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Original Article

Impact of myopic laser surgery and pregnancy-related hormonal fluctuations on corneal biomechanics

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Abstract: Objective: To investigate dynamic changes in corneal biomechanics during pregnancy and their effects on the outcomes of myopic laser surgery. Methods: A total of 100 women with early intrauterine singleton pregnancies and a history of high myopia were enrolled and divided into two groups according to prior myopic laser surgery. Fifty-three participants who had undergone myopic laser surgery comprised the observation group, and 47 without laser surgery comprised the control group. Corneal biomechanical parameters, including applanation times, deformation amplitude, and central corneal thickness (CCT), were measured using the Corvis ST system at three time points, namely, pre-pregnancy, during pregnancy, and six weeks postpartum. Ophthalmic biometric indices (CCT, corneal curvature, axial length, and intraocular pressure (IOP)) were also taken. Further, serum concentrations of estrogen, progesterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH), testosterone, and prolactin were assessed to evaluate hormonal effects on corneal changes. Logistic regression was used to identify factors influencing CCT, with particular attention to the roles of laser surgery and hormonal variation. Results: Uncorrected visual acuity (UCVA), corneal biomechanics, and ocular biometry varied significantly over pregnancy. The observation group achieved greater UCVA improvement compared to the control group, particularly at 6 and 9 months of gestation ($P < 0.001$). Notably, the Observation Group exhibited significant reductions in CCT and corneal curvature from the third month of pregnancy to six weeks postpartum ($P < 0.05$). Logistic regression identified prior laser surgery and estrogen levels as independent predictors of CCT, with laser surgery showing the strongest association (OR = 0.935, $P < 0.001$). Conclusions: Myopic laser surgery and hormonal fluctuations during pregnancy exert significant effects on corneal biomechanics, particularly on central corneal thickness and corneal curvature.

Keywords: Corneal biomechanics, pregnancy, LASIK, refractive stability, visual outcomes

Introduction

A range of systemic and ocular changes during pregnancy may influence vision and the outcomes of refractive procedures, including myopic laser surgery [1]. Refractive surgery corrects myopia primarily by reshaping and flattening the cornea; however, hormonal fluctuations and biomechanical alterations associated with pregnancy can affect corneal structure and surgical outcomes [2, 3]. Previous studies have reported pregnancy-related changes in corneal thickness, curvature, and rigidity, which can lead to unpredictable postoperative refractive stability [4-7]. Elevated levels of progesterone and relaxin are thought to modulate the biomechanics of connective tissues, contributing to these alterations [8, 9].

Key corneal biomechanical parameters, such as stiffness, deformation amplitude, and elastic modulus, are critical determinants of refractive surgery success [10-12]. Yet, the impact of pregnancy-related biomechanical changes on cornea healing and refractive stability after laser surgery remain incompletely understood. Pregnancy-related hormonal and structure changes may compromise corneal wound healing and increase the risk of complications, including postoperative ectasia [12]. This raises important questions regarding the optimal timing of laser refractive surgery and the most

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appropriate preoperative assessment for women who are pregnant or planning pregnancy.

Given that pregnancy can modify corneal biomechanics, it is essential to clarify how these changes affect the efficacy and safety of myopic laser surgery. A better understanding of these interactions may reduce surgical unpredictability, enhance patient safety, and inform surgeons' decision-making regarding timing and perioperative care. The present study aims to evaluate the influence of pregnancy on corneal biomechanics, explore their implications for refractive surgery in myopic patients, and provide guidance for routine ophthalmic management in women of childbearing potential.

Methods

Patient recruitment

This prospective study enrolled 100 women with early intrauterine singleton pregnancies who visited the obstetrics outpatient clinic of Lishui People's Hospital between January 2022 and January 2025. Fifty-three participants who had undergone myopic laser surgery (LASIK or PRK) at least 6 months prior to conception (n = 53) comprised the observation group, and forty-seven participants who didn't receive such surgery were grouped into the control group (n = 47). All participants had a history of high myopia (spherical equivalent ≤ -6.00 D). This study was approved by the institutional ethics committee of Lishui People's Hospital, and written informed consent was obtained from all participants. The flowchart of the experimental design was shown in the **Figure 1**.

Inclusion criteria: age 20-40 years; confirmed early intrauterine singleton pregnancy; regular prenatal care; good general health, with no ocular pathologies such as Keratoconus, glaucoma, corneal dystrophies, or severe corneal scarring; willingness to undergo ophthalmic and hormonal examinations.

Exclusion criteria: irregular or absent prenatal visits; systemic diseases that may affect corneal biomechanics (e.g., uncontrolled diabetes, autoimmune disorders, or poorly controlled hypertension); prior ocular surgeries other than myopic laser procedures; current use of systemic or topical medications known to influence corneal or hormonal status (e.g., corticosteroids, non-pregnancy-related hormonal therapy); history of pregnancy complications (e.g., preeclampsia or gestational diabetes); and nonadherence to scheduled ophthalmic or hormonal evaluations.

Data collection

Corneal biomechanical parameters were evaluated using the Corvis ST dynamic Scheimpflug analyzer (Oculus, Germany). During testing, participants were instructed to rest their chin on the support and fixate on a blinking target while avoiding eyelid movement to ensure optimal image quality for automated scanning.

The Corvis ST recorded the dynamic response of the cornea during air-puff-induced applanation and provided quantitative data on key parameters, including applanation time, applanation length, applanation velocity, radius of curvature at the highest concavity, deflection amplitude, and the distance to the point of maximum deformation. Central corneal thickness (CCT) and intraocular pressure (IOP) were also measured to obtain both individual and comprehensive evaluations of corneal biomechanics.

Outcome measurements

The primary outcomes included uncorrected visual acuity (UCVA), corneal biomechanical parameters, and ophthalmic biometric indices, assessed at three time points: pre-pregnancy, during pregnancy, and six weeks postpartum.

Corneal biomechanical variables, such as applanation times, deformation amplitude, were considered primary indicators because they directly reflect corneal pliability and its response to hormonal fluctuations. Structural parameters, including corneal curvature, CCT, axial length, and IOP, were defined as secondary outcomes. Serum concentrations of estrogen, progesterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH), testosterone, and prolactin were also monitored as secondary variables potentially influencing corneal biomechanics. Logistic regression analysis was performed to identify predictors of CCT variations, with particular attention the effects of prior laser surgery and hormonal changes on corneal biomechanics and their contribution to refractive surgery outcomes.

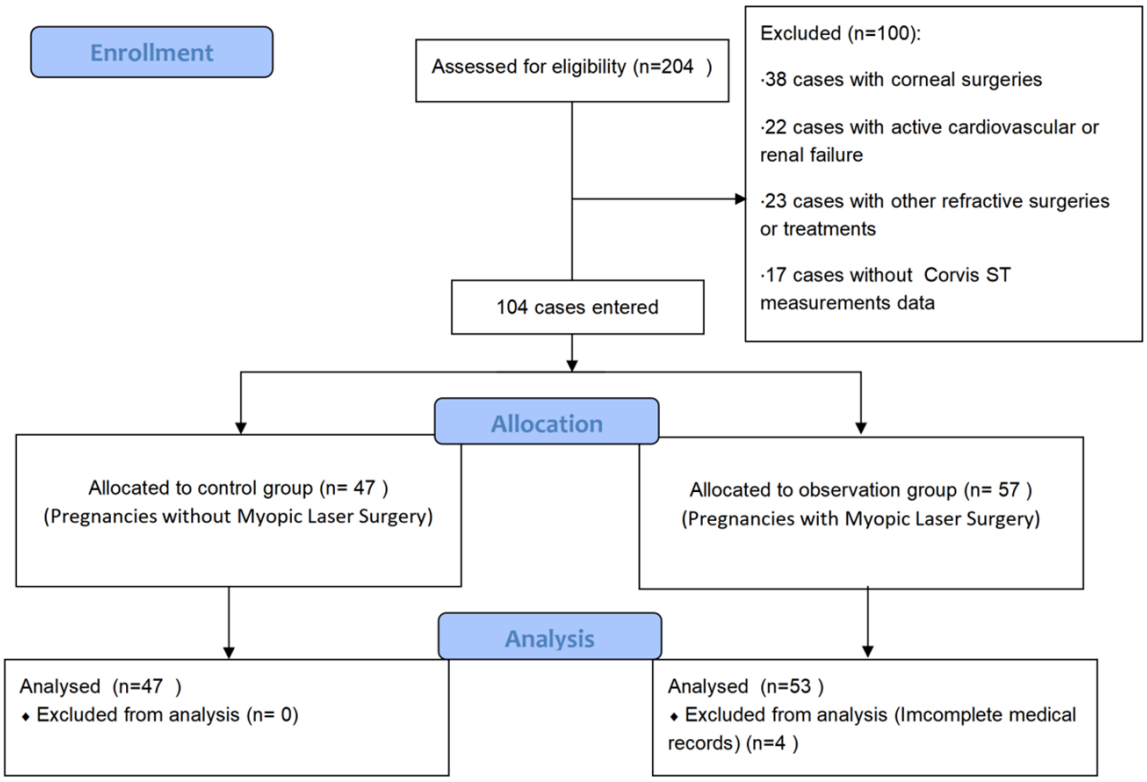

Figure 1. Flow diagram of study procedure.

Statistical methods

All analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation (SD) and compared using independent-samples t-test or repeated-measures analysis of variance (ANOVA) with least significant difference (LSD) post hoc testing, as appropriate. Categorical variables were expressed as counts and percentages, and analyzed using the Chi-square test. Logistic regression was applied to evaluate factors, including laser surgery and hormonal levels, that might influence changes in CCT. A two-sided *p*-value < 0.05 was considered statistically significant.

Results

Baseline characteristics of patients

No significant differences were observed between the two groups regarding age, marital status, body habitus, educational level, or occupation (all P > 0.05). Medical and obstetric histories, including vaginal infections, pelvic inflammatory diseases, miscarriage, menstrual disorders, infertility treatment, prior surgeries, and ocular diseases, were comparable between groups.

Refractive status prior to pregnancy was similar (SER: -7.15 ± 1.22 D vs. -7.43 ± 1.25 D; P = 0.268), as were vision changes during pregnancy (22.6% vs. 19.1%; P = 0.669) and family history of ocular disease (P = 0.493) (**Table 1**). These results confirm that the two groups were well matched at baseline.

Changes in uncorrected visual acuity

At 6 months of gestation, the UCVA improvement was significantly greater in the observation group than the control group (P < 0.001), and this trend persisted at 9 months of gestation (P < 0.001). These results suggest that prior laser surgery may enhance UCVA gains during pregnancy.

By 6 weeks postpartum, both groups experienced a slight decline in UCVA compared to pregnancy values; however, the between-group difference was no longer statistically signifi-

Table 1. Baseline characteristics of patients

Parameter	Observation Group (n = 53)	Control Group (n = 47)	t/X²	*P*-value
Age (years)	32.60 ± 4.75	31.04 ± 4.88	1.619	0.109
Marital Status	51 (96.23%)	45 (95.74%)	0.015	0.902
Height (cm)	162.76 ± 5.53	161.82 ± 5.56	0.843	0.401
Weight (kg)	57.15 ± 6.98	58.86 ± 7.10	1.213	0.228
Obstetric History	28 (52.83%)	24 (51.06%)	0.031	0.860
Gestational Age (weeks)	23.96 ± 3.66	24.45 ± 4.15	0.620	0.536
Educational Level	46 (86.79%) with university degree	42 (89.46%) with university degree	0.156	0.693
Occupation	40 (75.47%) office workers	39 (82.98%) office workers	0.846	0.358
Vaginal Infection History	5 (9.43%)	3 (6.38%)	0.315	0.575
Pelvic Inflammatory Disease History	2 (3.77%)	1 (2.13%)	0.232	0.630
Miscarriage History	7 (13.21%)	6 (12.77%)	0.004	0.948
Menstrual Disorder History	3 (5.66%)	2 (4.26%)	0.104	0.748
Infertility Treatment History	4 (7.55%)	3 (6.38%)	0.052	0.820
Previous Surgery History	10 (18.87%)	8 (17.02%)	0.058	0.810
Eye Disease History	3 (5.66%)	2 (4.26%)	0.104	0.748
Pre-Pregnancy Refractive Status (SER)	-7.15 ± 1.22	-7.43 ± 1.25	1.114	0.268
Vision Changes During Pregnancy	12 (22.64%)	9 (19.15%)	0.183	0.669
Family History of Eye Diseases	15 (28.30%)	13 (27.66%)	0.005	0.943

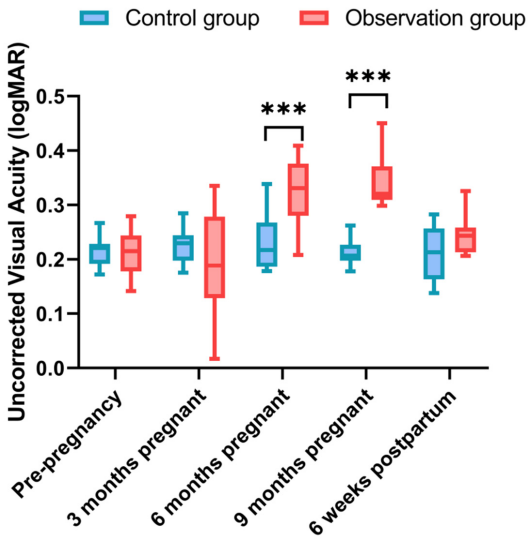

Figure 2. Comparison of uncorrected visual acuity (UCVA) between the two groups at various timepoints. ***P < 0.001.

cant (P > 0.05) (**Figure 2**). Overall, pregnancy appeared to improve UCVA, with more pronounced improvements in women who had undergone laser surgery, although this advantage diminished after delivery.

Changes in sex hormone levels

Hormone levels, including estrogen, progesterone, LH, FSH, testosterone, and prolactin fluctuated over pregnancy and postpartum periods; however, none of these hormones differed significantly between the two groups (all P > 0.05) (**Figure 3**).

Changes in corneal biomechanical parameters

At baseline, there were no significant differences between the two groups in any corneal biomechanical parameters (all P > 0.05), indicating comparable baseline corneal characteristics. By 6 months after conception, several parameters differed significantly between groups. The observation group exhibited greater alteration in first and second applanation times, maximum applanation time, and deformation amplitude, compared with the control group (all P < 0.05) (**Table 2**). These results suggest that the myopic laser surgery is associated with more pronounced changes in corneal biomechanics during pregnancy and into the postpartum period, relative to the natural course observed in the control group.

Ophthalmic biometric parameters

At baseline, no significant differences were observed between the two groups in any ophthalmic biometric parameter (P > 0.05), indicating comparable baseline values. During pregnancy, significant differences emerged, especially in CCT and corneal curvature. Notably, the

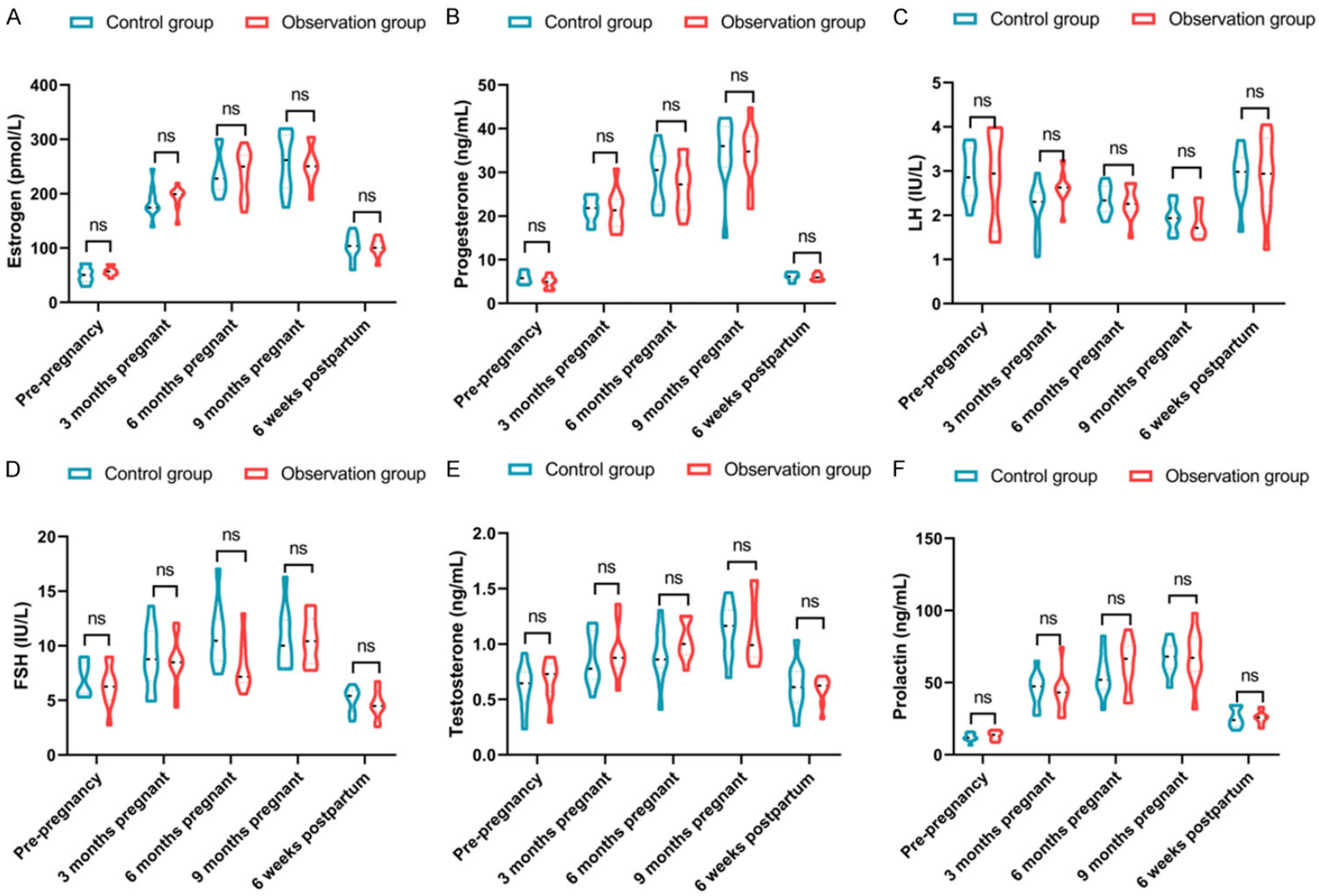

Figure 3. Compare serum hormone levels between the two groups at various timepoints. A. Estrogen; B. Progesterone; C. LH; D. FSH; E. Testosterone; F. Prolactin. Note: LH: Luteinizing Hormone, FSH: Follicle-Stimulating Hormone.

Table 2. Comparison of corneal biomechanical parameters between the two groups

	Time Point	Observation Group (n = 53)	Control Group (n = 47)	t	*P*-value
First Applanation Time (ms)	Baseline	120.10 ± 15.45	124.47 ± 14.96	1.433	0155
	6 months after conception	133.50 ± 18.65	123.27 ± 16.62	2.879	0.005
Second Applanation Time (ms)	Baseline	141.95 ± 15.95	135.53 ± 18.89	1.842	0.068
	6 months after conception	156.68 ± 18.98	138.08 ± 24.44	4.276	< 0.001
First Applanation Length (mm)	Baseline	2.36 ± 0.15	2.34 ± 0.15	0.367	0.715
	6 months after conception	2.51 ± 0.18	2.11 ± 0.11	13.573	< 0.001
Second Applanation Length (mm)	Baseline	2.43 ± 0.18	2.43 ± 0.16	0.006	0.995
	6 months after conception	2.65 ± 0.17	2.12 ± 0.14	17.033	< 0.001
First Applanation Rate (mm/s)	Baseline	5.21 ± 1.19	5.04 ± 1.04	0.757	0.451
	6 months after conception	4.65 ± 1.12	5.09 ± 1.03	2.045	0.042
Second Applanation Rate (mm/s)	Baseline	5.11 ± 0.89	4.92 ± 1.02	0.810	0.420
	6 months after conception	4.41 ± 0.91	5.10 ± 0.92	3.771	< 0.001
Maximum Applanation Time (ms)	Baseline	219.82 ± 29.45	223.29 ± 31.58	0.568	0.571
	6 months after conception	246.98 ± 35.10	217.26 ± 32.77	4.360	< 0.001
Maximum Applanation Curvature Radius (mm)	Baseline	7.54 ± 0.45	7.51 ± 0.45	0.307	0.760
	6 months after conception	7.42 ± 0.40	7.75 ± 0.43	4.041	< 0.001
Maximum Applanation Peak-to-Peak Distance (mm)	Baseline	0.75 ± 0.07	0.74 ± 0.06	0.670	0.505
	6 months after conception	0.79 ± 0.07	0.60 ± 0.01	18.740	< 0.001
Maximum Deformation Amplitude (μm)	Baseline	58.55 ± 10.83	55.28 ± 9.59	1.590	0.115
	6 months after conception	66.75 ± 12.30	56.87 ± 11.79	3.677	< 0.001
Central Corneal Thickness (μm)	Baseline	540.58 ± 28.56	541.37 ± 33.19	0.128	0.899
	6 months after conception	553.80 ± 34.49	509.76 ± 36.62	6.191	< 0.001
Intraocular Pressure (mmHg)	Baseline	15.23 ± 2.14	15.53 ± 2.11	0.693	0.490
	6 months after conception	15.92 ± 2.40	13.75 ± 2.24	4.648	< 0.001

observation group showed a marked reduction in both CCT and corneal curvature from the third month of gestation to 6 weeks postpartum, with all changes reaching statistical significance ($P < 0.05$).

Axial length increased slightly in both groups over the course of pregnancy, but no significant differences were noted between the groups ($P > 0.05$). IOP remained stable across all stages in both groups, with no statistically significant differences ($P > 0.05$) (**Table 3**).

Logistic regression analysis of factors influencing CCT

To further explore factors influencing CCT, patients were stratified into two groups according to their CCT values: a thin cornea group (CCT < 530 μm) and a normal cornea group (CCT ≥ 530 μm). Univariate analyses were first conducted to screen for potential risk factors, including prior laser surgery, serum hormone levels, and other clinical parameters. Variables with statistical significance in univariate analysis were subsequently entered into logistic regression modeling. The results demonstrated that both prior laser surgery and estrogen concentration were independent predictors of CCT variation (**Table 4**). Specifically, a history of laser surgery was strongly associated with reduced CCT (OR = 0.935, 95% CI: 0.903-0.969, $P < 0.001$), indicating a higher likelihood of thinning in surgically treated corneas. Elevated estrogen levels also significantly increased the risk of reduced CCT (OR = 0.198, 95% CI: 0.112-0.348, $P < 0.001$). These findings suggest that structural alterations from laser surgery, combined with pregnancy-related hormonal fluctuations, jointly contribute to corneal thinning.

Discussion

This study provides new insight into the dynamic alterations in corneal biomechanics during pregnancy and their potential impact on the outcomes of myopic laser surgery. Our findings indicate that pregnancy exerts a substantial influence on uncorrected visual acuity (UCVA). Women who had undergone myopic laser surgery prior to conception, achieved significantly greater UCVA improvements than those didn't,

Table 3. Comparison of ophthalmic biometric parameters between the two groups

	Time Point	Observation Group	Control Group	t	*P*-value
Axial Length (mm)	Baseline	24.39 ± 1.10	23.98 ± 1.07	1.914	0.058
	3 months of pregnancy	24.54 ± 1.10	24.49 ± 1.31	0.193	0.848
	6 months of pregnancy	24.95 ± 1.29	24.84 ± 0.98	0.485	0.629
	9 months of pregnancy	25.34 ± 1.07	24.96 ± 1.27	1.652	0.102
	6 weeks postpartum	25.06 ± 1.19	24.75 ± 1.15	1.312	0.193
Central Corneal Thickness (μm)	Baseline	545.46 ± 38.73	535.14 ± 32.07	1.441	0.153
	3 months of pregnancy	534.08 ± 30.54	571.29 ± 39.13	5.332	< 0.001
	6 months of pregnancy	517.89 ± 33.69	554.82 ± 34.61	5.400	< 0.001
	9 months of pregnancy	511.22 ± 34.92	558.15 ± 30.18	7.147	< 0.001
	6 weeks postpartum	500.72 ± 32.36	550.95 ± 36.27	7.318	< 0.001
Intraocular Pressure (mmHg)	Baseline	14.83 ± 1.91	14.56 ± 1.95	0.718	0.474
	3 months of pregnancy	15.95 ± 2.24	15.48 ± 1.99	1.107	0.271
	6 months of pregnancy	15.85 ± 2.53	15.71 ± 2.29	0.286	0.775
	9 months of pregnancy	15.39 ± 2.45	15.45 ± 1.83	0.152	0.879
	6 weeks postpartum	16.45 ± 2.74	16.06 ± 2.22	0.771	0.443
Corneal Curvature (D)	Baseline	43.16 ± 1.11	43.22 ± 1.15	0.276	0.783
	3 months of pregnancy	42.57 ± 1.10	47.81 ± 1.48	20.208	< 0.001
	6 months of pregnancy	41.80 ± 1.18	49.74 ± 1.99	24.646	< 0.001
	9 months of pregnancy	41.41 ± 1.00	48.86 ± 1.68	27.234	< 0.001
	6 weeks postpartum	41.43 ± 1.13	49.93 ± 2.83	20.143	< 0.001

Table 4. Logistic regression analysis of factors influencing central corneal thickness

	B	P	OR	95% CI of OR	
				Lower limit	Upper limit
Laser Surgery	0.067	< 0.001	0.935	0.903	0.969
Estrogen	1.622	< 0.001	0.198	0.112	0.348
Constant	5.479	< 0.001	23.559		

particularly at six and nine months of gestation. This enhancement may reflect pregnancy-related alterations in corneal biomechanics, likely mediated by hormonal fluctuations. The significant decline in UCVA observed in both groups at six weeks postpartum suggests that cornea changes occurring during pregnancy are, at least in part, reversible. These results support the hypothesis that the biomechanical and structural modifications affecting visual acuity during gestation are predominantly transient, corresponding to the temporary effects of hormonal changes on corneal tissue.

Our findings demonstrate that pregnancy can significantly influence UCVA, particularly in women who had undergone myopic laser surgery before conception. This observation enhances the understanding of how pregnancy-related hormonal fluctuations affect corneal biomechanics and, consequently, refractive outcomes. In the observation group, although the visual gains achieved by refractive surgery were partially diminished after pregnancy, the procedure appears to modify corneal properties in a way that persists beyond the immediate postoperative period [13-15]. Hormonal alteration during pregnancy, especially fluctuations in estrogen and progesterone, may affect corneal hydration, thickness, and curvature, leading to long-term biomechanical changes following refractive surgery [16, 17]. Because of hormonal changes during pregnancy, the cornea might become more flexible when a person receives refractive surgery [3, 18], which may explain the pronounced UCVA improvement observed at 6 and 9 months of gestation in the observation group. Elevated hormone levels

may transiently enhance corneal elasticity and curvature, augmenting the benefits of laser correction.

However, the decline in UCVA at 6 weeks postpartum indicates that these pregnancy-related advantages are largely reversible. As hormone levels stabilize, cornea rigidity and thickness tend to return toward baseline, thereby reducing UCVA. Estrogen, for instance, has been reported to increase corneal thickness and plasticity during pregnancy [19, 20], but its effects diminish once homeostasis is restored. These results suggest that visual changes after refractive surgery in pregnant women are time-dependent. The cornea, once altered by laser surgery, may be more sensitive to hormonal shifts, resulting in greater UCVA fluctuations compared with untreated myopic eyes [21, 22]. This highlights an important avenue for future research into the interaction between refractive surgery and pregnancy-related endocrine changes, with implications for optimizing surgical timing and counseling women of reproductive age.

Changes in corneal biomechanics observed during pregnancy may be influenced by prior laser refractive surgery. For example, variations in corneal applanation time and deformation amplitude can reflect corneal flexibility and provide insight into its biomechanical response after surgical reshaping. Elevated levels of estrogen and progesterone during pregnancy may alter corneal hydration, thickens, and curvature [23]. Consequently, the pronounced changes in corneal biomechanics observed in the observation group likely result from the combined effects of hormonal fluctuations and structural alterations induced by laser surgery. Furthermore, modifications of corneal curvature and thickness by laser refractive surgery may render the cornea more responsive to intraocular pressure as pregnancy progresses [24]. Hormonal influences may further enhance corneal compliance, contributing to more evident biomechanical changes during and after pregnancy. These findings suggest that laser-treated corneas may be more sensitive to hormone-driven biomechanical remodeling, as reflected by changes in corneal applanation and deformation parameters [25]. Clinicians managing women of reproductive age who have undergone refractive surgery should be aware of these potential interactions and carefully monitor corneal integrity before, during, and after pregnancy. Future research is warranted to clarify the long-term effects of gestational hormonal changes on corneal biomechanics and visual outcomes, and to elucidate the mechanisms underlying corneal responses following refractive surgery.

Laser refractive surgery rapidly corrects visual focus by reshaping the cornea; however, hormonal fluctuations during pregnancy may potentiate its effects. Previous research has shown that estrogen and progesterone influence corneal hydration, thickness, and elasticity, thereby altering its mechanical properties [26, 27]. These hormonal changes during pregnancy may enhance corneal compliance and modify the response of surgically treated corneas. This mechanism likely explains the pronounced reductions in CCT and corneal curvature observed in the observation group during pregnancy.

Despite these significant alterations in CCT and curvature, neither AL nor IOP differed significantly between groups, and IOP remained stable throughout the study. These findings suggest that, whereas refractive surgery affects corneal biomechanics, other ocular parameters such as globe length and pressure are less susceptible to pregnancy-related hormonal changes. The stability of IOP indicates that hormonal influences are largely confined to local corneal responses rather than global ocular dynamics. The observed effects may reflect the interaction between structural modifications induced by laser refractive surgery and hormonal regulation of corneal hydration and elasticity during gestation. Moreover, the persistence of some changes beyond delivery suggests that pregnancy-related hormonal effects on the cornea may extend into the postpartum period. Further research is needed to clarify the long-term impact of hormonal fluctuations and different refractive techniques on corneal integrity, in order to optimize the management of patients undergoing corneal refractive surgery who plan future pregnancies.

Several limitations within this research should be acknowledged. First, although this study provides valuable insights into corneal biomechanics during pregnancy, its relatively small sample size and the limited heterogeneity between groups may restrict the generalizabili-

ty of the findings. Potential confounding variables, such as pre-existing eye conditions or genetic factors affecting corneal behavior, were not comprehensively assessed. In addition, the postpartum follow-up period was relatively short; prolonged postpartum follow-up would be needed to clarify the persistence of pregnancy-related effects on corneal biomechanics and visual outcomes. Finally, variations in pregnancy characteristics (e.g., multiple gestations, gestational diabetes) were not fully controlled and may influence corneal responses.

Conclusion

Our findings indicate that hormonal fluctuations during pregnancy exert a substantial influence on corneal biomechanics and may interact with prior myopic laser surgery to modify corneal structure and visual outcomes. These results enhance understanding of the dynamic corneal behavior during pregnancy and underscore the importance of monitoring corneal health in women of reproductive age who undergo refractive surgery. To confirm and extend these observations, future studies with larger sample sizes and longer follow-up time are warranted to elucidate the clinical implications for managing patients undergoing refractive surgery in the context of pregnancy.

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Disclosure of conflict of interest

None.

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