Decoding the Relationship between Refractive Errors, Anterior Chamber Depth, and Axial Length: A Cross-Sectional Hospital Study

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ABSTRACT:
Clinical Relevance: This study underscores the significant correlation between axial length, anterior chamber depth, and refractive errors, offering valuable insights for the diagnosis, management, and prevention of visual impairments. The findings enhance the precision of intraocular lens (IOL) power calculations, facilitate myopia progression monitoring, optimize refractive surgery outcomes, and support early intervention strategies. **Background:** Refractive errors remain one of the leading causes of visual impairment globally, influenced by anatomical factors such as axial length and anterior chamber depth. This study aims to investigate the correlation between refractive errors, axial length, and anterior chamber depth across different age groups to better understand their interrelationship. **Methods:** A hospital-based cross-sectional study was conducted at the eye care hospital in Rohini, New Delhi, involving 214 eyes from 107 participants aged 10 to 40 years. Inclusion criteria encompassed patients with refractive errors ranging from ±0.25D to ±6D spherical and up to ±2D cylindrical. Exclusion criteria included individuals with ocular or systemic comorbidities and those with a history of ocular surgery. Visual acuity and refractive status were assessed using a Snellen's chart, auto-refractometer, and cycloplegic retinoscopy. Axial length and anterior chamber depth measurements were obtained using an optical coherence biometer. **Results:** Of the 214 eyes examined, 73.36% were myopic, with the highest prevalence in the 10–20-year age group (50.96%), while 26.64% were hyperopic, primarily in the 10–20 years (47.37%) and 31–40 years (42.10%) age groups. Myopic eyes exhibited significantly longer axial lengths (23.90 ± 0.99 mm) compared to hyperopic eyes (22.56 ± 0.68 mm, $P < 0.0001$). Although anterior chamber depth was greater in hyperopic eyes (3.95 ± 4.03 mm) than in myopic eyes (3.65 ± 0.28 mm), this difference was not statistically significant ($P = 0.3532$). A strong positive correlation was found between axial length and myopia ($r = 0.672$, $P < 0.0001$), while a strong negative correlation was observed between axial length and hyperopia ($r = -0.635$, $P < 0.0001$). Anterior chamber depth showed weak, non-significant correlations with both myopia ($r = -0.072$, $P = 0.3667$) and hyperopia ($r = -0.059$, $P = 0.6580$). **Conclusion:** Axial length demonstrates a significant correlation with refractive errors, with increased axial length associated with myopia and reduced axial length linked to hyperopia. In contrast, anterior chamber depth exhibits minimal, non-significant variation between refractive error groups, suggesting its limited role in refractive error prediction compared to

Keywords: Refractive errors, axial length, anterior chamber depth, myopia, hyperopia, correlation, optical coherence biometry.

INTRODUCTION:

The refractive state is influenced by various biometric factors, including corneal curvature, anterior chamber depth (ACD), vitreous cavity length, lens thickness, axial length (AL), and the refractive power of both the cornea and lens. (Fi-1) [1,2]

Axial length (AL) is the distance from the corneal surface to an interference peak corresponding to the retinal pigment epithelium membrane. Studies indicate that the depth and volume of the anterior chamber—measured as the distance from the posterior cornea to the anterior surface of the crystalline lens—diminish with age and are correlated with the degree of ametropia. [3,4]

Emmetropization is achieved through the coordination of the cornea's dioptric power and the crystalline lens, ensuring a clear retinal image and appropriate focal length adjustment. During this process, axial elongation is not solely dictated by refractive error. [5,6,7]

At birth, the cornea has an average refractive power of approximately 48 diopters (D), which decreases by about 4 D by the age of two. In infancy, the crystalline lens has an average power of 45 D, which gradually reduces to 20 D by the age of six. Simultaneously, axial length increases by approximately 5–6 mm. The stability of the refractive state is maintained by the combined influence of corneal refractive power, lenticular refractive power, and overall eye length. [8-12]

The average axial length of a newborn's eye is approximately 16 mm. During infancy, it grows to about 19.5 mm and further increases to 24–25 mm over the next two years, reaching adult size by around three years of age. The ACD in full-term newborns ranges from 1.5 to 2.9 mm and increases to 3–4 mm in the adult emmetropic eye. [13-16]

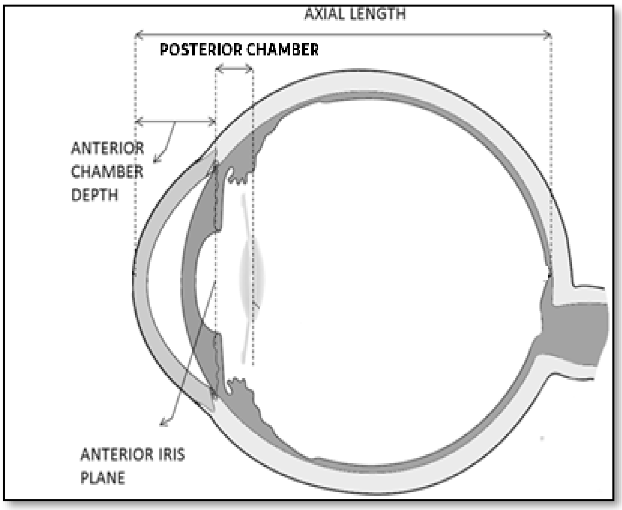

Fig 1 ***ANATOMY OF THE EYE***

In adulthood, axial length remains relatively stable. A gradual shift towards hyperopia is common, particularly after the age of 40. The human eye undergoes significant postnatal growth, with full-term newborns having a mean axial length of 16–18 mm and an ACD of 1.5–2.9 mm. In adults, the standard axial length is 22–25 mm. The anterior chamber depth in an adult emmetropic eye typically ranges from 3 to 4 mm. [17-20]

Axial length is a critical parameter in ophthalmic evaluations, playing a key role in determining refractive errors. It is also an essential diagnostic tool for identifying conditions such as staphyloma and assessing the risk of retinal detachment. [14,24] Cataract surgery, one of the most commonly performed procedures worldwide, relies on AL measurements along with other ocular parameters, such as ACD and corneal curvature (K), to ensure accurate intraocular lens (IOL) power calculations. [2] Myopic eyes typically exhibit characteristics such as increased AL, a deeper anterior chamber, and greater vitreous depth compared to non-myopic eyes.

EPIDEMIOLOGY:

Visual impairment is a major global health issue, with uncorrected refractive errors becoming the leading cause of vision problems as people age. As a treatable cause of blindness, second only to cataracts, early detection is crucial. The 2010 Global Burden of Disease study reported uncorrected refractive errors caused 1.2 million cases of moderate to severe visual impairment and 6.8 million cases of blindness. The roles of genetic and environmental factors in refractive error development remain uncertain.

Recent studies and WHO reports indicate that refractive errors are the first cause of visual impairment and the second cause of visual loss worldwide as 43% of visual impairments are attributed to refractive errors.[25] In a review study, Naidoo et al. showed that uncorrected refractive errors were responsible for visual impairment in 101.2 million people and blindness in 6.8 million people in 2010. [26]

A recent longitudinal study of children 6 to 14 years of age reported that normal development of the crystalline lens is characterized by thinning, flattening, and a decrease in power to maintain emmetropia. According to previous reports, axial length (AL) is increased by 3 mm between the ages of 9 months and 9 years, and corneal dioptric power does not change over this period. However, during the same period, because the crystalline lens power has decreased by more than 15.0 D, the change in the focal length is offset by a change in the power of the crystalline lens. Therefore, the relationship between changes in crystalline lens and axial elongation is considered essential for emmetropization. [27-29]

A review of the literature and medical databases reveals that many studies have been conducted on the epidemiology of refractive errors across the world since 1990. Although numerous studies report the prevalence of refractive errors every year, many new articles are published on the epidemiology of these errors annually due to their importance and prevalence. [30, 31]

MATERIAL AND METHOD:

The present cross-sectional study was conducted at Sector 7, Rohini, New Delhi after institutional ethical committee approval. A total of 214 eyes of 107 patients aged between 10 to 40 years and the refractive error in limits of ±0.25 to ± 6 spherical with ± 2 cylindrical were involved in the study whereas, exclusion criteria include corneal and lenticular opacities, glaucoma, retinal disorders, systemic illnesses, immunocompromised conditions, prior eye surgery, and failure to participate.

Written consent was obtained from all participants. A detailed history of the patient's complaints, onset, and duration of symptoms was recorded. Visual acuity for both distance and near was assessed using Snellen's chart. The refractive status was estimated using a standard auto-refractometer and retinoscope, and cycloplegic retinoscopy readings were compared with auto-refractometer results. Patients returned 2-3 days later for refractive correction. Axial length, and anterior chamber depth, were measured using an optical coherence biometer. Participants were divided into three age groups: 10-20, 21-30, and 31-40 years. Data such as age, gender, vision, and refraction were recorded to assess correlations with anterior chamber depth, and axial length.

STATISTICAL ANALYSIS:

Data was assessed using SPSS V 23.0 software. Continuous variables were expressed in mean and standard deviation whereas, categorical variables were shown in frequency and percentage. The T-test was used to compare continuous variables, whereas the chi-square test was used to assess the categorical variables. Pearson’s correlation coefficient test was used to find the correlation between variables. P<0.05 was considered as statistically significant.

RESULTS:

The mean age of the study subjects was 23±9.77 years. The majority of subjects were female (n=62, 57.94%). Based on objective refraction, n=157 (73.36%) and n=57 (26.64%) eyes were myopic and hyperopic respectively. (Fig-2) The mean spherical equivalent of the myopic and hyperopic eyes were 2.85 ± 2.10D, and 1.16 ± 3.35D, respectively. The mean age was comparable when compared between myopic and hyperopic subjects (22.46±9.79 years vs 23.52±9.90 years, P=0.4859). Myopia was most common in the 10-20 years age group (50.96%) whereas, hyperopia was most seen in the 10-20 years (47.37%) and 31-40 years (42.10%) age groups (Table-1, Fig-3).

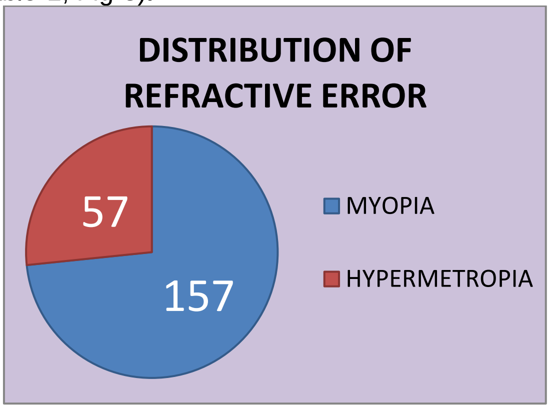

Fig 2-Distribution of refractive error

Age (years)	Myopia n, (%)	Hyperopia n, (%)	P-value
10-20	80 (50.96)	27 (47.37)	0.0086
21-30	40 (25.48)	6 (10.53)	
31-40	37 (23.56)	24 (42.10)	
Total	157 (100)	57 (100)	

Table 1. Distribution of subjects according to refractive error and age

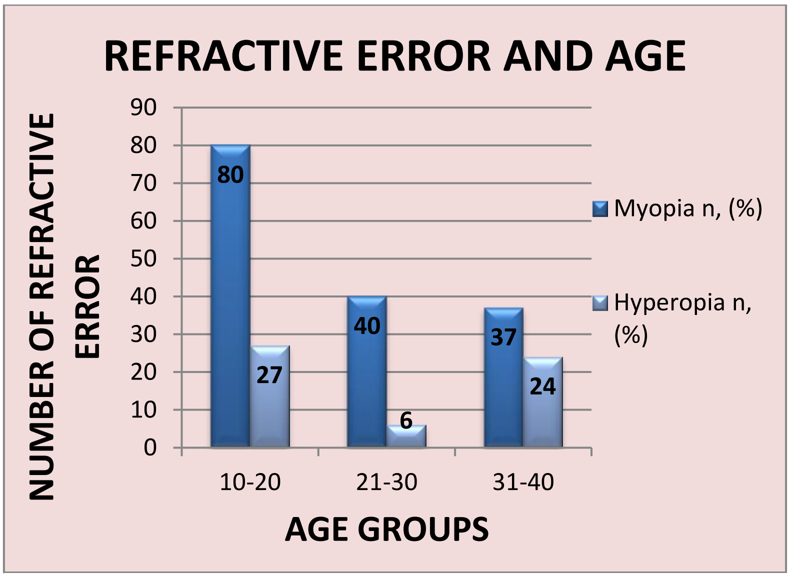

Fig 3-Distribution of subjects according to refractive error and age

AL was found to be significantly longer in myopic eyes compared to hyperopic eyes (23.90±0.99mm vs 22.56±0.68mm, P<0.0001). The ACD was deeper in hyperopic eyes than myopic eyes however, the difference was statistically insignificant (3.65±0.28mm vs 3.95±4.03mm, P=0.3532) (Table-2, Fig-4).

Parameters	Myopia (n=157)		Hyperopia (n=57)		P-value
	Mean	SD	Mean	SD	
Axial length (mm)	23.90	0.99	22.56	0.68	<0.0001
Anterior chamber depth (mm)	3.65	0.28	3.95	4.03	0.3532

Table 2. Comparison of study parameters according to refractive errors

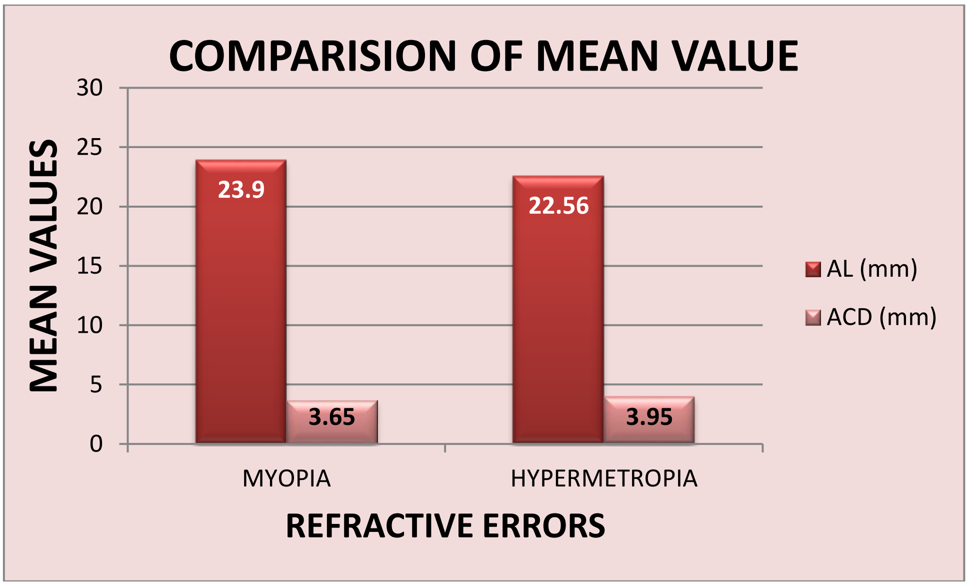

Fig 4 - Comparison of study parameters according to refractive errors

Parameters	Myopia (n=157)		Hyperopia (n=57)	
	Correlation (r)	P-value	Correlation (r)	P-value
Axial length (mm)	0.672	<0.0001	-0.635	<0.0001
Anterior chamber depth (mm)	-0.072	0.3667	-0.059	0.6580

Table 3. Correlation of refractive errors with study variables

Bivariate correlation revealed a strong negative correlation (-0.635) between the AL and the hyperopic SPH, which was significant P<0.0001. Conversely, there was a strong positive correlation (0.672) between AL and the myopic SPH, which was highly significant P<0.0001. A weak negative correlation of ACD with myopia (-0.072) and hyperopia (-0.059) was found however, the correlation was statistically insignificant (P=0.3667 and P=0.6580) (Table 3).

DISCUSSION:

The present study aimed to investigate the correlation among refractive errors, ACD, and AL in a hospital-based population. Refractive errors, including myopia and hyperopia, are among the most common ocular disorders and have multifactorial etiologies, including structural variations of the eye such as AL and ACD. Our findings provide valuable insights into the structural differences underlying these refractive states and their association with age.

The study revealed that the mean age of the participants was 23 ± 9.77 years, with a slight female predominance (57.94%). Myopia was predominantly observed in younger individuals, especially in the 10-20 years age group (50.96%). Hyperopia, on the other hand, was more evenly distributed, with higher prevalence in both younger (10-20 years, 47.37%) and middle-aged (31-40 years, 42.10%) groups. This pattern aligns with the natural progression of refractive errors, as myopia often develops during school years and stabilizes in early adulthood, while hyperopia is more prevalent in early and middle adulthood due to compensatory changes in lens accommodation with age.

The present study demonstrated a significant difference in AL between myopic and hyperopic eyes. Myopic eyes had a longer mean AL (23.90 ± 0.99 mm) compared to hyperopic eyes (22.56 ± 0.68 mm), with a highly significant P-value (<0.0001). This finding corroborates existing evidence that myopia is characterized by elongation of the eyeball, leading to a mismatch in the focal point of light on the retina, whereas hyperopia is associated with shorter axial dimensions. The strong positive correlation ($r = 0.672$, $P < 0.0001$) between AL and myopic SPH and the strong negative correlation ($r = -0.635$, $P < 0.0001$) between AL and hyperopic SPH underscore the critical role of axial elongation or shortening in determining the refractive state of the eye. Similarly, various other studies have reported comparable findings. [12, 13]

The present study also analyzed the association between ACD and refractive errors. Although hyperopic eyes had a deeper mean ACD (3.95 ± 4.03 mm) than myopic eyes (3.65 ± 0.28 mm), the difference was not statistically significant ($P = 0.3532$). This finding is similar to the study conducted by Mallampalli VB, and Bokka VS.[14]Furthermore, bivariate correlation analysis revealed weak and statistically insignificant correlations between ACD and both myopia ($r = -0.072$, $P = 0.3667$) and hyperopia ($r = -0.059$, $P = 0.6580$). These findings align partially with prior research by Alrasheed SH and Aldakhil S, who also reported no significant correlation between ACD and refractive errors but found deeper ACD in myopic eyes compared to hyperopic eyes, contrasting the current study.[11] This disparity may be attributed to variations in study populations, measurement techniques, and sample sizes. Another contributing factor could be the interplay of other anatomical parameters, such as AL, which is widely recognized as a more dominant determinant of refractive errors compared to ACD.

Our findings indicate that AL is a more critical parameter in explaining refractive errors than ACD. While ACD showed no significant variation with refractive error type or age, AL exhibited marked elongation in myopia, consistent with age-related ocular growth and remodeling patterns. Understanding the structural correlations of refractive errors, particularly the role of AL, has significant implications for both diagnosis and management. These findings reinforce the importance of axial length measurements in refractive surgery planning and myopia control strategies. Additionally, the insignificant correlation between ACD and refractive errors highlights the need for further research into other potential contributing factors, such as lens thickness and curvature.

This study has certain limitations. The cross-sectional design does not allow for causal inference between refractive errors and ocular biometry. Additionally, the relatively small sample size, especially for hyperopic eyes, may limit the generalizability of the findings. Longitudinal studies with larger cohorts and diverse populations are required to validate these correlations and explore potential age-related changes in greater depth.

CONCLUSION:

This study establishes a strong correlation between AL and refractive errors, emphasizing its pivotal role in determining refractive states. While ACD showed minimal influence, AL was significantly elongated in myopic eyes and shortened in hyperopic eyes. These findings contribute to a better understanding of the anatomical basis of refractive errors and highlight the need for targeted approaches in the management and prevention of these common visual disorders.

DECLARATION:

Acknowledgment - The authors extend heartfelt gratitude to the scholars whose works have been cited and referenced in this manuscript, also wish to acknowledge and thank the authors, editors, and publishers of the various articles, journals, and books that were consulted and discussed during the preparation of this article.
Source of Funding - None
Conflict of Interest - The authors declare no conflict of interest.

REFERENCE:

1. Khanna NS, Anitha J, Sushmitha H, et al. Correlation of axial length and anterior chamber depth with stature in young adults in tertiary care hospital. The Pan-American Journal of Ophthalmology. 2024;6:88.
2. Wang D, Zhao C, Huang S, et al. Longitudinal relationship between axial length and height in Chinese children: Guangzhou Twin Eye study. Eye Sci. 2015;30:12.
3. Hitzenberger CK. Optical measurement of axial length by laser Doppler interferometry. Invest Ophthalmol Vis Sci. 1991;32:616–20.
4. Schmid GF, Papastergiou GI, Nickla DI. Validation of laser Doppler interferometric measurement invivo of axial length and thickness of fundus layer in chicks. Curr Eye Res. 1996;15:691–96. doi: 10.3109/02713689609008911.
5. Wallman J Turkel J Trachtman J. Extreme myopia produced by modest change in early visual experience. *Science* . 1978; 201: 1249–1251.
6. Hodos W Kuenzel WJ. Retinal image degradation produces ocular enlargement in chicks. *Invest Ophthalmol Vis Sci* . 1984; 25: 652–659.
7. Mutti DO Mitchell GL Jones LA Accommodation, acuity, and their relationship to emmetropization in infants. *Optom Vis Sci* . 2009; 86: 666–676.
8. Inagaki Y. The rapid change of corneal curvature in the neonatal period and infancy. *Arch Ophthalmol* . 1986; 104: 1026–1027.
9. Insler MS Cooper HD May SE Donzis PB. Analysis of corneal thickness and corneal curvature in infants. *CLAO J* . 1987; 13: 182–184.
10. Mutti DO Zadnik K Fusaro RE Friedman NE Sholtz RI Adams AJ. Optical and structural development of the crystalline lens in childhood. *Invest Ophthalmol Vis Sci* . 1998; 39: 120–133.
11. Wood IC Mutti DO Zadnik K. Crystalline lens parameters in infancy. *Ophthalmic Physiol Opt* . 1996; 16: 310–317.
12. Larsen JS. The sagittal growth of the eye. IV. Ultrasonic measurement of the axial length of the eye from birth to puberty. *Acta Ophthalmol (Copenh)* . 1971; 49: 873–886.
13. Goldschmidt E. Refraction in the newborn. Acta Ophtahmol Scand. 1969;47:570–78. doi: 10.1111/j.1755-3768.1969.tb08143.x.
14. Hitzenberger CK. Optical measurement of axial length by laser Doppler interferometry. Invest Ophthalmol Vis Sci. 1991;32:616–20.
15. Schmid GF, Papastergiou GI, Nickla DI. Validation of laser Doppler interferometric measurement invivo of axial length and thickness of fundus layer in chicks. Curr Eye Res. 1996;15:691–96. doi: 10.3109/02713689609008911.
16. Duke elder WS. System of ophthalmology. Ophthalmic optics and refraction. 1970;Vol V:238.
17. Sorsby A, Benjamin B, Davey JB, Sheridan M, Tanner JM. Medical Research Council Special Report Series. London: Her Majesty's Stationery Office; 1957. Emmetropia and its aberrations; A study in the correlation of the optical components of the eye; p. 293.
18. Sorsby A, Leary GA, Richards MJ, Chaston J. Ultrasonographic measurements of the components of ocular refraction in life. 2. Clinical procedures: Ultrasonographic measurements compared with phakometric measurements in a series of 140 eyes Vision Res. 1963;3:499–505.
19. Goldschmidt E. Refraction in the newvorn. Acta Ophtahlmol Scnad 1969; 47: 570-578. Bomdahl S Ultrasonic measurements of the eye in the newborn infant. Acta Opthalmol Scand. 1979;57:1048–56. doi: 10.1111/j.1755-3768.1979.tb00536.x.
20. Fulton AB, Dobson V, Salem D, Mar C, Peterson RA, Hanson RM. Cyclopetic refractions in infants and young children. AM J Ophthalmol. 1980;90:239–47. doi: 10.1016/s0002-9394(14)74861-5.
21. Ali ZH, Abdulkareem SA. Measurement of Axial Length by Applanation Ultrasound Relative to Optical Biometry in Normal Eye. Iraqi Postgraduate Medical Journal. 2021;20:33-38.
22. Siddiqui F, Alkhairy S, Mirza AA, et al. Association of Refractive Errors with Axial Length and Anterior Chamber Depth in Different Age Groups. Pakistan Journal of Ophthalmology. 2024;40:385-390.

23. Bikbov MM, Kazakbaeva GM, Fakhretdinova AA, et al. Associations between axial length, corneal refractive power and lens thickness in children and adolescents: The Ural Children Eye Study. Acta Ophthalmol. 2024;102:94-104.
24. Sao Babawo L, Saccoh AF, Kpaka RB. Understanding vision impairment: a comprehensive study of uncorrected refractive errors among primary school teachers and pupils in nongowa chiefdom, kenema district, sierraleone. Midwifery. 2024;7:20-46. Volume 7 , Issue 2 (2024), DOI: 10.52589/AJHNM-8RXGK66G
25. Pascolini D., Mariotti S.P. Global estimates of visual impairment: 2010. Br J Ophthalmol. 2012;96(5):614–618. doi: 10.1136/bjophthalmol-2011-300539. [DOI] [PubMed] [Google Scholar]
26. Naidoo K.S., Leasher J., Bourne R.R. Global vision impairment and blindness due to uncorrected refractive error, 1990–2010. Optom Vis Sci. 2016;93(3):227–234. doi: 10.1097/OPX.0000000000000796. [DOI] [PubMed] [Google Scholar]
27. Mutti DO Mitchell GL Sinnott LT CLEERE Study Group. Corneal and crystalline lens dimensions before and after myopia onset. Optom Vis Sci . 2012; 89: 251–262. [CrossRef] [PubMed]
28. Twelker JD Mitchell GL Messer DH Children's ocular components and age, gender, and ethnicity. Optom Vis Sci . 2009; 86: 918–935. [CrossRef] [PubMed]
29. Mutti DO Mitchell GL Jones LA Axial growth and changes in lenticular and corneal power during emmetropization in infants. Invest Ophthalmol Vis Sci . 2005; 46: 3074–3080. [CrossRef] [PubMed]
30. Pan C.W., Dirani M., Cheng C.Y., Wong T.Y., Saw S.M. The age-specific prevalence of myopia in Asia: a meta-analysis. Optom Vis Sci. 2015;92(3):258–266. doi: 10.1097/OPX.0000000000000516. [DOI] [PubMed] [Google Scholar]
31. Rudnicka A.R., Kapetanakis V.V., Wathern A.K. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. Br J Ophthalmol. 2016;100(7):882–890. doi: 10.1136/bjophthalmol-2015-307724. [DOI] [PMC free article] [PubMed] [Google Scholar]