American Journal of Ophthalmology Case Reports 10 (2018) 38–47

Contents lists available at ScienceDirect

American Journal of Ophthalmology Case Reports

journal homepage: www.elsevier.com/locate/ajoc

Long-term visual outcomes of laser anterior ciliary excision

AnnMarie Hipsley[a,*], Brad Hall[b], Karolinne Maia Rocha[c]

[a] Ace Vision Group Inc, 39655 Eureka Drive Newark, CA, 94560, USA
[b] Sengi Data, 125 Queen St E, Cambridge, Ontario, N3C 2B3, Canada
[c] Storm Eye Institute, Medical University of South Carolina, 167 Ashley Avenue, Charleston, SC, 29425, USA

ARTICLE INFO

Keywords:
Presbyopia
Accommodation
Visual acuity
Laser anterior ciliary excision

ABSTRACT

Purpose: To determine the long-term visual outcomes of six eyes of 3 patients up to 13 years following the Laser Anterior Ciliary Excision (LaserACE) procedure.

Methods: Three male patients of ages 59, 59, and 60 presented for evaluation at Storm Eye Institute, Medical University of South Carolina at 8, 10, and 13 years after the LaserACE procedure for presbyopia, respectively. All 3 patients had a history of laser vision correction (LVC) prior to LaserACE treatment. Visual performance was evaluated using ray-tracing aberrometry, specifically higher-order aberrations, visual Strehl of the optical transfer function (VSOTF), depth of focus (DoF), and effective range of focus (EROF). VSOTF was computed as a function of defocus using a through-focus curve. Subjective DoF was overlaid on the VSOTF through-focus curve to establish the best image quality metric threshold value for correlation between subjective and objective DoF. EROF was determined by measuring the difference in diopters between the near and distance DoF curves, at 50% of VSOTF.

Results: Distance-corrected visual acuity, distance-corrected intermediate visual acuity, and distance-corrected near visual acuity for all patients remained at 20/20 or better up to 13 years postoperatively. EROF averaged 1.56 ± 0.36 (D) for all eyes.

Conclusions and Importance: LaserACE provided improvement in near vision functionality in these LVC patients with long-term stability. The LaserACE procedure is not on the visual axis, therefore these patients could still receive correction to their hyperopic regression.

1. Introduction

Presbyopia is an age-related loss in accommodative ability, affecting an estimated half a billion people worldwide.[1] It has been traditionally described following Helmholtz' theory of accommodation, wherein the loss of elasticity of the lens substance causes a reduction in accommodation, resulting in presbyopia.[2] This cannot be the sole explanation as recent studies have demonstrated the influence that ocular rigidity, the vitreous membrane, peripheral choroid, zonules, and ciliary muscles have on the loss of accommodation.[3–7]

In the particular case of ocular rigidity, the human sclera has been shown to lose virtually all its elasticity after 70 years.[8] This increased ocular rigidity with age has been correlated with a clinically significant loss of accommodation.[3] Laser Anterior Ciliary Excision (LaserACE) is designed to alter the biomechanical properties of the rigid sclera. LaserACE utilizes an excimer laser to create a matrix array of micro-excisions (micropores) in the sclera.[9] Within the matrix, there are areas of both positive stiffness (remaining interstitial tissue) and negative stiffness (removed tissue or micropores), which increase the plasticity and compliance of the scleral tissue during contraction of the ciliary muscles, and improve the efficiency of the accommodation apparatus.[9]

To treat presbyopia, spectacles and contact lenses are the prevailing treatments, however they do not attempt to restore accommodation to the presbyopic eye. Many current presbyopia treatments that do attempt to restore accommodation, only aim to increase the depth of focus (DoF) for patients. This can be done by the use of corneal refractive surgeries or intraocular lens replacement.[10] These treatment options may enhance the 'pseudoaccommodation' of presbyopic patients, but not their true accommodation. True accommodation is the ability of the eye to modify its focal length to see objects clearly when changing focus from distance to near. LaserACE is one of the only treatment options for presbyopia that aims to restore both true accommodation and pseudoaccommodation.

Wavefront analysis is a widely used method to assess the visual system,[11] and is typically used to measure higher-order aberrations (HOA), visual Strehl ratio, and DoF.[12] DoF is the variation in defocus that can be

* Corresponding author.
E-mail address: ahipsley@acevisiongroup.com (A. Hipsley).

https://doi.org/10.1016/j.ajoc.2018.01.033
Received 4 January 2017; Received in revised form 13 November 2017; Accepted 18 January 2018

tolerated by the eye without a noticeable change in image sharpness.[13] Ray-tracing aberrometry can objectively determine DoF by computing near and distance through-focus curves.[14] The visual Strehl of the optical transfer function (VSOTF) is a precise method to measure the objective visual performance of patients.[15,16] It is an optical wavefront error-derived metric that predicts patient visual acuity,[16] and is defined as:[15]

$$\text{VSOTF} = \frac{\text{the area under the contrast sensitivity}-\text{weighted optical transfer function}}{\text{the area under the contrast sensitivity}-\text{weighted optical transfer function for a diffraction}-\text{limited eye}}$$

We have previously reported the improvements in uncorrected near visual acuity (UNVA) and distance-corrected near visual acuity (DCNVA) immediately after the LaserACE procedure and up to 24 months postoperatively.[17] In this brief report, we describe the visual outcomes of three patients who were recently examined at 8, 10, and 13 years postoperatively, respectively. We present the long-term visual outcomes for three patients, following LaserACE, including the visual acuities at near and distance, HOA, effective range of focus, and VSOTF.

2. Materials and methods

Three male patients of ages 59, 59, and 60 presented for evaluation at Storm Eye Institute, Medical University of South Carolina at 8, 10, and 13 years after LaserACE procedure for presbyopia, respectively. All 3 patients had a history of laser vision correction (LVC) prior to LaserACE treatment.

An outline of the LaserACE procedure is shown in Fig. 1. In brief, an erbium-doped yttrium aluminum garnet (Er:YAG) laser is utilized to create 9 micropores in the sclera of the eye. Excisions were placed in a matrix pattern from 0.5 mm up to 6.0 mm from the anatomical limbus (AL) over the 3 critical anatomical and physiological zones of significance: 1) the scleral spur at the origin of the ciliary muscle (0.5–1.1 mm from AL); 2) the mid ciliary muscle body (1.1–4.9 mm from AL); and 3) insertion of the longitudinal muscle fibers of the ciliary, just anterior to the ora serrata at the insertion of the posterior vitreous zonules (4.9–5.5 mm from AL).[9,18,19] Excision depth was 85–90% the depth of the sclera, to the point that the blue hue of the choroid just became visible. An opaque corneal shield was placed on the cornea, and remained in place until the completion of the procedure. A representative postoperative slit lamp image is shown in Fig. 2.

Uncorrected and distance corrected visual acuities were measured using standard Early Treatment Diabetic Retinopathy Study (ETDRS) charts. Measurement of HOAs, VSOTF, DoF, and effective range of focus (EROF) were performed using ray-tracing aberrometry (iTrace, Tracey Technologies, Houston, TX, USA). The iTrace aberrometer is capable of creating corneal and lenticular maps as well as a difference map which can demonstrate independent image quality metrics (IQM) for the lens (Fig. 3). VSOTF was computed as a function of defocus using a through-focus curve, as described previously.[14] Subjective DoF was overlaid on the VSOTF through-focus curve to establish the best IQM threshold value for correlation between subjective and objective DoF. The EROF was determined by measuring the difference in diopters between the near and distance through-focus curves, at 50% of VSOTF. The EROF is the range of focus with acceptable blur, and will be a combination of both the true accommodation and the pseudoaccommodation.

The true accommodative ability of patient eyes was determined by first measuring the difference in distance and near refraction, shown in Fig. 4. The spherical equivalent of the refraction difference will be the true accommodation. For a young eye (Fig. 4A) this was ~2.65 D in true accommodation, while for a presbyope (Fig. 4B) there was little to no true accommodation.

This was an IRB monitored and registered international clinical pilot study, which followed the tenets of the Declaration of Helsinki. Patients provided written consent for imaging and publication of personal identifying information including medical record details.

3. Results

Summaries of each patient's visual outcomes prior to the LaserACE procedure are shown in Table 1. Summaries of each patient's visual outcomes after LaserACE are shown in Table 2. Despite the hyperopic regression observed in all eyes, the distance-corrected near visual acuity of the patients were stable following the LaserACE procedure and preserved for 8, 10, and 13 years postoperatively. Corrected distance visual acuity (CDVA), distance-corrected intermediate visual acuity (DCIVA), and DCNVA for all patients remained at 20/20 or better following the LaserACE procedure. These are large improvements compared to preoperative DCIVA and DCNVA, which ranged from 20/40 to 20/60 (OD) and 20/40 to 20/400 (OS), respectively. Additionally, both DCIVA and DCNVA maintained these improvements of 1–15 lines and 2–15 lines, respectively, up to 13 years postoperatively.

Figs. 5 and 6 show the DoF for near (red) and distance (green) and the effective range of focus (EROF) measurements for each patient eye. Patient DoF increased by 0.84 ± 0.74 D on average compared to preoperative DoF. The largest EROF for a single patient eye was 2.16 D (Fig. 5A). Patient EROF averaged 1.56 ± 0.36 D for all patient eyes (n = 6). This was higher than preoperative clinical accommodation, which averaged 0.92 ± 0.61 D. True accommodation and pseudoaccommodation averaged 0.23 ± 0.24 D and 1.33 ± 0.38 D respectively.

Ray-tracing aberrometry results for each patient eye are shown in Figs. 7 and 8. Averages of DoF, EROF, VSOTF, and HOA for OD, OS, and OU are summarized in Fig. 9.

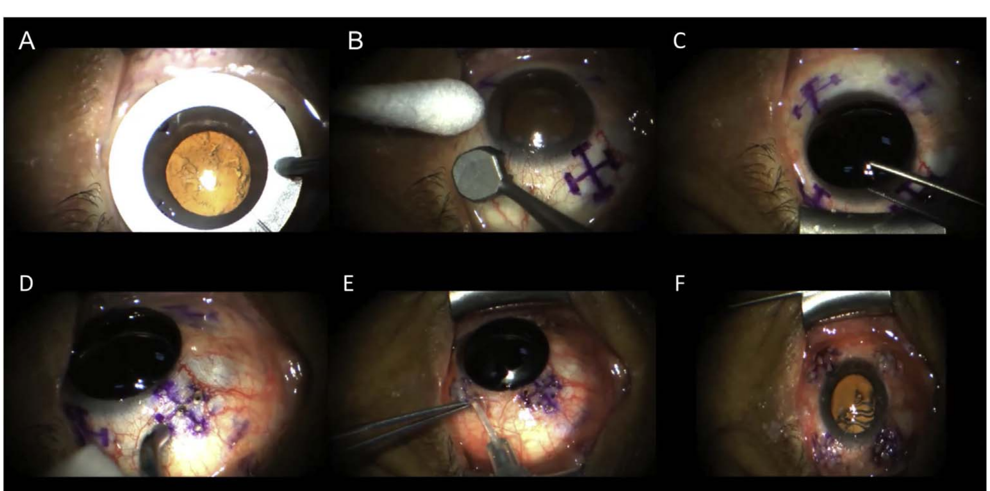

Fig. 1. Laser Anterior Ciliary Excision (LaserACE) surgical technique. Photo A. Quadrant marker; B. Matrix marker; C. Corneal Shield; D. LaserACE micropore ablation; E. Subconjunctival Collagen F. Completed 4 quadrants. Reprinted with permission from Hipsley et al.[17]