ABSTRACT

Purpose: To assess the visual outcome and refractive error following wavefront (WF)-optimized laser in situ keratomileusis (LASIK) retreatment after previous WF-guided LASIK in myopic patients.

Methods: A retrospective analysis of 19 eyes (14 patients) following WF-optimized LASIK retreatment after previous WF-guided LASIK that did not give desired refractive results was conducted. The primary LASIK procedures were performed using the Visx CustomVue™ laser with WF-guided technology. All of the subsequent retreatment LASIK procedures were performed with the WaveLight Allegretto™ Eye-Q 400 excimer laser using WF-optimized. Ophthalmic evaluations including uncorrected visual acuity (UCVA), best spectacle corrected visual acuity (BSCVA), and manifest refraction spherical equivalent (MRSE) were performed at baseline and postoperatively at 1, 3, 6 months.

Results: UCVA and BSCVA improved following retreatment from 0.27±0.18 and 0.0±0.05 to 0.01±0.05 and -0.03±0.05 respectively at 6 months (p<0.001 and p=0.38). The MRSE decreased from -0.5 D pre-retreatment to -0.2 D at 6 months post-retreatment. The pre-retreatment total HOA was 0.48±0.21 (0.24 to 1.01µm) and did not show correlation with the visual outcomes postoperatively. No intra-operative or post-operative complications occurred.

Conclusions: The results of this small case series with patients presenting low degrees of residual ametropia indicate that WF-optimized LASIK retreatment could be considered as an option after primary WF-guided LASIK. Retreatment with WF-optimized LASIK is safe and the results are predictable.

Key Words: Laser in situ keratomileusis (LASIK); retreatment; residual refractive error; wavefront-optimized; wavefront-guided.

INTRODUCTION

Conventional excimer corneal ablation profiles proved to be effective and well tolerated over the years. However, conventional treatments had a tendency to alter the average prolate corneal shape towards a more oblate profile and induce spherical aberrations. This change in the corneal asphericity would affect the quality of vision; mainly night vision symptoms and contrast sensitivity testing. New strategies were employed to advance laser profiles. Wavefront (WF)-guided ablation uses technology to plan ablation patterns based on higher and lower order aberration profiles unique to the eye being treated. Laser in situ keratomileusis (LASIK) procedures have been widely reported to be safe and predictable. However, 6.35% to 17.5% of these eyes require additional surgical interventions to achieve adequate visual outcomes. Overcorrection rarely occurs after LASIK procedures for myopia and
myopic astigmatism using current excimer laser algorithms.13 However, under-correction or regression of originally acceptable correction occurs in some eyes.14-16 The causes of under-correction and regression are not completely elucidated. Some possible contributory factors include corneal epithelial hyperplasia, the molecular memory of corneal stromal collagen, stromal remodeling and intraocular pressure.17,18

To date, there are few papers evaluating the results of LASIK retreatments after WF-guided LASIK treatments.18-20 The authors of this study have already evaluated the use of WF-guided LASIK retreatments, which proved to be effective.21

To the best of our knowledge the use of WF-optimized technology for LASIK retreatments with primary WF-guided LASIK for correction of myopia have not been described. The purpose of this retrospective analysis was to evaluate the visual outcome, and safety of WF-optimized LASIK retreatments after prior WF-guided LASIK in myopic patients (as all our primary LASIK patients underwent WF-guided LASIK).

METHODS

Retrospective analyses of 19 eyes of 14 patients whom underwent WF-optimized LASIK following prior WF-guided LASIK procedures were enrolled in this study. All of the primary LASIK procedures were performed with the VisX CustomVue™ laser platform during the interval from August 2005 to April 2010. In all cases, the retreatment was achieved with the Wavelight Allegro™ Eye-Q 400 excimer laser platform. All LASIK procedures were performed at the University of Texas Southwestern Medical Center at Dallas in accordance with Declaration of Helsinki. The retrospective analyses were conducted after the study was approved by the Institutional Review Board. The study group consisted of 14 patients (19 eyes). The mean age of the study group was 53 (37-70) year old.

The inclusion criteria for the study group were: 1) previous LASIK surgery with residual myopia, hyperopia or mixed astigmatism; 2) stable refractive error for at least 3 months prior to retreatment; 3) predictable post-retreatment residual stromal bed of 250 mm or more; 4) no contact lens wear for at least two weeks prior to the baseline evaluation pre-retreatment; 5) WF-optimized procedure was used for the retreatment if WF-guided refraction and manifest were inconsistent or it was a hyperopic retreatment. The main cause for inconsistency was astigmatism axis and amount. Refractions using WF-guided lower orders were assessed, however, if optimal visual acuity was not achieved, WF-optimized retreatment using manifest refraction was performed. The exclusion criteria were: 1) prior retreatment procedure(s); 2) corneal ectasia or keratoconus; 3) decentration of the pupil; 4) prior keratoplasty or intraocular surgery.

The original flaps were created by one of two techniques: in 14 eyes the flaps were cut with the Femtosecond laser (IntraLase™, Abbott Laboratories, Abbott Park, IL, USA); and, in five eyes flaps were cut with the Hansatome™ microkeratome (Bausch+Lomb, Rochester, NY, USA). All retreatments were done by re-lifting the original flap. Patient who had photorefractive keratectomy (PRK) was excluded from the study. The optical zone used was 6.5mm with total ablation zone 9 mm.

The mean pre-retreatment corneal thickness was 502 µm (410 to 590 µm). Complete ophthalmologic examinations were performed on all subjects prior to retreatment including manifest and cycloplegic refractions, UCVA and BSCVA, elevation computerized video keratography, slit lamp biomicroscopy, pneumotonometry, corneal pachymetry, and indirect ophthalmoscopy. Pre-operative data required for the retreatment were collected using the Pentacam® (Oculus Inc., Lynnwood, WA, USA) and WaveLight® Allegro Analyzer (Alcon Inc., Hünenberg, Switzerland). The ophthalmologic examinations were repeated at 1, 3, and 6 months post-retreatments. Pre-retreatment total root mean square (RMS) from third to sixth order- Zernike polynomials was calculated. Post-retreatment RMS was not determined.

The original LASIK procedures were performed by two ophthalmic surgeons (W.B. or J.M.). They utilized the same protocol and technique. Following proparacaine topical anesthesia and cleansing with povidone iodine, the cornea was marked with an eccentric 3 mm optical zone marker with methylene blue to facilitate the repositioning of the flap. Then,
the flap was lifted by dissection with a Sinskey hook, lifted and retracted with a forceps. This created a sharp delineation along the epithelial edge. Ablation was performed and the flap was repositioned to ensure that no epithelium was introduced in the interface. Post-retreatment the eye was treated with a topical antibiotic and corticosteroid four times a day for one week. The antibiotic was discontinued and the corticosteroid was tapered and stopped a one-month post-retreatment.

Statistical analyses were performed to compare various parameters prior to and 1, 3, and 6 months post-retreatment. A p value of ≤0.05 was considered statistically significant. The Snellen visual acuity results were converted to logarithms of the minimum angles of resolution (LogMAR) and then statistically analyzed.

RESULTS

The refractive error data comparing original pre-operative, pre-retreatment, and the three post-retreatment evaluations are summarized in Table 1. The mean sphere before the primary LASIK procedures was -5.0 ± 2.1 D (-9 to -1.5 D) and the mean cylinder was +0.6 ± 0.4 D (0 to +1.75 D). Prior to the retreatment LASIK, the mean sphere was -1.0 ± 1.2 D (-3.0 to +1.0 D) and the mean cylinder was +1.0 ± 0.5 D (0 to +2.0 D). At 6-months post-retreatment the mean sphere was -0.3 ± 0.2 D (-0.5 to 0 D) (p-value 0.022) and the mean cylinder was 0.12 ± 0.2 D (0 to 0.75 D) (p-value 0.025). The MRSE before the initial LASIK procedure was -4.7 ± 2 D (-8.8 to -1.25 D) and at 6-months post-retreatment was -0.2 ± 0.2 D (-0.4 to 0 D) (p-value 0.003). At 6-month post-retreat all eyes were within ±0.5 D of emmetropia (Figure 1).

The visual acuity results are tabulated in Table 2. The mean UCVA LogMAR improved from a pre-retreatment value of 0.27 ± 0.18 to a post-retreatment value of 0.01 ± 0.05 at the 6-month visit (p<0.001). The BSCVA was 0.0 ± 0.05 and reached -0.03 ± 0.05 at the 6-month post-retreatment visit (p=0.38). No patient lost one or more lines of vision and 37% gained one line of vision (Figure 2). A comparison between pre-retreatment BSCVA and post-retreatment UCVA at the 6-month visit demonstrates that all patients achieved 20/25 or better UCVA following retreatment (Figure 3). There were no complications associated with the retreatment procedure.

Table 1. Pre-operative, pre-retreatment and post-retreatment values of refractive error

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Pre-retreatment</th>
<th>PRM 1</th>
<th>PRM 3</th>
<th>PRM 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphere (D)</td>
<td>-5.0 ± 2</td>
<td>-1.0 ± 1.2</td>
<td>-0.2 ± 0.4</td>
<td>-0.1 ± 0.2</td>
<td>-0.3 ± 0.2</td>
</tr>
<tr>
<td>Range (D)</td>
<td>-9 to -1.5</td>
<td>-3 to 1</td>
<td>-1.25 to 0.5</td>
<td>-0.75 to 0.25</td>
<td>-0.5 to 0</td>
</tr>
<tr>
<td>Astigmatism (D)</td>
<td>0.6 ± 0.4</td>
<td>1.2 ± 0.5</td>
<td>0.08 ± 0.2</td>
<td>0.08 ± 0.2</td>
<td>0.12 ± 0.2</td>
</tr>
<tr>
<td>Range (D)</td>
<td>0 to 1.75</td>
<td>0 to 2</td>
<td>0 to 0.75</td>
<td>0 to 0.75</td>
<td>0 to 0.75</td>
</tr>
</tbody>
</table>

PRM= post-retreatment month. *Units = diopter. Values expressed as mean ± standard deviation.

Figure 1. Change in manifest refraction spherical equivalent (MRSE) over time. (PRM = post-retreatment month).

Figure 2. Distribution of best spectacle corrected visual acuity (BSCVA) at 6 months after wavefront-optimized LASIK.
or over the 6-month span following the procedure. Specifically, no flap complications including interface scarring, epithelial ingrowth or haze were observed. Figure 4 shows the pre-retreatment HOA. The pre-retreatment total HOA was 0.48±0.21 (0.24 to 1.01µm) and did not show correlation with the visual outcomes postoperatively.

**DISCUSSION**

In our retrospective analysis, WF-optimized LASIK was evaluated in cases of retreatment for under or overcorrection. The results demonstrate that within the parameters of this pre-retreatment group, WF-optimized LASIK was highly efficacious and safe.

WF-optimized LASIK profile is a population–based aspheric correction of myopia and myopic astigmatism, as well as hyperopia and mixed astigmatism, which preserves the natural aspheric shape of the cornea and neutralizes the laser-induced aberration that typically accompanies conventional laser vision correction.

Multiple studies have compared WF-guided with WF-optimized platforms for primary LASIK surgery. Moshirfar et al. and Awwad et al. compared outcomes of WF-guided LASIK with the Custom-Cornea platform (Alcon) and the WF-guided platform Visx S4 Star (Abbott Medical Optics); Moshirfar et al. reported a slight advantage for the Visx S4 WF-guided platform and Awwad et al. for the other platform. Padmanabhan et al. compared WF-guided and WF-optimized treatments and found no statistically significant differences in visual acuity or refractive outcomes; however, they did find a statistically significant difference in the induction of HOAs, with WF-guided technology outperforming WF-optimized technology. Stonecipher and Kezarian found similar equivalent acuity and refractive outcomes between WF-guided and WF-optimized treatments and found that only small subpopulations of eyes with high preoperative aberrations benefited from WF-guided treatments. Brint found that WF-guided technology induced fewer HOAs, especially coma, than WF-optimized treatments. In contrast, Tran and Shah found no significant differences between the 2 platforms.

Several studies approached the use of WF-guided LASIK retreatment but to the best of our knowledge we are the first to

| PRM= post-retreatment months; UCVA= uncorrected visual acuity; BSCVA= best spectacle corrected visual acuity; MRSE= manifest refraction spherical equivalent; UCVA & BSCVA = logMAR scale. *Units = diopter. |

<table>
<thead>
<tr>
<th></th>
<th>Pre-retreatment</th>
<th>PRM 1</th>
<th>PRM 3</th>
<th>PRM 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCVA</td>
<td>0.27±0.18</td>
<td>0.03±0.09</td>
<td>0.03±0.09</td>
<td>-0.01±0.05</td>
</tr>
<tr>
<td>BSCVA</td>
<td>0.0±0.05</td>
<td>-0.02±0.04</td>
<td>-0.01±0.04</td>
<td>-0.03±0.05</td>
</tr>
<tr>
<td>MRSEa</td>
<td>-0.5±1.2</td>
<td>-0.12±0.3</td>
<td>-0.1±0.2</td>
<td>-0.2±0.2</td>
</tr>
</tbody>
</table>

Table 2. Values of UCVA, BSCVA and MRSE over follow-up time

**Figure 3. Pre-retreatment best spectacle corrected visual acuity (BSCVA) versus post-retreatment uncorrected visual acuity (UCVA) at 6 months.**

**Figure 4. Pre-retreatment total high order aberrations (HOA).**
report the use of WF-optimized LASIK in cases of retreatment. Brahma et al. used WF-guided LASIK retreatment, which yielded less predictability than our WF-optimized technique at 6 months. A higher percentage of eyes receiving WF-optimized were within ±0.50 D (100% in our study compared to 58%). Montague and Manche conducted a study on WF-guided LASIK retreatment (Visx S4) on 120 eyes. Their study reported 83% of eyes with SE within ±0.5D at a 3 months follow-up, compared with 100% of eyes with WF-guided LASIK at 3 months in our study. Mohamed et al. investigated retreatment on 77 eyes and reported that in our study. Mohamed et al. investigated retreatment on 77 eyes and reported that in our study. Mohamed et al. investigated retreatment on 77 eyes and reported that in our study.

Our experience with WF-optimized LASIK for retreatments documents that this procedure achieves emmetropia in all patients. The results appear stable in terms of refractive error, BSCVA and UCVA. In our study a slight residual myopia was targeted based on the mean age of our group (53 years old), which is ideal considering their presbyopic state. The safety of the procedure and the lack of post-retreatment complications further validate the use of WF-optimized LASIK for this purpose.

We understand that our study has limitations, such as a small sample size and lack of post-retreatment HOA given that it was a retrospective study. However, our data demonstrates that WF-optimized LASIK seems to be a safe and predictable option to perform retreatments to achieve better visual results.

Further studies are needed to compare standard LASIK retreatments to WF-optimized and WF-guided LASIK retreatments.

Although the LASIK platforms and paradigms continue to improve and the proportion of patients needing retreatments decrease, it is unlikely that the need for retreatments will ever be eliminated. Thus, it is vital that methodologies for successful retreatments be determined.

REFERENCES