

Research Article

Changes in Corneal Epithelial Thickness in Relation to Vision, Contrast Sensitivity and Ocular Aberrations After Lasik

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Abstract

Purpose: The assessment of changes in corneal epithelial thickness at the center of the cornea (ET center) and at the apex of the cornea (ET peak) in relation to vision, corneal aberrations (LOAs and HOAs) and contrast sensitivity (C.S) after LASIK.

Material and Methods: Twenty-seven patients (27 eyes) with a mean age of 32 years (range 22-50), 9 males and 18 females were included in the study and underwent LASIK. Mean follow up was 12.18 +/- 1.48 (range from 9 to 18 months).

Results: A statistically significant difference was found between preoperative and postoperative measurements of ET center and ET peak as well as Zernike coefficients. No statistically significant difference was found for the variable of CS.

Conclusion: Changes in corneal aberrations after refractive surgery can be attributed to epithelial thickness increase which can be seen in patients that have undergone LASIK.

Keywords: LASIK; ETapex; ETcenter; Contrast Sensitivity; Aberrations

Introduction

The epithelium of the cornea is considered an important component in refractive surgery and has been intensively investigated in recent years [1].

Previous studies have shown an increase in corneal thickness after refractive surgery, which persists postoperatively and appears to be related to possible regression of refractive effect. The healing mechanisms of epithelial wounds that are created after Laser *In-Situ* Keratomileusis (LASIK) could contribute to understanding and predicting the clinical results of refractive surgery [2-4].

Usually, regular applications include the screening of candidates at higher risk for complications and particularly the understanding of wound healing mechanisms and clinical outcomes of refractive surgery. According to previous studies, LASIK modifies Higher Order Aberrations (HOAs). Specifically, HOAs increase after refractive surgery [2,3]. In our study, we investigated the change in the thickness of the Epithelium at the center (ET center) and at the apex of the cornea (ET peak) in relation to the change in the corneal aberrations and the change in the Contrast Sensitivity (CS).

Material and Methods

Twenty-seven patients (27 eyes) with a mean age of 32 years (range 22-50), 9 males and 18 females were included in the study. All patients underwent LASIK. The average follow-up was 12.18 +/- 1.48 (range 9 to 18 months). The refraction of all participants was stable for at least 2 years. Pregnant women, patients who had systemic disease or a history of previous eye disease or surgery were excluded from the study.

The Pentacam HR (Oculus GmbH, Wetzlar, Oculus, Germany) was used, which is a reliable device for measuring corneal aberrations. Specifically, the Zernike map was used to analyze anterior corneal surface aberrations (Z00, Z11, Z02, Z22, Z31, Z3, Z40, Z42, Z44). Only cases where the quality parameters of the test were displayed as "OK" were selected, which indicated a correct and qualitative image capture. Also, we used an epithelial map of an Optical coherence tomography (OCT, Avanti XR OCT, Optovue) to measure ET center and ET peak before and after surgery. Each eye was measured three times and the mean value was used for analysis. CS as a means of luminance gain, between a small object and its background divided by the mean background luminance (SC Weber) and its logarithm (SC Logs), preoperatively and postoperatively, were obtained with the Freiburg Vision Test ('FrACT' vs. 3.9.3 · 2015- 06-01 · F16.0). "FrACT" is a widely used visual test battery in the form of a free computer program with respect to objectivity and reliability [4]. The above checks were done in total darkness by the same qualified technician. The study protocol complied with the Declaration of Helsinki. Written informed consent was obtained from all patients.

Statistical Analysis

The Shapiro-Wilk test was used to assess the normal distribution of the parameters. All continuous variables had non-normal distribution and are expressed as median (range). Categorical variables are presented as frequencies or percentages. The Spearman correlation coefficient was used to evaluate associations between continuous variables. A p-value <0.05 (two-tailed) was considered to indicate a statistically significant difference. Statistical analysis was conducted using IBM SPSS-Statistics version 29.0 (IBM Corp.).

Results

Twenty-seven patients (18 females and 9 males) with a median age of 32 years (range 22-50) underwent LASIK. The characteristics of the study population are displayed in the Table 1.

Variable	Median	Minimum	Maximum
Age (years)	32	22	50
ODCDVA (logMar) preop	-0.060	-0.160	0.450
ODCDVA (logMar) 12 months	-0.160	-0.160	0.040
ODSC (weber) preop	1.350	0.250	22.60
ODSC (weber) 12 months	0.650	0.230	2.620
ODCS (logcs) preop	1.870	0.640	2.610
ODCS (logcs) 12 months	2.140	1.680	2.630
ODETcenter (μm) preop	52	44	60
ODETcenter (μm) 12 months	56	49	64
ODETpeak (μm) preop	52	44	60
ODETpeak (μm) 12 months	57	50	66
ODz00 preop	133.45	127.627	143.019
ODz00 12 months	1124.438	115.194	138.060
ODz11 preop	1.188	-1.014	2.663
ODz11 12 months	2.074	0.499	11.052
ODz02 preop	78.320	75.060	84.290
ODz02 12 months	74.634	68.663	9223.37
ODz22 preop	1.334	0.166	4.443
ODz22 12 months	1.032	0.376	1.948
ODz31 preop	0.306	0.238	0.809
ODz31 12 months	0.351	0.184	2.922
ODz33 preop	0.204	0.026	0.458
ODz33 12 months	0.233	0.057	0.795
ODz40 preop	1.136	0.878	1.632

ODz40 12 months	2.031	1.491	2.886
ODz42 preop	0.123	0.030	0.462
ODz42 12 months	0.168	0.042	0.823
ODz44 preop	0.096	0.045	0.760
ODz44 12 months	0.087	0.018	0.318
Gender	N	%	
Females	18	66.7	
Males	9	33.3	

Table 1: Characteristics of the study population.

The median values of variance of different variables (value at 12 months-value at the preoperative period) are displayed in Table 2.

Variable	Median	Minimum	Maximum
ODCDVAD (logMar)	-0.100	-0.610	0.030
ODSCD (weber)	-0.900	-22.36	1.820
ODCSD (logcs)	0.110	-0.093	1.980
ODETcenterD (μm)	4	-4	13
ODETpeakD (μm)	5	-4	14
ODz00D	-9.01	-17.69	1.130
ODz11D	0.958	-2.120	8.900
ODz02D	-3.874	-8.990	69502.16
ODz22D	-0.402	-3.380	1.300
ODz31D	0.121	-0.490	2.130
ODz33D	0.015	-0.320	0.340
ODz40D	0.859	0.120	1.740
ODz42D	0.082	-0.260	0.640
ODz44D	-0.017	-0.660	0.220

*OD: right eye; CDVA: corrected distance vision acuity; SC: sensitivity contrast; CS: contrast sensitivity; logcs: log of CS; ET peak: epithelial thickness changes at the corneal apex; ET center: epithelial thickness changes at the center of the cornea

Table 2: Median values of the variance of different variables (value at 12months-value at the preoperative period).

Regarding the OD there was a statistically significant negative correlation between the median value of CDVAD and the median value of z22D (Spearman's rho:-0.383; p=0.049), between the median value of CDVAD and the median value of z33D (Spearman's rho:-0.383; p=0.049), between the median value of CDVAD and the median value of z42 (Spearman's rho:-0.456; p=0.017), between the median value of SCD (weber) and the median value of CSD (logcs) (Spearman's rho:-0.456; p=0.017), between the median value of SCD (weber) and the median value of z11D (Spearman's rho:-0.456; p=0.017), between the median value of SCD (weber) and the median value of z02D (Spearman's rho:-0.839; p=0.001), between the median value of SCD (weber) and the median value of z42D (Spearman's rho:-0.391; p=0.044), between the median value of ETcenterD and the median value of z00D (Spearman's rho:-0.406; p=0.035), between the median value of z00D and the median value of z31D (Spearman's rho:-0.436; p=0.023), between the median value of z00D and the median value of z40D (Spearman's rho:-0.436; p=0.023), between the median value of z22D and the median value of z44D (Spearman's rho:-0.432; p=0.025) and between the median value of z02D and the median value of z44D (Spearman's rho:-0.457; p=0.016). We also observed a statistically significant positive correlation between the median value of CSD (logcs) and the median value of z11D (Spearman's rho:0.487; p=0.010), between the median value of CSD (logcs) and the median value of z42D (Spearman's rho:0.450; p=0.019), between the median value of ETcenterD and the median value of ETpeakD (Spearman's rho:0.980; p=0.001), between the median value of ETcenterD and the median value of z11D (Spearman's rho:0.472; p=0.011), between the median value of ETcenterD and the median value of z31D (Spearman's rho: 0.395; p=0.042), between the median value of ETcenterD and the median value of z40D (Spearman's rho:0.472; p=0.011), between the median

value of ETpeakD and the median value of z11D (Spearman's rho: 0.464; p=0.015), between the median value of ETpeakD and the median value of z31D (Spearman's rho: 0.382; p=0.049), between the median value of ETpeakD and the median value of z40D (Spearman's rho: 0.382; p=0.049), between the median value of z02D and the median value of z00D (Spearman's rho: 0.811; p=0.001), between the median value of z31D and the median value of z44D (Spearman's rho: 0.446; p=0.020) and between the median value of z11D and the median value of z02D (Spearman's rho: 0.762; p=0.001) (Table 3).

Variable		ODCDVA D (logMar)	ODSCD (weber)	ODCS D (logcs)	ODETcen terD (μm)	ODETpe akD (μm)	OD z00 D	OD z11 D	OD z02 D	OD z22 D	OD z31 D	OD z33 D	OD z40 D	OD z42 D	OD z44 D
ODCDVA D	Spearman's rho	1	0.243	-0.281	-0.151	0.098	- 0.15 1	- 0.34 4	- 0.11 2	- 0.38 3	0.29 6	- 0.38 3	0.29 6	- 0.45 6	0.01 7
(logMar)	p	.	0.221	0.155	0.451	0.627	0.45 1	0.07 9	0.57 9	0.04 9	0.13 4	0.04 9	0.13 4	0.01 7	0.93 5
ODSCD	Spearman's rho	0.243	1	-0.839	-0.082	0.041	- 0.08 2	- 0.44 1	- 0.43 2	0.10 4	0.19 5	0.10 4	0.19 5	- 0.39 1	- 0.00 7
(weber)	p	0.221	.	0.001	0.683	0.837	0.68 3	0.02 1	0.02 4	0.60 4	0.32 9	0.60 4	0.32 9	0.04 4	0.97 1
ODCSD	Spearman's rho	-0.281	-0.839	1	-0.131	0.195	- 0.13 1	0.48 7	0.30 2	0.00 2	0.08 7	0.00 2	0.08 7	0.45 7	- 0.13 3
(logcs)	p	0.155	0.001	.	0.514	0.329	0.51 4	0.01	0.12 6	0.99	0.66 5	0.99	0.66 5	0.01 9	0.50 8
ODETcent erD	Spearman's rho	0.148	0.081	0.145	-0.406	0.98	- 0.40 6	0.47 2	0.26 9	- 0.30 7	0.39 5	- 0.30 7	0.39 5	- 0.17 2	0.01 2
(μm)	p	0.461	0.687	0.471	0.035	0.001	0.03 5	0.01 3	0.17 5	0.12	0.04 2	0.12	0.04 2	0.39	0.95 2
ODETpeak D	Spearman's rho	0.098	0.041	0.195	-0.379	1	- 0.37 9	0.46 4	0.26 8	- 0.30 6	0.38 2	- 0.30 6	0.38 2	- 0.14 3	0.04 6
(μm)	p	0.627	0.837	0.329	0.051	.	0.05 1	0.01 5	0.17 6	0.12 1	0.04 9	0.12 1	0.04 9	0.47 8	0.81 9
ODz00D	Spearman's rho	-0.151	-0.082	-0.131	1	-0.379	1	- 0.25 2	- 0.25 1	0.06 7	- 0.43 6	0.06 7	- 0.43 6	- 0.19 6	- 0.33 4
	p	0.451	0.683	0.514	.	0.051	.	0.20 6	0.20 7	0.74 2	0.02 3	0.74 2	0.02 3	0.32 7	0.08 9
ODz11D	Spearman's rho	-0.344	-0.441	0.487	-0.252	0.464	- 0.25 2	1	0.76 2	- 0.29 1	- 0.01 8	- 0.29 1	- 0.01 8	0.16	0.20 1
ODCSD	Spearman's rho	-0.281	-0.839	1	-0.131	0.195	- 0.13 1	0.48 7	0.30 2	0.00 2	0.08 7	0.00 2	0.08 7	0.45	- 0.13 3
(logcs)	p	0.155	0.001	.	0.514	0.329	0.51 4	0.01	0.12 6	0.99	0.66 5	0.99	0.66 5	0.01 9	0.50 8
ODETcent erD	Spearman's rho	0.148	0.081	0.145	-0.406	0.98	- 0.40 6	0.47 2	0.26 9	- 0.30 7	0.39 5	- 0.30 7	0.39 5	- 0.17 2	0.01 2
(μm)	p	0.461	0.687	0.471	0.035	0.001	0.03 5	0.01 3	0.17 5	0.12	0.04 2	0.12	0.04 2	0.39	0.95 2
ODETpeak D	Spearman's rho	0.098	0.041	0.195	-0.379	1	- 0.37 9	0.46 4	0.26 8	- 0.30 6	0.38 2	- 0.30 6	0.38 2	- 0.14 3	0.04 6
(μm)	p	0.627	0.837	0.329	0.051	.	0.05 1	0.01 5	0.17 6	0.12 1	0.04 9	0.12 1	0.04 9	0.47 8	0.81 9
ODz00D	Spearman's rho	-0.151	-0.082	-0.131	1	-0.379	1	- 0.25	- 0.25	0.06 7	- 0.43	0.06 7	- 0.43	- 0.19	- 0.33

								2	1		6		6	6	4
	p	0.451	0.683	0.514	.	0.051	.	0.20 6	0.20 7	0.74 2	0.02 3	0.74 2	0.02 3	0.32 7	0.08 9
ODz11D	Spearman's rho	-0.344	-0.441	0.487	-0.252	0.464	-0.25 2	1	0.76 2	-0.29 1	-0.01 8	-0.29 1	-0.01 8	0.16	0.20 1
	p	0.079	0.021	0.01	0.206	0.015	0.20 6	.	0.00 1	0.14 1	0.92 8	0.14 1	0.92 8	0.42 5	0.31 5
ODz02D	Spearman's rho	0.115	-0.029	-0.17	0.811	-0.295	0.81 1	-0.3	-0.29 9	-0.11 7	-0.21 1	-0.01 7	-0.21 1	-0.27 4	0.45 7
	p	0.569	0.887	0.397	0.001	0.136	0.00 1	0.12 9	0.13	0.56	0.29	0.56	0.29	0.16 6	0.01 6
ODz22D	Spearman's rho	0.266	-0.036	-0.005	0.389	0.254	0.38 9	0.05 1	-0.08 1	-0.28 2	0.13 8	-0.28 2	0.13 8	-0.25 8	0.43 2
	p	0.18	0.858	0.981	0.045	0.201	0.04 5	0.79 9	0.68 9	0.15 4	0.49 3	0.15 4	0.49 3	0.19 5	0.02 5
ODz31D	Spearman's rho	-0.112	-0.432	0.302	-0.251	0.268	-0.25 1	0.76 2	1	-0.28 1	-0.24	-0.28 1	-0.24	0.04 5	0.44 6
	p	0.579	0.024	0.126	0.207	0.176	0.20 7	0.00 1	.	0.15 5	0.22 8	0.15 5	0.22 8	0.82 3	0.02
ODz33D	Spearman's rho	-0.383	0.104	0.002	0.067	-0.306	0.06 7	-0.29 1	-0.28 1	1	-0.15 8	1	-0.15 8	0.37 6	-0.18 4
	p	0.049	0.604	0.99	0.742	0.121	0.74 2	0.14 1	0.15 5	.	0.43 1	.	0.43 1	0.05 3	0.35 7
ODz40D	Spearman's rho	0.296	0.195	0.087	-0.436	0.382	-0.43 6	-0.01 8	-0.24	-0.15 8	1	-0.15 8	1	-0.12 1	-0.27
	p	0.134	0.329	0.665	0.023	0.049	0.02 3	0.92 8	0.22 8	0.43 1	.	0.43 1	.	0.54 8	0.17 3
ODz42D	Spearman's rho	-0.456	-0.391	0.45	-0.196	-0.143	-0.19 6	0.16	0.04 5	0.37 6	-0.12 1	0.37 6	-0.12 1	1	0.01 6
	p	0.017	0.044	0.019	0.327	0.478	0.32 7	0.42 5	0.82 3	0.05 3	0.54 8	0.05 3	0.54 8	.	0.93 7
ODz44D	Spearman's rho	0.017	-0.007	-0.133	-0.334	0.046	-0.33 4	0.20 1	0.44 6	-0.18 4	-0.27	-0.18 4	-0.27	0.01 6	1
	p	0.935	0.971	0.508	0.089	0.819	0.08 9	0.31 5	0.02	0.35 7	0.17 3	0.35 7	0.17 3	0.93 7	.
*OD: right eye; CDVA: corrected distance vision acuity; SC: sensitivity contrast; CS: contrast sensitivity; logcs: log of CS; ET peak: epithelial thickness changes at the corneal apex; ET center: epithelial thickness changes at the center of the cornea															

Table 3: Correlation between the median values of variance of different variables for OD.

Discussion

In this research we investigated changes in corneal epithelial thickness at the ET center and at the ETpeak in relation to vision, LOAs and HOAs and C.S after LASIK. We found that ET center and ET peak increased after refractive surgery. We also found that there was no change in C.S. This is consistent with previous studies that found an increase in epithelial thickness after LASIK surgery [1-4]. Epithelial changes after LASIK appeared to play a significant role at the successful outcome of refractive surgery. Changes in the thickness of the epithelium after LASIK have also been noted by previous studies [3,5]. In most of the studies an increase in epithelial thickness was noted in refractive surgery [5-10]. According to researches, there is hyperplasia of the epithelium after refractive surgery, which can affect the refractive effect, explaining the long-term regression of the refractive effect [5,6]. It has been suggested that refractive surgery induces an epithelial remodeling which may modify the epithelial

thickness profile after refractive surgery in myopic eyes. This remodeling / increase in epithelial thickness produced by refractive surgery could also explain the modification in the qualitative characteristics of post refractive surgery visual acuity (contrast sensitivity and higher order aberrations) [11]. Patel, et al., in their research they found that the epithelium in the center of the cornea increased by 24% in the first year after LASIK surgery and was stable in the following 7 years [5]. According to Hieda, et al., reported that CS did not change significantly after LASIK [12]. This is in agreement with the results of our own study in which there was no correlation between the increase in ET center and ET peak and CS. changes. We hypothesized that the small changes observed in HOAs after LASIK could have little or no effect on changes in CS. We also found that the alteration of ET peak and ET center were related to the alteration of HOAs and LOAs. We know that LASIK alters higher order aberrations [13]. Previously, a number of studies show that HOAS increases after LASIK [14]. These results are consistent with ours where we found that as the ET center increases HOAS (Z31, Z40), LOAS (Z11) increases and Z00 decreases as ET peak increases LOAS (Z11) and HOAS (Z31, Z40). In addition, changes in ET center and ET peak were shown to correlate with both LOAS (Z00, Z11) and HOAS such as coma (Z31) and spherical aberration (Z40). Ocular aberrations are influenced by factors such as individual differences in corneal biomechanical properties and corneal wound healing responses. The corneal wound-healing response in the upper incisional position could cause deflection asymmetry in the vertical direction. This is consistent with the nature of HOAs altered by LASIK, with higher horizontal coma possibly caused by the flap created on the nasal side of the eye and vertical coma by the flap in the superior position [15]. According to Chen, et al., the amount of refractive error that exists preoperatively determines the amount of induced aberration [14]. In their research Zheng, et al., reported that after refractive surgery there was an increase in HOAS. Possible causes are flap formation, alteration in corneal biomechanics after LASIK and healing of corneal wounds [16]. The HOAs corneal coma and spherical aberration were significantly increased. Researches has shown that increased coma is associated with corneal flap creation and small intraoperative eye movements [17,18]. Du, et al., reported that coma was the main aberration caused by corneal biomechanical changes [19]. One of the limitations of our study is the small sample that was studied. In conclusion, changes in LOAS and HOAS after refractive surgery could be partly induced by epithelial thickness increase which can be seen in patients that have undergone LASIK. Further studies and longer follow up are necessary to support our clinical findings.

Conclusion

In conclusion, after LASIK we had an increase in the epithelium. Changes in center ET and peak ET did not affect subjective vision, but neither did C.S. But they were found to be associated with changes in LOAs and HOAs.

Conflict of Interest

The author has no conflict of interest to declare.

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