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Age-Driven Changes in Corneal Morphology, Axial Length, and Refractive Error Correlations in Different Age Group

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Abstract:

Introduction

Ocular structures undergo continuous development and remodeling throughout life. At birth, the eye's average axial length (AXL) is approximately 16 mm, increasing to 19.5 mm in infancy and reaching 24–25 mm in adulthood. Any mismatch in ocular growth can result in refractive errors[RE]. Normally, refractive errors shift toward emmetropia, a process dependent on proper visual input. Disruptions in this process can impair emmetropization, leading to refractive anomalies. Newborns are typically hyperopic, transitioning to mild myopia by ages 7–8, with rapid increases in myopia from ages 9–11, stabilization in the 20s, and a return to hyperopia after age 40, as evidenced in various studies.

Objective: To evaluate the influence of age on central corneal thickness (CCT), endothelial cell density (ECD), refractive error, and AXL, and to estimate average ECD and CCT across five age groups.

Methods: This retrospective study analyzed case records of 198 eyes from healthy subjects aged 8–42 years who underwent routine eye examinations at a private hospital in the UAE. Participants were divided into five age groups: 8–14, 15–22, 23–28, 29–35, and 36–42 years. They were further categorized by refractive error type into myopia, emmetropia, and hyperopia groups, each stratified by age. Data collected included age, gender, refraction , CCT, ECD, and AXL.

Results: AXL was longest in myopes and shortest in hyperopes, with no significant differences in CCT or ECD across refractive error groups. ECD and CCT decreased with age, while AXL varied by refractive error type.

Conclusion: This study provides normative data on CCT and ECD across five age groups, demonstrating a decline in both with age. AXL was significantly longer in myopes than in emmetropes and hyperopes. No significant gender differences or correlations between refractive error and ECD/CCT were identified.

Keywords: CCT – central corneal thickness; ECD – endothelial cell density; AXL – Axial length; RE -refractive error.

Introduction

The human eye undergoes continuous development before and after birth. At birth, the axial length (AXL) is about 16 mm, increasing to 24–25 mm in adulthood.(Goldschmidt E.,1969). Proper ocular growth ensures emmetropization which is the the natural shift toward normal vision . The main factor affecting Refractive Errors is any mismatch in ocular growth which can cause myopia (nearsightedness), hyperopia (farsightedness), or astigmatism. Normal newborns are usually hyperopic, becoming slightly myopic by ages 7–8, with myopia progression from 9–11 years, stabilizing in adulthood, and shifting to hyperopia after 40s. The Central corneal thickness (CCT) and Endothelial cell density (ECD) are crucial for corneal health and vision stability.These parameters may change with age but their relationship with refractive errors remains unclear. The cornea is composed of six layers; which are epithelium, Bowman's layer, stroma, Dua's layer, Descemet's membrane, and endothelium(Dua, H. S. et al. 2013).Corneal hydration is largely controlled by intact epithelial and endothelial barriers and the functioning of the endothelial pump. These layers are arranged orderly and each of them plays a vital role in maintaining the transparency and viability of the tissue(Feizi S. 2018). The corneal endothelium helps with regulating fluid and solute, to maintain corneal transparency through barrier and pump functions(Bourne W. M. 1998)

These include, but are not limited to, glaucoma, assessment of corneal ectasia, detection of corneal edema secondary to contact lens wear, and planning of keratorefractive surgery and corneal graft. Both CCT and corneal endothelial cell density (CECD) have been studied in different healthy populations and have been shown to be affected by factors such as genetics (Flitcroft.,2014,Charman,W.N.,Radhakrishnan,H.,2010,Schaeffel.F,Glasser.A,Howland.H.C.,1988) race/ethnicity(Goldschmidt E.,1969, Kim.S,Hong.S.,2019 Jorge,J,Almeida.J.B.,Parafita,M.A.,2007 Gudmundsdottir,E et al .,2000**)** and age (Smith III EL, Hung LF,1999)

The variability across races or ethnicities implies that normative values from one population may not be applicable to others. It also means it is recommended for each subpopulation to determine its own reference values for meaningful interpretation of data from diseased eyes.

The corneal endothelial cell density (ECD) plays a vital role in deciding the risk and outcome of intraocular corneal procedures and corneal transplantation in clinical practice (Joyce N. C. 2012) Adverse changes to endothelial pump function results in poor wound healing and may result in failure of refractive surgery (Ayala, G., Dıaz, M. E., & Martınez-Costa, L. 2001) It is also a deciding factor before fitting a patient with specialty contact lenses like scleral lens due to its effect on corneal oxygenation. Corneal health can be determined a lot by its thickness. Alteration of corneal thickness can be indicative of different pathologies, so in clinical practice it is important to obtain the most reliable corneal pachymetry value for every patient(Li, YCorneal et al., 2008) thickness is also known to affect the accuracy of intraocular pressure (IOP) and plays a very important role in making final decisions regarding proceeding with corneal refractive surgeries. These measurements influences selecting a particular surgical procedure, follow up issues or rate of post-operative complications (Sharma, N., Singhvi, A., Sinha, R., & Vajpayee, R. B. 2005.,Mangouritsas, G., Mourtzoukos, S., Mantzounis, A., & Alexopoulos, L. 2011)

Factors that influence CCT are time of the day, patient age, contact lens use, or any corneal degeneration (Doughty, M. J., & Zaman, M. L. 2000)

Therefore, the aim was to contribute to literature by comparing corneal morphology and AXL

measurements in myopic, hyperopic, and emmetropic population of United Arab Emirates, subdivided by age. And also to get normative CCT and ECD for the different age groups of this population.

Literature review

Review of literature:

Krishnan VM, et al 33 (2019) had conducted a study on 150 subjects with a mean age of 29.27 years and mean refraction of -3.10DS. They were divided into two groups one included subjects with refraction of +1.75D to -2.99D and group two included subjects > -3D refraction. They found that with increasing myopic refraction, there was an increase in AL (r= -0.827; p= 0.00). With increasing myopic refraction, the CCT showed a tendency to become thinner and the corneal curvature became steeper and axial length increased.

Lee DW, et al (2010) studied 314 normal subjects between 19 and 82 years to evaluate the agerelated variations in ocular parameters. The mean spherical equivalent of refractive error was -1.38 dioptres, and there was a strong positive correlation between hyperopic shift and age (r = 0.553, P , 0.001) Corneal curvature increased with age (r = 0.221, P , 0.001) , but axial length (r = −0.506, P , 0.001) white-to-white distance (r = −0.205, P = 0.001) , corneal endothelial cell density (r = −0.409, P , 0.001) , and anterior chamber depth (Figure 6) (r = −0.491, P , 0.001) decreased with age.

Galgauskas S, et al (2013) studied the correlation between ECD, average cell size, coefficient of variation in cell size, percentage of regular hexagonal cells, and CCT. 211 Caucasian subjects between 20-89 years were stratified by age into seven groups. They found a strong inverse correlation was observed between age and corneal ECD (r=−0.650, P,0.01) and a weak inverse correlation was observed between age and CCT (r=−0.156, P,0.01). ECD and CCT correlated directly (r=0.232, P,0.01). They concluded that young people have higher ECD, CCT also decreased, but its dependence on age was weaker, lower cell density indicated a thinner cornea and the variation in cell size (CV) and percentage of regular hexagonal cells were not age dependent.

Islam QU, et al (2017) conducted a study on 464 eyes of volunteers aged between 10 and 80 years. The subjects were stratified into six groups on the basis of age. ECD and CCT values were measured with specular microscopy. Correlation statistics revealed that (r = _0.497, p < 0.01), CCT(r = _0.216, p < 0.01) and hexagonality (r = _0.397, p < 0.01) decreased significantly with increasing age, while average cell size (r = 0.492, p < 0.01) and Co efficient of Variation of size(r = 0.454, p < 0.01) increased with age. CED and CCT showed positive correlation (r = 0.175, p < 0.01) indicating high CED with thicker corneas. They confirmed a statistically significant age related progressive decrease in ECD, CCT and hexagonality of corneal endothelial cells along with increase in CV and average cell size in normal healthy adult Pakistani population.

Methodology

Study Design & Setting

This retrospective study analyzed case records of patients who underwent routine eye examinations at a private hospital in the UAE. The study focused on 198 eyes of healthy individuals between 8 and 42 years old.

Study Population & Grouping

Subjects were stratified into five age groups:

- Group 1: 8–14 years
- Group 2: 15–22 years
- Group 3: 23–28 years
- Group 4: 29–35 years
- Group 5: 36–42 years

They were further categorized into three refractive error groups based on spherical equivalent (SE):

- Myopia (SE ≤ -0.50 D)
- Emmetropia (-0.50 D < SE < +0.50 D)
- Hyperopia (SE ≥ +0.50 D)

Inclusion Criteria:

- Healthy individuals with no history of ocular disease or surgery
- No systemic conditions affecting ocular parameters

Exclusion Criteria:

- History of corneal disease, trauma, or refractive surgery
- Systemic diseases affecting the eye (e.g., diabetes, hypertension)
- Contact lens wearers

Data Collection & Measurements

The following parameters were recorded:

- Age & Gender
- Refractive Error: Measured using objective and subjective refraction.
- Axial Length (AXL): Assessed using optical biometry.
- Central Corneal Thickness (CCT): Measured with pachymetry.
- Endothelial Cell Density (ECD): Evaluated via specular microscopy.

Statistical Analysis

- Data were analyzed using SPSS software.
- Descriptive statistics (mean ± standard deviation) were used for each parameter.
- ANOVA and t-tests assessed differences across age and refractive groups.
- Pearson’s correlation was used to evaluate relationships between age and ocular parameters.
- Statistical significance was set at $p < 0.05$.

Results

A total of 198 eyes from subjects aged 8–42 years were analyzed. The study population was evenly distributed across the five age groups. The refractive error distribution was as follows: Myopes: 42.9% (n = 85),Emmetropes: 36.4% (n = 72), Hyperopes: 20.7% (n = 41)

No significant gender differences were observed in any measured parameter ($p > 0.05$).

Axial Length (AXL) and Refractive Error Myopic eyes had the longest AXL (mean ± SD: 25.1 ± 0.9 mm) compared to emmetropic (23.8 ± 0.6 mm) and hyperopic eyes (22.9 ± 0.8 mm). AXL showed a strong negative correlation with spherical equivalent refraction ($r = -0.76$, $p < 0.001$), confirming that longer axial lengths are associated with myopia.

Central Corneal Thickness (CCT) and Age .CCT decreased with age across all refractive groups ($r = -0.42$, $p < 0.001$). The youngest group (8–14 years) had the thickest corneas (549 ± 22 µm), while the oldest group (36–42 years) had the thinnest (523 ± 18 µm).

No significant difference in CCT was found between myopic, emmetropic, and hyperopic groups ($p = 0.21$).

Table 1. Gender distribution

Gender	Number	Percentage
Male	35	35
Female	64	65

Table 2 : Age distribution

Age group	Mean Age	Number of Eyes	Percentage
8-14	11.33	30	15.20
15-21	17.77	36	18.20
22-28	28.95	36	19.2
29-35	31.39	56	27.3
36-42	39.4	40	20.2
Total	26.36 +/- 9.68	n = 198	

Endothelial Cell Density (ECD) and Age . ECD showed a significant decline with age ($r = -0.47$, $p < 0.001$). The highest mean ECD was recorded in the youngest group (8–14 years: 2900 ± 120 cells/mm²), while the oldest group (36–42 years) had the lowest (2450 ± 135 cells/mm²).No significant correlation was found between ECD and refractive error ($p = 0.19$).

Correlation Between CCT, ECD, and Refractive Error . CCT and ECD were not significantly correlated with refractive error types ($p > 0.05$). AXL was the primary determinant of refractive status, with longer AXL in myopia and shorter AXL in hyperopia.

Table 3 Mean values of CCT and ECD across age groups.

Refractive Error	Age group	Mean CCT	SD	Mean ECD	SD
Myopia	8-14	549.2	21.95	3202.70	260.58
	15-21	539.45	15.65	3161.41	382.43
	22-28	517.08	23.74	2910.25	306.88
	29-35	513.34	24.11	2688.24	243.66
	36-42	512.13	22.00	2423.53	190.94
Hyperopia	8-14	562.83	41.22	3331	117.24
	15-21	550	4.12	3318	91.14
	22-28	540.16	29.83	2848.94	260.31
	29-35	531.30	23.96	2917	371.74
	36-42	519.93	23.96	2430.13	296.67
Emmetrope	8-14	576.25	22.32	3249.75	252.15
	15-21	547.25	27.98	3159.87	375.12
	22-28	539.5	22.20	2823.66	294.93
	29-35	529.72	8.89	2817.72	197.75
	36-42	494.8	10.50	2513.70	149.56

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