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Correlations Between Facial Anthropometry and Ocular Biometry in School-Aged Children

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Abstract

Background and Objectives: Understanding the relationship between craniofacial and ocular growth could provide further insight into the association between facial development and ocular biometric characteristics in children. However, facial anthropometric measurements and ocular biometric parameters in this population have not yet been sufficiently investigated. This study aimed to explore the correlations between these parameters in school-age children. *Materials and Methods*: A total of 112 school-aged children participated in the study. Facial anthropometric measurements were obtained using photogrammetric analysis, and ocular biometric parameters were measured with the IOLMaster 700. *Results*: Several facial anthropometric and ocular biometric parameters differed significantly across age groups. Boys had significantly greater lower facial height than girls ($p = 0.0074$), as well as higher values of axial eye length, anterior chamber depth, and horizontal corneal diameter. Significant positive correlations were identified between axial eye length and lower facial height, mandibular height, mouth height, facial width, facial height, and maxillary and mandibular depth. The strongest correlation was observed between axial eye length and lower facial height ($r = 0.305$; $p = 0.0011$). Anterior chamber depth was also positively correlated with lower facial height, mandibular height, and mouth height, with the strongest association again found for lower facial height ($r = 0.287$; $p = 0.0021$). *Conclusions*: The study identified several correlations between facial anthropometric measurements and ocular biometric parameters in children, with lower facial height showing the strongest correlation with both axial eye length and anterior chamber depth, suggesting a potential link between craniofacial morphology and ocular development. However, further longitudinal studies are needed to clarify these associations and their potential relevance to myopia development.

Keywords: anthropometry; face; eye biometry; children; myopia

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1. Introduction

Facial anthropometry is an important method for the objective assessment of the morphology and growth of craniofacial structures. Anthropometric measurements can be categorised into linear, angular, and proportional measurements; linear measurements describe distances between defined anatomical landmarks, whereas angular and index measurements allow for the assessment of spatial relationships and facial proportions [1–3]. During childhood, measurements of facial height and width, as well as those of specific facial regions, are particularly significant, as they reflect changes associated with the growth

and development of craniofacial structures [4,5]. Recent developments in digital photogrammetry and three-dimensional methods have enabled more precise and reproducible determination of facial anthropometric measurements, while maintaining the standardised anatomical landmarks and measurement definitions required for comparing different populations [6,7]. However, the relationship between facial morphology and the development of other anatomical structures of the head, particularly the eye, remains insufficiently explored. Ocular biometry plays an important role in monitoring the growth and development of the eye during childhood. Key biometric parameters include axial eye length, anterior chamber depth, lens thickness, central corneal thickness, and horizontal corneal diameter [8,9]. The process of emmetropisation occurs during childhood and involves the coordinated interaction of the eye's anatomical and optical components. Axial eye length is a key indicator of eyeball growth, and its excessive elongation is associated with the development and progression of myopia [10,11]. Advances in optical biometry have enabled non-invasive and precise measurement of ocular biometric parameters. Devices such as the IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany), which utilises swept-source optical coherence tomography, allow for the simultaneous determination of multiple anatomical eye parameters with high precision and reproducibility [12]. Monitoring axial eye length is particularly important in the paediatric population, as it can help identify children at increased risk of developing myopia before the onset of significant refractive changes [13]. Although previous studies have demonstrated a link between anthropometric body characteristics and ocular biometric parameters, the relationship between facial anthropometry and ocular biometry, particularly in childhood, has been far less explored. A better understanding of the potential relationship between the growth of craniofacial structures and the growth of the eyeball could contribute to clarifying the mechanisms associated with myopia development. Therefore, the aim of this study is to examine whether there is a connection between specific facial anthropometric measurements and biometric parameters of the eye in children.

2. Materials and Methods

This cross-sectional study included 112 children aged 7–14 years, recruited consecutively at the Department of Ophthalmology, University Hospital Center Sestre milosrdnice in Zagreb, Croatia, between March 2025 and March 2026. A total of 130 children were screened for eligibility. Eligibility was assessed through a comprehensive ophthalmological examination performed on all participants, review of available medical records, and information obtained from parents or guardian. Of the 130 children screened, nine were excluded because they did not meet the eligibility criteria, while the parents or legal guardians of another nine children declined participation. The remaining 112 children were included in the study. Complete anthropometric and ocular biometric data were available for all participants, and no observations were excluded because of missing data. Age was defined as completed years at the time of examination and was treated as a continuous variable in the descriptive statistical analysis. For comparative analyses, participants were additionally divided into four groups: Group 1 (participants aged 7 and 8 years), Group 2 (9 and 10 years), Group 3 (11 and 12 years), and Group 4 (13 and 14 years). The age of the study population ranged from 7 to 14 years, with a median of 10.5 years (IQR 8.5–12.5 years). Each group consisted of 28 participants, with equal age and gender representation (14 boys and 14 girls). All participants included in the study were of Caucasian European ancestry and belonged to the same broad ethnic background. No participants from other reported ethnic backgrounds were included.

Inclusion criteria were children aged 7 to 14 years, signed informed consent from a parent or guardian, and children who were able to cooperate during the examination.

Exclusion criteria were previous eye surgery or ocular trauma, corneal disease (including keratoconus), prior infection or inflammation of the anterior segment of the eye, contact lens wear within one month prior to imaging, strabismus, amblyopia, and craniofacial anomalies or other systemic diseases preventing the examination. Participants with a history of previous myopia-control treatment were also excluded. Additionally, children who were unable to maintain adequate fixation or cooperate sufficiently to obtain reliable ocular biometric measurements were excluded.

All imaging procedures were non-invasive and included photographic documentation of the face from frontal and lateral perspectives, as well as non-contact measurement of ocular parameters using the IOLMaster 700 device (Carl Zeiss Meditec AG, Jena, Germany). For each subject, biometric parameters were measured three times for each eye, and the mean value was used for statistical analysis. Photographic documentation of the subjects' faces was performed by a single examiner using standardised photography conditions and a calibration scale. On the frontal photographic documentation of the face, the following were measured:

1. Height of the upper facial third: from the anthropometric point trichion to the anthropometric point nasale (TR-N).
2. Height of the middle facial third: from nasale to subnasale (N-SN).
3. Height of the lower facial third or lower facial height: from subnasale to gnathion (SN-GN) (Figure 1).
4. Mandibular height: from stomion to gnathion (ST-GN).
5. Mouth height: from labiale superius to labiale inferius (LS-LI).
6. Mouth width: from cheilion dextrum to cheilion sinistrum (CHD-CHS).
7. Chin height: from supramentale to gnathion (SM-GN).
8. Facial width (bizygomatic width): from zygion dextrum to zygion sinistrum (ZYD-ZYS).
9. Facial height (anterior facial height): from nasion to gnathion (N-GN).

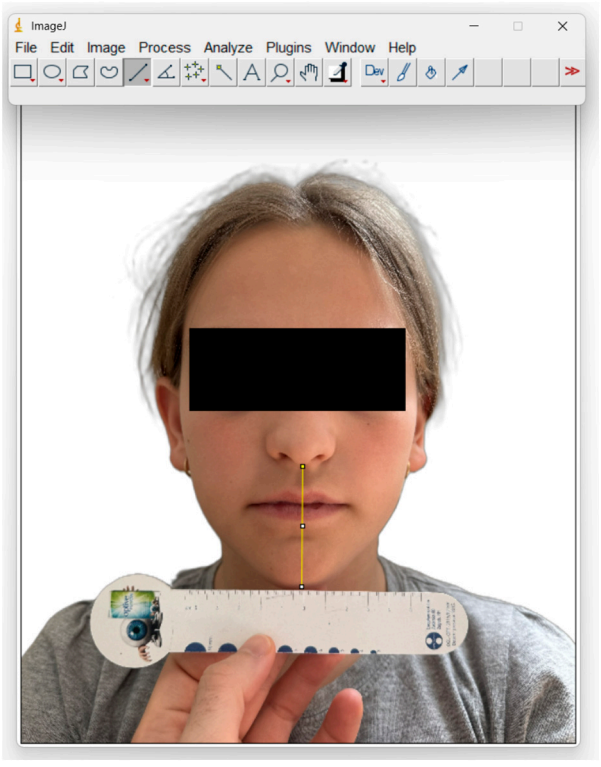


Figure 1. Anthropometric measurement of lower facial height (SN-GN) in frontal view using ImageJ (National Institutes of Health, Bethesda, MD, USA, version 1.54g) software.

On lateral facial photographic documentation, the following measurements were taken:

10. Maxillary depth on the right and left sides of the face: from tragion dextrum/sinistrum to subnasale (TD-SN/TS-SN).
11. Lower facial depth and mandibular depth on the right and left sides of the face: from tragion dextrum/sinistrum to gnathion (TD-GN/TS-GN) (Figure 2).

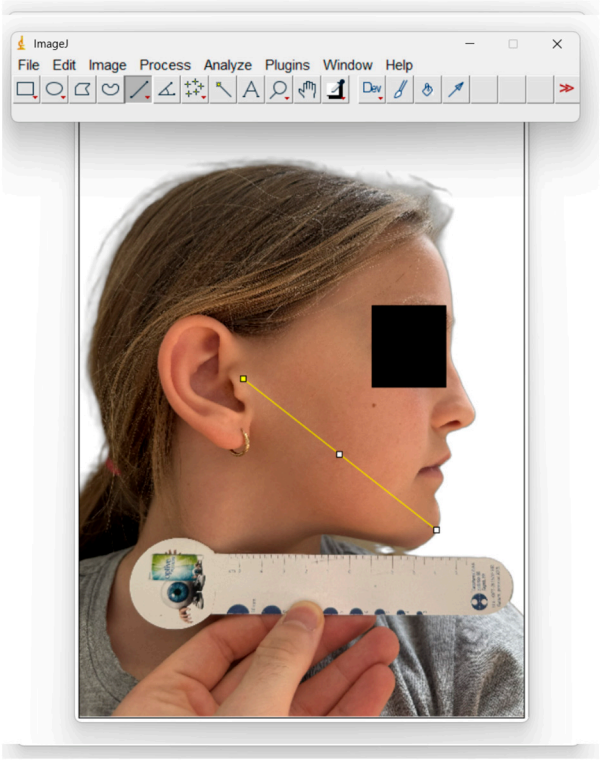


Figure 2. Anthropometric measurement of the mandibular depth on the right side of the face (TD-GN) in lateral view using ImageJ software.

The selection of anthropometric variables was based on standardised and validated anthropometric landmarks used in the relevant scientific literature on craniofacial morphology, as classified by Caple and Stephan [3].

Photos were calibrated as follows:

1. Use of the calibration object: a value scale in the form of a ruler marked in centimetres and millimetres, placed below the face and next to a standardised point for analysis (landmark), the gnathion point, which represents the most inferior part of the chin in frontal and lateral photo documentation (Figure 3). The ruler was included in the photographic field and used to establish the pixel-to-millimetre conversion.
2. Standardisation of head position, camera distance, and photographic orientation: all photographs were taken at a standardised distance of 1.5 m using a camera mounted on a tripod. The camera was positioned at the same height as the subject's face, with its optical axis perpendicular to the corresponding anatomical reference plane. For frontal photographs, the camera was positioned perpendicular to the frontal plane, whereas for lateral photographs, it was positioned perpendicular to the sagittal plane. Care was taken to maintain a horizontal camera orientation and avoid vertical or horizontal tilting. The subjects maintained a natural head position (NHP), with their teeth in maximum intercuspation. Both right and left lateral profile photographs were obtained. To standardise the orientation of the profile images for subsequent photogrammetric analysis, the photographs were digitally mirrored, where necessary, so that all profiles

were presented in the same orientation. Photographs were obtained using an iPhone 16 (Apple Inc., Cupertino, CA, USA), equipped with a 48-megapixel Fusion main camera (26 mm equivalent focal length, f/1.6 aperture). Images were captured using the standard Photo mode at 1× magnification, without digital zoom, at a resolution of 24 megapixels.

3. Use of photogrammetry software with an automatic calibration function: ImageJ software (National Institutes of Health, Bethesda, MD, USA), version 1.54g.

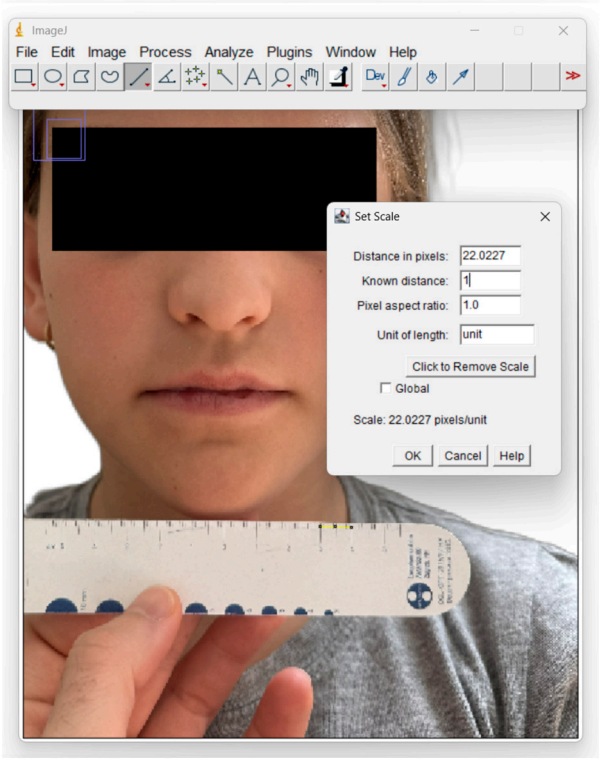


Figure 3. Measurement calibration according to the value scale placed next to the standardised analysis point (landmark) in the ImageJ software.

All facial anthropometric measurements were performed by a single examiner using ImageJ software (version 1.54g; National Institutes of Health, Bethesda, MD, USA). Each measurement was performed three times, and the arithmetic mean of the three measurements was used for statistical analysis.

Ocular biometric parameters were measured using the IOLMaster 700 and included axial eye length (AL), anterior chamber depth (AC), lens thickness (LT), central corneal thickness (CCT), and horizontal corneal diameter (white-to-white corneal diameter, WTW). All parameters were measured in both eyes, with the suffixes -D and -S denoting the right and left eyes, respectively. All facial anthropometric measurements were expressed in centimetres (cm). Ocular biometric parameters, including axial length, anterior chamber depth, lens thickness, and horizontal corneal diameter, were expressed in millimetres (mm), while central corneal thickness was expressed in micrometres (µm). There were no unsuccessful or low-quality measurements requiring exclusion.

The sample size was calculated using G*Power software (v3.1.9.6, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) for anthropometric correlations as the primary analysis. With $\alpha = 0.05$, a test power of 0.90, and an expected correlation coefficient of $r = 0.30$, the required sample size was 112 participants. The parameters were selected based on the recommendations of Serdar et al. [14], given the lack of prior data on effect sizes for the anthropometric measures under study. Gender-based comparisons were con-

sidered exploratory. With $\alpha = 0.05$, a power of 0.80, and an expected medium effect size ($d = 0.50$), it was estimated that approximately 64 participants per group were required. Data were analysed using MedCalc Statistical Software (v23.0; MedCalc Software, Ostend, Belgium). Unless explicitly indicated otherwise, the statistical analysis was performed on the mean value of both eyes for ocular measurements. Continuous variables are presented as mean ± standard deviation or median (interquartile range), depending on the data distribution. Pearson or Spearman correlation coefficients were used for correlation analysis, depending on the data distribution. Distribution normality was assessed with the Kolmogorov–Smirnov test. Comparison of the right and left eyes revealed no statistically significant differences for most ocular biometric parameters, with the exception of central corneal thickness (CCT), for which a small mean paired difference was observed (1.47 µm; $p = 0.0301$). However, the effect size (Cohen's $d = 0.04$) was negligible, indicating that the magnitude of this difference was extremely small. Therefore, despite the statistically significant finding, this marginal difference was not considered substantial enough to preclude averaging the measurements from both eyes. Accordingly, the mean value of the right and left eye measurements for each participant was used in subsequent correlation analyses. Differences between sexes were analysed using the *t*-test or Mann–Whitney U-test, and differences between age groups using ANOVA or the Kruskal–Wallis test with post hoc testing by Dunn and Tukey–Kramer, respectively. Statistical significance was defined as $p < 0.05$. Given the exploratory nature of the study, multiplicity adjustments were not performed unless explicitly indicated by the Holm–Bonferroni method. Effect sizes for parametric tests were estimated with Cohen's d (difference between group means divided by pooled standard deviation) and for non-parametric tests by $r = z/\sqrt{N}$ [15].

The study received approval from the Ethics Committee of the University Hospital Center Sestre Milosrdnice in November 2024 (Class: 003-06/24-03/049; Ref. No.: 251-29-11/3-24-04) and was conducted in accordance with ethical guidelines. Written informed consent to participate in the study and consent for publication were obtained from the parents or legal guardians of all participants prior to their inclusion and before any study-related procedures were performed.

3. Results

Statistically significant differences between age groups were observed across the majority of anthropometric parameters, with measurements generally increasing with age (Table 1). The exceptions were TR-N and ZYD-ZYS, which showed lower values in Group 2, followed by an increase in Groups 3 and 4. Among the ocular biometric parameters, axial eye length and anterior chamber depth showed a statistically significant increase with age, whereas the other parameters examined did not differ significantly between age groups (Table 2).

Table 1. Values of facial anthropometric measurements according to the subjects' age.

	Group 1 7–8 Years (*n* = 28)	**Group 2 9–10 Years (*n* = 28)**	**Group 3 11–12 Years (*n* = 28)**	**Group 4 13–14 Years (*n* = 28)**	***p* ***	***p* adj ****
TR-N (cm)	6.9 ± 0.6	6.4 ± 0.8 [a]	7.0 ± 0.8	7.4 ± 0.9 [a]	<0.0001	<0.0001
N-SN (cm)	4.9 (4.6–5.1) [a]	5.2 (4.7–5.7) [a]	5.0 (4.7–5.4)	5.3 (4.8–5.5)	0.0219	0.0657
SN-GN (cm)	5.5 (5.1–5.8) [a]	5.5 (5.2–5.8) [b]	5.9 (5.2–6.2)	6.1 (6.0–6.3) [a,b]	0.04	0.08
ST-GN (cm)	3.3 (3.2–3.6) [a]	3.5 (3.2–3.7) [b]	3.6 (3.5–3.9)	3.8 (3.6–4.0) [a,b]	0.0011	0.0077
LS-LI (cm)	1.3 (1.1–1.5) [a]	1.4 (1.3–1.7)	1.5 (1.3–1.7)	1.6 (1.4–1.8) [a]	0.0109	0.0545

Table 1. *Cont.*

	Group 1 7–8 Years (n = 28)	Group 2 9–10 Years (n = 28)	Group 3 11–12 Years (n = 28)	Group 4 13–14 Years (n = 28)	p *	p adj **
CHD-CHS (cm)	4.2 (4.2–4.7)	4.3 (4.1–4.5)	4.3 (4.2–4.9)	4.6 (4.3–4.8)	0.04	0.08
SM-GN (cm)	2.0 (1.7–2.1) [a]	2.0 (1.9–2.2)	2.1 (1.9–2.2)	2.2 (2.1–2.4) [a]	0.0119	0.0545
ZYD-ZYS (cm)	11.8 (10.8–12.0) [a]	11.3 (11.1–12.1) [b]	11.8 (11.2–12.2)	12.0 (11.7–12.8) [a,b]	0.0048	0.0288
N-GN (cm)	10.4 (9.8–10.6) [a]	10.6 (10.3–11.0)	10.7 (10.2–11.3)	11.4 (10.6–11.7) [a]	0.0002	0.0018
TD-SN (cm)	10.1 ± 0.7 [a,b]	10.8 ± 1.0 [a]	10.7 ± 1.1	11.4 ± 0.8 [b]	<0.0001	<0.0001
TS-SN (cm)	10.3 ± 0.9 [a,b]	10.9 ± 1.1	11.0 ± 1.1 [a]	11.4 ± 0.7 [b]	0.0008	0.0064
TD-GN (cm)	10.8 ± 1.1 [a,b]	11.5 ± 0.8 [c]	11.6± 1.3 [a]	12.4 ± 0.9 [b,c]	<0.0001	<0.0001
TS-GN (cm)	11.1 ± 1.1 [a,b]	11.8 ± 0.9 [c]	12.0 ± 1.3 [a]	12.5 ± 0.9 [b,c]	<0.0001	<0.0001

TR-N: height of the upper facial third; N-SN: height of the middle facial third; SN-GN: height of the lower facial third; ST-GN: mandibular height; LS-LI: mouth height; CHD-CHS: mouth width; SM-GN: chin height; ZYD-ZYS: facial width; N-GN: facial height; TD-SN: maxillary depth on the right side of the face; TS-SN: maxillary depth on the left side of the face; TD-GN: mandibular depth on the right side of the face; TS-GN: mandibular depth on the left side of the face. * Variables with non-normal distributions were compared using the Kruskal–Wallis test, whereas variables with normal distributions were compared using one-way ANOVA. Superscript letters a, b, c indicate significant intergroup differences in post hoc testing by Tukey–Kramer (ANOVA) or Dunn (Kruskal–Wallis) tests. ** Holm–Bonferroni-adjusted p values.

Table 2. Values of biometric parameters according to the subjects' age.

	Group 1 7–8 Years (n = 28)	Group 2 9–10 Years (n = 28)	Group 3 11–12 Years (n = 28)	Group 4 13–14 Years (n = 28)	p *	p adj **
AL-D (mm)	23.0 (22.4–23.9) [a]	23.5 (23.1–24.1)	23.8 (23.3–24.1)	24.0 (23.6–24.5) [a]	0.001	0.009
AL-S (mm)	23.1 ± 0.9 [a,b]	23.7 ± 0.9	23.7 ± 0.8 [a]	24.0 ± 0.8 [b]	0.0011	0.009
CCT-D (µm)	549.1 ± 42.1	546.4 ± 30.0	551.6 ± 28.9	551.2 ± 41.6	0.9469	1
CCT-S (µm)	551.2 ± 42.0	546.9 ± 29.9	553.3 ± 29.6	552.8 ± 42.1	0.9097	1
AC-D (mm)	3.8 ± 0.3 [a]	3.8 ± 0.2 [b]	3.8 ± 0.2	4.0 ± 0.2 [a,b]	<0.0001	<0.0001
AC-S (mm)	3.7 (3.5–4.0) [a]	3.7 (3.6–4.0) [a]	3.8 (3.6–4.0)	4.0 (3.8–4.1) [a,b]	0.0013	0.0091
LT-D (mm)	3.4 ± 0.2	3.4 ± 0.1	3.4 ± 0.2	3.3 ± 0.2	0.3353	1
LT-S (mm)	3.5 (3.2–3.7)	3.4 (3.3–3.4)	3.4 (3.3–3.6)	3.3 (3.2–3.4)	0.63	1
WTW-D (mm)	12.3 ± 0.5	12.4 ± 0.4	12.4 ± 0.4	12.3 ± 0.5	0.9199	1
WTW-S (mm)	12.3 ± 0.5	12.4 ± 0.4	12.4 ± 0.4	12.3 ± 0.4	0.706	1

AL-D: axial eye length of the right eye; AL-S: axial eye length of the left eye; CCT-D: central corneal thickness of the right eye; CCT-S: central corneal thickness of the left eye; AC-D: anterior chamber depth of the right eye; AC-S: anterior chamber depth of the left eye; LT-D: lens thickness of the right eye; LT-S: lens thickness of the left eye; WTW-D: horizontal corneal diameter of the right eye; WTW-S: horizontal corneal diameter of the left eye. * Variables with non-normal distributions were compared using the Kruskal–Wallis test, whereas variables with normal distributions were compared using one-way ANOVA. Superscript letters a, b indicate significant intergroup differences in post hoc testing by Tukey–Kramer (ANOVA) or Dunn (Kruskal–Wallis) tests. ** Holm–Bonferroni-adjusted p values.

Statistically significant differences between the sexes were found in certain facial anthropometric and biometric parameters. Male subjects exhibited a significantly greater lower facial height (SN-GN) (Table 3), as well as higher values for axial eye length, anterior chamber depth, and horizontal corneal diameter (WTW) compared to female subjects (Table 4). It is important to note that sex-based comparisons were considered exploratory,

as the final number of participants in each group was below the sample size estimated for these analyses. Results were therefore interpreted cautiously, with emphasis on effect estimates and their corresponding 95% confidence intervals rather than on statistical significance alone.

Table 3. Values of facial anthropometric measurements according to the subjects' sex.

	Female (n = 56)	**Male (n = 56)**	p *	**Test Statistics**	p **adj** **	**Effect Size (95% CI)**
TR-N (cm)	7.0 ± 0.8	6.9 ± 0.9	0.2561	−1.142	1	−0.22 (−0.6–0.16)
N-SN (cm)	5.1 (4.7–5.5)	5.0 (4.7–5.5)	0.3614	−0.913	1	−0.09
SN-GN (cm)	5.5 (5.1–6.0)	5.9 (5.5–6.2)	0.0074	−2.676	0.0962	−0.25
ST-GN (cm)	3.5 (3.2–3.8)	3.6 (3.3–4.0)	0.1522	−1.432	1	−0.14
LS-LI (cm)	1.4 (1.3–1.7)	1.5 (1.3–1.7)	0.5759	−0.559	1	−0.05
CHD-CHS (cm)	4.4 (4.2–4.7)	4.3 (4.2–4.7)	0.958	−0.053	1	0
SM-GN (cm)	2.1 (1.9–2.2)	2.1 (1.9–2.2)	0.8487	−0.191	1	−0.02
ZYD-ZYS (cm)	11.8 (11.1–12.1)	11.3 (11.3–12.2)	0.4297	−0.790	1	−0.07
N-GN (cm)	10.5 (10.0–11.1)	10.6 (10.3–11.3)	0.2557	−1.137	1	−0.11
TD-SN (cm)	10.7 ± 0.9	10.7 ± 1.1	0.9329	−0.084	1	−0.02 (−0.39–0.36)
TS-SN (cm)	10.9 ± 1.0	10.9 ± 1.1	0.9268	−0.092	1	−0.02 (−0.39–0.36)
TD-GN (cm)	11.7 ± 1.1	11.5 ± 1.3	0.4064	−0.833	1	−0.16 (−0.54–0.22)
TS-GN (cm)	12.0 ± 1.1	11.8 ± 1.2	0.4202	−0.809	1	−0.15 (−0.53–0.22)

TR-N: height of the upper facial third; N-SN: height of the middle facial third; SN-GN: height of the lower facial third; ST-GN: mandibular height; LS-LI: mouth height; CHD-CHS: mouth width; SM-GN: chin height; ZYD-ZYS: facial width; N-GN: facial height; TD-SN: maxillary depth on the right side of the face; TS-SN: maxillary depth on the left side of the face; TD-GN: mandibular depth on the right side of the face; TS-GN: mandibular depth on the left side of the face. * Variables with non-normal distributions were compared using the Mann–Whitney test (test statistic z), whereas variables with normal distributions were compared using the t-test. ** Holm–Bonferroni-adjusted p values. For the t-test, effect size equals the standardised mean difference with 95% CI. For the Mann–Whitney test, effect size equals $z/\sqrt{N}$.

Table 4. Values of biometric parameters according to the subjects' sex.

	Female (n = 56)	**Male (n = 56)**	p *	**Test Statistic**	p **adj** **	**Effect Size (95% CI)**
AL-D (mm)	23.4 ± 0.9	23.9 ± 0.9	0.0035	2.983	0.0288	0.56 (0.19–0.96)
AL-S (mm)	23.3 ± 0.9	23.9 ± 0.8	0.0014	3.289	0.0140	0.62 (0.25–1.02)
CCT-D (µm)	551.3 ± 37.8	547.9 ± 33.9	0.6103	−0.511	1	−0.1 (−0.47–0.28)
CCT-S (µm)	552.7 ± 38.6	549.4 ± 33.5	0.6333	−0.478	1	−0.09 (−0.47–0.28)
AC-D (mm)	3.8 (3.6–4.0)	3.9 (3.7–4.1)	0.0381	−2.074	0.2286	−0.2
AC-S (mm)	3.8 (3.7–4.0)	3.9 (3.4–4.1)	0.0439	−2.015	0.2286	−0.19
LT-D (mm)	3.4 (3.3–3.6)	3.3 (3.2–3.5)	0.1147	−1.578	0.4588	−0.15
LT-S (mm)	3.4 (3.3–3.4)	3.3 (3.2–3.5)	0.1949	−1.296	0.5847	−0.12

Table 4. *Cont.*

	Female (n = 56)	Male (n = 56)	p *	Test Statistic	p adj **	Effect Size (95% CI)
WTW-D (mm)	12.2 ± 0.5	12.5 ± 0.4	0.0032	3.01	0.0288	0.57 (0.20–0.96)
WTW-S (mm)	12.3 ± 0.5	12.4 ± 0.4	0.0184	2.392	0.1288	0.45 (0.08–0.84)

AL-D: axial eye length of the right eye; AL-S: axial eye length of the left eye; CCT-D: central corneal thickness of the right eye; CCT-S: central corneal thickness of the left eye; AC-D: anterior chamber depth of the right eye; AC-S: anterior chamber depth of the left eye; LT-D: lens thickness of the right eye; LT-S: lens thickness of the left eye; WTW-D: horizontal corneal diameter of the right eye; WTW-S: horizontal corneal diameter of the left eye. * Variables with non-normal distributions were compared using the Mann–Whitney test (test statistic z), whereas variables with normal distributions were compared using the t-test. ** Holm–Bonferroni-adjusted p values. For the t-test, effect size equals the standardised mean difference with 95% CI. For the Mann–Whitney test, effect size equals $z/\sqrt{N}$.

An exploratory analysis of the relationship between anthropometric and mean biometric measurements of both eyes revealed statistically significant positive correlations between specific parameters. Spearman's rank correlation coefficient was used to assess correlations between facial anthropometric measurements and mean biocular biometric parameters (Tables 5 and 6). Statistically significant positive correlations were found between axial eye length (AL) and lower facial height (SN-GN), mandibular height (ST-GN), mouth height (LS-LI), facial width (ZYD-ZYS), facial height (N-GN), and maxillary and mandibular depth on the right (TD-SN, TD-GN) and left (TS-SN, TS-GN) sides of the face. The strongest positive correlation among the listed variables was observed with lower facial height (SN-GN; Spearman's rho = 0.305; 95% CI 0.126–0.464; p = 0.0011). Statistically significant positive correlations were also found between anterior chamber depth (AC) and lower facial height (SN-GN), mandibular height (ST-GN), and mouth height (LS-LI). In this instance as well, the highest correlation was recorded with lower facial height (SN-GN; Spearman's rho = 0.287; 95% CI 0.108–0.449; p = 0.0021).

Table 5. Correlations between anthropometric and biocular mean biometric measurements.

		TR-N	N-SN	SN-GN	ST-GN	LS-LI	CHD-CHS
AL	rho	0.069	0.036	0.305	0.24	0.212	0.132
	p	0.4715	0.7026	0.0011	0.0109	0.0245	0.1663
CCT	rho	−0.067	−0.112	0.114	0.141	0.088	0.068
	p	0.4811	0.2411	0.2314	0.1372	0.3585	0.4745
AC	rho	0.137	−0.011	0.287	0.217	0.237	0.057
	p	0.15	0.9067	0.0021	0.0218	0.012	0.5486
LT	rho	−0.015	−0.106	−0.153	−0.162	−0.196	−0.216
	p	0.9236	0.494	0.3204	0.2943	0.2014	0.1583
WTW	rho	0.073	0.004	−0.033	−0.104	0.043	0.113
	p	0.4427	0.966	0.7326	0.2748	0.655	0.2354

TR-N: height of the upper facial third; N-SN: height of the middle facial third; SN-GN: height of the lower facial third; ST-GN: mandibular height; LS-LI: mouth height; CHD-CHS: mouth width; AL: axial eye length of both eyes; CCT: central corneal thickness of both eyes; AC: anterior chamber depth of both eyes; LT: lens thickness of both eyes; WTW: horizontal corneal diameter of both eyes; rs: Spearman rank correlation coefficient rho and accompanying p-value.

Table 6. Correlations between anthropometric and binocular mean biometric measurements.

		SM-GN	ZYD-ZYS	N-GN	TD-SN	TS-SN	TD-GN	TS-GN
AL	rho	0.157	0.188	0.231	0.246	0.215	0.257	0.227
	p	0.0988	0.0475	0.0143	0.0089	0.0227	0.0063	0.0161
CCT	rho	0.036	−0.024	−0.034	0.098	0.04	0.152	0.074
	p	0.7036	0.8005	0.7257	0.3051	0.6775	0.109	0.4391
AC	rho	0.182	0.126	0.197	0.119	0.083	0.084	0.066
	p	0.0549	0.1871	0.0377	0.2133	0.3823	0.3814	0.4866
LT	rho	−0.038	−0.234	−0.224	−0.032	−0.212	−0.071	−0.154
	p	0.8056	0.1259	0.143	0.8366	0.1664	0.6486	0.3182
WTW	rho	−0.095	0	−0.007	0.013	−0.034	−0.03	−0.119
	p	0.319	0.9982	0.9439	0.8952	0.7195	0.7531	0.2098

SM-GN: chin height; ZYD-ZYS: facial width; N-GN: facial height; TD-SN: maxillary depth on the right side of the face; TS-SN: maxillary depth on the left side of the face; TD-GN: mandibular depth on the right side of the face; TS-GN: mandibular depth on the left side of the face; AL: axial eye length of both eyes; CCT: central corneal thickness of both eyes; AC: anterior chamber depth of both eyes; LT: lens thickness of both eyes; WTW: horizontal corneal diameter of both eyes; rs: Spearman's rank correlation coefficient rho and accompanying *p*-value.

4. Discussion

This study identified correlations between several facial anthropometric measurements and ocular biometric parameters. The strongest correlation was observed between lower facial height and axial eye length; however, its magnitude was modest ($r = 0.305$; $p = 0.0011$). A modest positive correlation was also observed between lower facial height and anterior chamber depth ($r = 0.287$; $p = 0.0021$). Axial eye length was positively correlated with lower facial height, mandibular height, mouth height, facial width, facial height, and certain depth measurements of the upper and lower jaws. The results indicate that specific dimensions of craniofacial development are associated with parameters of ocular growth, particularly axial eye length. Axial eye elongation is an important biometric feature associated with myopia development; however, axial eye length alone does not define refractive status. Previous studies have demonstrated a link between a child's somatic growth and refractive status. Du et al. associated general anthropometric measurements, such as height, weight, and growth rate, with the risk of developing myopia in school-aged children. However, a limitation of that study was that biometric parameters, such as axial eye length, were not investigated [15]. Li et al. observed an association of height and weight with axial eye length, a deeper vitreous chamber, and a flatter cornea [16]. Our study identified significant differences in most anthropometric measurements across age groups, with the values of most facial dimensions increasing with age. A similar pattern was observed for axial eye length and anterior chamber depth, which also increased significantly with age, whereas no significant differences across age groups were found for the other biometric parameters examined. The observed associations may reflect the concurrent development of craniofacial structures and ocular growth during childhood. Studies on newborns and children up to three years of age have observed rapid growth in axial eye length throughout the follow-up period, paralleling somatic growth; however, research encompassing other parameters remains limited [17]. Some studies have shown that the growth of craniofacial structures associated with the eye is not an independent process. Maturation of the viscerocranium involves changes in orbital and other craniofacial dimensions, which occur concurrently with development of the eyeball throughout childhood and adolescence. However, the precise link between these processes has not yet been fully elucidated, and

future research should investigate their temporal relationship [18–20]. Our results indicate that this relationship may be part of shared developmental processes; however, they do not prove that changes in craniofacial growth cause changes in ocular biometric parameters, or vice versa. Certain facial anthropometric measurements and axial eye length showed age-related changes, suggesting a shared developmental trend. Similar conclusions can be drawn from the gender analysis, as boys in our sample exhibited significantly greater lower facial height, as well as larger values for axial eye length, anterior chamber depth, and horizontal corneal diameter. These findings demonstrate differences in certain craniofacial and ocular biometric measurements between boys and girls in our sample; however, the clinical significance of these differences remains uncertain. Furthermore, the study included slightly fewer participants ($n = 56$) for each gender than indicated by the power analysis ($n = 64$), suggesting that some medium or weaker associations could not be identified. However, given that gender-based differences are present in most developmental parameters during childhood and adolescence, it is not possible to determine whether gender is a contributing factor to this association. Other authors have reported similar findings regarding biometric parameters and gender [21,22]. It is particularly interesting to examine the relationship between facial anthropometry and axial eye length, given that axial elongation of the eyeball is a primary cause of the onset and progression of myopia. The strongest association was observed with lower facial height; however, the correlation was modest ($r = 0.305$; $p = 0.0011$). Consequently, although facial anthropometric measurements showed associations with certain ocular biometric parameters, their clinical utility for assessing ocular growth or predicting myopia onset remains unestablished. Their potential contribution to broader predictive models should be investigated in future studies. Facial anthropometry alone cannot fully account for the complex processes of emmetropisation and eye growth. One limitation of our study is that it does not account for the influence of external and environmental factors. To date, numerous studies have linked increased time spent on near-work activities, reduced time spent outdoors, and other lifestyle habits to the progression of myopia [23,24]. These environmental factors were not assessed in our study and may represent important variables to consider in future research investigating the relationship between craniofacial morphology and ocular development. Furthermore, genetic factors can influence the development of myopia; therefore, an anatomical variable alone cannot be considered a specific risk factor for developing myopia [25]. Another limitation of this study is its cross-sectional design, meaning that both anthropometric and biometric measurements were taken at a single point in time. Future research should track longitudinal changes in children throughout the entire period of craniofacial development and ocular growth. An additional limitation concerns the statistical power of the sex-based comparisons. Although the sample size was determined primarily for the correlation analysis, the number of participants in each sex group (56 boys and 56 girls) was lower than the approximately 64 participants per group estimated for detecting medium-sized differences. Consequently, these comparisons should be interpreted as exploratory, and the possibility of failing to detect smaller sex-related differences cannot be excluded. Further studies with larger and adequately powered samples are needed to confirm these findings. Although each facial anthropometric measurement was repeated three times by the same examiner, the individual measurements were not retained separately, and therefore formal intra-examiner reliability analysis could not be performed. Furthermore, inter-examiner reliability was not systematically assessed. Consequently, potential measurement variability related to landmark placement cannot be excluded. This limitation should be considered when interpreting the observed associations, particularly those of modest magnitude. Future studies should incorporate formal intra- and inter-examiner reliability assessments, including intraclass correlation coefficients and absolute measurement error. A further

methodological limitation concerns the photographic calibration procedure. Differences in depth between the ruler and facial structures may have introduced perspective-related scaling errors. It might be better to use three-dimensional methods in future studies. It is important to emphasise that the observed correlations should not be interpreted as evidence of clinical significance or predictive value. Our study was exploratory in design, aiming to investigate whether associations exist between facial anthropometric measurements and ocular biometric parameters and to characterise their direction and magnitude. Although several statistically significant associations were identified, their clinical relevance remains uncertain and requires further investigation.

5. Conclusions

This study identified correlations between specific facial anthropometric measurements and ocular biometric parameters in children. Lower facial height showed the strongest correlation with axial length of the eye, followed by anterior chamber depth. Differences observed across age and sex groups further suggest that craniofacial and ocular biometric characteristics are related to developmental changes during childhood. Given the role of axial eye elongation in myopia development, these findings may contribute to a better understanding of the relationship between craniofacial morphology and ocular growth. However, the cross-sectional design of this study does not allow conclusions to be drawn regarding the temporal or causal relationship between these developmental processes. Furthermore, the observed associations do not establish the predictive value or clinical utility of facial anthropometric measurements for assessing ocular growth or myopia risk. Longitudinal studies involving repeated craniofacial and ocular biometric measurements, together with relevant environmental and genetic factors, are needed to further investigate and validate these associations.

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