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The effect of retinopathy of prematurity on visual acuity, refraction, biometric values, retinal and choroidal thickness in school-aged children

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Abstract

Background This study aimed to investigate the long-term effects of retinopathy of prematurity (ROP) on visual function and ocular anatomy. We compared biometric values, foveal thickness, and choroidal thickness among children with a history of ROP (stratified by treatment status), premature infants without ROP, and term-born children.

Methods This cross-sectional study was conducted between september 2021 and february 2022 at the Ophthalmology Department of Ankara Bilkent City Hospital. The study included 54 eyes from 29 children who received laser photocoagulation treatment for ROP (ROP-Tx Group), 52 eyes from 26 children who developed ROP but did not require treatment (ROP-nonTx Group), 51 eyes from 25 children born prematurely without ROP (Premature Group), and 54 eyes from 27 healthy term children of the same age group (Control Group). One eye of a single premature infant was included in the ROP-nonTx group, while the other eye was included in the Premature group. The first three groups included patients who were followed up under the Retinopathy of Prematurity protocol at Zekai Tahir Burak Hospital between 2008 and 2016, while the control group consisted of 5–12 years old who presented for a routine eye examination without any ocular complaints or history of prematurity. Non-cycloplegic and cycloplegic refractive errors, best corrected visual acuity (BCVA), keratometry, axial length (AL) and anterior chamber depth (ACD), optical coherence tomography (OCT) central macula and choroid thickness measurements were performed in all cases.

Results Premature infants treated with laser photocoagulation for retinopathy of prematurity exhibited significant differences in all measured ocular parameters compared to the term-born control group ($p < 0.05$). These parameters included reduced best corrected visual acuity (0.1 logMar), steeper keratometry values (K2: 47.95 Dioptre, K1: 45.83 Dioptre), more myopic spherical equivalent (-0.87 Dioptre), shorter axial length (21.67 mm), decreased anterior chamber depth (3.04 mm), as well as increased central macular thickness (300.50 µm) and decreased central choroidal thickness (268.27 µm). Infants who developed ROP but did not require laser treatment also exhibited significant differences compared to the control group, including steeper keratometry values (K2: 46.62 Dioptre, K1: 45.24 Dioptre) shorter axial length (22.01 mm), and increased central macular thickness (250.05 µm). Interestingly, anterior chamber

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depth was significantly unexpected way different (3.47 mm) only in the premature group without ROP compared to the term-born controls ($p < 0.05$).

Conclusions The study found that prematurity, ROP, and eye development are closely connected. Premature infants who treated with laser photocoagulation for ROP had the most significant differences in eye structure and vision compared to full-term infants. Even premature infants who showed spontaneous regression of ROP still demonstrated differences in ocular anatomy. These results emphasize the importance of closely monitoring premature infants, especially those treated for ROP, to ensure their vision develops properly.

Keywords Biometry, Foveal thickness, Choroidal thickness, Laser photocoagulation, OCT, Prematurity, Premature retinopathy

Introduction

ROP is a vasoproliferative retinopathy primarily affecting infants born before 32 weeks of gestation or with a birth weight below 1500 g. The pathogenesis of ROP involves abnormal retinal vascular development in response to extrauterine conditions. Despite advances in neonatal care, ROP remains a significant public health concern, particularly in developing countries, where limited resources in intensive care units can further exacerbate the risk [1]. Globally, the prevalence of ROP among preterm infants is estimated to be [%33.9] [2]. In Turkiye, studies suggest a prevalence of %27 among ROP screening babies [3].

Both prematurity and ROP can disrupt the normal development of ocular structures, including the retina, anterior segment, and optic nerve, potentially leading to long-term visual impairment and an increased risk of amblyopia. It is a condition often associated with reduced visual acuity but encompassing a broader range of visual dysfunctions. These include reduced contrast sensitivity, visual field loss, abnormal stereopsis, and impaired motion perception and visuomotor integration. Such impairments can significantly affect an individual's well-being, social interactions, and academic achievement [4, 5].

Key developmental milestones, such as retinal and macular architecture development, anterior chamber angle formation occur during the later stages of gestation, making the premature eye particularly vulnerable [6, 7]. Premature birth interrupts these crucial processes, potentially affecting ocular development. While previous research has examined the short-term effects of ROP, there is limited data on the long-term impact of ROP and prematurity on ocular biometry in preadolescent children.

This study aimed to evaluate ocular anatomical and functional differences in children with and without a history of ROP and prematurity to better understand the long-term visual consequences. We hypothesized that children with a history of ROP would exhibit greater alterations in ocular biometry and visual function compared to premature infants without ROP and term-born controls.

Subjects and methods

Study design and participants

This cross-sectional study was conducted at the Ankara Bilkent City Hospital Ophthalmology Clinic between September 2021 and February 2022. Participants were selected from a cohort of children born between 2008 and 2016 at Zekai Tahir Burak Hospital who had undergone ROP screening (ETROP Protocol) by the ophthalmology department.

A target sample size of 25 participants per group was planned. Patients were randomly selected from the eligible pool within each group and invited for examination after obtaining informed consent from their families. A total of 107 participants (211 eyes) were included in the study. 54 eyes from 29 children who received laser photocoagulation treatment for ROP (ROP-Tx Group), 52 eyes from 26 children who developed ROP but did not require treatment (ROP-nonTx Group), 51 eyes from 25 children born prematurely without ROP (Premature Group), and 54 eyes from 27 healthy term children of the same age group (Control Group). One eye of a single premature infant was included in the ROP-nonTX group, while the other eye was included in the Premature group. The first three groups included patients who were followed up under the Retinopathy of Prematurity protocol at Zekai Tahir Burak Hospital between 2008 and 2016, while the control group consisted similar age (5–12 years) who presented to the Ankara City Hospital Ophthalmology Clinic for a 'routine eye examination' without any ocular complaints or history of prematurity. (Table 1)

Participants were excluded if they had: missing medical data, hydrocephalus or intracerebral hemorrhage above stage 3, having family history of degenerative myopia, poor device orientation (strabismus, extrafoveal fixation), ocular trauma or surgery history, and corneal surface opacity or media opacities (e.g., cataracts) affecting image quality. In cases where one eye met exclusion criteria, only the eligible eye was included in the analysis.

Table 1 Groups and participant distribution

ROP-Tx Group 29 patients, 54 eyes	ROP-nonTx Group 26 patients, 52 eyes	Premature Group 25 patients, 51eyes	Control Group 27 patients, 54 eyes)
One patient had a unilateral lamellar cataract, and one eye was excluded due to poor device signal quality. One patient had undergone unilateral corneal cross-linking treatment for keratoconus, so that eye was excluded from the analysis. One patient had exotropia and extrafoveal fixation, so one eye was excluded due to poor device orientation. One eye of a patient was treated with laser photocoagulation, while the other eye was just diagnosed with ROP. Therefore, one eye was not included in the ROP-Tx Group.	One eye of the patient had ROP, while the other eye did not. A patient in the ROP non-treatment group had ROP in only one eye, so that eye was included in the premature group instead.		All eyes of children routine eye examination group were included in the control group

Table 2 Demographic characteristics of study groups. Data is written as 'average +/- SD (min-max)'

	ROP-Tx Group	ROP-nonTx Group	Premature Group	Control Group
Age (year)	8.8 ± 2.2 (5–13)	9.2 ± 2.2 (5–13)	8.8 ± 1.8 (7–12)	8.7 ± 2.2 (5–13)
Sex (male/female)	10/19	14/12	12/13	15/12
Birth Week	26.5 ± 1.7 (23–30)	29.2 ± 3.0 (24–32)	32.8 ± 1.8 (29–36)	37.8 ± 0.9 (37–42)
Birth Weight (gr)	976 ± 353 (590–1900)	1234 ± 410 (640–2060)	1778 ± 399 (890–2890)	3350 ± 270 (2800–3950)

Ophthalmological examination

Following a detailed systemic and ocular history, participants underwent a comprehensive ophthalmological examination. Non-cycloplegic and cycloplegic refraction and spherical equivalent (SE) was measured by auto refractometer (Accuref K-900, Shin-Nippon, Japan), age-standardized best corrected visual acuity (BCVA) was determined ETDRS Chart. Axial length (AL) and anterior chamber depth (ACD) were measured with IOL Master 500, Carl Zeiss Meditec AG, Germany. Central macular thickness (CMT) and choroidal thickness (CCT) were measured with Cirrus HD-OCT 500, Carl Zeiss Meditec, Dublin, CA. CMT and CCT measurements were performed manually by a single ophthalmologist, repeated twice, and averaged. Dilated fundus examination performed, including evaluation of the peripheral retina. All medical data were recorded.

Statistical analysis

All statistical analyses were performed using R software (R Core Team, 2021). The normality of each variable was tested using the Anderson-Darling test. Multiple comparisons were conducted based on the results of the normality test: the independent t-test was applied for variables with a normal distribution, while the Kolmogorov-Smirnov test was used for non-normally distributed samples. For normal distributions, mean comparisons were performed; for non-normal distributions, median comparisons were done. The significance level was set at $p < 0.05$ for all analyses. To visualize differences in distribution between treatment groups, frequency plots were used. Mean differences between groups were illustrated using box-and-whisker plots. These graphics were generated with the ggpubr and ggplot2 packages in R software.

The Shapiro-Wilk normality test was used to test the normality of the distribution of the measurement data. T test was used for normally distributed traits while the Wilcoxon test was used for other variables.

Classification and Regression Tree (CRT) analysis was used to determine cutoff points for the investigated traits in the evaluation of Spherical Equivalent (SE) [8]. For this purpose, SE was designated as the dependent variable, while other traits were used as predictive variables. The CRT parameters were set as follows: minbucket = 7, max pooling = 20, and minnode size = 0.010. This analysis was conducted using the rattle package in R software [9].

Results

Study groups

A total of 211 eyes from 107 patients were included in this study. Participants were divided into four groups: ROP-Treated: 29 patients diagnosed with retinopathy of prematurity who received laser photocoagulation treatment (n:54), ROP-Untreated: 26 patients diagnosed with ROP who experienced spontaneous regression without treatment (n:52), Preterm: 25 patients born prematurely but without a diagnosis of ROP (n:51), Control: 27 healthy term-born infants (n:54). The kurtosis values describe the distribution shapes for each parameter within the groups. Table 2 shows the distribution characteristics for factors (age, sex, birth weight and gestational age) across the groups. The mean age of participants was similar across all groups and the sex distribution was balanced. As it should be, birth week and birth weight showed clear

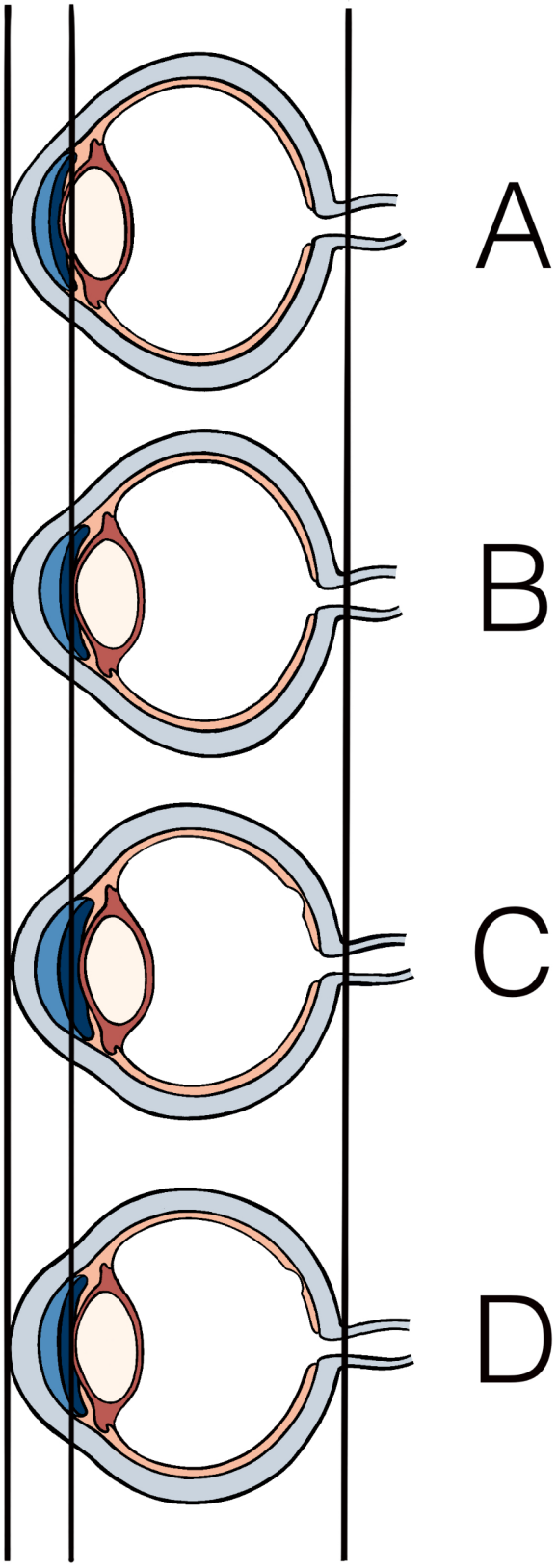

Fig. 1 Ocular Anatomy. Kanac, Burcu (2024) Digital Illustration. Schematic representation of four groups: ROP-Tx Group: [**A**], ROP-nonTx Group: [**B**], Premature Group [**C**], Control Group: [**D**]

progression from the most premature (ROP-Tx group) to the full-term infants (control group). The ROP-Tx group had the earliest mean gestational age was 26.5 weeks and the lowest mean birth weight was 976 g. The ROP-nonTx group and the premature group showed intermediate values for both parameters, while the control group represents the expected values for full-term births, with a mean gestational age of 37.8 weeks and a mean birth weight of 3350 g.

Ocular parameters were compared among the four study groups

Figure 1 presents sample differences between the four study groups, and Table 3 shows group comparisons of optical and functional parameters. It was determined that K1, AL and CCT variables were normally distributed. It was observed that the distribution of other variables did not fit the normal distribution. For this reason, t test was used in the comparison of group averages for K1, AL and CCT variables. The ROP-Tx group exhibited significant differences from the control groups. ROP-Tx Group has higher spherical equivalent and astigmatism power, steeper K1 (flat) and K2 (steep) values, shorter axial length, lower anterior chamber depth, increased macular thickness, reduced choroidal thickness, poorer BCVA than the control group. The ROP-untreated group also showed significant differences from the control group has steeper K1 and K2, shorter axial length, increased macular thickness within the control group. The preterm group (without ROP) differed significantly from the control group only in anterior chamber depth, which was wider within the control group. While choroidal thickness was thinner in all three premature birth groups compared to the control group, this difference reached statistical significance only for the ROP-treated group.

The graphic Figs. 2, 3 and 4, and 5 shows differences in eye structure measurements among the study groups. For K2 (Fig. 2), the ROP-Tx and ROP-nonTx groups exhibit comparable median values, with no significant differences between them. However, both groups show significantly higher K2 values compared to the Control groups ($p < 0.001$). These findings suggest that ROP, regardless of treatment, is associated with increased corneal steepness compared to Control groups, potentially reflecting alterations in corneal development due to ROP. For SE (Fig. 2), the ROP-Tx group demonstrates the most myopic refractive error (lowest median SE), with significant differences compared to all other groups ($p < 0.01$). Not only is the SE refractive error myopic, but the frequency of SE changes also varies significantly among the groups in our study, as shown in Fig. 3. According to this graph, the frequencies of SE measurements were similar in all groups except the ROP-Tx group. The ROP-nonTx group shows

Table 3 Group comparisons of optical and functional parameters

	ROP-Tx Group ($n=54$)	ROP-nonTx Group ($n=52$)	Premature Group ($n=51$)	Full-Term Group ($n=54$)
	Mean (SD) or Median (IR) / *P* value[†]			
Best-Corrected Visual Acuity (logMar)	0.1 (0.3) / **0.001**[†]	0.00 (0.00) / 0.120	0.00 (0.00) / 0.483	0.00 (0.00)[††]
Spherical Equivalent (Dioptre)	-0.87 (5.84) / **0.001**[†]	0.81 (1.47) / 0.098	0.50 (1.50) / 0.085	0.56 (1.25)[††]
K1 flat (Dioptre)	45.83 (2.05)[†††] / **0.001**[†]	45.24 (1.93)[††] / **0.001**[†]	42.99 (1.59)[†††] / 0.330	43.29 (1.54)[†††]
K2 Steep (Dioptre)	47.95 (2.32)[†††] / **0.000**[†]	46.62 (2.45)[††] / **0.000**[†]	44.01 (1.99)[†††] / 0.162	44.51 (1.62)[†††]
Astigmatism (Dioptre)	1.92 (1.02) / **0.000**[†]	1.05 (0.87) / 0.805	0.82 (0.83) / 0.169	1.01 (0.98) [††]
Axial Length (mm)	21.67 (1.56)[††] / **0.000**[†]	22.01 (0.84)[†††] / **0.000**[†]	23.02 (0.57)[†††] / 0.167	22.79 (0.96)[†††]
Anterior Chamber Depth (mm)	3.04 (0.33) / **0.000**[†]	3.33 (0.27) / 0.881	3.47 (0.28) / 0.022	3.34 (0.30)[†††]
Central Macular Thickness (µm)	300.50 (53.50) / **0.000**[†]	250.05 (35.25) / **0.000**[†]	219.00 (20.0) / 0.212	215.50 (15.0)[††]
Central Choroidal Thickness (µm)	268.27 (109.0) / **0.000**[†]	310.90 (89.75) / 0.184	304.11 (110.0) / 0.97	328.16 (99.25)[†††]

[†] *p*-value obtained results when compared with Control Group ($p<0.05$)

[††] Non-parametric Test and used median, interquartile range (IR) measurements used

[†††] Parametric Test and mean, std. deviation (SD) measurements used

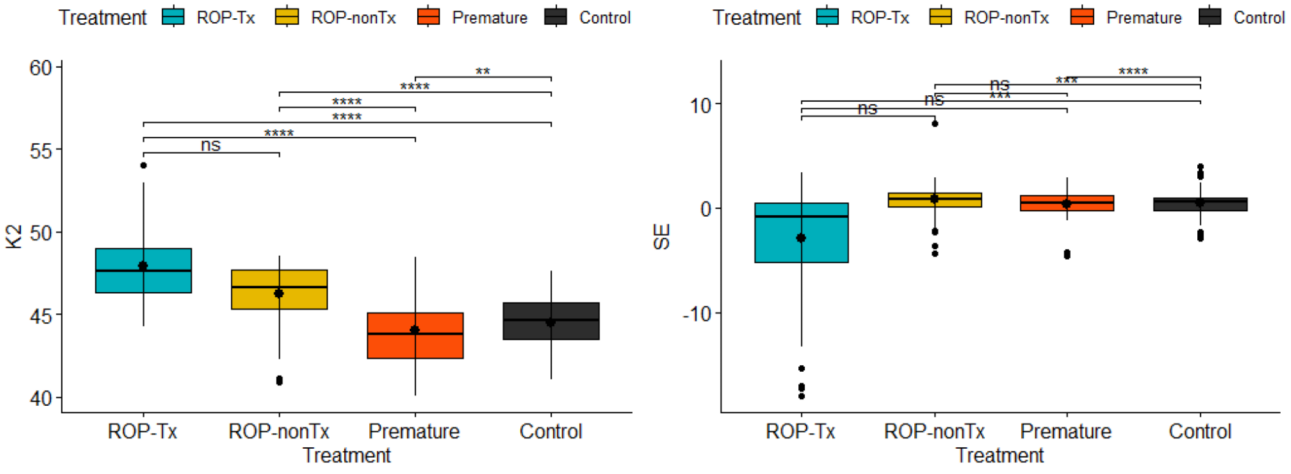

Fig. 2 Illustration showing the mean/median comparisons of the variables. K2 (a measure of corneal curvature) and SE (spherical equivalent). Error bars represent interquartile range

a less pronounced but still myopic SE, which does not significantly differ from the control group. These results indicate that ROP and its treatment are associated with increased myopia, with the most severe refractive outcomes observed in the treated ROP group. The statistical analyses further emphasize the significant differences in astigmatism observed between the ROP-Tx group and the Control group. Figure 4 shows that the ROP-Tx group exhibited the highest median best-corrected visual acuity, with a wide distribution that was significantly different from all other groups.

Classification of study groups by parameters using classification and regression tree

The Classification and Regression Tree graphs presented in Fig. 6 (The CRT analysis) identify critical limit values that can be used to separate the study groups based on the measured properties. According to the graph, individuals with central macular thickness above 249 µm are classified into the ROP-NonTx group if their astigmatism value is below 1.3 Dioptre, or the ROP-Tx group if it is above 1.3. For those with CMT below 249 µm, those with a K1 value above 45 Dioptre are included in the ROP-nonTx group. The analysis also reveals that the Premature and Control groups can be primarily differentiated based on axial length and central corneal thickness. For individuals with K1 below 45 Dioptre, those with AL above 23 mm are in the Control group, indicating axial length distinguishes normal and premature eyes. Individuals with AL above 23 mm and CCT above 309 µm are classified as Premature, suggesting both parameters are crucial markers of prematurity.

Overall, the classification and regression tree approach effectively identify key thresholds to separate the groups, supporting diagnosis and management of conditions like ROP and assessment of premature infant eye health. This structured methodology aids clinicians in accurate patient classification and personalized treatment strategies.

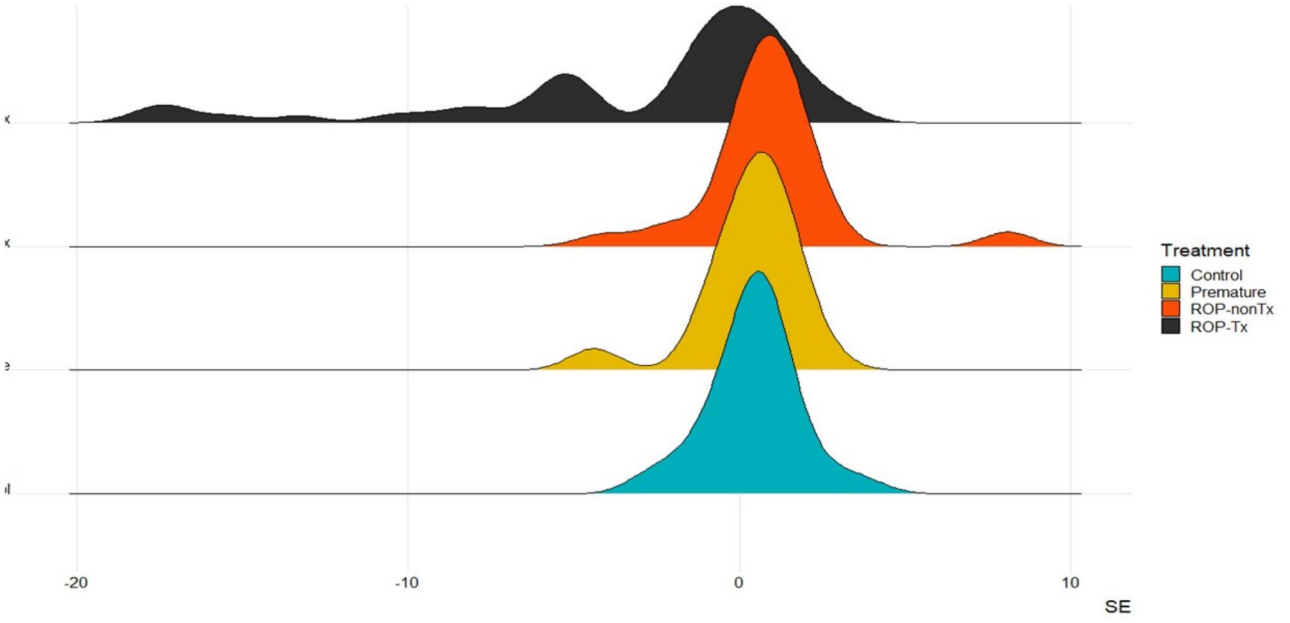

Fig. 3 Distribution of SE (spherical equivalent) for each group

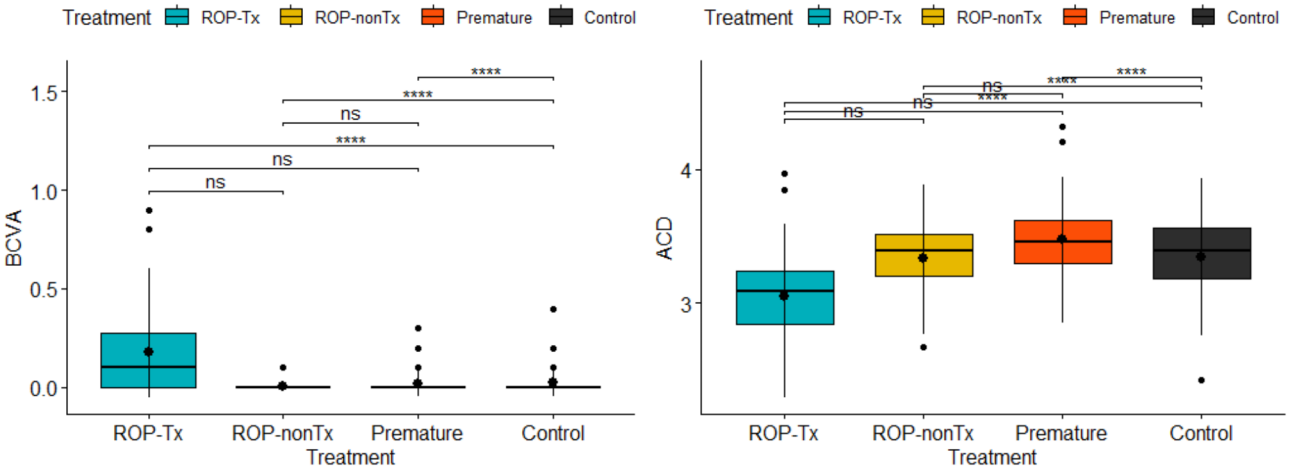

Fig. 4 Illustration showing the mean/median comparisons of the variables. BCVA: Best Corrected Visual Acuity, ACD: Anterior Chamber Depth. Error bars represent interquartile range

Discussion

This study demonstrates that premature infants treated with laser photocoagulation for ROP exhibit the most significant deviations in ocular anatomical development and visual function (BCVA) compared to full-term infants. While premature infants with ROP who did not require treatment showed functional vision similar to the term group, the laser-treated group showed statistically significant differences in all measured parameters. These findings underscore the need for close monitoring and management of laser-treated infants to preserve visual function.

The survival rate of newborns born with significantly lower birth weight and gestational age has increased due to the improved standard of care during pregnancy and in the neonatal intensive care setting. However, this has also led to a rise in the severity and morbidity of chronic ailments, including vision-related issues, in these infants [10]. Preterm children are particularly susceptible to visual complications, with retinopathy of prematurity being a major public health concern, especially in developing nations [11, 12].

In term infants, axial length typically ranges from 15 to 19 mm at birth and increases to approximately 22 mm by age three [13]. This growth is closely linked to emmetropization and peripheral defocus, a process involving coordinated changes in corneal and lens power [14]. However, prematurity can disrupt this delicate process,

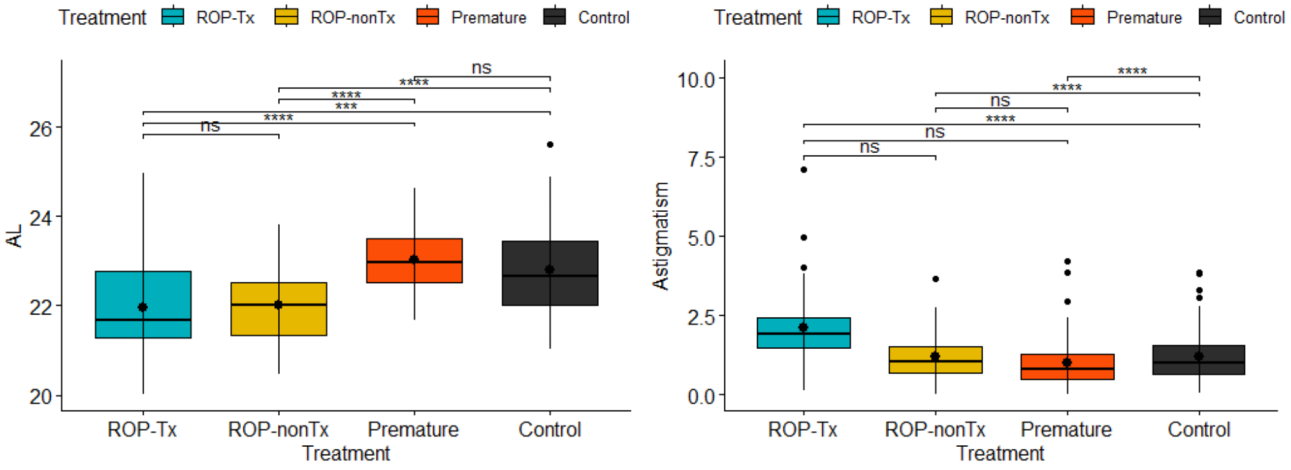

Fig. 5 Illustration showing the mean/median comparisons of the variables. Astigmatism and AL (axial length). Error bars represent interquartile range

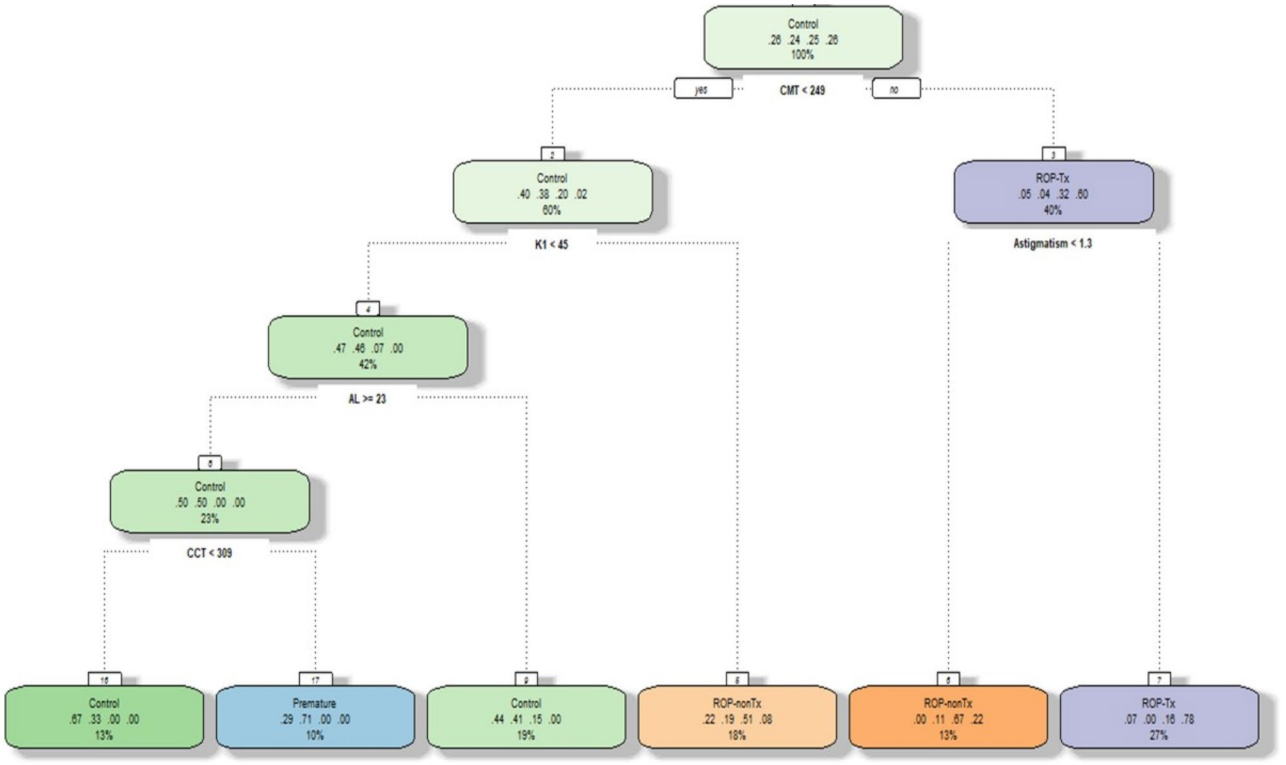

Fig. 6 CRT model for four groups

potentially leading to anterior segment maldevelopment and myopia distinct from school-age or pathological myopia [15, 16]. Our study proves this by giving similar results to the associated premature myopia (short AL, high corneal power and myopia). While some preterm infants may catch up visually within six months, the question remains whether myopia in ROP patients is a direct consequence of prematurity or a sequela of ROP itself [17]. Additionally, our study demonstrates that patients in the regressed ROP group exhibited visual function similar to term patients, despite some differences in ocular anatomy.

As previous studies have shown, school-age children treated with laser photocoagulation for ROP often experience poorer visual outcomes and a higher prevalence of refractive errors [18, 19]. Our findings corroborate these observations, demonstrating significantly lower spherical equivalent values (indicative of myopia) in the laser-treated group compared to the full-term group. This is consistent with the hypothesis that laser therapy disrupts the peripheral hyperopic defocus mechanism,

potentially halting axial elongation without a corresponding decrease in corneal and lenticular refraction [14–20]. Furthermore, our study also revealed a higher incidence of astigmatism in the laser photocoagulation group, a finding that raises concerns about the long-term risks of amblyopia and strabismus. The similarity in astigmatism values between the premature group without ROP and the full-term group suggests that emmetropization can proceed normally in premature infants without ROP, further highlighting the impact of laser treatment on ocular development.

The etiology of myopia in preterm infants is likely multifactorial, involving potential changes in globe elongation, lens characteristics, and corneal curvature [13, 14]. While some studies emphasize the role of increased corneal refractive power, others suggest that lenticular changes may be more significant [21]. Our findings show higher keratometer values (indicating steeper corneal curvature) in infants with ROP compared to term infants, consistent with previous reports [20]. While anterior segment development may contribute, myopia of prematurity is primarily attributed to excessive axial elongation of the eye, leading to a mismatch between the eye's optical power and its length [15, 16, 22]. Our study also encountered mismatches between optical power and eye length, with differences in spherical equivalent measurements ranging from −20 to +5 diopters in the ROP-Tx group (Fig. 2). However, without lens thickness or lenticular curvature data, we cannot definitively determine the relative contributions of corneal versus lenticular changes to the observed myopia in our ROP group. Interestingly, the corneal refractive power in premature infants without ROP was similar to that of the term group. Even if we had these data, lens paradox and accommodation are important considerations when interpreting the findings of this study [23]. This suggests that the hyperopic defocus mechanism, crucial for emmetropization, may be preserved in these infants, potentially obviating the need for high level corneal power. Our data also revealed a correlation between shorter axial length, lower gestational age, and the presence/severity of ROP. ROP-Tx group exhibits the lowest median axial length, while the ROP-nonTx group has a higher median, though still lower than the Premature and Control groups (Fig. 5). Statistical analyses again highlight significant differences between this group and the Control group. This is consistent with the idea that the hyperopic defocus mechanism may be compromised in infants with an immature peripheral retina or those treated with laser photocoagulation, thereby impairing globe elongation. The similarity in axial length between premature infants without ROP and term infants further supports the notion that peripheral retinal function plays a key role in axial development. This observation differs from some previous studies, perhaps highlighting the complex interplay between gestational age, peripheral retinal maturity, and axial elongation [24].

O'Connor et al. reported that mild ROP and the absence of ROP did not significantly affect long-term best-corrected visual acuity [25]. Our study demonstrates that ROP group who has laser photocoagulation treatment exhibited significantly higher best-corrected visual acuity compared to the control group. Potential contributing factors for this difference may include variations in refractive error, anisometropia, central macular thickness, or central choroidal thickness between the groups. The data suggest that ROP treatment has a profound impact on corneal curvature, refractive development, and overall visual function. Specifically, increased corneal steepness and myopia were more prominent sequelae in the ROP-treated group, displaying more severe refractive changes. The study results demonstrate that the anatomical deviations observed in this cohort lead to abnormal deviations in spherical equivalent. In contrast, the ROP-nonTx, Premature, and Control groups displayed consistent median BCVA values. Consistent with previous literature, BCVA did not differ significantly between the term group and either the ROP group without laser treatment or the premature group without ROP. These findings suggest that maintaining emmetropization, as well as close monitoring and refractive correction, may play a crucial role in preserving visual acuity in these premature infants.

Previous studies have reported lower ACD and thicker lenses in children with ROP compared to premature infants without ROP [26, 27]. The reduced ACD in ROP has been attributed to both disrupted anterior chamber development and lenticular thickening [20]. Our findings show a similar pattern: children with ROP treated with laser photocoagulation had lower ACD than term-born children. The ROP-Tx group exhibited the lowest median anterior chamber depth for the ACD parameter (Fig. 4), while the Premature group had a higher median than the Control group. Statistical analyses further revealed significant differences in ACD between these groups and the Control group. However, ACD did not differ between term infants and those with ROP without laser treatment. Interestingly, premature infants without ROP exhibited significantly greater ACD than term infants. While ACD is influenced by multiple factors (race, genetics, age, gender, axial length, refractive error), the similar spherical equivalents, gender distribution, and axial lengths between our term and premature groups suggest that lens thickness may be the primary driver of the increased ACD in the premature group without ROP. Given the strong correlation between age and lens thickness, we hypothesize that this ACD difference reflects the varying stages of ocular development in our premature cohort. Specifically, the premature infants without ROP in our

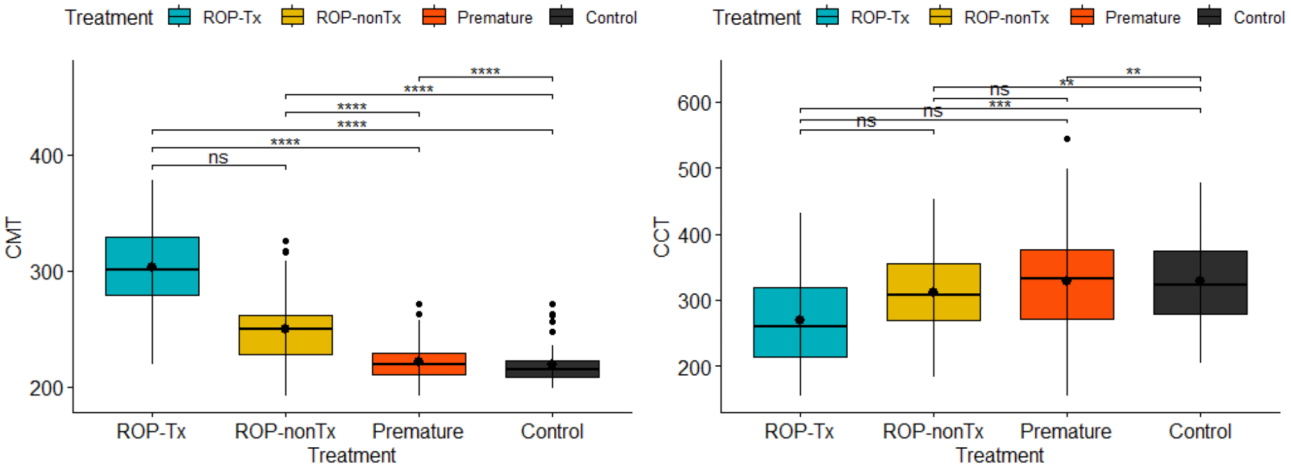

Fig. 7 Illustration showing the mean/median comparisons of the variables. CMT(Central Macular Thickness) and CCT (Central Choroidal Thickness). Error bars represent interquartile range

study may represent a later stage of prematurity, unlike those in previous reports [27, 28]. However, without data on iris thickness, iridocorneal angle, and lens thickness, we cannot definitively determine the underlying cause of the observed ACD differences. The Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error study, which examined children aged 6–14 years, also highlighted the influence of age on optical parameters such as refractive error and ACD [29]. Further research incorporating these parameters is needed to fully elucidate the relationship between prematurity, ROP, and ACD.

Children with a history of ROP have been reported to exhibit deterioration and alterations in retinal morphology [30]. Foveal architecture in preterm infants follows an atypical developmental trajectory, beginning in the inner retinal layers as early as 22 weeks of gestation. Between 24 and 26 weeks, ganglion cells and inner nuclear layer cells migrate laterally, initiating foveal formation. This centrifugal migration continues for up to 15–45 months postnatally [31]. Prematurity, the presence and severity of ROP, and treatment interventions have all been linked to alterations in foveal thickness [30, 32]. For CMT, the ROP-Tx and ROP-nonTx group exhibited the highest median values with a wide distribution (Fig. 7), significantly differing from the Control group ($p < 0.001$). This may suggest that laser photocoagulation treatment prevents or hinders the development of central foveal depression. However, we observed no significant difference between our premature and full-term groups, possibly because the 30th week of gestation represents a critical point in foveal depression formation [33]. ROP and its treatment, gestational age, and birth week can influence macular morphology. While mild ROP or moderate prematurity may not always result in significant functional deficits, severe ROP and extreme prematurity can lead to substantial visual impairment. The relationship between structural changes and functional outcomes is complex and depends on the severity of ROP and the degree of prematurity. Furthermore, children with ROP treated with laser photocoagulation exhibited significant choroidal thinning, consistent with previous studies [34, 35]. This suggests that ROP-related ischemia may cause degeneration or involution of the choriocapillary layer, similar to changes observed in diabetic retinopathy after laser treatment. The Premature and Control groups exhibited higher and similar median CCT values (Fig. 7).

Clinicians often encounter adult patients presenting with immature retinas lacking foveal depression. Determining the underlying cause, whether due to retinal immaturity, vitreomacular traction, or edema-related thickening, can be challenging. The classification and regression tree approach has proven effective in defining baseline thresholds to differentiate patient groups based on ocular biometric measurements. This structured methodology supports the diagnosis and management of conditions associated with a history of retinopathy of prematurity and the assessment of prematurity-related ocular changes. This analytical framework assists clinicians in accurately stratifying patients and tailoring personalized treatment strategies.

Study encountered challenges with patient compliance, resulting in inconsistent measurements and participant exclusions. The IOL Master's inability to measure lens thickness further limited our investigation. Future longitudinal studies with larger sample sizes are needed to address these limitations and provide more robust statistical data, particularly through analysis incorporating normally distributed parametric values. As anti-VEGF treatment is becoming increasingly common in the management of ROP, our findings may not fully reflect the spectrum of ocular outcomes in this population. Future

studies with larger sample sizes are needed to compare the long-term ocular effects of laser therapy versus anti-VEGF treatment. Such research will be crucial for determining the potential benefits and drawbacks of each treatment modality and for optimizing the management of ROP to minimize long-term visual complications. Specifically, investigating the potential superiority of laser therapy in terms of ocular parameters, as suggested by our findings, will be an important area of focus for future research.

Conclusion

Our study provides insights into the complex relationship between prematurity, retinopathy of prematurity, and ocular biometry. Laser photocoagulation treatment for ROP in premature infants is associated with significant deviations in ocular anatomical development and visual function. In contrast, premature infants with ROP who did not require treatment had functional vision more similar to the term group, despite some anatomical differences. Premature infants without retinopathy of prematurity exhibited ocular anatomy and visual function nearly identical to those of full-term infants. These findings underscore the critical importance of long-term monitoring and management for premature infants treated with laser photocoagulation, as they exhibit greater deviations in ocular biometry and visual function compared to premature infants with or without ROP who did not receive laser intervention. Abnormal refractive errors can hinder effective amblyopia management, necessitating more frequent patient monitoring. While follow-up examinations may not fully prevent anatomical changes or guarantee emmetropization, they are essential for early detection and intervention to mitigate potential complications and optimize visual outcomes. Further research is warranted to determine if children with ROP can achieve emmetropization.

Abbreviations

ACD	Anterior Chamber Depth
BCVA	Best Corrected Visual Acuity
CCT	Central Choroidal Thickness
CMT	Central Macular Thickness
SE	Spherical Equivalent

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Author contributions

KAK: Study design, data collection of patient, analysis and interpretation of patient data, drafting the manuscript. ÖÖ and DEA: Study design, drafting the manuscript. IMU: Revising the manuscript for content, study supervision. All authors read and approved the final manuscript.

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Data availability

The data collected for this study cannot be made publicly available due to the need to safeguard the privacy and confidentiality of the participants involved in the current analysis. The datasets for the analysis of the current study are reserved by the author. Datasets are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study received approval from the institutional ethics review committee (E1-22-2288) at the Bilkent City Hospital. The study examined individuals younger than sixteen years old and obtained ethical approval and informed consent from the participating families who were called for the examination.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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