Original Article

Comparison of Ocular Biometric Parameters at High Altitude vs Low Altitude

PJO – Official Journal of Ophthalmological Society of Pakistan

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ABSTRACT

Purpose: To compare ocular biometric parameters inpatients of cataract at high and Low altitudes of Pakistan.

Study Design: Cross-sectional, comparative study.

Place and Duration of Study: KMDC, Karachi Metropolitan University from 1st September to31st December 2024.

Methods: Data of 100 patients was retrieved from a hospital 4 meters above the sea Level for low altitude (Group L) and 100 from a place 2,438 meters above the sea level for high altitude (Group H). Patients with corneal opacities, pterygium, traumatic, and congenital cataracts were excluded. Keratometry readings (K1 and K2), axial length (AL), and intraocular lens (IOL) power were compared between the two groups using an independent sample t-test.

Results: Group H had a shorter mean AL (22.2 ± 1.29 SD mm) compared to Group L (23.11 ± 1.22 SD mm) with a p-value = 0.000. Group L required a lower mean IOL power (21.64 ± 3.3D) than Group H (24.69 ± 3.61D) with a p-value of 0.000. The mean K1 and K2 for Group H were 43.14 ± 1.8D and 44.19 ± 1.63D, respectively, while for Group L, they were 43.48 ± 1.63D and 4 3.53 ± 1.89D. Females exhibited higher mean K1 and K2 as compared to males. No significant difference was observed in mean AL and mean IOL power among genders.

Conclusion: Cataract patients at low altitude have longer AL and lower IOL power than those at high altitudes. These findings suggest that geographical altitude may influence ocular biometry and should be considered during preoperative assessment and IOL power calculation in cataract surgery.

Keywords: Biometry, Keratometry, Axial Length, Intra-Ocular Lens, Cataract, Altitude.

How to Cite this Article: Shahid E, Shahzaib M, Fasih U, Jafri AR. Comparison of Ocular Biometric Parameters at High Altitude vs Low Altitude. 2026;42(3):297-302. **Doi:10.36351/pjo.v42i3.2218**

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Received: September 06, 2025
Revised: May 1, 2026
Accepted: May 16, 2026

INTRODUCTION

Worldwide, 94 million individuals aged 50 years and older experienced blindness or impaired vision due to cataract.[1] As the population ages, the number of cataract-related cases of blindness is expected to rise among patients 60 years and older. However, with increasing life expectancy and uneven global development and medical resource distribution, cataracts reduce patients' quality of life and pose risks due to rising demand for surgery, placing a significant economic burden on families and society.[2]

Cataract surgery is a widely performed procedure in ophthalmology settings. Axial length (AL), keratometry power, anterior chamber depth (ACD), and corneal astigmatism are vital ocular biometric parameters for the desired refractive power calculation and for minimizing post-operative astigmatism.[3]

High altitudes have different physiological factors compared to low altitudes. Hypoxia, ultraviolet radiation, and the longer duration of sun exposure at high altitudes affect the body mechanisms and impose a greater risk factor in the development of cataracts.[4]

Several studies have been published regarding ocular biometric data of various populations,[5,6,7] comparing age, gender, race, and environmental factors,[8] association of ocular biometric measurements with systemic diseases,[9] use of different techniques and equipment.[10]

Despite existing research on ocular biometric changes at high altitudes, a comprehensive comparison with low-altitude populations remains uninvestigated.[11]

This study aims to assess the ocular biometric parameters, including keratometry measurements, AL and IOL power, of cataract patients undergoing surgery at low altitudes compared to those at high altitudes in Pakistan. It will also explore gender differences related to biometric parameters and the relation between AL and IOL power.

METHODS

This is a retrospective cross-sectional comparative study conducted at the KMDC, Karachi Metropolitan University. It aimed to analyze the differences in ocular biometric parameters between cataract patients at low and high altitudes. The data was collected from the hospital records within the last four months, from 1st September to 31st December 2024.

The study was approved by the ethical review committee of the Ophthalmological Society of Pakistan **(Reference Number: OSP/IRB-001-2025)** dated10-2-25 and adheres to the tenets of the Declaration of Helsinki. Informed consent from the patients was waived as the data was retrieved from records.

The total number of patients was 200, with 100 patients in each group. Data was obtained from the records of the patients who underwent cataract surgery in the ophthalmology department of a government Hospital in Karachi, over the past four months. These patients were residing at low altitudes (10 meters above these a level, group L). The data at high altitudes was collected from the records of an eye hospital situated in Skardu, Gilgit, Baltistan (2,438 meters above sea level, group H).

Patients with co-existing corneal opacities, pterygium, traumatic and congenital cataracts were excluded from the study. Only one eye of the patients was included for analysis.

Data comprised of age, gender, laterality, keratometry measurement in two meridians, AL and IOL power. Keratometry was done with an automated refractor-keratometer in two meridians flat K1 and steep K2. AL was measured with A-scan (ultrasound contact method) and IOL power was measured using SRKII formula for targeted refraction of 0.00 diopters. A constant of 118.4 was chosen.

Data was entered and analyzed on SPSS version 26. Data was evaluated for normal distribution by the Shapiro-Wilk test. The frequencies and percentages were calculated for categorical data such as gender and laterality. Means with standard deviation were computed for numerical variables including age, K1 and K2, AL and IOL power. An independent sample t-test was applied to compare K1, K2, AL, and IOL values between low-altitude and high-altitude groups. The association of ocular biometric characteristics of both groups with gender was analyzed, association of AL with the power of IOL was evaluated with p-value of <0.05 considered statistically significant.

RESULTS

The mean age of Group H was 65.66 ± 12.09 years (range 19-90 years), and that of Group L was61.79 ± 11.18 years (range 25-85 years). Group H comprised 71 males and 29 females, while Group L included 57 males and43 females.

The mean IOL power of group H was 24.69 ± 3.61D (range 17 t o37D) which was significantly higher than the mean IOL power of group L 21.64 ± 3.3D (range 10 to 32D).

The mean K2 value was also higher in group H (44.19 ± 1.63D) than in group L (43.53 ± 1.89D; p:0.009). Mean AL was significantly shorter in Group H (22.2 ± 1.29mm) than in Group L (23.11 ± 1.22 mm; p:0.000). No significant difference was observed for gender distribution (p:0.36) and mean K1 (p:0.16) among the two groups. The details are given in Table 1.

The gender-based comparison revealed that females had significantly higher mean K1 and K2 values than males (p:0.004), however, no statistically significant difference was observed in mean AL and mean IOL values (Table 2).

Independent sample t-test was used to see association between AL and IOL power between the two groups. AL was inversely proportional to the power of an IOL (p-value 0.000) given in Table 3.

Table1: *ComparisonofmeansofocularbiometricparametersbetweenGroupHandGroupL.*

Variables	Group H	95% CI	Group L	95% CI	P value
Gender male*	71		57		0.366
Laterality Right Eye	50		54		0.009
Mean age (yrs)^	65.66±12.09SD	63.26-68.06	61.79±11.18SD	59.57-64.01	0.020
Mean K1(D)^	43.14±1.8SD	42.78-43.49	43.48±1.63SD	43.15-43.80	0.161
Mean K2(D)^	44.19±1.63SD	43.86-44.51	43.53±1.89SD	43.15-43.90	0.009
Mean AL (mm)^	22.2±1.29SD	21.94-22.46	23.11±1.22SD	22.87-23.35	0.000
Mean IOL(D)^	24.69±3.61SD	23.97-25.40	21.64±3.3SD	20.98-22.29	0.000

*Chi-square test
^Independent sample t-test
IOL; Intraocular Lens. K1 &K2; Keratometry at steep and flat meridian, AL; Axial length

Table2: *Comparison of means of ocular biometric characters with gender Independent sample t-test.*

Biometric Variables	Male (n=128)	Female (n=72)	P value
k1 (D)	42.82±1.66SD	43.92±1.91SD	0.004
k2 (D)	43.9±1.46SD	44.91±1.83SD	0.004
AL(mm)	22.24±1.12SD	22.11±1.66SD	0.657
IOL(D)	23.26±3.46SD	23.00±4.04SD	0.862

IOL: Intraocular lens. K: Keratometry. AL: Axial length.

Table3: *Association of AL with IOL power of both groups.*

Variable	Mean±SD	95% CI	P value
Group H Axial length (mm) IOL (D)	22.2±1.29 24.69±3.61	-3.41to -1.55	0.000
Group L Axial length (mm) IOL (D)	23.11±1.22 21.64±3.3	0.59–2.34	0.000

Independent sample t-test

Spearman's rank correlation coefficient was used because the IOL values were not normally distributed. In group L, a strong and statistically significant negative correlation was found between AL and IOL power (ρ= -0.813, p<0.001), indicating that an increase in AL was associated with a decrease in the required IOL power.

The scatter plot illustrates a clear negative linear trend between two variables. Similarly, a robust negative correlation was found (ρ=-0.814, p<0.001) in group H, nearly identical to group L, emphasizing the consistency of the relationship between AL and IOL power across the groups. The scatter plot for group H displays a similar distribution pattern to group L, further supporting this relationship. This has been shown in Figure 1.

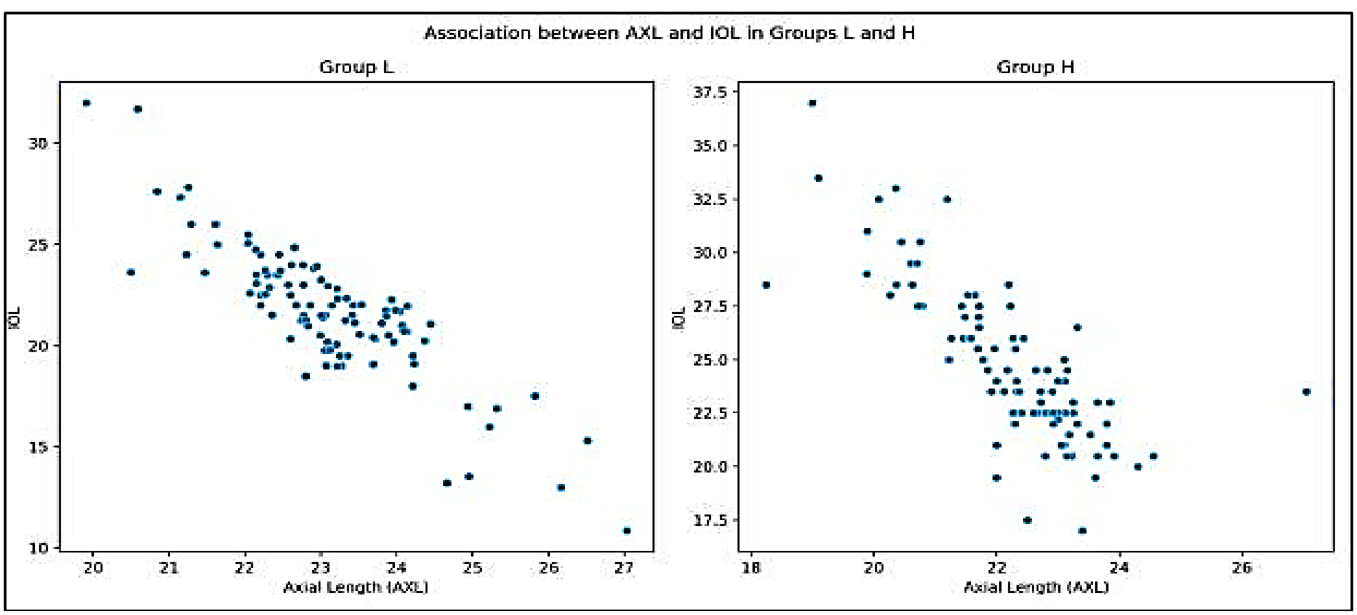

Figure1: Scatter plot of the relationship between AL and IOL power of groups L and H.

DISCUSSION

Our study has focused on ocular biometric characteristics in cataract patients undergoing surgery at low and high altitudes. The low-altitude area is a coastal, multicultural, multi-ethnic, and densely populated area, whereas the high-altitude region is amount ain ouster rain with a scattered population of specifically Balti inhabitants.

In this study, there was no significant difference in the K readings at the horizontal meridian in patients of both altitudes. However, cornea has significantly more dioptric power in the vertical meridian at high altitudes than at low altitudes. If we compare these results with other studies given in Table 4, the corneal refractive power ranges between 43-44 diopters. However, there is a significant difference between the K readings of males and females. In this study, the cornea of females had greater dioptric power regardless of the altitude. The results of our study are like those of the other national and international studies.[4,7,12-16] Contrary to this, a study by Kassa et al, found steeper corneas in males.[17]

Another study reported that hypoxia and hypobaric environment at high altitudes did not influence the shape of cornea.[5] However, the central corneal thickness was thinner in Tibet an adolescents' residing at high altitudes, which was attributed to high ultraviolet ray exposure.[18]

The AL in this study was smaller (22.2mm) in individuals at high altitudes than in individuals at low-altitudes (23.11mm). Other studies conducted at low land (less than 100m) reported 24.35mm and 22.9.[8,13] Areas 100m above these a level had an axial length of 23.3, 23.5, 23.22, 23.5, 23.46, and 22.98.[7,8,12,15,16,17] The AL reported by a study conducted in Kamdo, Tibet at an altitude of 3250m was 23.45 and in Nepal at an altitude of 3000 meters was 22.68.[18,19] The details of AL are given in Table 4.

There is an increase in ultraviolet radiation A at high altitudes with more daily average sunshine duration. It is now well-known that an increase in dopamine release stimulated by bright light inhibits axial length elongation and myopia prevalence.[20] AL has been influenced by age, gender, ethnicity, body stature, and biometrics, challenging the generalization of AL and ocular biometry.[21]

One of the studies has reported 0.8mm longer AL in the population residing in urban areas located at4m above sea level than the rural areas situated at 109m.[8] In this study, Karachi is a metropolitan city built on coastal plains in South of Pakistan, urbanized and densely populated. In contrast, Skardu is a major city of Gilgit, Baltistan, situated in the north of Pakistan, surrounded by the highest mountain ranges and the most rugged terrain. It is a catchment area for inhabitants from the surrounding valleys. Most of their elder generation are farmers and uneducated. Other factors to consider for AL should be age, gender, near work, urbanization, ethnicity, and altitude.

This study has reported the high dioptric power of an IOL (24.69D) at high altitude as compared to low altitude (21.64D). Nizamani NB et al, reported 21.10D from the plains and Rashid et al, reported a mean of 23.17D of IOL at 980m.[13,22] Other studies have stated IOL power ranges between 19 to 22D.[7,12-15,17,18] The diversity in IOL power in different regions is to have an emmetropic outcome. The AL and IOL power of other studies are given in Table 4.

Table4: *Comparison of ocular biometric characters with other studies.*

Author	Country	Altitude	No of Patients	K (D)	AL(mm)	IOL(D)
Haungetal.[6]	Western China	500m	6933	44.23	24.32	-
Natungetal.[7]	India	550m	641	44.41	23.34	20.53
LiuHetal.[8]	China Jinshan Shanghai	109m 4m	2676 2839	44.53 44.38	23.58 24.35	-
ShoaibKKetal.[12]	Pakistan Pindi	508m	752	42.87	23.22	21.20
NoorBakhtetal.[13]	Pakistan Hyderabad	13m	886	44.25	22.96	21.10
Hameedetal.[14]	Pakistan Pindi	508m	908	43.46	23.45	20.22
YoonJJetal.[15]	New Zealand Auckland	196m	2073	44.38	23.57	20.22
ZvornicaninEetal.[16]	Bosnia	500m	1278	43.42	23.46	-
KassaMSetal.[17]	Ethiopia	1500-2300m	765	-	22.98	19.34
XiangY et al.[18]	China Chongqing Tibet	300m – 870m	748 448	43.26 43.06	23.92 23.45	-
BaralPetal.[19]	Nepal	3000m	1055	44.11	22.68	21.60
Rashid H etal.[22]	PakistanSwat	980m	1359	(K1)42.65 (K2)42.48	22.52	23.17

The relationship between axial length and intraocular lens power demonstrated in our study perfectly aligns with prior research findings. Specifically, we have observed a significant inverse correlation between AL and IOL power. Eyes with longer axial lengths require low-power IOLs to become emmetropes. Errors in measuring AL can lead to poor postoperative refractive outcomes. A change of 1mm in AL will result in a significant IOL power change.[23] The varying ranges of AL and IOL power reported in different studies highlight the importance of accurate preoperative axial length measurement to ensure optimal IOL power calculation and desired postoperative outcomes.[6-9,12-15,17,18]

One important aspect we want to highlight is the complications of cataract surgery that can been countered due to the variability of ocular biometric parameters at different altitudes. The incidence of posterior capsular rupture and nucleus fragment drop is high with an increase in axial length.[24] In short AL cases, the anterior chamber's crowdedness makes surgery more difficult and increases the risk of uveal effusion.[25] Surgeon should be prepared to manage complications due to a shorter or longer AL.

One of the limitations of this study is its retrospective design. We could not retrieve relevant data, including demographic details, education, occupation, height, and weight. Additionally, some ocular measurements, such as anterior chamber depth and corneal white-to-white distance, were missing. This data can help us understand how the eye adapts to changes in atmospheric pressure, temperature, and humidity at different altitudes. Another limitation is the small sample size, which restricts the ability to generalize the findings to the broader population.

The strength of this study is that it has generated preliminary data and opened the door for further comprehensive research to better understand this topic. Comparing ocular biometry at high and low altitudes will help develop guidelines and protocols for eye care in these populations. It can also facilitate the creation of specialized eye care programs and services for these residents.

CONCLUSION

Corneal dioptric power does not vary significantly with altitude. Patients at high altitudes tend to have short AL and require higher IOL power, while those at low altitudes typically have longer AL and need lower IOL power. High AL is negatively associated with IOL power. Gender has no significant effect on ocular biometric parameters**.**

Funding: This study was not funded by any organization.

Patient's Consent: Researchers followed the guidelines set forth in the Declaration of Helsinki.

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval: The study was approved by the Institutional review board/Ethical review board **(OSP-IRB/001-2025)**

REFERENCES

1. **Cicinelli MV, Buchan JC, Nicholson M, Varadaraj V, Khanna RC.** Cataracts. Lancet. 2023;**401(10374):**377-389. Doi: 10.1016/S0140-6736(22)01839-6.
2. **Ginel J, Burguera N, Piñero D, Sáez-Martín A, Haro De Rosario A, Fernández J.** Economic evaluations in cataract surgery: a narrative review. Eye (Lond). 2024;**38(8):**1418-1424. Doi: 10.1038/s41433-024-02965-x.
3. **Hill W, Angeles R, Otani T.** Evaluation of a new IOL Master algorithm to measure axial length. J Cataract Refract Surg. 2008;**34(6):**920-924. Doi: 10.1016/j.jcrs.2008.02.021.
4. **Vashist P, Tandon R, Murthy GVS, Barua CK, Deka D, Singh S, et al.** ICMR-EYE SEE Study Group. Association of cataract and sun exposure in geographically diverse populations of India: The CASE study. First Report of the ICMR-EYE SEE Study Group. PLoS One. 2020;**15(1):**e0227868. Doi: 10.1371/journal.pone.0227868.
5. **Wu Y, Qiong Da CR, Liu J, Yan X.** Intraocular pressure and axial length changes during altitude acclimatization from Beijing to L has a. PLoS One. 2020;**15(1):**e0228267. Doi: 10.1371/journal.pone.0228 267. Erratum in: PLoS One. 2020;**15(3):**e0231208. Doi: 10.1371/journal.pone.0231208.
6. **Huang Q, Huang Y, Luo Q, Fan W.** Ocular biometric characteristics of cataract patients in Western China. BMC Ophthalmol. 2018;**18(1):**99. Doi: 10.1186/s12886-018-0770-x.
7. **Natung T, Shullai W, Nongrum B, Thangkhiew L, Baruah P, Phiamphu ML.** Ocular biometry characteristics and corneal astigmatisms in cataract surgery candidates at a tertiary care center in North-East India. Indian J Ophthalmol. 2019;**67(9):**1417-1423. Doi: 10.4103/ijo.IJO_1353_18.

8. **Liu H, Xu Z, Qian Z, Liang J, Wei K, Zu L, et al.** Comparison of Ocular Biometry Profiles in Urban and Rural Cataract Candidates in Eastern China. J Ophthalmol. 2020;**2020:**2863698. Doi: 10.1155/2020/2863698.
9. **Amornpetchsathaporn A, Chantra S, Annopawong K, Seresirikachorn K, Kongsomboon K, Wanichwecharungruang B.** Ocular Biometry Profile and Its Associations with Systemic and Demographic Factors in Thai Cataract Patients. Clin Ophthalmol. 2025;**19:**1155-1166. Doi: 10.2147/OPTH.S515960.
10. **Wasser LM, Tsessler M, Weill Y, Zadok D, Abulafia A.** Ocular Biometric Characteristics Measured by Swept-Source Optical Coherence Tomography in Individuals Undergoing Cataract Surgery. Am J Ophthalmol. 2022;**233:**38-47. Doi: 10.1016/j.ajo.2021.06.032.
11. **Bali J, Chaudhary KP, Thakur R.** High altitude and the eye: a case controlled study in clinical ocular anthropometry of changes in the eye. High Alt Med Biol. 2005Winter;**6(4):**327-338. Doi: 10.1089/ham.2005.6.327.
12. **Shoaib KK, Shakoor T.** Biometric Findings in Patients Undergoing Cataract Surgery; Gender Comparison. Pak J Ophthalmol. 2018;**34(4):**242-246.
13. **Nizamani NB, Surhio SA, Memon S, Talpur KI.** Axial length variability in cataract surgery. J Coll Physicians Surg Pak. 2014;**24(12):**918-921. PMID: 25523728.
14. **Hameed IM, Chaudhry S.** Keratometry, Axial Length And Intra-ocular Lens Power Variations Observed During Biometry. ISRA Med J. 2015;**7(3):**164.
15. **Yoon JJ, Misra SL, McGhee CNj, Patel DV.** Demographics and ocular biometric characteristics of patients undergoing cataract surgery in Auckland, New Zealand. Clin Exp Ophthalmol. 2016;**44(2):**106-113. Doi: 10.1111/ceo.12634.
16. **Zvorničanin E, Vatavuk Z, Popović M, Zvorničanin J.** Gender-and Age-Related Differences of Ocular Biometric Parameters in Patients Undergoing Cataract Surgery in Bosnia and Herzegovina. J Ophthalmol. 2023;**2023:**1950257. Doi: 10.1155/2023/1950257.
17. **Kassa MS, Gessesse GW.** Ocular Biometry and Intra Ocular Lens Power among Cataract Patients in Rural Eastern Ethiopia. Ethiop J Health Sci. 2021;**31(4):**823-830. Doi: 10.4314/ejhs.v31i4.17.
18. **Xiang Y, Cheng H, Sun K, Zheng S, Du M, Gao N, et al.** Myopia prevalence and ocular biometry in children and adolescents at different altitudes: a cross-sectional study in Chongqing and Tibet, China. BMJ Open. 2024;**14(5):**e078018. Doi: 10.1136/bmjopen-2023-078018.
19. **Baral P, Baral N, Maharjan IM, Gautam BR, Bhandari M.** Biometric parameters and intraocular lens power used for cataract eyes in Karnali, Nepal. Nepal J Ophthalmol. 2014;**6(2):**192-196. Doi: 10.3126/nepjoph.v6i2.11690.
20. **Zhou X, Pardue MT ,Iuvone PM, Qu J.** Dopamine signaling and myopia development: What are the key challenges. Prog Retin Eye Res. 2017;**61:**60-71. Doi: 10.1016/j.preteyeres.2017.06.003.
21. **Chikara AT, Evans T, Mathebula SD.** Ocular axial length and its associations: A systematic review. Afr Vis Eye Health. 2025;**84(1):**1063
22. **Rashid H, Naseem A, Rahman F.** Two years review of intraocular lens power calculation in Ophthalmology Department of Saidu Teaching Hospital, Swat. Pak J Ophthalmol. 2007;**23(3):**122-124.
23. **Gupta A, Singh P.** Intraocular Lens Power Calculation. 2022 Dec8. In: StatPearls. Treasure Island (FL): Stat Pearls Publishing; 2026 Jan–. PMID: 36943961. Accessed: May 15, 2026.
24. **Fesharaki H, Peyman A, Rowshandel M, Peyman M, Alizadeh P, Akhlaghi M, et al.** A comparative study of complications of cataract surgery with phacoemulsification in eyes with high and normal axial length. Adv Biomed Res. 2012;**1:**67. Doi: 10.4103/2277-9175.102971.
25. **El-Husseiny AM, Sallam AB.** Cataract surgery in adult eyes with short axial length. 276. Curr Opin Ophthalmol. 2023;**34(1):**84-93. Doi: 10.1097/ICU.0000000000000913.

Authors Designation and Contribution

Erum Shahid; Associate Professor: *Concepts, Design, Literature Search, Data Acquisition, Data Analysis, Statistical Analysis, Manuscript Preparation, Manuscript Editing, Manuscript Review.*

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Uzma Fasih; Professor: *Concepts, Design, Manuscript Editing, Manuscript Review.*

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