Correlation of vitreous chamber depth with ocular biometry in high axial myopia

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Purpose: The proportion of axial length (AL) occupied by vitreous chamber depth (VCD), or VCD:AL, consistently correlates to ocular biometry in the general population. Relation of VCD:AL to ocular biometry in high myopia is not known. The purpose of this study is to evaluate the relation of VCD and VCD:AL to ocular biometry of highly myopic eyes. **Methods:** This was a cross-sectional retrospective study of records of 214 myopic eyes (<−1 D SE, aged 20–40 years) attending the refractive surgery services. High axial myopia was defined as AL >26.5 mm. Eyes with posterior staphyloma and myopic maculopathy were excluded. Records were assessed for measurements of AL, central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), white to white diameter (WTW), and vitreous chamber depth (VCD). Groups were formed based on increasing AL, while the sum of CCT, ACD, and LT was recorded as anterior segment depth (AS). The main outcome measure was the correlation of VCD and VCD:AL to ocular biometry. A comparison was also performed based on of degree of axial myopia. **Results:** Mean age of the patients was 27.0 ± 5.2 years. VCD showed a very strong correlation with AL ($R = 0.98$, $P < 0.001$) but did not correlate to any anterior parameter. VCD:AL showed moderate negative relation with AS ($R = -0.43$, $P < 0.001$) and ACD ($R = -0.3$, $P < 0.001$), while it had a weakly negative relation with LT ($R = -0.18$, $P = 0.006$). VCD:AL showed strong negative relation ($R > \sim0.7$) with AS in all individual groups of AL. Among anterior parameters, WTW showed the most consistent relation with ocular biometry. **Conclusion:** VCD:AL is a better correlate of ocular biometry in high myopia as compared to VCD. However, the correlation is weaker than that noted by previous studies done on the general population. Longitudinal studies of VCD:AL in the younger age group is recommended.

Key words: Myopia, ocular growth, vitreous chamber depth

The recent increase in the prevalence of myopia has made it a public health challenge. It is estimated that the prevalence of myopia may reach 5 billion by the year 2050, affecting approximately half of the world's population.[1,2] Myopia is much more than simply a refractive error and can cause visually threatening complications. It can lead to severe pathological changes such as chorioretinal atrophy, choroidal neovascularization, macular hole, and retinal detachment because of unabated axial growth of the posterior eye.[3] However, the dynamics of ocular elongation in myopia still elude us. Several genetic and environmental risk factors have been considered as the cause of myopia. These include excessive near work and reduced outdoor activities, less exposure to sunlight, and more digital gadget usage in dim light conditions.[4-7] Recent studies show that people with high educational qualifications have longer eyeballs compared to people with a lower education background.[8]

Though the endpoint of eye growth is the elongation of outer coats of the eye (i.e., retina, choroid, and sclera), the role of anterior segment biometry and visual/optical focus has long been evaluated as a possible initiating point. It has been shown in experimental models that eye elongation depends on the location of the point focus of light on the posterior segment. This, in turn, switches on molecular mechanisms and leads to changes in the ultra-structure of the choroid and sclera resulting in myopia.[9-14] Literature is abundant on the relationship between anterior and posterior segment biometry in emmetropia or lower degrees of ametropia. Authors have previously shown that the amount of anisomyopia is related to biometric changes in the anterior segment parameters.[15,16] Larsen in his multiple studies of sagittal ocular growth with ultrasound also showed a balance between anterior and posterior biometry in children with less or no refractive error.[17]

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However, the literature lacks in the relationship between ocular biometric components in high myopia.

In the perspective of high refractive error, the anterior segment in hyperopic patients has more effect on the refractive error as compared to myopes.[18] Similarly, a study on Chinese subjects with advanced corneal topography showed minimal anterior segment change in myopic eyes.[19,20] There are very few studies evaluating anterior segment parameters in high myopia. These studies included a very small sample size or participants with cataract or used refractive error instead of axial length (AL) as the measure of myopia.[18,19,21,22] In a previous study by our author group on anterior segment biometry and AL changes in high myopes, we showed that there is minimal change in the anterior segment with respect to high AL.[23] A major limitation of that study was the absence of analysis on vitreous chamber depth and lens thickness. Later, in another study, we evaluated the vitreous chamber depth (VCD) and its relation to anterior biometry in the general population undergoing cataract surgery and found a good and consistent relationship between the ratio of VCD to AL (VCD:AL) and the rest of the biometry.[24] However, the later study was limited by a low sample of myopic patients, especially those with high myopia, and we could not infer our findings for the axially myopic subset.

In the current study, we analyze the relationship between VCD and anterior biometry in myopic eyes planned for refractive surgery. We also explore the possibility of using VCD:AL as a marker of pan-ocular growth in high myopia.

Methods

This was a retrospective hospital-based study conducted at a tertiary eye care center in South India. The study followed the tenets of the declaration of Helsinki. The study protocol was reviewed by the institutional review board and ethical clearance was obtained (LEC BHR-R-04-20-397). Informed consent had been obtained from all the participants for performing the investigative scans.

Consecutive records of patients presenting at our refractive surgery services for myopic refractive error (<−1 D SE) during a period of 6 months (January–June, 2019) were included. Patients aged between 20–40 years were included. High axial myopia was defined as AL >26.5 mm. Patients with a history of prior ocular trauma, any ocular or systemic diseases, and those with the best-corrected distance visual acuity less than 20/40 were excluded from the study. Patients with posterior staphyloma or myopic maculopathy were also excluded from the study. This was done because posterior staphyloma causes posterior bulging of the eyeball and patients with myopic maculopathy can have reduced visual acuity (worse than 20/40); thus, these could have potentially been inferred in biometric evaluation.[25] An optical non-contact biometer (Lenstar LS 900, Haag-Streit, Switzerland) was used by a single ophthalmic technician for assessing the biometry of all eyes. Measurements that were recorded included AL (from the corneal epithelium to the internal limiting membrane of the retina), central corneal thickness (CCT; from the corneal epithelium to the endothelium), average Keratometry, anterior chamber depth (ACD; from corneal endothelium to the anterior capsule of the crystalline lens), lens thickness (LT; from the anterior capsule of the lens to the posterior capsule of the lens),

and white to white diameter (WTW; the horizontal distance between nasal limbal border to the temporal limbal border). Anterior segment (AS) depth was calculated as a sum of CCT, ACD, and LT. VCD was calculated as the difference between AL and AS depth. All the measurements were obtained without cycloplegia between 9 AM and 1 PM. All the participants underwent comprehensive eye examination along with dilated fundus examination after obtaining the biometry. The primary outcome measure was the correlation of VCD and VCD:AL with the anterior biometry (CCT, ACD, and LT). The correlation amongst the anterior segment parameters (CCT, ACD, and LT) was also studied secondarily.

Analysis

The data obtained from all the participants were entered into Microsoft Excel sheets and statistical analysis was performed using SPSS software (IBM statistics, version 22). Three groups were created based on AL (similar to previous studies):[23] group 1 had AL < 26.5 mm (non-high axial myopia), group 2 had AL ranging 26.5–28.5 mm (high axial myopia), and group 3 had AL > 28.5 mm (very high axial myopia). Means of all parameters in these groups were compared using analysis of variance test (ANOVA) and Tukey's honest significant difference test. Kolmogorov–Smirnov test was used to determine the distribution of data, which was found to be normal. Pearson's correlation (R) was used to assess the strength and direction of correlation amongst the continuous variables. A strong correlation was defined as $R > 0.7$, while moderate relation was defined as $R = 0.3–<0.7$. Right and left eyes were also compared for correlation findings. Two-tailed $P < 0.05$ was considered as statically significant.

Results

The mean age of the study population was 27.0 ± 5.2 (Mean ± SD) years, and males were slightly higher in number (59, 55.12%). A total of 214 eyes were included for analysis based on the inclusion and exclusion criteria. Right and left eyes were equally distributed (107 each). Single eye of 12 participants was included in the study. Both eyes of 101 patients were included and studied for interocular differences. Mean AL, CCT, average keratometry, WTW, LT, ACD, AS, vitreous chamber depth, and VCD:AL were 26.95 ± 1.63 mm, 0.526 ± 0.032 mm, $44.31 + 1.48$ D, 12.20 ± 0.41 mm, 3.57 ± 0.21 mm, 3.71 ± 0.24 mm, 7.82 ± 0.29 mm, 19.13 ± 1.60 mm, and 0.708 ± 0.018, respectively. Number of eyes in groups 1, 2, and 3 were 99 (46.3%), 84 (39.3%), and 31 (14.5%), respectively. Detailed distribution of data is presented in Table 1.

Correlation analysis performed between different biometric parameters is presented in Table 2. AL showed a very strong positive relation with VCD ($R = 0.983$, $P < 0.001$), but neither AL nor VCD correlated well with anterior biometry [Fig. 1]. VCD:AL showed a strong relation with VCD and AL but only a moderate negative relation with anterior chamber depth ($R = −0.362$, $P < 0.001$) and AS ($R = −0.435$, $P < 0.001$) [Fig. 1]. CCT and keratometry did not correlate well with any parameter. Apart from the positive relation with ACD and LT, AS was found to have a moderate positive correlation with WTW (0.448, $P < 0.001$). Among the individual anterior parameters, WTW and ACD showed a moderately positive relationship with each other ($R = 0.510$, $P < 0.001$), while the remaining anterior parameters correlated poorly.
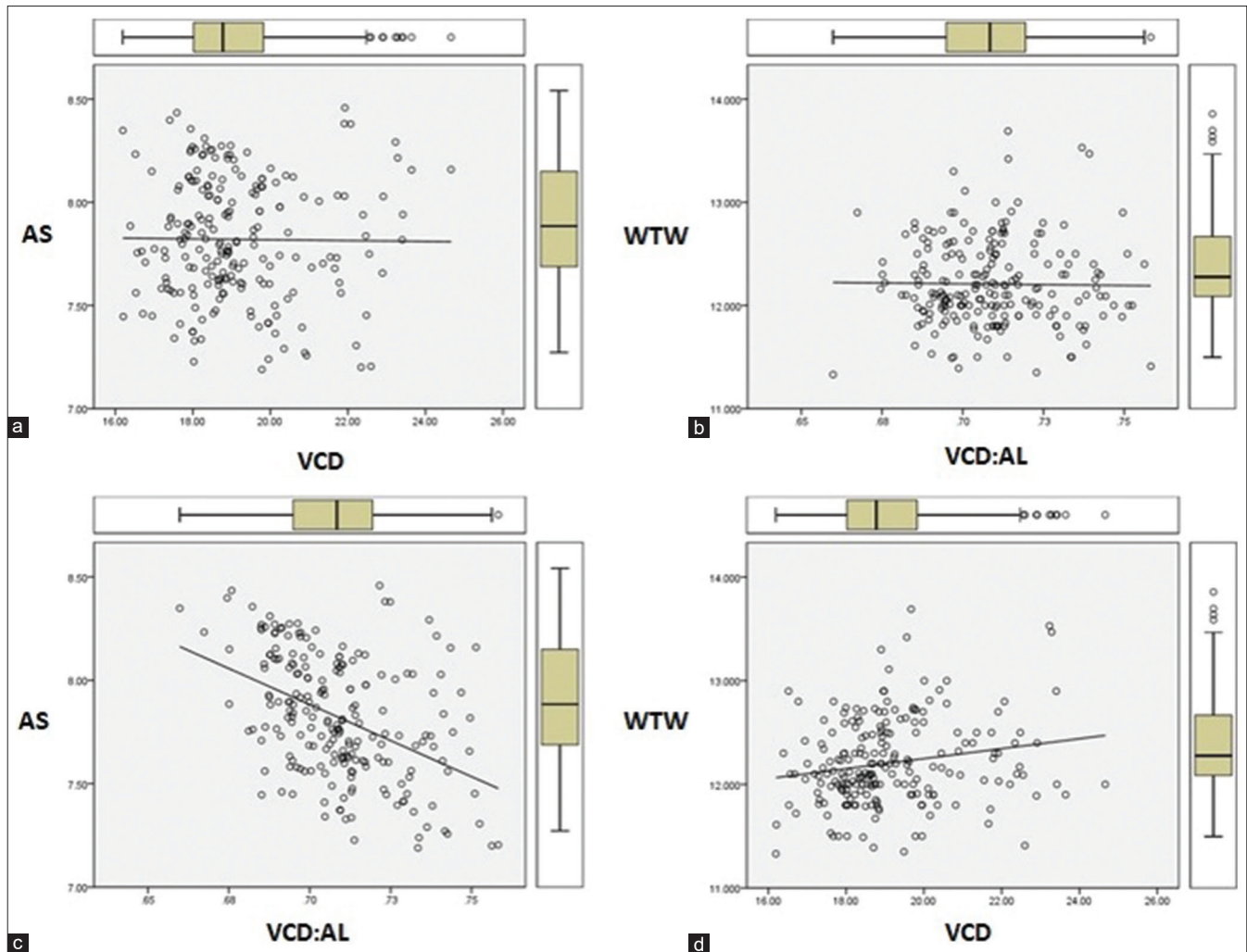
Figure 1: Correlation matrices showing the relationship between anterior and posterior biometry in high myopia. A moderate relation is seen between VCD:AL and AS, but there is a poor relationship between other variables. (a) Relationship between AS and VCD. (b) Relationship between WTW and VCD:AL. (c) Relationship between AS and VCD:AL. (d) Relationship between WTW and VCD. VCD- Vitreous chamber depth, AL- Axial length, WTW- White to white, AS- Anterior segment. VCD, WTW, and AS are plotted in mm; VCD:AL is plotted as percent ratio.

VCD:AL was divided into two groups considering the mean value of VCD:AL (0.708) as a cut-off, thus dividing 214 eyes into approximately equal numbers. Groups 1, 2, and 3 (based on AL) were compared for variation of VCD:AL [Table 3]. While nearly 80% of the group 1 eyes had VCD:AL < 0.708, all eyes in group 3 had VCD:AL > 0.708 ($P < 0.001$). WTW, VCD, and VCD:AL showed higher mean values in groups with higher AL ($P < 0.001$). LT also showed significant differences when all three groups were compared together with ANOVA, but on the application of Tukey's honest significance differentiation, only the difference between groups 2 and 3 was found to be significant ($P = 0.02$). Thus, most anterior parameters apart from WTW did not show significant differences in mean values of biometric parameters among the three groups.

Further, subgroups of AL were evaluated individually for correlation between AL, AS, VCD, and VCD:AL [Table 4]. In the results, VCD:AL showed the most consistent correlations with AS. It showed a good to strong correlation with AS in groups 1 and 3, while a very strong correlation in group 2. However, though VCD individually showed a very strong correlation

with AL in all three groups, it showed a good correlation with AS in group 2 only. No strong correlation could be established between AS and AL in any of the groups.

We also compared the biometric correlations of right eyes to the left eyes in 101 patients where both eyes had been included in the study. There was generally an agreement on correlations between the right and left eyes, and in no case, the difference exceeded 0.2.

Discussion

In our study, mean values of anterior biometric parameters were in the normal range.[8,26] This is despite our study subjects being a highly myopic subset with mean AL of nearly 27 mm [Table 1]. VCD did not show a meaningful correlation with any of the anterior biometric parameters overall, while VCD:AL showed moderate and significant negative relation with ACD and AS. AS did not show any significant correlation with AL or VCD. VCD:AL correlated weakly and negatively with LT but did not correlate well with either keratometry, CCT, or WTW [Table 2]. In contrast to other variables, VCD:AL

Table 1: Distribution of variables

	n	Range	Minimum	Maximum	Mean	Standard deviation	Variance	Inter quartile range
AL	214	9.17	23.65	32.82	26.95	1.63	2.66	1.65
CCT	214	0.151	0.451	0.602	0.526	0.032	0.001	0.045
Km	214	7.71	40.61	48.32	44.31	1.48	2.2	2
LT	214	1.16	3.08	4.24	3.57	0.21	0.047	0.3
ACD	214	1.51	2.96	4.47	3.71	0.24	0.062	0.34
VCD	214	8.46	16.19	24.66	19.13	1.6	2.58	1.83
WTW	214	2.3	11.33	13.69	12.2	0.41	0.17	0.58
AS	214	1.26	7.18	8.4	7.82	0.29	0.087	0.46
VCD: AL	214	0.098	0.659	0.758	0.708	0.018	0	0.025

Frequencies								
Groups	*n*	%	**Laterality**	*n*	%	**Gender**	*n*	%
AL: <24.5 mm	99	46.3	Right eye	107	50	Male	59	55.1
AL: 24.5-26.5 mm	84	39.3						
AL: >26.5 mm	31	14.5	Left eye	107	50	Female	48	44.9

AL: axial length, CCT: central corneal thickness, Km: average Keratometry, LT: Lens thickness, ACD: anterior chamber depth, VCD: vitreous chamber depth, WTW: white to white, AS: anterior segment. All measurements are in mm, Km is in diopters

Table 2: Correlation matrix

	AL	CCT	Km	LT	ACD	VCD	WTW	AS	VCD: AL
AL									
r	1	0.198**	-0.142	0.163*	0.034	0.983**	0.264**	0.170*	0.811**
P		0.004	0.037	0.017	0.626	0	0	0.013	0
CCT									
r	0.198**	1	-0.07	0.074	-0.017	0.173*	-0.217**	0.151*	0.089
P	0.004		0.307	0.28	0.806	0.011	0.001	0.027	0.195
LT									
r	0.163*	0.074	0.015	1	-0.222**	0.063	0.056	0.556**	-0.189**
P	0.017	0.28	0.823		0.001	0.357	0.416	0	0.006
ACD									
r	0.034	-0.017	-0.051	-0.222**	1	-0.091	0.510**	0.680**	-0.362**
P	0.626	0.806	0.461	0.001		0.185	0	0	0
VCD									
r	0.983**	0.173*	-0.137	0.063	-0.091	1	0.186**	-0.011	0.903**
P	0	0.011	0.045	0.357	0.185		0.006	0.873	0
WTW									
r	0.264**	-0.217**	0.065	0.056	0.510**	0.186**	1	0.448**	-0.015
P	0	0.001	0.346	0.416	0	0.006		0	0.831
AS									
r	0.170*	0.151*	-0.039	0.556**	0.680**	-0.011	0.448**	1	-0.435**
P	0.013	0.027	0.568	0	0	0.873	0		0
VCD:AL									
r	0.811**	0.089	-0.108	-0.189**	-0.362**	0.903**	-0.015	-0.435**	1
P	0	0.195	0.116	0.006	0	0	0.831	0	

AL: axial length, CCT: central corneal thickness, Km: average Keratometry, LT: Lens thickness, ACD: anterior chamber depth, VCD: vitreous chamber depth, WTW: white to white, AS: anterior segment

showed strong relation with AS across all the subgroups based on AL [Table 4]. Most of the studies evaluating biometry in myopia are limited by their sample size of myopic patients, the inclusion of cataractous patients, and selecting refractive error as a measure of myopia rather than AL.[18-22] Similar to our previous study on myopic eyes, we could not establish a strong or even a modest correlation between AL and anterior biometric parameters.[23] However, AL proved to be a very strong correlate of VCD. Table 3 shows that the proportion of eye length occupied by vitreous; in other words, VCD:AL is

Table 3: Inter group distribution of variables

	VCD: AL <0.708 (105)	VCD: AL >0.708 (109)	Mean VCD: AL (SD)	Mean CCT (SD)	Mean Km (SD) (diopters)	Mean ACD (SD)	Mean LT (SD)	Mean AS (SD)	Mean WTW (SD)	Mean VCD (SD)
AL										
<26.5 mm	80	19	0.696 (0.011)	0.523 (0.033)	44.5 (1.57)	3.69 (0.23)	3.57 (0.22)	7.79 (0.27)	12.07 (0.32)	17.89 (0.63)
26.5-28.5 mm	25	59	0.712 (0.012)	0.525 (0.031)	44.21 (1.37)	3.75 (0.27)	3.54 (0.20)	7.82 (0.29) 1	12.30 (0.44)	19.45 (0.63)
>28.5 mm	0	31	0.737 (0.011)	0.538 (0.033)	43.94 (1.45)	3.66 (0.21)	3.67 (0.21)	7.87 (0.33)	12.34 (0.48)	22.19 (0.94)
P	< 0.001		<.001	0.078	0.14	0.137	0.026	0.358	<.001	<.001

AL: Axial length, VCD: Vitreous chamber depth, Km: Average keratometry, CCT: Central corneal thickness, ACD: Anterior chamber depth, LT: Lens thickness, AS: Anterior segment, WTW: White to white, VCD: Vitreous chamber depth SD: standard deviation. All measurements are in mm unless specified.

Table 4: Group based description of VCD: AL

	Group 1 (AL <26.5mm)			Group 2 (AL 26.5-28.5 mm)			Group 3 (AL >28.5mm)		
	AS	VCD	VCD: AL	AS	VCD	VCD: AL	AS	VCD	VCD: AL
AL									
Correlation coefficient	0.329	0.911	0.401	-0.122	0.884	0.532	0.378	0.946	0.412
P	0.001	0	0	0.268	0	0	0.036	0	0.021
AS									
Correlation coefficient	1	-0.09	-0.733	1	-0.571	-0.905	1	0.056	-0.688
P		0.374	0		0	0		0.765	0
VCD									
Correlation coefficient	-0.09	1	0.744	-0.571	1	0.866	0.056	1	0.686
P	0.374		0	0		0	0.765		0
VCD: AL									
Correlation coefficient	-0.733	0.744	1	-0.905	0.866	1	-0.688	0.686	1
P	0	0		0	0		0	0	

AS: Anterior segment, AL: Axial length, VCD: Vitreous chamber depth

higher in high myopic eyes. This corroborates with both our previous studies.[23,24]

AL is a better measure of eye growth in myopia than refractive error as the refractive error is dependent on many components and their interactions. Thus, we chose AL as the dependent study parameter in place of refractive error.[26] In a previous study, Xie *et al.*[26] divided their sample into groups as emmetropia, low, moderate, and high myopia based on the amount of refractive error. Like our findings, they also showed that ACD did not correlate to the degree of myopia and that VCD was a better predictor of myopia. The other ocular parameters such as keratometry and LT did not show significant association with the degree of myopia. Another longitudinal study done by Davis *et al.*[27] showed that there is only a slight increase in ACD with myopia-genesis. The elastic biomechanical nature of vitreous (in contrast to a firm and rigid anterior segment) and posterior scleral expansion in response to elongating stimuli may be considered as the reasons behind this asymmetric growth of the eyeball.[24,28,29] It is worth mentioning here that among the bulk of the outer coats of the eye, corneal stroma and sclera proper originate through mesoderm, while scleral tissue is also contributed by neural crest cells.[30] Choroid, which is now considered as one of the initial points in the cascade of ocular elongation, originates from mesodermal tissue as well as neural crest cells just like the sclera.[30]

As we showed previously, across all spectrum of ocular biometric parameters, VCD:AL had better relation to AS and anterior parameters individually in comparison to VCD. However, the correlation coefficients proved to be weaker than what we had noted in the earlier study.[24] More so, we found the relation between VCD:AL and AS to be the weakest in the longest eyes. Clinically, it may be extrapolated that eyes with proportionately longer vitreous chamber may be at higher risk of developing posterior complications. Exclusion criteria of our study prevented us from analyzing this aspect, but the role of axial ocular biometry and VCD:AL in predicting retinal complications of myopia may be evaluated in the future. Further research is required to evaluate this parameter in early childhood and follow it over a long period for better insights into the elongation of the myopic eyeball. From our data, it appears that longer eyeballs in myopic patients may not be protective in terms of angle-closure glaucoma as we did not find a corresponding increase in ACD. The prevalence of angle-closure disease in highly myopic patients is another interesting research question.

The genesis of myopia has been evaluated for a long time with evolving concepts. As per Van Alphen *et al.*'s suggestions in 1952, the process of emmetropization (beginning from the stage of hypermetropia during early childhood) happens through a feedback mechanism regulated by the parasympathetic activity of higher centers in the brain. The

process pivots on ciliary muscle tone and stretch forces acting on the sclera.[31,32] However, recent experimental studies on animal and human models have shown that the eye can regulate its growth based on the visual defocus it may be exposed to.[14,33,34] Based on their animal model studies where optic nerve had been cut experimentally, Troilo *et al*.[35] showed that eyes exposed to defocus continued to show compensatory biometric changes. Thus, they stated that the genesis of myopia or its progression is mainly based on intraocular mechanisms rather than involving the cortical or the higher centers. In such a scenario, it is possible that all the factors determining myopia may converge on a single biometric parameter to decide the overall growth of the eye.[36] We evaluated VCD:AL for such a possibility and found that VCD:AL relates well to the overall length of the eye in the myopic population but its relation with LT (and therefore the AS too) was much weaker than that noted in the general population tested previously.

WTW proved to be the most consistent anterior segment parameter, showing some correlation to CCT, ACD, AS, and AL. Importantly, WTW and ACD showed a positive moderate correlation. This is very crucial as both ACD and WTW are important factors for accurate sizing of the phakic IOL in refractive surgery,[36] while AL is a very important measure of refractive error.[37] However, the overall lack of correlation between the ocular biometrics in myopia can be a cause of concern for the refractive surgeon as even in cases with seemingly less refractive error, no refractive surgery may be possible in some cases due to inadequacy of the anterior segment. We had raised these concerns in our previous biometric study on myopia too.[23]

Our study is primarily limited by its retrospective and cross-sectional nature, and inclusion of only adults where the refractive errors would have been stabilized. A longitudinal study done in children with "growing" eyeballs would be key to understanding the relations in ocular biometry, and more importantly to know "when" and "how" these relations get deviated to produce high myopia. Nevertheless, our study with its strengths discussed before shows that vitreal proportion of the eye may be a key factor or a key resultant in growth dynamics of the myopic eye. Our study criteria limited evaluation of the relationship between retinal complications and AL in high myopia, and whether ocular biometrics could be used as a surrogate for predicting them. Our findings also need to be corroborated with research in different ethnicities.

Conclusion

In summary, VCD and AL does not correlate with anterior biometry in highly myopic eyes. VCD:AL may be a useful parameter for future studies on myopia and ocular growth. It should be evaluated for its consistency with longitudinal studies during the growing phase of the eyeball. The lack of proportion between anterior biometry and AL can be a cause of concern for the refractive surgeon.

Conflicts of interest

There are no conflicts of interest.

References

1. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, *et al*. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology 2016;123:1036-42.

2. Kempen JH. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. Arch Ophthalmol 2004;122:495-505.

3. Saw SM, Gazzard G, Shin-Yen EC, Chua WH. Myopia and associated pathological complications. Ophthalmic Physiol Opt 2005;25:381-91.

4. Sivak J. The cause(s) of myopia and the efforts that have been made to prevent it. Clin Exp Optom 2012;95:572-82.

5. Chen Y, Wang W, Han X, Yan W, He M. What twin studies have taught us about myopia. Asia-Pacific J Ophthalmol 2016;5:411-4.

6. McBrien NA, Adams DW. A longitudinal investigation of adult-onset and adult-progression of myopia in an occupational group: Refractive and biometric findings. Investig Ophthalmol Vis Sci 1997;38:321-33.

7. Agarwal D, Id RS, Gupta V, Mani K, Id RD. Prevalence of myopia in Indian school children: Meta-analysis of last four decades. PLoS One 2020;15:e0240750.

8. Pan CW, Wong TY, Chang L, Lin XY, Lavanya R, Zheng YF, *et al*. Ocular biometry in an Urban Indian population: The Singapore Indian Eye study (SINDI). Investig Ophthalmol Vis Sci 2011;52:6636-42.

9. Berntsen DA, Barr CD, Mutti DO, Zadnik K. Peripheral defocus and myopia progression in myopic children randomly assigned to wear single vision and progressive addition lenses. Investig Ophthalmol Vis Sci 2013;54:5761-70.

10. DeCherney A, Berkowitz G. An animal model of myopia. N Engl J Med 1982;306:424-6.

11. Read SA, Fuss JA, Vincent SJ, Collins MJ, Alonso-Caneiro D. Choroidal changes in human myopia: Insights from optical coherence tomography imaging. Clin Exp Optom 2019;102:270-85.

12. Radhakrishnan H, Allen PM, Calver RI, Theagarayan B, Price H, Rae S, *et al*. Peripheral refractive changes associated with myopia progression. Investig Ophthalmol Vis Sci 2013;54:1573-81.

13. Pauné J, Morales H, Armengol J, Quevedo L, Faria-Ribeiro M, González-Méijome JM. Myopia control with a novel peripheral gradient soft lens and orthokeratology: A 2-Year clinical Trial. Biomed Res Int 2015;2015. doi: 10.1155/2015/507572.

14. Chiang STH, Phillips JR, Backhouse S. Effect of retinal image defocus on the thickness of the human choroid. Ophthalmic Physiol Opt 2015;35:405-13.

15. Zeng J, Cui Y, Li J, Xie W, Li Z, Zhang L, *et al*. Correlation of axial length and corneal curvature with diopter in eyes of adults with anisometropia. Int J Clin Exp Med 2015;8:13639-43.

16. Singh N, Rohatgi J, Kumar V. A prospective study of anterior segment ocular parameters in anisometropia. Korean J Ophthalmol 2017;31:165.

17. Larsen JS. The sagittal growth of the eye: IV. Ultrasonic measurement of the axial length of the eye from birth to puberty. Acta Ophthalmol 1971;49:873-86.

18. Hashemi H, Khabazkhoob M, Emamian MH, Shariati M, Miraftab M, Yekta A, *et al*. Association between refractive errors and ocular biometry in Iranian adults. J Ophthalmic Vis Res 2015;10:214-20.

19. Tokoro TE. Myopia Updates: Proceedings of the 6th International Conference on Myopia. 1964.

20. Lin SY, Shih YF, Huang LL, Huang JK, Lin LLK, Hung PT. The changes of anterior segment in myopic eyes - Analysis with Scheimpflug system. Tzu Chi Med J 1997;9:99-105.

21. Dong J, Tang M, Zhang Y, Jia Y, Zhang H, Jia Z, *et al*. Comparison of anterior segment biometric measurements between Pentacam HR and IOLMaster in normal and high myopic eyes. PLoS One 2015;10:e0143110.

22. Meng W, Butterworth J, Malecaze F, Calvas P. Axial length of myopia: A review of current research. Ophthalmologica 2011;225:127-34.

23. Khokhar S, Takkar B, Agarwal E, Gaur N, Ravani R, Venkatesh P. Biometric evaluation of myopic eyes without posterior staphyloma: Disproportionate ocular growth. Int Ophthalmol 2018;38:2427-34.

24. Takkar B, Gaur N, Saluja G, Rathi A, Sharma B, Venkatesh P. Original article evaluation of the vitreous chamber depth: An assessment of correlation with ocular biometrics. Indian J Ophthalmol 2019;67:1645-9.

25. Wong CW, Yanagi Y, Shih A, Tsai H, Shihabuddeen WA, Cheung N, *et al*. Correlation of axial length and myopic macular degeneration to levels of molecular factors in the aqueous. Sci Rep 2019;1–8. doi: 10.1038/s41598-019-52156-y.

26. Ruozhong Xie X-TZ, Lu F, Chen M, Xue A, Chen S, Qu J. Correlation between myopia and major biometric parameters of the eye: A retrospective clinical study. Optom Vis Sci 2009;86:503-8.

27. Davis WR, Raasch TW, Mitchell GL, Mutti DO, Zadnik K. Corneal asphericity and apical curvature in children: A cross-sectional and longitudinal evaluation. Investig Ophthalmol Vis Sci 2005;46:1899-906.

28. Ferreira TB, Hoffer KJ, Ribeiro F, Ribeiro P, O'Neill JG. Ocular biometric measurements in cataract surgery candidates in Portugal. PLoS One 2017;12:1-12.

29. Harper AR, Summers JA. The dynamic sclera: Extracellular matrix remodeling in normal ocular growth and myopia development. Exp Eye Res 2015;176:100-11.

30. Bron A TR and TB. Wolff's Anatomy of the Eye and Orbit. 8th ed. Chapman and Hall; 1998.

31. Council NR. Myopia: Prevalence and Progression. Washington, DC: The National Academies Press; 1989.

32. Van Alphen WH, Lely C, Nass AG, Van Leeuwen H. Comparative psychodiagnostic study of myopic and emmetropic subjects. Ned Tijdschr Geneeskd 1952;96:1425-6.

33. Smith EL, Hung LF. Form-deprivation myopia in monkeys is a graded phenomenon. Vision Res 2000;40:371-81.

34. Smith EL, Ramamirtham R, Qiao-Grider Y, Hung LF, Huang J, Kee CS, *et al*. Effects of foveal ablation on emmetropization and form-deprivation myopia. Investig Ophthalmol Vis Sci 2007;48:3914-22.

35. Troilo D, Wallman J. The regulation of eye growth and refractive state: An experimental study of emmetropization. Vision Res 1991;31:1237-50.

36. Fernández J, Rodríguez-vallejo M, Martínez J, Tauste A. Confounding sizing in posterior chamber phakic lens selection due to white-to-white measurement bias. Indian J Ophthalmol 2019;67:344-9.

37. Mutti DO, Hayes JR, Mitchell GL, Jones LA, Moeschberger ML, Cotter SA, *et al*. Refractive error, axial length, and relative peripheral refractive error before and after the onset of myopia. Investig Ophthalmol Vis Sci 2007;48:2510-9.