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ORIGINAL ARTICLE

Corneal Biomechanical Changes after Laser Assisted in Situ keratomileusis (LASIK), Femtosecond LASIK and Photo Refractive Keratectomy (PRK)

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Abstract

Background: ***Refractive errors can be corrected surgically, which lessens the need for contacts or glasses. Myopia is one of the most prevalent forms of refractive error.***

Aim and objectives: ***To assess, using the Corvis ST Machine, alterations in the biomechanical characteristics of the cornea following LASIK, FS-LASIK, and PRK procedures.***

Patients and methods: ***This is a prospective study carried out from April 2021 to the end of December 2021 at Clear Vision Laser-Assisted in Situ keratomileusis (LASIK)Medical Center in Cairo, out using the Corvis ST Machine on 45 patients, 90 eyes, and 30 eyes each in the LASIK, Photorefractive keratectomy (PRK), and femtosecond LASIK groups to assess modifications to corneal biomechanical parameters following LASIK, FS-LASIK, and PRK procedures.***

Results: ***The post-PRK SSI showed an insignificant change from the pre-operative measurement. Conversely, LASIK and FS-LASIK induced a significant decrease. So, PRK had the most minor adverse effect on corneal stiffness. Also, there was an insignificant difference between LASIK, PRK, and FS-LASIK regarding the mean SP-A1 change, where SP-A1 decreased significantly after the surgery in the three groups.***

Conclusion: ***LASIK had the highest effect on corneal biomechanics, followed by PRK, then FS-LASIK.***

Keywords: keratomileusis LASIK; Femtosecond LASIK; Photo refractive keratectomy

1. Introduction

Refractive surgery is a method used to rectify the defects and decrease reliance on eyeglasses or contact lenses. Myopia is a prevalent form of refractive error. The global prevalence ranges from 15% to 49%.[1]

PRK received initial approval from the Food and Drug Administration (FDA) for refractive surgery in 1996. The number is .[2] (LASIK) was approved in 1998.[3]

The femtosecond laser (FS) was first introduced to the market in 2002 to create the corneal flap in a surgical technique known as FS-LASIK.[4]

Corneal ectasia following refractive surgery is a severe condition that can lead to vision loss and may require corneal transplantation surgery. The prevalence ranges from 0.04 to 0.6%.[5]

Corneal biomechanical property changes may precede corneal ectasia, characterized by alterations in corneal geometric features.[6]

Corneal biomechanics can be evaluated using the Corneal Visualization Scheimpflug Technology (Corvis ST), which was introduced to the market in 2010. The Corvis ST utilizes a high-speed camera to collect sequential horizontal Scheimpflug images of the cornea, allowing for calculating both the time and length of the corneal inward and outward movement.[7]

The surgeon can accurately anticipate surgical outcomes and prevent severe complications by comprehending the biomechanical characteristics of the cornea.[8]

The present study seeks to assess alterations in corneal biomechanical characteristics following LASIK, FS-LASIK, and PRK procedures utilizing the Corvis ST Machine.

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2. Patients and methods

This prospective study was conducted from April 2021 to December 2021 at Clear Vision LASIK Medical Center in Cairo. It involved 45 patients and 90 eyes, which were divided into three groups: the LASIK group (30 eyes), the PRK group (30 eyes), and the femtosecond LASIK group (30 eyes). The study aimed to assess the alterations in corneal biomechanical parameters following LASIK, femtosecond LASIK, and PRK procedures using the Corvis ST Machine.

Ethical approval: The Ethical Committee of the Faculty of Medicine at Al-Azher University approved the operation. Before the operation, each patient provided written consent after receiving a comprehensive explanation of all pertinent data, including the procedure, potential benefits, foreseeable intraoperative and postoperative risks, reasonable expectations, and the potential occurrence of further issues.

Inclusion Criteria: Candidates who were 18 years old or older for refractive surgeries. Myopia is less than -8D, and astigmatism is less than 4D, with a total spherical equivalent (SE) of 10D or less.

Exclusion Criteria:

The patient has a central corneal thickness of less than 500µm and has local eye disease (severe dryness, corneal opacity, glaucoma, cataract, retinal disorder), a previous ocular operation, or trauma in the same eye. The patient takes systemic medication such as steroids or has systemic disease (systemic lupus erythematosus, rheumatoid arthritis). The patient has abnormal corneal topography, such as pellucid marginal degeneration.

Examination:

The assessment includes measuring visual acuity without and with correction, examining the front part of the eye using a slit-lamp biomicroscope, and evaluating the back part of the eye called the fundus.

Investigations:

All patients were examined by Corvis ST (Model D-35582 Wetzlar, Oculus, Typ 72100, Germany) before and after three months of surgery to detect corneal biomechanical changes.

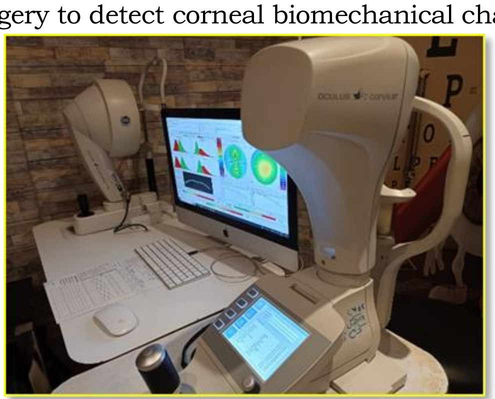

Figure 1. Shows the Corvis ST Machine.

Procedures:

LASIK: The range of flap thickness is 90 to 110 µm. The diameter of the flap ranges from 7.5 to 9 mm. The optical zone ranges from 5.5 to 6.5 mm, with a blend zone of 1.25 mm.

FS-LASIK: The flap will be created using a femtosecond laser with a thickness of 110 µm and a diameter of 9 mm.

PRK: The corneal epithelium is removed using a 20% ethyl alcohol solution administered for 20 seconds, resulting in an 8.5 mm diameter loss.

A postoperative regimen of treatment: Administer Moxifloxacin 0.5% ophthalmic solution every four times a day for one week. Administer Prednisolone acetate 1% eye drops at a frequency of four times per day for one week, followed by a gradual reduction in dosage every week. Administer artificial tears four times daily and as necessary to relieve any ocular discomfort for at least three months.

Statistical analysis:

The data underwent analysis using SPSS (Statistical Package for the Social Sciences) version 26.0 on an IBM-compatible computer (SPSS Inc., Chicago, IL, USA). Numerical values and percentages characterized the qualitative data, which was examined by applying Chi-square analysis. The normality of the quantitative data was assessed using the Shapiro-Wilks test, assuming that normality is present when P>0.05. The quantitative data was characterized by its mean and standard deviation, and it was evaluated using statistical tests such as the t-test, Mann-Whitney U test, One Way ANOVA, and Kruskal Wallis test. The initial significance level adopted in this study was set at 0.05 (P<0.05 was deemed statistically significant).

3. Results

Table 1. Sociodemographic and baseline characteristics of the studied patients (N=45).

		LASIK (N=15)	PRK (N=15)	FEMTO-SECOND LASIK (N=15)	P VALUE
AGE (Y)	Mean±SD	27.0±5.4	25.1±3.2	26.8±6.2	0.278
SEX	Male	6 (40%)	9 (60%)	9 (60%)	0.200
	Female	9 (60%)	6 (40%)	6 (40%)	
SE OF THE EYES.	Right (n=45)	5.5±1.5	4.5±1.3	4.6±1.3	0.141
	Left (n=45)	5.4±1.6	5.0±1.6	4.7±1.4	0.457

The average age of the LASIK group was 27.0±5.4, 25.1±3.2 in the PRK group, and 26.8±6.2 years in the femto-second LASIK group. There were no notable disparities among the three groups in terms of age, sex, or socioeconomic status (SE).

Table 2. Corneal biomechanics and other measurements of the LASIK group (n=30 eyes).

		PRE-OPERATIVE	POST-OPERATIVE	P VALUE
CORNEAL BIOMECHANICS	(SSI) stress-strain index	1.0±0.2	0.9±0.1	<0.001
	(DA) Deformation Amplitude ratio	4.4±0.5	5.3±0.6	<0.001
	Integrated radius	7.8±1.3	9.9±0.8	<0.001
	(ARTh) Ambrósio's Relational Thickness to the horizontal profile	467.3±87.6	224.3±142.0	<0.001
	(SP-A1) Stifness parameter-A1	106.1±12.9	85.7±13.7	<0.001
	(CBI) Corneal Biomechanical Index	0.4±0.3	0.15±0.32	0.004
(IOPNCT) INTRAOCULAR PRESSURE MEASURED BY NON-CONTACT TONOMETER		15.9±2.4	13.1±1.6	<0.001
(IOPB) INTRAOCULAR PRESSURE MEASURED BY BIOMECHANICALLY CORRECTED INTRAOCULAR PRESSURE		15.7±2.0	14.8±1.5	0.005
(CCT) CENTRAL CORNEAL THICKNESS		546.2±36.1	474.4±31.2	<0.001

The SSI, ARTh, SP-A1, CBI, IOPnct, IOPb, and CCT were significantly lower after the LASIK operation than pre-operative measurements. While the DA ratio, and integrated radius were significantly higher after the LASIK operation than pre-operative measurements.

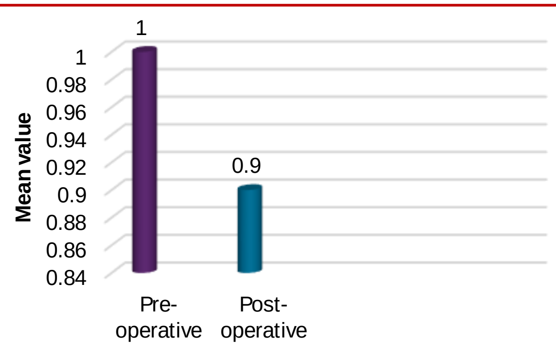

Figure 2: Bar chart graph displaying SSI measurements pre and post operatively among the LASIK group (n=30 eyes).

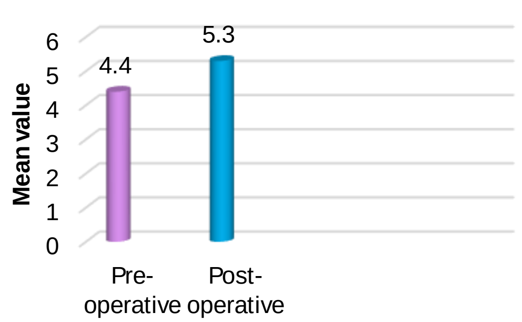

Figure 3: Bar chart graph displaying DA ratio measurements pre and post operatively among the LASIK group (n=30 eyes).

Table 3. Corneal biomechanics and other measurements of the PRK group (n=30 eyes).

		PRE-OPERATIVE	POST-OPERATIVE	P VALUE
CORNEAL BIOMECHANICS	SSI	0.9±0.1	0.9±0.3	0.428
	DA ratio	4.8±0.4	5.5±0.4	<0.001
	Integrated radius	8.5±0.6	10.1±1.0	<0.001
	ARTh	407.7±119.8	177.9±70.3	<0.001
	SP-A1	98.5±14.1	72.7±15.1	<0.001
	CBI	0.6±0.3	0.24±0.38	<0.001
IOPNCT		14.4±1.4	12.5±2.3	<0.001
IOPB		15.1±1.7	14.6±2.3	0.162
CCT		517.3±35.0	446.5±36.9	<0.001

The ARTh, SP-A1, CBI, IOPnct, IOPb, and CCT were significantly lower after the PRK operation than pre-operative measurements. While the DA ratio, and integrated radius were significantly higher after the PRK operation than pre-operative measurements. There was no significant difference in the SSI.

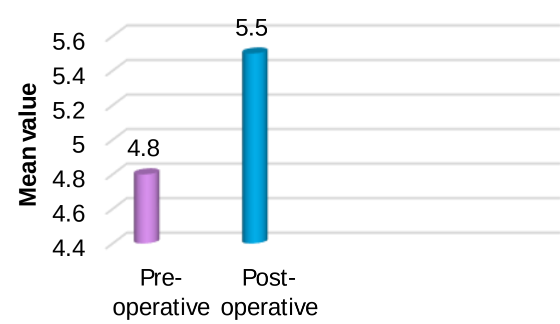

Figure 4: Bar chart graph displaying DA ratio measurements pre and post operatively among the PRK group (n=30 eyes).

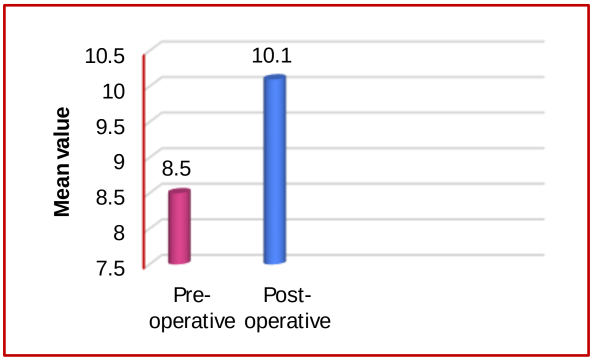

Figure 5. Bar chart graph displaying Integrated radius measurements pre and post operatively among the PRK group (n=30 eyes).

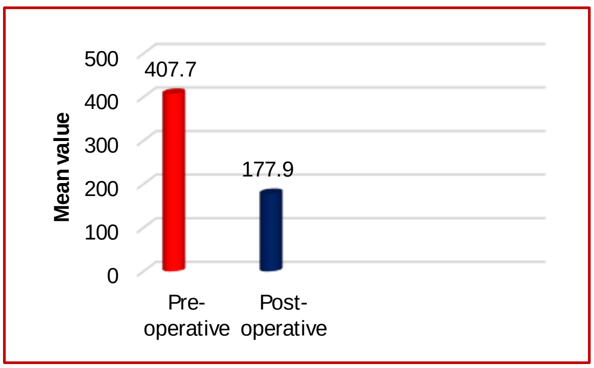

Figure 6. Bar chart graph displaying ARTh measurements pre and post operatively among the PRK group (n=30 eyes).

Table 4. Corneal biomechanics and other measurements of the Femto-second LASIK group (n=30 eyes).

		PRE-OPERATIVE	POST-OPERATIVE	P VALUE
CORNEAL BIOMECHANICS	SSI	1.1±0.1	1.0 ±0.2	0.002
	DA ratio	4.4±0.4	4.9±0.7	<0.001
	Integrated radius	7.7±1.0	9.1±1.3	<0.001
	ARTh	505.8±108.8	317.0±162.6	<0.001
	SP-A1	102.2±15.8	80.8±14.7	<0.001
	CBI	0.3±0.3	0.01±0.02	<0.001
IOPNCT		16.1±1.3	13.6±2.4	<0.001
IOPB		16.3±1.3	15.1±2.0	<0.001
CCT		532.3±28.2	473.8±44.7	<0.001

The SSI, ARTh, SP-A1, CBI, IOPnct, IOPb, and CCT were significantly lower after the femto-second LASIK operation than pre-operative measurements. While the DA ratio, and integrated radius were significantly higher after the femto-second LASIK operation than pre-operative measurements.

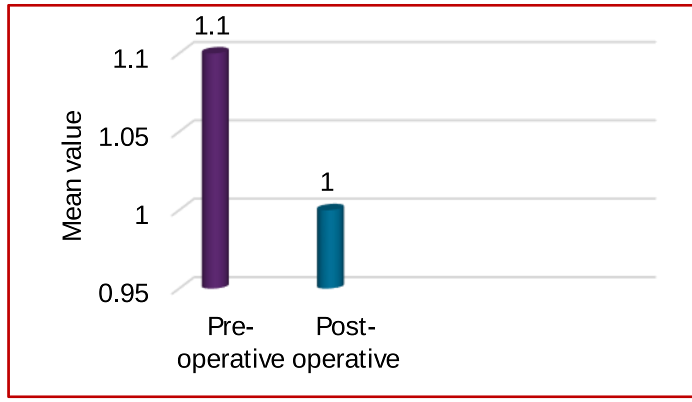

Figure 7. Bar chart graph displaying SSI measurements pre and post operatively among the femto-second LASIK group (n=30 eyes).

Table 5: Change in corneal biomechanics and other measurements of the studied eyes in the 3 operations (N=90).

		LASIK (N=30)	PRK (N=30)	FEMTO-SECOND LASIK (N=30)	P VALUE
CORNEAL BIOMECHANICS	SSI	0.11±0.11	0.04±0.27	0.13±0.21	0.233
	DA ratio	-0.97±0.40	-0.68±0.40	-0.54±0.74	0.009
	Integrated radius	-2.09±1.11	-1.58±0.70	-1.33±1.20	0.017
	ARTh	243.01±180.95	229.87±88.54	188.84±156.98	0.337
	SP-A1	20.36±11.02	16.88±14.32	21.39±19.59	0.495
	CBI	0.26±0.47	0.37±0.44	0.28±0.24	0.561
IOPNCT		2.80±2.07	1.82±1.87	2.52±1.94	0.145
IOPB		0.97±1.78	0.42±1.60	1.14±1.59	0.217
CCT		71.87±34.62	58.47±35.80	67.02±31.43	0.188

There is a significant difference between the 3 operations regarding the change in DA ratio and integrated radius. While there is no significant difference between the 3 operations regarding other corneal biomechanics, IOPnct or IOPb measurements post-operatively.

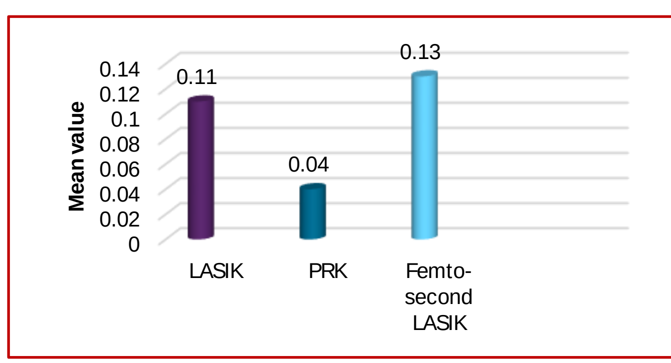

Figure 8. Bar chart graph displaying change in SSI among the 3 groups (n=90 eyes).

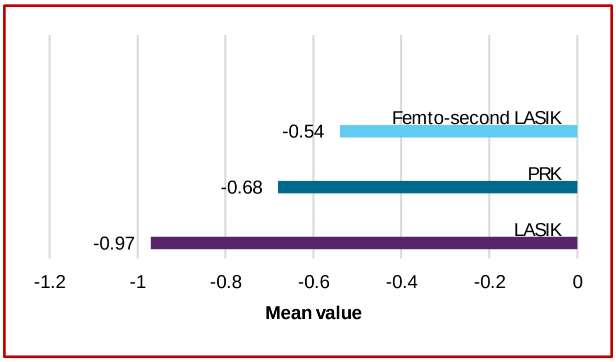

Figure 9. Bar chart graph displaying change in DA ratio among the 3 groups (n=90 eyes).

4. Discussion

The post-PRK SSI exhibited negligible alteration in the present investigation compared to the preoperative measurement. On the other hand, LASIK and FS-LASIK caused a notable reduction. PRK exhibited the lowest level of negative impact on corneal rigidity.

In agreement with this study, Kenia et al. It was stated that there were no observed changes in SSI (Spherical Equivalent Refraction) among patients who underwent either microkeratome Blade LASIK or FS-LASIK compared to the data collected before the procedure.[9]

Among the patients with PRK, LASIK, and FS-LASIK in this study, ARTh was significantly lower after surgery than preoperative ARTh. However, no significant difference was detected when comparing the changes in the three groups.

Supporting the present study, Kenia and colleagues reported that ARTh was reduced significantly when comparing Patients after LASIK (Group I) and FS- LASIK (Group II).[9]

Similarly, Lee et al. When comparing the dynamic corneal response parameters prior to and following transepithelial photorefractive keratectomy using femtosecond laser-assisted laser in situ keratomileusis, it was demonstrated that the ARTh dramatically decreased after surgery. However, there was no significant difference between the two groups.[10]

Within the study participants, the DA ratio and integrated radius showed a substantial increase following refractive surgeries such as PRK, LASIK, and FM-LASIK compared to the measures taken before the procedure. There was a notable disparity among the three surgeries regarding the alteration in DA ratio and integrated radius. The integrated radius (IR) refers to the radius of curvature during the concave phase of deformation. It is a valuable measure for quantifying the effect of cross-linking since an increase in IR indicates a softer cornea.

The DA ratio quantifies the corneal resistance to deformation, with a more significant number indicating a lower resistance level. Therefore, the rise in the DA ratio values after refractive surgery indicates that the cornea undergoes a decrease in stiffness after the procedure.[7]

According to this study, the Deformation Amplitude ratio of 1mm (DAR1), Deformation Amplitude Ratio of 2mm (DAR2), and integrated inverse radius were shown to have significantly increased following PRK.[11]

In concordance with this study, El-Fattah et al. It was observed that the infrared (IR) levels showed a substantial increase from the values before the surgery to the values six months after the surgery in individuals who underwent LASIK ($p<0.001$). The degree of aberration of the eye (DAR) showed a substantial rise in patients who underwent LASIK surgery.[12]

The average decrease in DA ratio was -0.97±0.40, -0.68±0.40, and -0.54±0.74 in the LASIK, PRK, and FS-LASIK groups, respectively.

Similarly, Chou and coworkers the study found a statistically significant distinction between patients who received FS-LASIK and those who underwent trans-epithelial PRK.[13]

However, according to Kenia et al. Upon examination, it was observed that the rise in the DA ratio was comparable in both groups. The post-LASIK group had a 0.7 unit rise in the DA ratio, whereas the FS-LASIK group showed an increase of 0.8 units.9 The variation in findings could be attributed to the distinct assessment of the dopamine (DA) ratio at 1 mm or 2 mm, referred to as DAR1 and DAR2, respectively. The smaller region of the DAR1, which quantifies the ratio of the deformation amplitude at the apex to that at a distance of 1.0 mm from the apex, may have lower sensitivity and may not adequately represent the overall corneal biomechanics following photorefractive surgery, in comparison to the DAR2. The DAR2 measures the changes in deformation amplitude at the apex and a distance of 2.0 mm from the apex.

This study revealed that no significant distinction was observed among LASIK, PRK, and FS-LASIK in terms of the average SP-A1 change. However, SP-A1 reduced significantly following the surgery in all three groups.

Xin et al. The study found that the change in SP-A1 was more significant in FS-LASIK (-34.15±13.17 mmHg/mm) when comparing the measurements taken six months after surgery to the preoperative measurements. This difference was statistically significant when compared to PRK ($p=0.008$).[14]

The study found a significant decrease in CBI after surgery in all three groups. However, the mean CBI change among LASIK, PRK, and FM-

LASIK procedures was not significantly different.

The (CBI) was established to establish a standardized set of biomechanical parameters. In 2016, Vinciguerra et al. The study demonstrated that the CBI had high sensitivity and specificity in distinguishing between healthy eyes and eyes with keratoconus. They suggest that a CBI value of 0.5 or above is linked to an elevated risk of developing corneal ectasia.[7]

In Abd El-Fattah et al. The study found a significant difference in CBI between the preoperative and 6-month postoperative levels.[12]

The average (CCT) decreased substantially following the surgical procedure across all three groups examined in this study. A study revealed a negligible disparity in the average change in corneal thickness (CCT) between LASIK, PRK, and FS-LASIK procedures.

In concordance with the present study, Hashemi and colleagues It was claimed that when LASIK and PRK were compared, no significant difference was discovered in terms of the average change in corneal thickness (CCT).[15]

Supporting this study, Bao et al. The study found that the average preoperative (CCT) was 550.7± 22.6 µm. This value was dramatically decreased to 460.9±37.1 µm after the procedure ($p < .01$). After undergoing FS-LASIK surgery.[16]

IOPnct and bIOP were significantly lower after the refractive surgery than preoperative measurements in the three groups, with insignificant differences between the three groups.

Agreeing with this study, Kenia and colleagues reported that the mean preoperative bIOP was 18.10±1.52 mmHg and the post-LASIK was 15.85±1.86 mmHg, with a statistically significant difference, while the preoperative measurement in the FS-LASIK group was 17.60±1.93 mmHg, which decreased significantly to 15.77±1.25 mmHg after FS-LASIK.[9]

As reported in the current study by Eliasy et al. Analyzed data revealed a statistically significant disparity between the biomechanically adjusted IOP estimates acquired prior to and following LASIK surgery ($p< .05$).[17]

Abd El-Fattah and colleagues reported that bIOP decreased by 0.762±1.211mmHg in patients who received LASIK ($p=0.092$).[12]

In the present study, we detected that all three assessed procedures (LASIK, PRK and FS-LASIK) induced cornea biomechanics changes, with different amounts of change. FS-LASIK induced the most minor biomechanical changes, followed by PRK; the current study found a discrepancy between the literature and the results, as the mean preoperative central corneal thickness (CCT) was thinner in the PRK group (517.3±35.0 mm) compared to the FS-LASIK group (532.3±28.2 mm). Furthermore, the average preoperative (SE) in the left eyes of the PRK group was greater than that in the FS-LASIK group. This indicates that PRK patients required more manipulation of the corneal tissue, which can explain the more pronounced impact of PRK on corneal biomechanics observed in this study. Kamiya and colleagues, It was revealed that there was a strong link between the degree of myopia correction and alterations in biomechanical characteristics following PRK and LASIK procedures.[18]

Consistent with prior research, we determined that LASIK exhibited the most significant alterations in corneal biomechanics. Kamiya et al. It has been reported that both PRK and LASIK procedures can impact the biomechanical integrity of the cornea, with the extent of this effect being dependent on the degree of myopia correction. The magnitude of biomechanical alterations is greater following LASIK compared to PRK.[18]

4. Conclusion

LASIK had the highest effect on corneal biomechanics, followed by PRK, then FS-LASIK.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

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Conflicts of interest

There are no conflicts of interest.

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