ORIGINAL ARTICLE/KLİNİK ÇALIŞMA

Anterior Segment Optical Coherence Tomography Assessment of Stromal Pocket and Opaque Bubble Layer in Femtosecond Laser Assisted Laser In Situ Keratomileusis

Femtosaniye Lazer Yardımıyla Yapılan Lazer İn Situ Keratomileusis Ameliyatında Oluşan Stroma Cebi ve Opak Kabarcık Tabakasının Ön Segment Optik Koherens Tomografisi ile Değerlendirilmesi

Raciha Beril KÜÇÜMEN[1], Umut Aslı DİNÇ[1], Nursal Melda YENEREL[1], Ebru GÖRGÜN[1], Ferda ÇİFTÇİ[2]

ABSTARCT

Purpose: To analyze the stromal pocket and opaque bubble layer (OBL) formation during femtosecond laser flap creation using the anterior segment optical coherence tomography (AS-OCT).

Materials and Methods: During femtosecond laser assisted laser in situ keratomileusis (LASIK), 20 eyes of 10 patients were examined prospectively by AS-OCT to evaluate the flap-OBL-pocket relations immediately after flap creation. High resolution corneal images in four quadrants were recorded and analyzed using the software's flap tool.

Results: The mean age of the patients (3 women, 7 men) was 42.0□6.2 years. No preoperative or postoperative complications were observed. An OBL was observed in 10 eyes without pocket formation; the mean OBL thickness was 251 µm, and the mean OBL depth was 393.8 µm. Pocket formation was programmed to be performed on 10 eyes; it was rudimentary and could hardly be detected in 3 eyes by AS-OCT. In eyes containing stromal pocket, a lower amount of OBL was also found to expand to the limbus. The mean pocket thickness was 85 µm and the mean pocket depth was 301.2 µm.

Conclusion: AS-OCT is a useful tool to evaluate the flap-OBL-pocket relations in vivo immediately after femtosecond laser during LASIK procedures. The presence of flap related stromal pockets significantly decrease OBL formation in femtosecond laser assisted LASIK.

Key Words: Femtosecond laser; LASIK; anterior segment optical coherence tomography; pocket; opaque bubble layer.

ÖZ

Amaç: Femtosaniye lazerle flep oluşturulurken meydana gelen stroma cebi ve opak kabarcık tabakası gelişiminin (OPKT) ön segment optik koherens tomografisi (ÖS-OKT) ile analiz edilmesi.

Gereç ve Yöntem: Femtosaniye lazer yardımıyla yapılan lazer in situ keratomileusis (LASİK) ameliyatı esnasında flep-OPKT-cep ilişkisini incelemek amacıyla 10 hastanın 20 gözü flep oluşturulmasından hemen sonra ÖS-OKT ile geriye dönük olarak incelendi. Yüksek çözünürlüklü kornea görüntüleri 4 kadranda kaydedildi ve yazılımdaki flep aracı ile analiz edildi.

Bulgular: Hastaların (3 kadın, 7 erkek) yaş ortalaması 42.0±6.2 yıldı. Ameliyat öncesi ve sonrası komplikasyon gelişmedi. OPKT cep formasyonu olmayan hastalarda gözlendi; ortalama OPKT kalınlığı 251µm ve ortalama OPKT derinliği 393.8 µm idi. On hastada cep oluşumu önceden programlanmıştı; bu gözlerden üçünde cebin güçlükle saptanabilecek kadar küçük oluştuğu gözlendi. Stroma cebi olan hastalarda az miktarda OPKT'nin limbusa kadar yayıldığı gözlemlendi. Ortalama cep kalınlığı 85 µm ortalama cep derinliği 301.2 µm idi.

Sonuç: ÖS-OKT, LASİK prosedürlerinden hemen sonra flep-OPKT-cep ilişkilerini in vivo değerlendirmek bakımından faydalı bir gereçtir. Femtosaniye lazer yardımıyla yapılan LASİK ameliyatında fleple bağlantılı stroma cebinin varlığı OPKT oluşumunu anlamlı olarak azaltmaktadır.

Anahtar Kelimeler: Femtosaniye lazer, LASİK, ön segment optik koherens tomografisi, stroma cebi, opak kabarcık tabakası.

1- M.D. Associate Professor, Yeditepe University Faculty of Medicine, Department of Ophthalmology, İstanbul/TURKEY
KUCUMEN R.B. berilkucumen@hotmail.com
DINC U.A., uadinc@yeditepe.edu.tr
YENEREL N.M., meldayen@hotmail.com
GORGUN E., ebrugorgun@gmail.com
2- M.D. Professor, Yeditepe University Faculty of Medicine, Department of Ophthalmology, İstanbul/TURKEY
CIFTCI F., fciftci@yeditepe.edu.tr

Geliş Tarihi - Received: 04.05.2012
Kabul Tarihi - Accepted: 08.06.2012
Glo-Kat 2012;7:159-162

Yazışma Adresi / Correspondence Adress: M.D. Associate Professor, Raciha Beril KÜÇÜMEN
Yeditepe University Faculty of Medicine, Department of Ophthalmology, İstanbul/TURKEY

Phone: +90 212 211 25 00
E-Mail: berilkucumen@hotmail.com

INTRODUCTION

The advantages of femtosecond laser over microkeratome systems for flap creation during laser in situ keratomileusis (LASIK) have been reported to be more predictable in obtaining thin and uniform flaps and a reduction in intraoperative complications.[1] The IntraLase femtosecond laser creates a photodisruption at the desired depth and of the desired pattern resulting in the formation of a cleavage plane in the cornea; the end products of the photodisruption are microcavitation bubbles consisting of water and carbon dioxide that may coalesce and occasionally travel within the cornea.[2] The pocket created during the femtosecond laser procedure is a free space that is used for the evacuation of these microcavitation bubbles, formed at the resection plane.[3] The opaque bubble layer (OBL) is defined as the accumulation of microcavitation bubbles in the intralamellar space above and below the IntraLase resection plane that may occur in the early or late intra-operative period.[3]

Anterior segment optical coherence tomography (AS-OCT) supplies high-resolution images of the cornea using low-coherence interferometry at a wavelength of 1310 nm without any contact or penetration.[4] The aim of the present report is to analyze OBL and pocket formation created by femtosecond laser intraoperatively by AS-OCT.

MATERIALS AND METHODS

The study prospectively examined 20 eyes of 10 patients who then underwent an uneventful refractive surgery performed by the same surgeon (RBK) with the IntraLase femtosecond laser (IntraLase Corp, Irvine, Calif). The mean age of the patients (3 women, 7 men) was 42.0±6.2 years. The study was performed with informed consent and followed all the guidelines for experimental investigation concerning human subjects required by the Instituitional Review Board of which all authors are affiliated. Eyes having had preoperative corneal disease, cataract, glaucoma, retinopathy, other ocular disease and a history of previous ocular surgery were excluded.

Preoperative Evaluation

All patients were evaluated by a detailed ophthalmological examination including slitlamp and fundus examinations, manifest and cycloplegic refractions, keratometry, ultrasonic pachymetry, Orbscan (Orbscan IIz, Bausch & Lomb) and AS-OCT (Visante OCT, Carl Zeiss Meditec) assessment.

Surgical Technique

A corneal flap was created using the IntraLase (30 kHz) laser in the raster mode and a standardized superior-hinged flap was planned for each patient. The docking technique used for the applanation cone was the standard method as recommended by the manufacturer. When the applanation was complete, the lock of the suction ring was released, and, depending on the amount of meniscus that was present, some adjustment on the applanation was made. This is defined as the soft docking technique. A superior-hinge flap depth of 110 µm with raster delivery pattern was attempted on each patient. Other laser parameters that did not vary were: Hinge angle (55°), bed energy (1.20 µJ), spot and line separation (9x9), side-cut energy (1.20 µJ), side-cut angle (70°), pocket width (0.220 mm), pocket start depth (240 µm) and pocket spot separation (6x6). The spherical equivalence of each eye with flap diameter and pocket on-off information are listed in the table. A pocket creation was selected in 5 myopic patients (10 eyes) to cause easy dissipation of microcavitation bubbles. Since large diameter flaps are required for hyperopic LASİK and pocket creation is not convenient for flap diameters greater than 9.2 mm, pocket enable was off in 5 hyperopic patients (10 eyes).

Despite the fact that individual corneal anatomy can affect the way femtosecond gases are formed, microcavitation bubbles appeared instantly after flap creation by femtosecond laser. We waited about 15 to 30 minutes for the bubbles to dissipate to guarantee that these bubbles did not impede the eye-tracker system of the excimer laser.

***Table:** Spherical equivalence, femtosecond laser flap diameter and pocket on-off parameters of the patients.*

Patient	Eye	SE	Diameter (mm)	Pocket
1	OD	-5.50	9.0	On
	OS	-6.0	9.0	On
2	OD	-1.50	9.0	On
	OS	-1.25	8.9	Off
3	OD	-6.0	8.9	On
	OS	-6.0	8.9	On
4	OD	-5.25	9.2	On
	OS	-6.0	9.2	On
5	OD	-3.75	8.8	On
	OS	-4.0	8.8	On
6	OD	-4.25	9.0	Off
	OS	-4.5	9.0	Off
7	OD	3.50	9.3	Off
	OS	4.50	9.3	Off
8	OD	3.50	9.3	Off
	OS	2.50	9.4	Off
9	OD	2.0	9.4	Off
	OS	3.0	9.5	Off
10	OD	3.0	9.4	Off
	OS	3.0	9.4	Off

OD= Right eye, OS = Left eye. SE= Spherical equivalence.

Intraoperative Assessment

During the waiting period, all eyes were evaluated by AS-OCT to visualize the flap, OBL and pocket immediately after flap creation. Image acquisition and measurements were obtained by the same examiner (RBK). To avoid deficiencies, 7-10 consecutive images were saved and reviewed, and the best-centered and qualified one was chosen and analyzed by two observers. We performed high-resolution corneal scans with 512A-scan-per-line sampling and 0.25 seconds per line acquisition time (2048 scans/second). Visante OCT allows high resolution corneal imaging which can be cross sectioned and examined on any desired axis. All corneas were centered on the vertex and the upper lid was held up during the process to be able to visualize the complete upper section of the cornea, including the limbus. During the scanning procedure, the scan which showed the best pocket image was recorded. The flap hinge was also examined to rule out any rotations of the pocket away from 90º; it had also been checked through a synchronized axis shift maneuver during the examination. These images were marked with the flap tool and digital calipers of the software; pocket depth at the 90º meridian and the OBL dimensions were calculated.

After AS-OCT assessment and the disappearance of microcavitation bubbles, the flap was lifted with a spatula. Using an excimer laser (Allegretto Wave Eye-Q 400Hz excimer laser, WaveLight Laser Technologie AG) the stroma was ablated.

RESULTS

The mean age of the patients (3 women, 7 men) was 42.0±6.2 years. No preoperative or postoperative complications were observed. A thick OBL was observed in 10 eyes without planned pocket formation (Figure 1). The mean OBL thickness was 251 µm (range:120 µm-330 µm) and the mean OBL depth was 393.8 µm (range: 264 µm-500 µm). The mean OBL-endothelium distance was 330 µm (range: 234-450 µm).

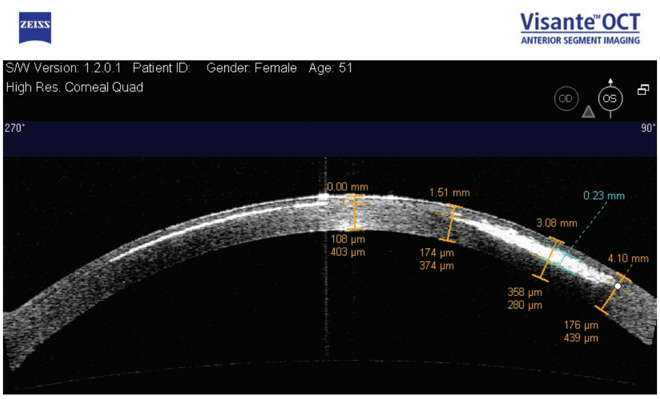

Figure 1: *Vertical cross-sectional high resolution AS-OCT (Visante OCT) image of the left eye of case 6.*

The mean pocket thickness was 85 µm (range: 50 µm-160 µm) and the mean pocket depth was 301.2 µm (range: 269 µm-512 µm), (Figure 2). The mean pocket length was 0.88 mm (range: 0.40 mm-1.03 mm). In eyes containing a stromal pocket, a lesser amount of OBL was found to expand to the corneal limbus in the upper quadrants between the 11 and 1 o'clock positions. Although pocket formation was programmed to be performed on 10 eyes, it was found to be rather rudimentary in 3 eyes of three cases. These eyes were left eyes and the OBL was observed to be thick and distinctive in the AS-OCT images (Cases 1, 2, and 5).

DISCUSSION

The creation of a pocket, that is deeper than the flap, is an optional process during femtosecond laser procedure with a raster pattern. The pocket acts as a reservoir for the microcavitation bubbles formed by the photodisruption during the femtosecond laser procedure. Since the cornea becomes clear in a couple of minutes shorter waiting period for the resorption of bubbles is necessary before the ablation stage of the LASIK operation.

The pocket is made below the resection plane at the hinge position and outside the limits of the side cut at a surgeon-defined distance. The pocket ramp is subsequently cut up to the level of the flap depth. Next, the width of the pocket ramp is determined by the hinge angle, and finally the standard raster resection is started. The pocket option is usually turned on in smaller flap diameters (e.g. in myopic LASIK).

However, it is usually turned off, especially for large flaps, to preserve the intended flap diameter and this may consequently lead to the appearance of more bubbles adjacent to the hinge (e.g. LASIK in hypermetropia where flap diameter larger than 9.2 mm is required). Moreover, when the flap localization is decentralized, recentralization also requires the "pocket-off" modality. The left eye of our second case is an example of this situation.

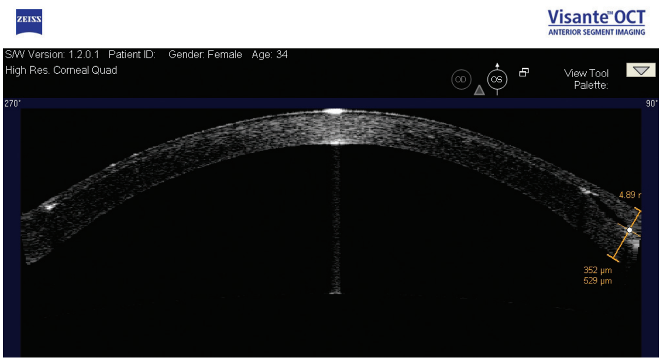

Figure 2: *Vertical cross-sectional high resolution AS-OCT image of the left eye of case 4. The pocket thickness is 160 µm and the pocket length is 1.03 mm.*

OBL may interfere with the effectiveness of the additional laser pulses and make the flap lifting more difficult. It may additionally interfere with the excimer laser eye tracking systems, especially if located around the pupillary axis. OBL is also known to affect intraoperative pachymetry measurements due to its high reflectivity of acoustic signals such as those of ultrasound pachymetry, generally resulting in thicker than actual flap thickness. In case of prominent OBL we have observed that the excimer laser ablation had to be postponed for a longer period (half an hour) to allow the air bubbles to dissipate.

Microcavitation gas bubbles that occur during femtosecond laser ablation find a path of least resistance and may appear underneath the flap, in the pocket, behind the hinge, occasionally in the episclera, in the subepithelial area and in the anterior chamber.[4-8] Wright[6] observed the occurence of gas bubbles in the anterior chamber when the ablation was close to the limbus, and in doing so concurred with the theory of the retrograde passage. Srinivasan and Rootman[7] supported the retrograde passage theory.

Recently, Kaiserman et al.,[9] have reported that thicker corneas and smaller flaps were associated with a more opaque bubble layer, but they have not brought any interpretation to flap-OBL-pocket relations to light. We found that the OBL was very thin or almost invisible in the case of the existence of a pocket, whereas a hard and diffuse OBL was always present in "pocket off" cases. Although their study consisted of all "pocket enabled" cases their OBL depth and penetration was similar to our findings.

AS-OCT shows a cross-section of the cornea in real time so that the flap can be visualized in high resolution and measured precisely.[10] In the current study, the AS-OCT acquisitions were performed approximately three minutes after flap creation by femtosecond laser. Our limited results revealed a deeper pocket depth than intended. In spite of the pocket being rudimentary and nonfunctional in 3 eyes, the lack of any problems with flap or hinge creation indicates that the applanations were complete. In the presence of the pocket, OBL was much thinner and dissipated very quickly. Although we didn't observe gas bubbles in the anterior chamber in any of these cases, we detected OBL beyond the pocket in the peripheral corneal stroma by AS-OCT in 4 eyes.

Additionally, we have recorded no OBL expansion to the corneal endothelium in our series; every quadrant being meticulously scanned.

However, we should point out that this study was conducted using a rather early version of IntraLase with 30 kHz repetition whereas the current version of the machine delivers 150 kHz. Therefore, our conclusions from the results may not be fully applicable to modern IntraLase devices.

In conclusion, our preliminary report is the first study analyzing the flap-OBL-pocket relations in vivo by Visante OCT immediately after femtosecond laser flap creation; further studies of larger series could also be enlightening.

REFERENCES/KAYNAKLAR

1. Binder PS. One thousand consecutive IntraLase laser in situ keratomileusis flaps. J Cataract Refract Surg 2006;32:962-9.
2. Vayr F, Chastang P, Hoang-Xuan T. Laser and mechanical microkeratomes. In: Refractive Surgery. Azaar DT, ed. 2nd edition 2007:147-55.
3. Wright JR. Gass bubbles after flap creation with femtosecond laser. J Cataract Refract Surg 2006;32:1076.
4. Kim JH, Lee D, Rhee KI. Flap thickness reproducibility in laser in situ keratomileusis with a femtosecond laser: optical coherence tomography measurement. J Cataract Refract Surg 2008;34:132-6.
5. Lifshitz T, Levy J, Klemperer I, et al. Anterior chamber gas bubbles after corneal flap creation with a femtosecond laser. J Cataract Refract Surg 2005;31:2227-9.
6. Kuo AN, Kim T. Persistant anterior chamber gas bubbles during IntraLASIK. J Cataract Refract Surg 2007;33:1134-5.
7. Srinivasan S, Rootman DS. Anterior chamber gas bubble formation during femtosecond laser flap creation for LASIK. J Refract Surg 2007;23:828-30.
8. Srinivasan S, Herzig S. Sub-epithelial gas breakthrough during femtosecond laser flap-creation for LASIK. Br J Ophthalmol 2007;91:1373.
9. Kaiserman I, Maresky HS, Bahar I, et al. Incidence, possible risk factors, and potential effects of an opaque buble layer created by a femtosecond laser. J Cataract Refract Surg. 2008;34:417-23.
10. Radhakrishnan S, Rollins AM, Roth JE, et al. Real-time optical coherence tomography of the anterior segment at 1310 nm. Arch Ophthalmol 2001;119:1179-85.