity (HCT), central curvature radius at highest concavity (HCR), peak distance (PD), deformation amplitude (DA), central corneal thickness (CCT), integrated radius (IR), ambrosia relational thickness-horizontal (ARTh), first applanation stiffness parameter (SP-A1), corvis biomechanical index (CBI), and topographic and biomechanics index (TBI).

Statistical analysis
The Kolmogorov–Smirnov test analyzed the distribution of variables. Normally, distributed data were expressed as the mean ± SD. The one-ANOVA test compared the three groups’ general ocular measurement and corneal biomechanical parameters. Correlations between corneal biomechanical and general ocular measurement parameters were analyzed using a Pearson correlation coefficient. All statistical analyses were performed using the SPSS 23.0 software package and MedCalc 15.2.2 software. P < 0.05 was considered a statistically significant difference.

RESULTS
Comparison of general ocular measurement parameters among the three groups of subjects
There were statistically significant (P < 0.05) differences in the general ocular measurement parameters SE, IOP, and AL among subjects in three groups. However, there were no significant differences in the general ocular measurement parameters CCT and Km among subjects in three groups (P > 0.05), as shown in Table 1.

Comparison of corneal biomechanical parameters among the three groups of subjects
The corneal biomechanical parameters A1V, A1L, A1T, A1DA, A2V, A2DA, HCR, PD, IR, ARTh, SP-A1, CBI, and TBI were significantly different (P < 0.05) among subjects in three groups. However, the corneal biomechanical A2L, A2T, HCT, DA were not significantly different subjects in three groups (P > 0.05, Table 2).
Table 1 Comparison of general ocular measurement parameters among the three groups of subjects

<table>
<thead>
<tr>
<th></th>
<th>Number of cases</th>
<th>SE (D)</th>
<th>IOP (mmHg)</th>
<th>AL (mm)</th>
<th>CCT (μm)</th>
<th>Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia group</td>
<td>207</td>
<td>-2.543 ± 0.493</td>
<td>17.04 ± 2.88</td>
<td>25.61 ± 0.77</td>
<td>560.31 ± 36.13</td>
<td>43.15 ± 2.05</td>
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<tr>
<td>Emmetropia group</td>
<td>102</td>
<td>-0.104 ± 0.025</td>
<td>15.40 ± 2.09</td>
<td>23.35 ± 0.68</td>
<td>559.23 ± 38.43</td>
<td>43.05 ± 1.96</td>
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<tr>
<td>Hyperopia group</td>
<td>109</td>
<td>2.465 ± 1.025</td>
<td>15.32 ± 2.93</td>
<td>22.08 ± 0.79</td>
<td>561.92 ± 40.50</td>
<td>43.61 ± 2.34</td>
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<td></td>
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<td>19.94</td>
<td>855.1</td>
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<td>2.279</td>
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<td>P value</td>
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<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>0.8725</td>
<td>0.1036</td>
</tr>
</tbody>
</table>

SE: Spherical equivalent; IOP: Intraocular pressure; AL: Axial length; CCT: Central corneal thickness.

Correlation of general ocular measurement parameters with corneal biomechanical parameters in children

Children’s general ocular measurement parameter SE positively correlated with corneal biomechanical parameters A2V and A2L while negatively correlated with PD, DA, and IR. In children, the general ocular measurement parameter IOP was positively correlated with corneal biomechanical parameters PD and DA and negatively correlated with A2L and IR. The general ocular measurement parameter AL positively correlated with corneal biomechanical parameter A2V and negatively correlated with A2T, HCT, and PD. The general ocular measurement parameter CCT in children was positively correlated with corneal biomechanical parameters A1L, A1T, A1DA, A2V, A2L, A2T, A2DA, HCR, PD, DA, IR, ARTh, SP-A1, CBl, and TBI and negatively correlated with A1V. Children’s general ocular measurement parameter Km positively correlated with corneal biomechanical parameters DA and IR but negatively correlated with A2L, HCR, and PD (all P < 0.05), as shown in Table 3.

The general ocular measurement parameters ΔIOP was positively correlated with the corneal biomechanical parameters ΔDA, ΔIR, and negatively with ΔA2L, and increased ΔAL was positively correlated with corneal biomechanical parameters ΔA2V and ΔPD.

Correlation between myopia development and corneal biomechanical parameters in children

There was a positive correlation between the increase in general ocular measurement ΔSE and the change in corneal biomechanical parameters ΔA2V and ΔA2L and a negative correlation with ΔIR. There was a positive correlation between ΔIOP and ΔDA and a negative correlation between ΔA2L and ΔIR. There was a positive correlation between the increase in the general ocular measurement parameter ΔAL and the change in the corneal biomechanical parameters ΔA2V and ΔPD in children. There was a positive correlation between the general ocular measurement parameter ΔCCT and the corneal biomechanical parameters ΔA1L, ΔA1T, ΔA2V, ΔA2L, ΔA2T, ΔA2DA, ΔHCR, ΔPD, ΔDA, ΔIR, ΔARTh, ΔSP-A1, ΔCBl, and ΔTBI and a negative correlation with ΔA1V. There was a positive correlation between the increase in general ocular measurement parameter ΔKm and the change in corneal biomechanical parameters ΔDA and ΔIR and a negative correlation with ΔHCR and ΔPD in children (all P < 0.05), as shown in Table 4.

The corneal biomechanical parameters A1V, A1L, A1T, A1DA, A2V, A2DA, HCR, PD, IR, ARTh, SP-A, CBl, and TBI were statistically different in the myopic, emmetropic, and hyperopic groups (all P < 0.05).

DISCUSSION

The prevalence of myopia is rather high worldwide, reaching 80% in some Asian populations[6]. Well-documented changes in myopia include prolonged AL, deeper anterior chamber and vitreous depth, thinner retina, higher incidence of retinal detachment, and reduced scleral thickness and elasticity[6]. This study measured general ocular and corneal biomechanical parameters in myopic, emmetropic, and hyperopic children. The analysis revealed statistically significant (P < 0.05) differences in general ocular measurement parameters SE, IOP, and AL among subjects in three groups. Corneal biomechanical parameters A1V, A1L, A1T, A1DA, A2V, A2DA, HCR,
<table>
<thead>
<tr>
<th>Number of cases</th>
<th>A1V (ms⁻¹)</th>
<th>A1L (mm)</th>
<th>A1T (ms)</th>
<th>A1DA (mm)</th>
<th>A2V (ms⁻¹)</th>
<th>A2L (mm)</th>
<th>A2T (ms)</th>
<th>A2D (mm)</th>
<th>HCT (ms)</th>
<th>HCR (mm)</th>
<th>PD (mm)</th>
<th>DA (mm)</th>
<th>IR</th>
<th>ARTh</th>
<th>SP-A1</th>
<th>CBI</th>
<th>TBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia group</td>
<td>207</td>
<td>0.13 ± 0.02</td>
<td>1.85 ± 0.29</td>
<td>7.63 ± 0.29</td>
<td>0.12 ± 0.01</td>
<td>1.73 ± 0.39</td>
<td>21.33 ± 0.93</td>
<td>1.37 ± 0.08</td>
<td>0.79 ± 0.08</td>
<td>7.59 ± 0.88</td>
<td>3.42 ± 0.09</td>
<td>0.98 ± 0.09</td>
<td>9.23 ± 1.93</td>
<td>472.03 ± 131.43</td>
<td>102.01 ± 18.43</td>
<td>0.53 ± 0.35</td>
<td>0.56 ± 0.25</td>
</tr>
<tr>
<td>Emmetropia group</td>
<td>102</td>
<td>0.15 ± 0.05</td>
<td>1.93 ± 0.33</td>
<td>7.41 ± 0.22</td>
<td>0.13 ± 0.01</td>
<td>1.70 ± 0.55</td>
<td>21.57 ± 0.91</td>
<td>0.41 ± 0.09</td>
<td>0.49 ± 0.02</td>
<td>16.73 ± 0.54</td>
<td>3.77 ± 0.09</td>
<td>0.99 ± 0.09</td>
<td>9.05 ± 1.93</td>
<td>451.61 ± 114.03</td>
<td>14.62 ± 0.14</td>
<td>0.23 ± 0.23</td>
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<td>Hyperopia group</td>
<td>109</td>
<td>0.14 ± 0.03</td>
<td>1.77 ± 0.29</td>
<td>7.39 ± 0.29</td>
<td>0.13 ± 0.02</td>
<td>1.63 ± 0.53</td>
<td>21.35 ± 0.47</td>
<td>0.32 ± 0.09</td>
<td>0.66 ± 0.10</td>
<td>16.59 ± 0.54</td>
<td>3.02 ± 0.09</td>
<td>0.99 ± 0.09</td>
<td>11.34 ± 256.45</td>
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<td>0.6079</td>
<td>47.99</td>
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<td>6.681</td>
<td>150.6</td>
<td>158.2</td>
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</table>

A1V: First velocity of applanation; A1L: First applanation length; A1T: First applanation time; A1DA: First applanation deformation amplitude; A2V: Second velocity of applanation; A2L: Second applanation length; A2T: Second applanation time; A2D: Second applanation deformation; HCT: Time from the start until the highest concavity; HCR: Central curvature radius at highest concavity; PD: Peak distance; DA: Deformation amplitude; IR: Integrated radius; ARTh: ambrosia relational thickness-horizontal; SP-A1: First applanation stiffness parameter; CBI: Corvis biomechanical index; TBI: Topographic and biomechanics index.

PD, IR, ARTh, SP-A1, CBI, and TBI were significantly different ($P < 0.05$) in three groups. Despite the limited tracking time and the number of participants compared to the large scale of clinic studies, our data were effectively valid because of highly professional supervision and appropriate statistics.

IOP is an important biometric parameter in myopic eyes. Previous studies have shown that thinner corneas may lead to underestimation errors in IOP measurements [7]. However, recent studies have found significantly higher mean IOP values in myopic children than in non-myopic children [8]. In this study, children’s general eye measurement parameter IOP was positively correlated with corneal biomechanical parameters PD and DA and negatively correlated with A2L and IR. The change in $\Delta$IOP was positively correlated with the corneal biomechanical parameter $\Delta$DA and negatively correlated with $\Delta$A2L and $\Delta$IR (all $P < 0.05$). Glaucoma is a blinding eye disease and the major ocular disease causing vision loss and blindness worldwide that shows characteristic damage to the optic nerve and loss of visual function [9]. Primary open-angle glaucoma is the most common form of glaucoma globally, where the degree of visual field damage is already severe, and the damage to visual acuity and visual field is irreversible [10]. Elevated IOP is considered the most important risk factor for developing and progression of primary open-angle glaucoma [11]. Therefore, alterations in DA in myopia development in children can be used as potential markers for glaucoma development.

In the present study, the general ocular measurement parameter CCT in children positively correlated (P < 0.05) with the corneal biomechanical parameters A1L, A1T, A2V, A2L, A2T, A2DA, HCR, PD, DA, IR, ARTh, SP-A1, CBI, and TBI, while it was
Table 3 Correlation of corneal biomechanical parameters with general ocular measurement parameters

<table>
<thead>
<tr>
<th>SE (D)</th>
<th>IOP (mmHg)</th>
<th>AL (mm)</th>
<th>CCT (μm)</th>
<th>Km</th>
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<td>p</td>
<td>P value</td>
<td>p</td>
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<tr>
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<td>0.5141</td>
<td>-0.024</td>
<td>0.6246</td>
</tr>
<tr>
<td>CBI</td>
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<td>0.6985</td>
</tr>
<tr>
<td>TBI</td>
<td>0.027</td>
<td>0.5820</td>
<td>-0.020</td>
<td>0.6835</td>
</tr>
</tbody>
</table>

SE: Spherical equivalent; IOP: Intraocular pressure; AL: Axial length; CCT: Central corneal thickness; A1V: First velocity of applanation; A1L: First applanation length; A1T: First applanation time; A1DA: First applanation deformation amplitude; A2V: Second velocity of applanation; A2L: Second applanation length; A2T: Second applanation time; A2DA: Second applanation deformation; HCT: Central curvature radius at highest concavity; PD: Peak distance; DA: Deformation amplitude; IR: Integrated radius; ARTh: ambrosia relational thickness-horizontal; SP-A1: First applanation stiffness parameter; CBI: Corvis biomechanical index; TBI: Topographic and biomechanics index.

The refractive error results from a mismatch between various optical components of the eye, one of the most important parts of which is AL[13]. In the present study, there was a positive correlation between the general ocular measurement parameter ΔCCT in children positively correlated with corneal biomechanical parameters ΔA1L, ΔA1T, ΔA2V, ΔA2L, ΔA2T, ΔA2DA, ΔHCT, ΔPD, ΔDA, ΔIR, ΔARTh, ΔSP-A1, ΔCBI, and ΔTBI (P < 0.05), while negatively correlated with ΔA1V (P < 0.05). Studies of CCT in children of different ages have shown that CCT increases with age so that the average CCT is thicker in older than in young children[12]. CCT and the change in CCT positively correlated with most corneal biomechamics except for A1V and ΔA1V, so these corneal biomechanical parameters may also increase with the child’s age.

The refractive error results from a mismatch between various optical components of the eye, one of the most important parts of which is AL[13]. In the present study, there was a positive correlation between the general ocular measurement parameter AL and the corneal biomechanical parameter A2V (P < 0.05) and a negative correlation with A2T, HCT, and PD (P < 0.05) in children. There was a positive correlation between the increased general ocular measurement parameter ΔAL and the change in the corneal biomechanical parameter ΔA2V and ΔPD in children (P < 0.05). This usually corresponds to an AL ≥ 26 mm, which significantly increases the risk of serious complications later in life, including myopic macular degeneration, retinal detachment, and glaucoma[14,15]. The mean AL of the subjects in the myopic group included in this study was 25.61 ± 0.77 mm. Therefore, the corneal biomechanical parameters A2V, A2T, HCT, and PD may identify children at low risk. The application of corneal biomechanical parameters will allow clinicians to implement preventive measures to minimize the further increase in AL. These measures include pharmacological agents, such as atropine, and optical applications, such as multifocal contact lenses. There are still limitations in this study, including that this study is a prospective study and cannot determine the causal relationship between various variables. At the same time, this study only collected children from the same hospital, and the sample size is small. There may still be other influencing factors that have not
been found. The age range of children included in this study is not large enough. In addition, due to time constraints, the children were not followed up for a longer time.

**CONCLUSION**

Myopia development in children was associated with multiple corneal biomechanical parameters. These findings may help clinics take preventive measures to minimize the further increase in myopic children’s axial length.

**ARTICLE HIGHLIGHTS**

**Research background**

Patients with myopia, especially those with high myopia, are much more likely to have serious complications such as retinal detachment and open-angle glaucoma than normal patients. High myopia may have a degenerative disorder, including cornea, sclera, choroid, optic disc, vitreous, macula, and peripheral retina.

**Research motivation**

The increasingly high incidents of myopia in children and the association with multiple corneal biomechanical parameters in local community and worldwide.
Research objectives
This study is to determine the change of corneal biomechanical parameters after onset and progression of myopia.

Research methods
A total of 207 myopic subjects were enrolled according to local clinic criteria and one-way ANOVA test was applied to determine whether there is statistical evidence between different general ocular measurement parameters.

Research results
There is a correlation between the development of myopia and various corneal biomechanical parameters in children.

Research conclusions
There are positive and negative correlations between myopia and general eye measurement parameters, corneal biomechanical parameters and other multiple parameters.

Research perspectives
Corneal ophthalmometric parameters and biomechanical properties including multiple baselines may be able to predict the development of myopia.

REFERENCES

