

RELATIONSHIP AND ANALYSIS OF AXIAL LENGTH AND ANTERIOR CHAMBER DEPTH AMONG PATIENTS PRESENTING FOR CATARACT SURGERY IN SOUTHERN RAILWAY HEADQUARTERS HOSPITAL, CHENNAI

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ABSTRACT

Background: Aim: This study aimed to determine the relationship between anterior chamber depth (ACD) and axial length (AL) in the railway population at Railway Hospital, Perambur, Chennai, Tamil Nadu, and to differentially analyze the strength of this correlation. **Materials and Methods:** A cross-sectional retrospective analytical study was conducted using ocular biometric parameters obtained from the records of 996 patients with cataracts who attended the Ophthalmology Department at Southern Railway Headquarters Hospital, Perambur, Chennai, from November 2023 to June 2025. Optical Biometry (Lenstar) was used to measure the AL, ACD, and IOL power. Statistical analyses were performed using SPSS software (version 21). All tests were two-tailed, and a p-value of <0.05 was considered statistically significant. **Result:** Of the 996 patients, 491 (49.3 %) were male and 505 (50.7%) were female. The patients' ages ranged from 20 years to more than 80 years. The majority were between 61 and 70 years of age (52.2%). The mean AL for females was 22.66 ± 0.97 mm, and in males it was 23.07 ± 0.88 mm. The mean ACD in females was 2.81 ± 0.37 mm, and in males, it was 2.89 ± 0.40 mm. Thus, males had a greater mean AL and ACD than females, and this difference was statistically significant ($p < 0.0001$ and 0.001 , respectively). It was also observed that for every 1 mm increase in AL, ACD increased by 0.153 mm ($\beta = 0.1525$, 95%CI:0.129, $p < 0.0001$). **Conclusion:** Sex had a measurable impact on ocular biometry, while age exerted minimal influence in this adult railway cohort, and there was a positive correlation between AL and ACD in our study in either sex. These findings were similar to those of various studies involving different populations in different regions of the world.

INTRODUCTION

Cataracts are the leading cause of preventable blindness worldwide. It is characterized by opacification of the lens, leading to poor vision, decreased contrast sensitivity, and sometimes monocular diplopia. As of 2025, cataracts are responsible for almost 51% of global blindness, affecting approximately 15 million people.^[1] According to the National Programme for Control of Blindness and Visual Impairment (NPCB VI) survey 2015-2019, cataract contributes to 66.2% of

blindness and 71.2% of visual impairment in the population above 50 years in India.^[2] The increase in the prevalence of cataracts in India is due to increased life expectancy, comorbid conditions such as diabetes, environmental factors, and lack of awareness regarding cataracts. More than a million cataract surgeries are performed each year in India, making it the most frequently performed surgery in the country.

The key to successful cataract surgery is achieving emmetropia. The most common cause of not achieving good vision or emmetropia post-surgery is

miscalculation of IOL power or biometry, which is a crucial component of the preoperative workup. Hence, there is a need for accurate preoperative determination of intraocular lens power. Numerous formulas exist for determining the IOL power accurately, and most of these are based on the estimation of axial length (corneal epithelium to RPE), refractive power of the cornea, and ACD (corneal epithelium to anterior surface of lens). The relationship between AL and ACD has been widely studied, but population-specific variations exist.^[3,4,5,6] influenced by factors such as age, sex, ethnicity, and environmental background. AL and ACD play a crucial role in understanding the structural characteristics of the eye and determining refractive outcomes. An error of 0.1 mm in AL measurement will result in a 0.25 D change in postoperative refraction.^[7] Precise measurements of ocular biometric parameters are essential for intraocular lens power calculation, cataract planning, and assessing the risk of ocular conditions such as angle closure glaucoma, and retinal vein occlusions in shorter AL, while longer AL was associated with Myopic progression, increased incidence of cataracts, posterior staphyloma, and risk of retinal detachment.

Numerous ocular biometry formulas have evolved over time to accurately measure IOL power for cataract planning and IOL power calculations. Second-generation regression formulas, such as SRK I and SRK II, are based on linear regression between AL, keratometry(K), and IOL power. They were simple but less accurate in the extremes of AL measurements. Third-generation theoretical formula-based biometry, such as SRK/T, Holladay1, and Hoffer Q, incorporates AL, keratometry, and estimation of effective lens position (ELP). Fourth-generation formulas, such as Haigis, Holladay 2, Barrett Universal II, and Olsen, use multiple biometric parameters, including AL, keratometry, ACD, Lens thickness (LT), and white-to-white (WTW). Preoperative assessment of ACD and AL is a constant part of fourth-generation formulas and an important factor in IOL calculations.

As basic anatomical parameters (such as AL and ACD) are variable in different countries, according to ethnic groups, genetics, and environmental factors, likewise, the railway population represents a heterogeneous mix of individuals from diverse ethnic, cultural, and geographic backgrounds. Studying ocular biometric parameters, such as AL and ACD depth, in this group provides valuable data that are not limited to a single region but instead reflect the diversity of the Indian population and are vital for post-cataract evaluations and comparisons with other studies from other regions of the world.

MATERIALS AND METHODS

This retrospective cross-sectional analytical study was conducted using patient data from November

2023 to June 2025. A total of 996 eyes were included, and data were obtained from the digital case records of patients who reported to the Ophthalmology outpatient department for cataract surgery evaluation. All patients diagnosed with cataract were included in the study. Exclusion criteria were: coexisting glaucoma, diabetic retinopathy with cataract, pterygium, history of intraocular injury, history of uveitis, and incomplete biometry data. Optical biometry was performed using the Lenstar device (Haag-Streit AG), which employs partial coherence interferometry, for each eye, a minimum of five reliable readings were taken to ensure accuracy and reproducibility of the measurements. An Axial Length of 22.0–24.5 mm was considered normal. Values <22.0 mm were classified as short AL, and values >24.5 mm as long AL. An Anterior Chamber Depth of 2.5–4.0 mm was considered normal. Values <2.5 mm were defined as shallow ACD, and values >4.0 mm as deep ACD. Formula used to calculate IOL power was SRK/T (normal AL range), Hoffer Q for AL less than 22mm, and Barrette Universal II for AL more than 24.5mm.

Statistical analysis: Continuous variables were expressed as mean $\pm$ standard deviation (SD), and categorical variables as frequencies with percentages. Differences in mean AL and ACD between sexes were compared using the independent sample t-test, while variations across age groups were assessed using one-way analysis of variance (ANOVA) followed by post hoc pairwise comparisons. Associations between continuous variables (age, AL, ACD, and intraocular lens [IOL] power) were analyzed using Pearson's correlation coefficients. Linear regression analysis was applied to examine the effects of age and sex on AL and ACD, the relationship between AL and ACD, and the determinants of IOL power. All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant. Analyses were performed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA). The study adhered to the tenets of the Declaration of Helsinki. Institutional ethics committee approval was obtained prior to data collection and analysis. As this was a retrospective study using anonymized patient records, individual informed consent was waived.

RESULTS

Nine hundred and ninety-six subjects of an adult population with cataracts were included in this study. In bilateral cataract cases, the right eye measurements were taken. The majority of the population age group ranged between 61-70 years, followed by 51-60 years, making up 77.4% of the study group as shown in Table 1. Females constituted 50.7% of the population and males 49.3%, with an almost equal distribution of either sex in our study as summarized in Table 2. The majority of the study group, 802 eyes (both males and females), included had axial length

between 22 and 24.5, and 749 eyes had ACD between 2.5 and 4 mm as shown in Table 3.

The mean axial length between various age groups varied from 23.77 $\pm$ 2.18 mm in the 20-40 years group to 22.80 $\pm$ 0.91 mm in the 51-60 years group, and the p-value across all groups was 0.078. The mean axial length was 22.66 $\pm$ 0.97 mm in females and 23.07 $\pm$ 0.88 mm in males ($p < 0.0001$) as shown in Table 4. Post-hoc analysis revealed that the 20-40 years group had a significantly deeper anterior chamber depth than all other age groups ($p < 0.05$). No significant differences were found among the older age groups (41-50, 51-60, 61-70, 71-80, and >81 years).

Males had a slightly deeper ACD than females, and this difference was statistically significant. The mean ACD values are presented in Table 5, age has a very weak negative correlation with AL ($r = -0.039$), and the correlation is not statistically significant. Age also has a weak correlation with ACD ($r = -0.138$), but it is statistically significant as summarized in Table 6. In the bivariate regression model, both age was a significant predictor of AL and ACD as shown in Figure 1 and 2. The mean AL decreased by 0.011 mm for each additional year of age ($\beta = -0.0108$, 95% CI: -0.0182 to -0.0034 , $p = 0.0045$). Males had, on average, 0.45 mm longer AL than females ($\beta = +0.451$, 95% CI: 0.333 to 0.569 , $p < 0.0001$). The model explained about 5.5% of the variability in AL ($R^2 = 0.055$). Age and sex also had significant effects on ACD. Each additional year of age was associated with a 0.008 mm reduction in ACD ($\beta = -0.0081$, 95% CI: -0.0111 to -0.0050 , $p < 0.0001$). Males had, on average, 0.10 mm deeper ACD than females ($\beta = +0.102$, 95% CI: 0.053 to 0.150 , $p < 0.0001$). The model explained about 3.5% of the variability in ACD ($R^2 = 0.035$).

In the simple linear regression model, axial length was a significant predictor of anterior chamber depth as shown in Table 7, Figure 3. For every 1 mm increase in AL, ACD increased by 0.153 mm ($\beta = 0.1525$, 95% CI: 0.129 – 0.176 , $p < 0.0001$). AL alone explained about 14.1% of the variability in ACD (R^2

$= 0.141$). After adjusting for age and sex in a multivariable regression model, the association remained highly significant. Each 1 mm increase in AL was associated with a 0.146 mm increase in ACD ($\beta = 0.1463$, 95% CI: 0.122 – 0.170 ; $p < 0.0001$). Age also had an independent effect, with each additional year associated with a 0.0065 mm reduction in ACD ($\beta = -0.0065$, 95% CI: -0.0093 to -0.0036 ; $p < 0.0001$). The effect of sex was attenuated and not statistically significant after adjustment ($\beta = +0.036$ mm for male vs female, 95% CI: -0.011 to $+0.082$, $p = 0.134$). The adjusted model explained about 15.8% of the variability in ACD ($R^2 = 0.158$).

In our study, we also analyzed the influence of AL and ACD on IOL power as shown in Table 8, Figure 4 and 5. For every 1 mm increase in AL, IOL power decreased by 1.91 D ($\beta = -1.913$, 95% CI: -2.035 to -1.791 , $p < 0.0001$). This indicates that longer eyes require substantially lower dioptric power lenses. Each 1 mm increase in ACD was associated with a 0.60 D decrease in IOL power ($\beta = -0.598$, 95% CI: -0.900 to -0.296 , $p < 0.0001$). Thus, deeper anterior chambers were associated with lower IOL power. Males required, on average, 0.28 D higher IOL power than females ($\beta = +0.284$, 95% CI: $+0.059$ to $+0.509$, $p = 0.013$). The effect of age was not statistically significant ($\beta = -0.0069$ D/year, 95% CI: -0.021 to $+0.007$, $p = 0.34$).

When IOL power was predicted using axial length alone, each 1 mm increase in AL was associated with a -2.04 D change in IOL power ($\beta = -2.04$, $p < 0.0001$), and the model explained 56.5% of the variability in IOL power ($R^2 = 0.565$). When anterior chamber depth (ACD) was added to the model alongside AL, the predictive accuracy improved slightly. In this model, each 1 mm increase in AL was associated with a -1.91 D change in IOL power ($\beta = -1.91$, $p < 0.0001$), and each 1 mm increase in ACD was associated with a -0.60 D change in IOL power ($\beta = -0.60$, $p < 0.0001$). The combined model explained 57.8% of the variability in the IOL power ($R^2 = 0.578$).

Table 1: Age distribution of patients (n=996)

Age Group in years	Number of eyes (n)	Percentage
20 - 40	6	0.60%
41 - 50	44	4.40%
51 - 60	251	25.20%
61 - 70	520	52.20%
71 - 80	163	16.40%
>81	12	1.20%

Table 2: Sex distribution of patients (n=996)

Sex	Number of eyes (n)	Percentage
Female	505	50.7%
Male	491	49.3%

Table 3: Distribution of AL and ACD (n=996)

Description	Number of Eyes	Percentage
AL group (mm)	<21.9	163
	22-24.5	802
	>24.51	31
ACD group (mm)	<2.4	244
	2.5-4	749

	>4.1	3	0.3%
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Table 4: Comparison of axial length in different age groups and sex

Description		Axial Length	P value
		Mean $\pm$ SD	
Age Group in Years	20-40	23.77 $\pm$ 2.18	0.078
	41-50	23.03 $\pm$ 1.24	
	51-60	22.80 $\pm$ 0.91	
	61-70	22.86 $\pm$ 0.96	
	71-80	22.87 $\pm$ 0.85	
	>81	23.12 $\pm$ 0.69	
Sex	Female	22.66 $\pm$ 0.97	<0.0001
	Male	23.07 $\pm$ 0.88	

Table 5: Comparison of anterior chamber depth in different age groups and sex

Description		Anterior Chamber Depth (ACD)	P value
		Mean $\pm$ SD	
Age Group (Years)	20-40	3.41 $\pm$ 0.77	0.001
	41-50	2.9 $\pm$ 0.51	
	51-60	2.89 $\pm$ 0.38	
	61-70	2.84 $\pm$ 0.38	
	71-80	2.79 $\pm$ 0.34	
	>81	2.70 $\pm$ 0.28	
Sex	Female	2.81 $\pm$ 0.37	0.001
	Male	2.89 $\pm$ 0.40	

Table 6: Correlation between Age vs AL and ACD

Age	Description	AL	ACD
	Pearson Correlation	-0.039	-0.138
	P value	0.221	<0.0001

Table 7: Correlation between AL and ACD

AL	Description	ACD
	Pearson Correlation	0.376
	P value	<0.0001

Table 8: Correlation of AL and ACD on IOL power

AL	Description	IOL power
	Pearson Correlation	-0.754
	P value	<0.0001
ACD	Pearson Correlation	-0.352
	P value	<0.0001

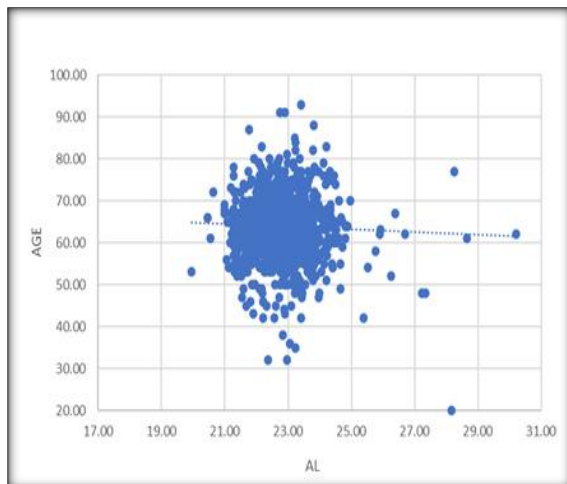


Figure 1: Relationship between Age and AL, Bivariate linear regression

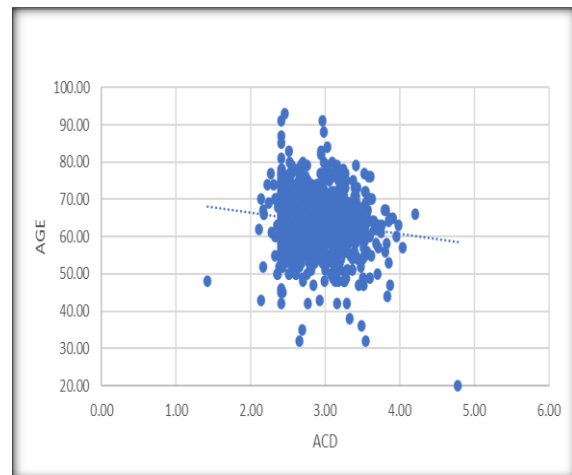


Figure 2: Relationship between Age and ACD, Bivariate linear regression

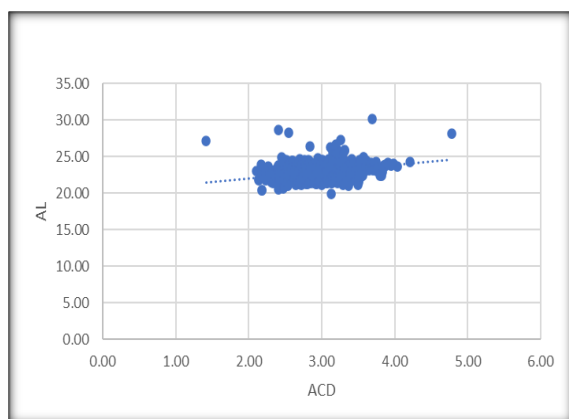


Figure 3: Relationship between AL and ACD, Bivariate linear regression

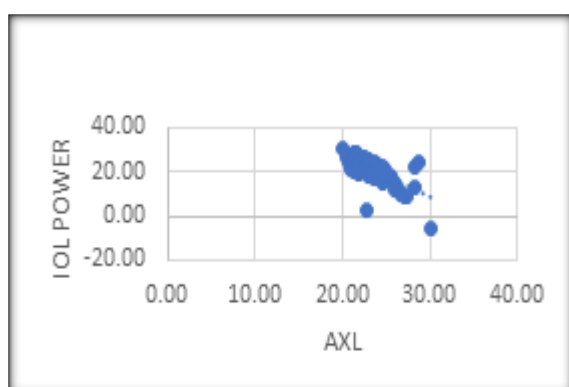


Figure 4: Relationship between AL and IOL power, Bivariate linear regression

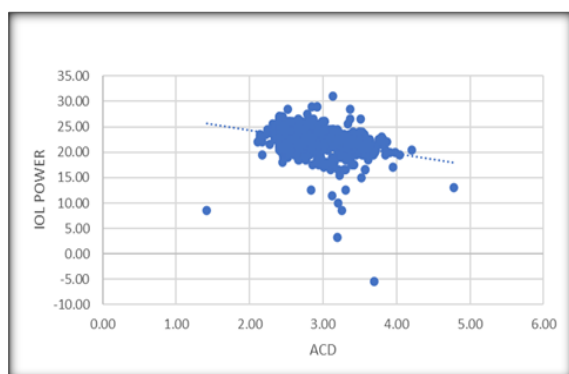


Figure 5: Relationship between IOL power and ACD

DISCUSSION

In our study of 996 eyes of the adult population of railway employees, both serving and retired, and their dependents, belonging to various regions and ethnicities, we aimed to study the relationship between axial length and anterior chamber depth in normal adults. By including a wide age range (20–>80 years) and nearly equal distribution of males and females, the study evaluated the relationship between axial length and anterior chamber depth and its influence on IOL power calculation.

The majority of eyes belonged to the age group between 61–70 years (52.2%), followed by the 51–60 years group (25.2%), consistent with the peak

incidence of visually significant cataracts reported in earlier population-based studies.^[2,8]

The mean axial length for males was 23.07 ± 0.88 mm, and for females, it was 22.66 ± 0.97 mm ($p < 0.0001$), which was slightly smaller than that reported in other studies. Sedaghat et al,^[9] reported a mean axial length of $23.7 \text{ mm} \pm 2.4$ vs 22.9 ± 2.1 mm. In a study of the population in Nigeria,^[7] the mean AL across all age groups was 23.2 ± 1.0 mm. In a Chinese study by Zhao et al,^[10] the mean AL was 23.82 ± 1.83 mm. The mean AL reported by Nangia et al,^[11] which measured AL in central India, was 22.6 mm. In our group, the younger age group (20–40 years) had the maximum mean AL across all groups, as has been noted in several studies.

Previous studies have consistently shown a positive correlation between AL and ACD, which was more pronounced in males than in females. The normal axial length is in the range of 22 to 24.5 mm.^[9]

The mean ACD in our study was 2.89 ± 0.40 mm and 2.81 ± 0.37 mm in males and females, respectively, and was shallower than that in the Nigerian study.^[7] The recorded mean ACD in males was 3.2 mm, and in females was 3.1 mm. Sedaghat et al,^[9] reported a mean ACD of $2.93 \text{ mm} \pm 0.45$ vs $2.82 \text{ mm} \pm 0.42$ in males vs females. AL demonstrated only a weak correlation with age ($r = -0.039$, $p = 0.22$); however, regression analysis revealed a statistically significant negative effect. The mean AL decreased by 0.011 mm for every additional year of age ($\beta = -0.0108$, 95%CI: -0.0182 to -0.0034, $p = 0.0045$). Over several years, this translates to modest shortening (0.4 mm over 40 years). However, this observation should be interpreted cautiously.

Since the present study was cross-sectional, it could not differentiate between true age-related shortening and cohort effects, whereby older generations have grown up with less educational pressure and fewer near-work demands and naturally have shorter ALs due to the lower prevalence of myopia.^[12] Longitudinal studies, such as those by Fotedar et al,^[13] suggest a small but significant reduction in AL with advancing age, possibly attributable to scleral remodelling and changes in choroidal thickness. Nevertheless, the effect is small compared to the anterior chamber changes and is unlikely to be of major clinical significance.

Sex was a strong determinant of AL. Males had significantly longer eyes than females. Males had a significantly longer AL than females, with an average of 0.45 mm longer AL than females ($\beta = +0.451$, 95%CI: 0.333 to 0.569, $p < 0.0001$). This finding is consistent with many studies that have reported that males have longer AL than females. This was similar to many Asian studies,^[12,14,15] and AL ranged from 0.3 mm to 0.5 mm. These findings are clinically relevant because shorter eyes (more common in females) are predisposed to hyperopia and angle closure, whereas longer eyes (more common in men) have a higher risk of myopia-related complications.

In contrast to axial length, ACD showed a clear and clinically significant age relationship as shown in

Figure 2. Pearson's correlation analysis demonstrated a negative association ($r=-0.138$, $p<0.0001$), and regression analysis confirmed that each additional year of age reduced ACD by 0.008 mm ($\beta=-0.008$, $p<0.0001$). This finding is well documented in the literature; age-related lens thickening and anterior displacement of the lens-iris diaphragm progressively reduce ACD and narrow the anterior chamber. Such changes are risk factors for primary angle closure, especially in the Asian population.

Sex also influenced ACD in the present study. Males had a 0.10 mm deeper anterior chamber than females ($p<0.0001$). Our findings are similar to those of the Beijing Eye Study,^[16] many other studies worldwide have found that women have a shallower ACD than men. A shallower anterior chamber depth may explain the higher prevalence of angle-closure glaucoma. However, after adjusting for AL, sex lost statistical significance ($\beta=+0.036$, $p=0.13$), suggesting that much of the difference is attributable to ocular size rather than sex-specific anatomy.

A key finding was the significant positive correlation between AL and ACD ($r=0.376$, $p<0.0001$). Each 1 mm increase in AL was associated with a 0.153 mm increase in ACD after adjusting for age and sex. This relationship is consistent with prior biometric studies, which have shown that eyes with longer AL, typically associated with myopia, tend to have a deeper anterior chamber.^[9,15,17] However, the correlation was moderate ($R^2=0.158$), implying that other biometric parameters, such as lens thickness, lens vault, and corneal curvature, also play important roles in determining ACD. While AL showed only a weak correlation with age, ACD was strongly age-dependent. This suggests that the anterior chamber depth is more dependent on lens changes than on the overall increase or decrease in AL.

While the aim of the study was mainly to find the correlation between AL and ACD in our study population, a few other findings were determined: IOL power was strongly determined by AL, each 1 mm increase in AL was associated with a -1.91D change in lens power ($\beta=-1.913$, 95%CI: 2.035 to -1.791, $p<0.0001$). Longer eyes required a lower-diopter IOL. ACD also contributed independently; every 1 mm increase in ACD was associated with a 0.60 D increase in IOL power ($\beta=-0.598$, 95% CI: 0.900 to -0.296, $p<0.0001$). Thus, a deeper anterior chamber required a lower IOL power. When ACD was added to the model alongside AL, the predictive accuracy improved from $R^2=0.565$ to $R^2=0.578$. This finding highlights the importance of ACD in estimating the effective lens position (ELP), a critical determinant of the refractive outcome in cataract surgery. Modern IOL calculation formulas, such as Haigis, Holladay 2, Olsen, and Barrett universal II, incorporate ACD and other related parameters and outperform older formulas.

One of the major limitations of this study is its retrospective design, which may be associated with inherent selection and information biases. In addition, the relatively small sample size restricts the

generalizability of the findings. Future research with a prospective design and a larger study population is warranted to validate and expand upon these observations.

CONCLUSION

This study demonstrated a significant positive correlation between AL and ACD in patients undergoing cataract surgery in a diverse railway population. While age showed only a minimal effect on AL, it had a clear inverse relationship with ACD, reflecting age-related changes in the eye. Sex was an important determinant, with males having longer axial lengths and deeper anterior chambers compared to females, though the influence of sex diminished after adjusting for ocular size. Importantly, both AL and ACD were found to independently influence IOL power calculations, with AL exerting the strongest effect. These findings reaffirm the importance of incorporating multiple biometric parameters, apart from AL, into the modern IOL calculation formulas to improve refractive outcome.

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