Axial Eye-Length Measurements Before and After Myopic Laser Refractive Surgery

Miyopik Refraktif Lazer Cerrahisi Öncesinde ve Sonrasında Aksiyel Göz Uzunluğu Ölçümleri

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ABSTRACT

Purpose: The purpose of the present study was to evaluate the relationship between axial length (AL) measurements and the theoretical ablation depth (TAD) in eyes that had undergone excimer laser treatment for myopia.

Material and methods: We retrospectively reviewed the medical records for 35 eyes of 18 patients who had undergone refractive laser surgery for the treatment of myopia and/or myopic astigmatism. We measured AL, anterior chamber depth (ACD) and central corneal thickness (CCT) using AL-Scan (Nidek CO, Gamagori, Japan). We analyzed the differences between the measurements using a two-tailed paired *t* test.

Results: The mean age of the patients was 26.26±6.43 years, and their mean refractive change (at the corneal plan) was -3.02±1.83 in 21 eyes of 11 patients who had undergone laser in situ keratomileusis and 14 eyes of 7 patients who had undergone photorefractive keratectomy. The AL was significantly shortened after laser surgery, the mean difference in AL [ΔAL] was 56.86±34.45 µm;($P<0.001$). Preoperative AL values strongly correlated with postoperative values ($r^2=0.999$). The postoperative CCT was significantly thinner than the preoperative CCT ($P<0.001$). Mean difference between these two values (ΔCCT) was 55.89±27.23 µm. There were not significant differences between the mean ΔAL and TAD or between ΔAL and ΔCCT ($P>0.05$). On the other hand, ΔAL and TAD ($r^2=0.215$) and ΔAL and ΔCCT ($r^2=0.184$) were poorly correlated with each other, but TAD and ΔCCT were strongly correlated ($r^2=0.814$).

Conclusion: The AL-Scan device gave AL values that were inconsistent with the TAD. Since the TAD and ΔCCT values were similar and were correlated with each other, this disparity might have resulted from incorrect AL measurements by the device due to a clinically subtle loss of corneal transparency in patients who had undergone myopic excimer laser surgery.

Key words: Eye length, Refractive surgery, AL-Scan.

ÖZ

Amaç: Bu çalışmamızın amacı, miyopi nedeniyle refraktif lazer tedavisi uygulanan gözlerde aksiyel uzunluk(AU) ölçümleri ile teorik ablasyon derinliği (TAD) arasındaki ilişkiyi değerlendirmektir.

Gereç ve yöntem: Miyopi ve/veya miyop astigmatizma için refraktif lazer cerrahisi geçirmiş 18 hastanın 35 gözüne ait tıbbi kayıtları retrospektif olarak gözden geçirdik. AL-Scan (Nidek CO, Gamagori, Japan) cihazını kullanarak AU, ön kamara derinliği (ÖKD) ve santral kornea kalınlığını (SKK) ölçtük. Ölçümler arası farkları çift yönlü *t* test kullanarak analiz ettik.

Bulgular: Hastaların ortalama yaşı 26.3±6.4 yıl idi, ve ortalama refraktif değişim (kornea düzleminde) −3.02±1.83 D idi. Onbir hastanın 21 gözünde laser in situ keratomileusis (LASİK) ve 7 hastanın 14 gözünde fotorefraktif keratektomi (PRK) uygulandı. Ameliyat sonrası AU değerleri ortalama 56.86±34.45 µm kısaldı ve bu fark istatistiksel olarak anlamlı idi ($P<0.001$). Ameliyat öncesi AU değerleri, ameliyat sonrası değerler ile güçlü bir şekilde korele idi ($r^2=0.999$). Ameliyat sonrası SKK, ameliyat öncesi SKK'ya göre anlamlı derecede ince idi ($P<0.001$). Bu iki değer arasındaki ortalama fark (ΔSKK) 55.89±27.23 µm idi. ΔAU ile TAD arasında ve ΔAL ile ΔCCT arasında anlamlı bir fark bulunamadı($P>0.05$). Bunun yanısıra, ΔAU ile TAD arasında ($r^2=0.215$) ve ΔAL ile ΔCCT arasında zayıf bir korelasyon bulundu fakat TAD ile ΔSKK güçlü bir şekilde korele idi ($r^2=0.814$).

Sonuç: AL-Scan cihazı, TAD ile uyumlu olmayan AU değerleri verdi. Aradaki bu uyumsuzluk, miyopik excimer lazer cerrahisi geçirmiş hastalarda klinik olarak hafif derecede korneal saydamlık azalmasından dolayı cihaz tarafından hatalı AU ölçümleri sonucu olabilir.

Anahtar kelimeler: Göz Uzunluğu, Refraktif Cerrahi, AL-scan.

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INTRODUCTION

The safety and efficacy of laser vision correction has made it the most frequently performed elective surgery, and it has even been endorsed by the US military for naval pilots[1,2]. After laser-assisted in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) for the treatment of myopia, the cornea becomes flattened, and the axial length (AL) is expected to shorten accordingly. An accurate assessment of AL in patients who have undergone refractive laser surgery is crucial for understanding the corneal changes induced by the surgery, and since intraocular lens (IOL) power assessment in cataract surgery is mainly based on keratometry and AL, this issue is also relevant for IOL power calculation. Historically, A-scan ultrasound was used to measure AL. However, the IOL Master optical biometer (Carl Zeiss, Jena, Germany), which uses partial coherence interferometry (PCI), is the current gold standard in AL evaluation[3]. The AL-Scan optical biometer (Nidek CO, Gamagori, Japan) is a relatively new device that was introduced in 2012 and also uses PCI for AL measurements. Its agreement with the gold-standard IOL Master has been established for AL and anterior chamber depth (ACD) measurements[3]. Additionally, it has high repeatability for AL, ACD and central corneal thickness (CCT) measurements, as reported in previous studies[4,5].

Only a few studies have investigated AL changes in eyes that have undergone refractive laser surgery or the relationship between AL and theoretical ablation depth (TAD)[6-9]. The results of these studies are controversial, and surprisingly, to the best of the authors' knowledge, no study has evaluated the relationship between the AL changes measured with AL-Scan and TAD while taking into consideration the CCT changes that occur before and after laser refractive surgery.

METHODS

The Medical Ethics Committee of the Bakirkoy Dr. Sadi Konuk Education and Research Hospital of the Ministry of Health University approved the current study, which also adhered to the tenets of the Declaration of Helsinki. We retrospectively reviewed the medical records on 35 eyes of 18 patients who had undergone LASIK or PRK surgeries for the treatment of myopia and/or myopic astigmatism at the Asya Eye Medical Center. The inclusion criteria for the refractive surgery were age older than 18 years and stable refraction for at least one year. The exclusion criteria for our study were intraoperative complications, retreatment, ocular diseases other than myopia and/or myopic astigmatism, systemic diseases, autoimmune diseases, immunosuppressive treatment, pregnancy and breastfeeding.

Preoperative and postoperative cycloplegic refraction, dilated fundus examination, anterior segment evaluation with a slit lamp and air-puff tonometry were performed on all the patients. AL, CCT and ACD were measured preoperatively and from 1–3 months postoperatively using the AL-Scan. The AL-Scan optical biometer measures AL from the surface of the corneal epithelium to the retinal pigment epithelium and uses an 830-nm infrared laser with PCI. ACD and CCT measurements were performed using the rotating Scheimpflug camera of the AL-Scan. Additionally, we measured preoperative and postoperative ACD with the Sirius rotating Scheimpflug camera combined with Placido disc corneal topography (CSO, Florence, Italy). The Sirius measures the ACD from the corneal endothelium to the anterior surface of the crystalline lens, and the high repeatability of those measurements has been established in several previous studies[10,11]. The laser treatments were performed using a MEL 90 excimer laser (Carl Zeiss Meditec, Jena, Germany), and the TAD values were collected from the resulting treatment data page. The optical zone of treatment was chosen as 6 or 6.5 mm according to the patients' preoperative corneal topography, refractive status and CCT. A Moria M2 microkeratome (Moria, Antony, France) with a 90-µm head was used to constitute superior hinged flaps for the LASIK patients. Statistical analyses were performed using Prism 7.0 software (Graphpad Software Inc.). The normality of the data was tested with a D'Agostino-Pearson normality test. The differences between measurements were evaluated with a two-tailed paired *t* test. Correlations among the AL, TAD and CCT were assessed with Pearson's correlation coefficient (r^2). A *P* value <0.05 was considered to be statistically significant.

RESULTS

Table 1 shows the patient characteristics of our study population. The postoperative AL was significantly shorter than the preoperative AL ($P<0.001$). The mean difference (ΔAL) was 56.86±34.45 µm, and the preoperative and postoperative values were strongly correlated with each other ($r^2=0.999$). Similarly, the postoperative CCT was significantly thinner than the preoperative CCT (mean preoperative vs. postoperative CCT ΔCCT of 55.89±27.23 µm, $P<0.001$). The mean TAD was 65.26±24.23 µm. There was no significant difference between the mean ΔAL and the mean TAD (mean difference between these two values=-8.4±31.62 µm, $P>0.05$), but the correlation between these values was poor ($r^2=0.215$). Similarly, the difference between the mean ΔAL and ΔCCT was not significant (0.97±33.52 µm, $P>0.05$), but correlation between them was poor ($r^2=0.184$). The difference between the mean TAD and mean ΔCCT was significant (9.37±11.75 µm, $P<0.001$), and these two values were well correlated ($r^2=0.814$). The mean preoperative ACD (3.36±0.36 mm) was significantly deeper than the mean postoperative ACD (3.26±0.33 mm, $P>0.05$).

Table 1. *Patient clinical characteristics.*	
Parameter	**Value**
Age	
Mean±SD	26.26±6.43
Range	18-39
Gender	
Male	9
Female	9
Type of refractive surgery LASIK/PRK	21/14
Optical zone of the treatment	
Range	6 or 6.5 mm
Refractive change at corneal plane	
Mean±SD	-3.02±1.83
Range	-0.38 to -7.36
SD: standard deviation.	

DISCUSSION

The present study revealed that while there were no significant differences between the mean ΔAL and TAD or between ΔAL and ΔCCT, ΔAL was poorly correlated with TAD and ΔCCT. On the other hand, TAD and ΔCCT correlated well with each other. Winkler von Mohrenfels *et al.*[6] were the first to evaluate AL changes occurring after laser-assisted subepithelial keratomileusis (LASEK) for myopia. They found that the ΔAL values obtained with the IOL Master were well correlated with TAD, but they did not specify any difference or similarity between the mean values (and the version of the IOL Master and the brand name of the excimer laser suite were unspecified). Tay *et al.*[9] showed that AL measurements from the IOL Master version 5 were correlated with and similar to the TAD values in patients who had undergone myopic LASIK surgery using a Nidek CXIII excimer laser suite (Nidek, Fremont, CA). Disparity between our study and Tay *et al.*'s[9] study may be due to the different laser suites and partial coherence interferometry devices used in the studies. On the other hand, Rosa *et al.*[7], who used the IOL Master 3.01 in patients who had undergone PRK using a Nidek EC 5000 excimer laser suite (Nidek, Gamagori, Japan), and Chalkiadakis *et al.*[8], who used the IOL Master version 5.02 in patients who had undergone LASIK using an Alcon Laser vision excimer laser suit (Alcon, Texas, USA) for the treatment of myopia and/or myopic astigmatism, also reported that ΔAL correlated poorly with TAD. Additionally, both papers found significant differences between these values. Unfortunately, neither of these studies investigated the relationship between the CCT and TAD.

Rosa *et al.*[7] suggested two hypotheses to explain the disparity between TAD and ΔAL. First, it might have originated from the inaccurate calculation of TAD by the excimer laser software. Since the mean TAD and ΔCCT values were well correlated in the present study, our results do not agree with that hypothesis. Their second hypothesis was a posterior shift of the corneal plane, which might have occurred after myopic laser surgery. As a secondary outcome measure, we investigated the ACD from the corneal endothelium to the anterior surface of the crystalline lens with the Sirius, and we believe it might be much more convenient to evaluate

Table 2.				
	Preoperative (mean±SD)	**Postoperative (mean±SD)**	**Difference (mean±SD)**	***P value***
AL, mm	24.75±1.09	24.69±1.09	-0.057±0.034	<0.001
CCT, µm	549.1±44.21	493.3±57.25	-55.89±27.23	<0.001
ACD, mm	3.36±0.36	3.26±0.33	-0.1±0.14	<0.001
Difference: Postoperative value - preoperative value. SD: standard deviation, AL: axial length CCT: central corneal thickness, ACD: anterior chamber depth				

Table 3.			
	ΔAL vs. TAD	**ΔAL vs. ΔCCT**	**TAD vs. ΔCCT**
Difference (mean±SD), µm	-8.4±31.62	-0.97±33.52	-9.37±11.75
Difference, *P*	0.125	0.864	<0.001*
Correlation, r^2	0.215	0.184	0.814
ΔAL: the difference between preoperative and postoperative axial length values, TAD: theoretical ablation depth, ΔCCT: the difference between preoperative and postoperative central corneal thickness values, SD: standard deviation, *: *P*<0.05.			

a possible shift of the corneal plane after surgery than to use the AL-Scan's ACD measurements (which measure the ACD from the anterior surface of the corneal epithelium to the anterior surface of the crystalline lens). We found that preoperative ACD values significantly decreased after surgery. Nishimura *et al.*[12] also reported that ACD significantly decreased in patients younger than 40 years old who had undergone LASIK surgery for the treatment of myopia. So, we agree with the second hypothesis of Rosa *et al.*[7] LASIK causes a hypocellular and variably thick scar at the stromal interface, and since this scar tissue always includes brightly reflective particles, interface wounds can always be identified by using confocal microscopy[13]. We hypothesized that the same reflective particles might interfere the AL-Scan's AL measurements in patients who have undergone LASIK. Similarly, a marginal corneal haze develops in all patients who have undergone PRK[14]. Tomás-Juan *et al.*[15] reported that this haze leads to light scatter, and we hypothesize that light scatter might caused the incorrect AL measurements of AL-Scan in patients who have undergone PRK. This light scatter issue was also considered by Chalkiadakis *et al.*[6] and Winkler von Mohrenfels *et al.*[8] as a possible reason for incorrect AL measurements of the IOL Master in patients who had undergone LASEK and LASIK, respectively. Meanwhile, CCT measurements of the AL-Scan gave values consistent with and similar to those of the TAD. This might be because the device uses a different method of measuring the CCT—a rotating Scheimpflug camera instead of PCI—that does not interfere with light scattering to the same degree as AL measurements.

This study has some limitations. First, we included both eyes of the patients in the study which might be a possible bias due to the intercorrelation of both eyes. Analysis of only one eye of the subjects might resolved this statistical issue. Nevertheless, a higher statistical power is produced through the inclusion of both eyes and all similar studies also used both eyes[6-9]. Second, the follow-up time was short. Tay *et al.*[9] found no changes in the AL measurements performed in the first and third months, and Rosa *et al.*[7] found that measurements at 1, 3 and 6 months were similar; Chalkiadakis *et al.*[6] and Winkler von Mohrenfels *et al.*[8] had similar follow-up times. Third, both LASIK and LASEK patients were included in our study. This might be criticized; however, light scatter occurs in eyes that have undergone either LASIK or PRK, and we believe that both techniques affect the AL-Scan similarly. Fourth, a single measurement was performed on all the patients because the repeatability of the AL-Scan[4,5] and the Sirius[10,11] device have been shown in several studies.

In conclusion, the AL-Scan gave AL measurements that were inconsistent with the TAD values in patients who had undergone LASIK and PRK surgeries for the treatment of myopia and/or myopic astigmatism. This disparity is likely to be a result of backscattering caused by surgery. Determining whether this inconsistency is relevant for IOL power calculations requires further prospective studies.

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