OPEN

No Change in Anterior Chamber Dimensions After Femtosecond LASIK for Hyperopia

Xiaodong Zhou, M.D.*, Tao Li,* M.D.*, Zhi Chen,* M.D.*, Lingling Niu,* M.D.*, Xingtao Zhou,* M.D., Ph.D.*, and Zimei Zhou,* M.D., Ph.D.

Objective: To compare the changes in anterior chamber volume (ACV), anterior chamber depth (ACD) and anterior chamber angle (ACA) before and 6 months after femtosecond laser in situ keratomileusis (LASIK) for hyperopia using the Pentacam HR device.

Methods: A total of 24 eyes of 24 consecutive hyperopic patients undergoing femtosecond LASIK were examined preoperatively and 6 months postoperatively. Anterior chamber volume; ACDs in the central, superior, inferior, nasal, and temporal quadrants; and ACA were measured using the Pentacam HR device. Comparisons of preoperative versus postoperative values were performed using paired Student *t* test. Linear regression analysis was performed to evaluate correlations between ACV change, central ACD change, age, and attempted maximum ablation depth.

Results: Preoperative and postoperative mean ACVs were 153.6 and 158.2 μL, respectively. Preoperative and postoperative mean ACDs were 2.81, 2.28, 2.53, 2.16, and 2.61 mm, and 2.84, 2.31, 2.54, 2.16, and 2.65 mm, respectively. Preoperative and postoperative mean ACAs were 33.3° and 32.0°, respectively. There were not statistically significant differences in ACV, ACDs, and ACA from preoperatively to 6 months after femtosecond LASIK (all $P>0.05$). The change of central ACD was correlated significantly with age at 6 months postoperatively ($R^2=0.18$, $P=0.039$).

Conclusions: Anterior chamber profiles, including ACV, ACA, and central and peripheral ACDs did not significantly change after femtosecond LASIK for hyperopia.

Key Words: Anterior chamber volume—Anterior chamber depth—Anterior chamber angle—Femtosecond LASIK—Hyperopia.

(*Eye & Contact Lens* 2015;41: 160–163)

From the Department of Ophthalmology (Xiaodong Zhou, T.L.), Jinshan Hospital of Fudan University, Shanghai, China; Department of Ophthalmology (Z.C., L.N., Xingtao Zhou), Eye and ENT Hospital of Fudan University, Shanghai, China; and Department of Ophthalmology (Z.Z.), Bronx Lebanon Hospital Center, Bronx, NY.

Supported by The National Natural Science Foundation of China (11074052).

The authors have no conflicts of interest to disclose.

Xiaodong Zhou and T. Li contributed equally to this work.

Address correspondence and reprint requests to Xingtao Zhou, M.D., Ph.D., Department of Ophthalmology, Eye and ENT Hospital of Fudan University, Shanghai, China, 19 Baoqing Road, Shanghai, China 200031; e-mail: doctzhouxingtao@163.com

Accepted August 18, 2014.

DOI: 10.1097/ICL.0000000000000087

Hyperopia is a common ophthalmic condition that can be corrected using nonsurgical and surgical modalities. Although refractive surgical correction of hyperopia has dragged behind myopic surgery, similar refractive procedures have successfully addressed this condition, including photorefractive keratectomy (PRK), laser epithelial keratomileusis (LASEK), laser in situ keratomileusis (LASIK).[1–7] Hyperopic laser procedures ablate a paracentral annulus of tissue to steepen the corneal refractive power so that the image of a distance object is focused on the retina of eye. According to previously reported studies, the postoperative outcomes are exciting and promising. Mean postoperative manifest spherical equivalent refraction was less than 0.50 diopter (D) in the hyperopic eyes treated by PRK,[1] LASEK,[6] or LASIK performed with a mechanical microkeratome[1,3–5,7] or a femtosecond laser.[5] In addition, Utine et al.[2] found that mean best spectacle-corrected visual acuity significantly increased postoperatively compared with preoperatively in children with anisometropic amblyopia treated by unilateral LASIK.

The effects of laser refractive surgeries on ocular anatomical structures have been of concern for several years. Numerous studies have evaluated the anterior segment anatomical changes following myopic corneal ablative refractive surgeries.[8–18] Orbscan Topography Systems (Orbscan, Inc., Salt Lake, UT) have documented anterior shifting of the posterior corneal surface following corneal ablative procedures because of reduction in overall corneal biomechanical strength.[8–11] Pentacam system (Oculus, Inc., Wetzlar, Germany), a newly developed anterior segment imaging device, provides reliable measurements for anterior chamber volume (ACV), anterior chamber depth (ACD), and anterior chamber angle (ACA).[19] Previous studies suggested that data obtained by Orbscan did not always concur with those by Pentacam, even in the same patient.[14,15] Compared with Orbscan, Pentacam revealed no significant change in the posterior corneal surface after refractive surgery.[12–16,18] The fact that no changes in ACV or central ACD were observed further suggested that the anterior segment of the eye was relatively stable after myopic keratorefractive surgery.[13–15]

A few studies have evaluated the anterior segment structure changes after hyperopic surgery. The purpose of this study was to compare the changes in the anterior chamber dimensions before and 6 months after femtosecond LASIK in hyperopic patients using the Oculus Pentacam HR device.

METHODS

Patient Population

This is a prospective noncontrolled case series of 24 eyes of 24 hyperopic patients undergoing femtosecond LASIK. All the subjects were consecutively recruited at the Department of Ophthalmology and Vision Science of Fudan University Eye and ENT Hospital. All recruited patients underwent a comprehensive ophthalmic examination. Exclusion criteria included unstable refraction for the preceding 2 years, keratoconus suspect, concurrent ocular pathologies, and systemic diseases deemed to impact surgical wound healing. All eyes had a stable refraction with ≥1.50 D of spherical hyperopia and less than 1.50 D of refractive astigmatism (expressed in minus form) and were targeted for a plano refractive outcome. All procedures conformed to the tenets of the Declaration of Helsinki, and written informed consents were obtained from all the subjects.

Surgical Procedures

Before surgery, patients were instructed to use antibiotic drops (levofloxacin 0.5%; Santen, Ishikawa, Japan) four times daily for 3 day. VisuMax femtosecond laser (Carl Zeiss Meditec, Inc., Jena, Germany) was the laser platform of the choice to create LASIK flap in all patients. A single surgeon (X.T.Z.) carried out laser ablation using MEL 80 excimer laser (Carl Zeiss Meditec, Inc.) after flap lifting. The optical zone was set at 6.50 mm in 20 eyes and 6.75 mm in 4 eyes, with a transition zone of 1 mm (total ablation zone of 8.5 or 8.75 mm). Then the flap was repositioned using standard techniques. A bandage contact lens was placed on the surgically treated eye for 1 day. Immediately after surgery, a combination of antibiotics (levofloxacin 0.5%; Santen) and steroids (fluorometholone 0.1%; Santen) drops was applied. Levofloxacin 0.5% was applied four times daily in the first week, and fluorometholone 0.1% was used six times daily in the first postoperative 3 days and were gradually tapered every week to once a day. In addition, non-preserved artificial tears (sodium carboxymethyl cellulose 0.5%; Allergan, Irvine, CA) were applied for 6 months.

Data Collection

In all cases, ACV, central and peripheral ACDs, and ACA were measured using Pentacam HR device before and 6 months after femtosecond LASIK. Proper visual fixation was noted for all patients. A single experienced technician performed all imaging acquisitions.

The technology of the Pentacam device is based on the rotating Scheimpflug imaging. Pentacam device with a blue light source (light-emitting diode, 475 nm) rotates together around the optical axis of the eye and acquires 100 images within 2 sec without contact. It generates three-dimensional images with a compensatory function for correcting eye movements in the process of measurements and provides quantitative information of ocular anatomical structural changes postsurgerically.[19]

Central ACD was defined as the distance from the posterior surface of the corneal endothelium to the anterior surface of the crystalline lens along the optical axis.[16] Peripheral ACDs were defined as the distance from the posterior surface of the corneal endothelium to the anterior iris surface 4 mm away from the corneal apex in the superior, inferior, nasal, and temporal quadrants. The mean ACA was automatically calculated from all the ACAs collected in the imaging process by the Pentacam software.

Data Analysis

Statistical Package for the Social Sciences software (version 16.0, SPSS, Inc., Chicago, IL) was used for statistical analysis. Comparisons of preoperative versus postoperative values were performed using paired Student *t* test with the standard assumptions. Regression analysis was performed between (1) the change of ACV and age; (2) the change of ACV and attempted maximum ablation depth; (3) the change of central ACD and age; and (4) the change of central ACD and attempted maximum ablation depth. $P<0.05$ was considered statistically significant.

RESULTS

Twenty-four eyes of 24 patients (13 male and 11 female patients) were enrolled. The preoperative parameters were shown in Table 1. There were no complications after hyperopic femtosecond LASIK in our study. Manifest refractive spherical equivalent was 0.14±0.56 D at 6 months postoperatively. Mean preoperative central corneal true net power was 41.4±2.1 D (range: 37.4–46.9 D), which increased postoperatively to 47.3±3.6 D (range: 40.4–57.4 D), the difference being statistically significant ($P<0.001$).

Comparisons of preoperative versus postoperative anterior chamber dimensions, including ACV, ACDs, and ACA, are presented in Table 2. Preoperative and postoperative mean ACVs were 153.6 and 158.2 μL, respectively. The deepest location of ACD was in the center followed by the temporal, inferior, superior, and nasal quadrants (Table 2). Preoperative and postoperative mean ACAs were 33.3° and 32.0°, respectively. There were not statistically significant differences in ACV, ACDs, or ACA from preoperatively to 6 months after hyperopic femtosecond LASIK (all $P>0.05$). The change of central ACD was correlated significantly with the age at 6 months postoperatively ($R^2=0.18$, $P=0.039$; Fig. 1A), although there was no significant correlation between the central ACD and attempted maximum ablation depth ($P>0.05$; Fig. 1B). There were no statistically significant linear relationships between the change of ACV and age ($P>0.05$; Fig. 1C) or attempted maximum ablation depth ($P>0.05$; Fig. 1D).

DISCUSSION

This study evaluated optical variables associated with anterior chamber following hyperopic LASIK using the Pentacam device. To the best of our knowledge, this is the first study to comparatively analyze and report the changes in ACA following hyperopic LASIK. Previous studies on hyperopic refractive surgery mainly focused on the refractive outcomes after surgery while the postoperative anterior segment structural changes were paid less attention to.[20–22] de Ortueta et al.[20,21] found that topography could be used as an objective method to analyze regression after hyperopia treatment, and its maps showed the corneal power change of Maloney indices correlated with the intended correction. Reinstein

TABLE 1. *Preoperative Patient Characteristics*

Parameters	Mean±SD (Range)
Age, y	26.3±12.8 (11–63)
Spherical equivalent, D	5.19±1.71 (1.62–8.62)
Attempted maximum ablation depth, μm	106±31 (50–163)
Central corneal thickness, μm	561±32 (510–629)
Axial length, mm	21.66±0.88 (19.97–23.88)
Posterior corneal curvature, mm	6.41±0.30 (5.86–7.01)

SD, standard deviation.

TABLE 2. *Preoperative vs. Postoperative Changes in ACV, ACDs, and ACA*

Parameters	Preoperative	Postoperative	Changes	*P*
ACV, μL	153.6±35.2	158.2±37.4	4.6±12.0	0.07
ACDs, mm				
Center	2.81±0.30	2.84±0.30	0.03±0.10	0.16
Superior	2.28±0.39	2.31±0.37	0.03±0.28	0.59
Inferior	2.53±0.32	2.54±0.34	0.00±0.27	0.94
Nasal	2.16±0.36	2.16±0.38	0.00±0.24	0.99
Temporal	2.61±0.38	2.65±0.35	0.04±0.29	0.55
ACA, °	33.3±5.5	32.0±4.7	−1.4±3.5	0.08

Values are expressed as mean±SD.

ACA, anterior chamber angle; ACDs, anterior chamber depths; ACV, anterior chamber volume; SD, standard deviation.

et al.[22] found the paracentral epithelial thickening and the central epithelial thinning after hyperopic LASIK, which demonstrates that the epithelium was compensating for the paracentral stromal tissue removal because of the hyperopic ablation.

The preoperative ACV, central ACD, and ACA were obtained with Pentacam HR device with a median value of 153.6±35.2 μL, 2.81±0.30 mm, and 33.3±5.5°, respectively. Mean ACV measured by the Visante Anterior Segment Optical Coherence Tomography (AS-OCT; Carl Zeiss Meditec, Inc.) was 171.4±42.4 μL.[23] Mean central ACD taken with AS-OCT (Heidelberg Engineering GmbH, Heidelberg, Germany) were 3.32±0.26 mm on right eyes and 3.31±0.28 mm on left eyes, whereas ACA were 46.18±5.50° (temporal side) and 45.13±5.89° (nasal side) on right eyes and 46.67±5.98° (temporal side) and 44.90±5.94° (nasal side) on left eyes.[24] The anterior chamber dimensions data obtained in this study were significantly less than those measured by optical coherence tomography (OCT) in nonhyperopic eyes.[23,24]

In the current study, there were no significant changes in ACV and central ACD, which agreed with the findings of previous investigations on myopic surgery using the Pentacam device.[13,14] In contrast, Nishimura et al.[25] found that the ACV and central ACD significantly decreased after myopic LASIK in patients younger than 40 years using a Pentacam device. Savini et al.[26] reported greater amount of postoperative ACV and ACD in patients younger than 50 years than those older than 50 years, performed with a dual Scheimpflug analyzer (Galilei). These studies indicated that age might have an impact on anterior chamber changes after surgery. We found the central ACD change was correlated significantly with age at 6 months postoperatively (Fig. 1A). This finding was similar to that reported by Nishimura et al.[25] However, the change of central ACD had no correlation with the attempted maximum ablation depth in our study, which was in agreement with that of Sun et al.[27]

Furthermore, peripheral ACDs did not significantly change after hyperopic LASIK in this study. In evaluating posterior corneal surface 6 months after myopic epi-LASIK using Pentacam device, Zhang and Wang[17] showed the displacement in central and peripheral parts displayed slightly backward and forward shift trends, respectively. Although there is no consensus on the definite changes in posterior corneal surface after laser surgery for myopia, our data showed that there may not be a forward or backward shift of posterior paracentral corneal surface after femtosecond LASIK for hyperopia. With the cornea healing, the biomechanical response would be minimized.[28]

Anterior chamber angle was also evaluated by Pentacam HR device in this study. There was no statistically significant difference in ACA between preoperatively and 6 months postoperatively. Previous published reports in the literature have used other imaging devices, such as wide spectrum OCT and ultrasound biomicroscopy, both of which directly measure anterior chamber variables in comparison with Pentacam, which indirectly measures these parameters. In healthy untreated eyes, Yi et al.[24] showed that the temporal and nasal ACAs did not differ between Pentacam and OCT. As a result of this study, we assume that Pentacam device is

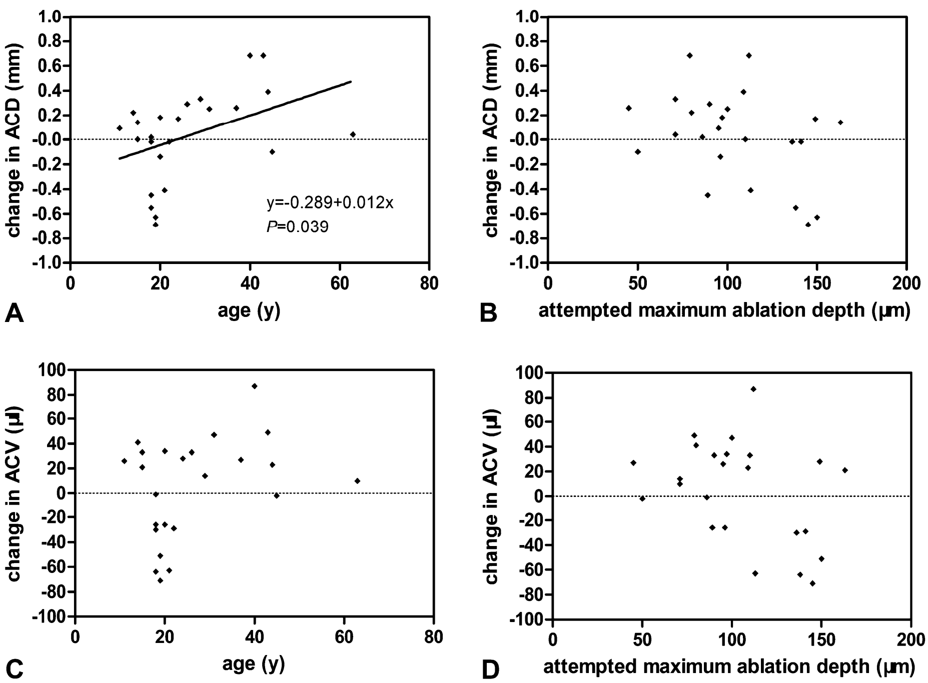

FIG. 1. Linear regression of central anterior chamber depth (ACD) change as a function of age (A) or attempted maximum ablation depth (B) at 6 months postoperatively, and linear regression of anterior chamber volume (ACV) change as a function of age (C) or attempted maximum ablation depth (D) at 6 months postoperatively. A significant correlation is seen between the central ACD change and age (R^2=0.18, P=0.039), although there is no significant correlation between the central ACD change and attempted maximum ablation depth (P>0.05). There were no statistically significant linear relationships between the change of ACV and age or attempted maximum ablation depth (both P>0.05).

reliable in reporting the anterior chamber variables, that is, angle, volume, depth, in comparison with OCT after refractive surgery.

No complications were observed after hyperopic femtosecond LASIK in our study. de Medeiros et al.[29] found decreases in corneal hysteresis and corneal resistance factor after hyperopic LASIK, although its effect was considered less significant in hyperopic surgery than in myopic surgery. The reduction in corneal biomechanical integrity constitutes one of the most important reasons for keratectasia.[30]

Our study has certain limitations that may be taken into consideration, including (1) the great scope of treated hyperopia, ranging from 1.62 to 8.62 D; (2) the enrollment patients with a wide age range between 11 and 63 years; (3) the anterior chamber dimensions data were obtained from one time point only; and (4) a small sample in the study population.

CONCLUSIONS

Anterior chamber profiles, including ACV, ACA, and central and peripheral ACDs did not significantly change after femtosecond LASIK for hyperopia using Pentacam HR device.

REFERENCES

1. Spadea L, Sabetti L, D'Alessandri L, et al. Photorefractive keratectomy and LASIK for the correction of hyperopia: 2-year follow-up. *J Refract Surg* 2006;22:131–136.
2. Utine CA, Cakir H, Egemenoglu A, et al. LASIK in children with hyperopic anisometropic amblyopia. *J Refract Surg* 2008;24:464–472.
3. Durrie DS, Smith RT, Waring GT, et al. Comparing conventional and wavefront-optimized LASIK for the treatment of hyperopia. *J Refract Surg* 2010;26:356–363.
4. Keir NJ, Simpson T, Hutchings N, et al. Outcomes of wavefront-guided laser in situ keratomileusis for hyperopia. *J Cataract Refract Surg* 2011;37: 886–893.
5. Gil-Cazorla R, Teus MA, de Benito-Llopis L, et al. Femtosecond laser vs mechanical microkeratome for hyperopic laser in situ keratomileusis. *Am J Ophthalmol* 2011;152:16–21.
6. McAlinden C, Skiadaresi E, Moore JE. Hyperopic LASEK treatments with mitomycin C using the SCHWIND AMARIS. *J Refract Surg* 2011;27:380–383.
7. Soler V, Benito A, Soler P, et al. A randomized comparison of pupil-centered versus vertex-centered ablation in LASIK correction of hyperopia. *Am J Ophthalmol* 2011;152:591–599.
8. Baek T, Lee K, Kagaya F, et al. Factors affecting the forward shift of posterior corneal surface after laser in situ keratomileusis. *Ophthalmology* 2001;108:317–320.
9. Cheng AC, Tang E, Lam DS. Residual bed thickness and corneal forward shift after laser in situ keratomileusis. *J Cataract Refract Surg* 2004;30: 2251–2252.
10. Miyata K, Tokunaga T, Nakahara M, et al. Residual bed thickness and corneal forward shift after laser in situ keratomileusis. *J Cataract Refract Surg* 2004;30:1067–1072.
11. Twa MD, Roberts C, Mahmoud AM, et al. Response of the posterior corneal surface to laser in situ keratomileusis for myopia. *J Cataract Refract Surg* 2005;31:61–71.
12. Ciolino JB, Belin MW. Changes in the posterior cornea after laser in situ keratomileusis and photorefractive keratectomy. *J Cataract Refract Surg* 2006;32:1426–1431.
13. Hashemi H, Mehravaran S. Corneal changes after laser refractive surgery for myopia: Comparison of Orbscan II and Pentacam findings. *J Cataract Refract Surg* 2007;33:841–847.
14. Nishimura R, Negishi K, Saiki M, et al. No forward shifting of posterior corneal surface in eyes undergoing LASIK. *Ophthalmology* 2007;114: 1104–1110.
15. Ha BJ, Kim SW, Kim SW, et al. Pentacam and Orbscan II measurements of posterior corneal elevation before and after photorefractive keratectomy. *J Refract Surg* 2009;25:290–295.
16. Perez-Escudero A, Dorronsoro C, Sawides L, et al. Minor influence of myopic laser in situ keratomileusis on the posterior corneal surface. *Invest Ophthalmol Vis Sci* 2009;50:4146–4154.
17. Zhang L, Wang Y. The shape of posterior corneal surface in normal, post-LASIK, and post-epi-LASIK eyes. *Invest Ophthalmol Vis Sci* 2010;51: 3468–3475.
18. Grewal DS, Brar GS, Grewal SP. Posterior corneal elevation after LASIK with three flap techniques as measured by pentacam. *J Refract Surg* 2011; 27:261–268.
19. Oliveira CM, Ribeiro C, Franco S. Corneal imaging with slit-scanning and Scheimpflug imaging techniques. *Clin Exp Optom* 2011;94:33–42.
20. de Ortueta D, Arba-Mosquera S, Baatz H. Topographic changes after hyperopic LASIK with the SCHWIND ESIRIS laser platform. *J Refract Surg* 2008;24:137–144.
21. de Ortueta D, Arba-Mosquera S. Topographic stability after hyperopic LASIK. *J Refract Surg* 2010;26:547–554.
22. Reinstein DZ, Archer TJ, Gobbe M, et al. Epithelial thickness after hyperopic LASIK: Three-dimensional display with Artemis very high-frequency digital ultrasound. *J Refract Surg* 2010;26:555–564.
23. Labiris G, Gkika M, Katsanos A, et al. Anterior chamber volume measurements with Visante optical coherence tomography and Pentacam: Repeatability and level of agreement. *Clin Experiment Ophthalmol* 2009;37: 772–774.
24. Yi JH, Hong S, Seong GJ, et al. Anterior chamber measurements by pentacam and AS-OCT in eyes with normal open angles. *Korean J Ophthalmol* 2008;22:242–245.
25. Nishimura R, Negishi K, Dogru M, et al. Effect of age on changes in anterior chamber depth and volume after laser in situ keratomileusis. *J Cataract Refract Surg* 2009;35:1868–1872.
26. Savini G, Carbonelli M, Barboni P, et al. Repeatability of automatic measurements performed by a dual Scheimpflug analyzer in unoperated and post-refractive surgery eyes. *J Cataract Refract Surg* 2011;37:302–309.
27. Sun HJ, Park JW, Kim SW. Stability of the posterior corneal surface after laser surface ablation for myopia. *Cornea* 2009;28:1019–1022.
28. Roberts C. Biomechanics of the cornea and wavefront-guided laser refractive surgery. *J Refract Surg* 2002;18:S589–S592.
29. de Medeiros FW, Sinha-Roy A, Alves MR, et al. Differences in the early biomechanical effects of hyperopic and myopic laser in situ keratomileusis. *J Cataract Refract Surg* 2010;36:947–953.
30. Ramos JL, Li Y, Huang D. Clinical and research applications of anterior segment optical coherence tomography—a review. *Clin Experiment Ophthalmol* 2009;37:81–89.

