EXCIMER LASER ASSISTED IN-SITU KXRATOMILEUSIS FOR HYPEROPIA

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ABSTRACT

INTRODUCTION

While myopia has received the bulk of attention for the past 30 years, hyperopic surgical correction has remained an elusive goal. Hexagonal keratotomy, keratophakia and epikeratophakia, thermokeratoplasty and hyperopic ALK have all shown some promise but have been abandoned due to irregular astigmatism and / or loss of effect over time. Recently, hyperopic PRK has shown promise but with six and seven millimeter optical zones the results often regress due to epithelial hyperplasia. We present a technique using LASIK with a six millimeter optical zone which shows stable and predictable results up to five diopters of hyperopia.

METHODS

We present 14 eyes of 14 patients having undergone Hyperopic Excimer Laser In-Situ Keratomileusis with a VISX Star laser. Mean follow-up was 5 months. These patients represent a variety of preoperative situations including five primary RK, two primary ALK, three primary LASIK and one congenital hyperopia. The remainder are combinations of ALK, RK and LASIK. All patients underwent a torroidal shaped ablation constructed with the use of a 3.5mm diameter soft contact lens used as a blocking agent centrally with a 6.0mm beam profile.
RESULTS
Mean preoperative spherical equivalent was $+1.33 \pm 0.5$ diopters (range, +0.5D to +1.88D). The mean spherical equivalent at one month was $-0.32 \pm 1.2$ diopters (range, -1.25 to +2.63 diopters). The mean postoperative spherical equivalent at last follow-up was $-0.22 \pm 0.6$ diopters (range, -1.25 to +0.5 diopters). 20/40 uncorrected visual acuity was obtained by 13 eyes (93%). No eyes lost two or more lines of best corrected visual acuity at last follow-up. Two eyes required a postoperative LASIK enhancement operation to correct induced myopia. No significant complications were encountered.

CONCLUSIONS
Hyperopic LASIK performed with this technique appears to be safe, predictable and stable and represents a simple way to add the correction of hyperopia to any existing laser system. The advantage of a simple hyperopic correction in this limited range is that nomograms may be targeted to emmetropia rather than overcorrections with a decrease in the rate of reoperations and an improvement in the results of the primary procedure. In addition, the significant problem of hyperopic drift in radial keratotomy may be treated with this technique resolving an otherwise difficult problem and extending the usefulness of radial keratotomy as a primary procedure.
INTRODUCTION

While the correction of myopia and astigmatism has been a focus of intense interest and innovation for the past 30 years with great success, the surgical correction of hyperopia has remained an elusive goal. Many procedures have been proposed with encouraging early results, however with the passage of time, most of these have been abandoned due to the induction of irregular astigmatism and/or loss of effect over time. A good example is keratophakia in which large hyperopic corrections were described with a steep learning curve for a difficult operation with a large scatter of results and 79% losing one line or more of best corrected visual acuity\(^1\). Other studies have confirmed the instability and unpredictability of both keratophakia and epikeratophakia.\(^2,3,4,5,6\)

Hexagonal keratotomy and its variants have been suggested in the past as an effective means of correcting hyperopia however highly variable results and significant complications including large amounts of induced astigmatism and irregular astigmatism have prevented this operation from being used in standard clinical practice.\(^7,8,9,10,11,12,13\)

Another operation that appeared promising in early results was thermokeratoplasty followed by regression of effect.\(^14,15,16,17\) Additionally, complications such as delayed epithelial healing, recurrent epithelial erosions, aseptic stromal necrosis, and melting and vasculization led to withdrawal from general clinical use. Both contact and noncontact holmium: YAG laser thermal keratoplasty have attempted to improve upon the previous results with fewer complications although evidence suggests the same significant
regressions of effect with the progression of time with minimal clinical impact\textsuperscript{18}. (private communication with Marvin Quitko (March, 1997))

Hyperopic ALK is a technique which proposes to steepen the central cornea by means of a "controlled" ectasia by creating a deep lamellar incision in the cornea. The problem has been that the technique appears unpredictable and the ectasia may or may not occur along or near the visual axis.\textsuperscript{19} Several significant complications have been reported with previous radial keratotomy and despite early optimism even in eyes with no previous corneal surgery the induction of irregular astigmatism with contaminant loss of best corrected visual acuity and glare has gradually pushed this procedure out of the realm of clinical practice.

With the tremendous success of excimer laser photorefractive keratectomy in reshaping the cornea, the possibility of torroidal ablations to correct hyperopia has been widely discussed. Although few references appear in the literature,\textsuperscript{20,21} it has been clear that hyperopic corrections performed on the surface with a 6-7mm optical zone appear to have a problem with significant regression due to epithelial hyperplasia in the ablation zone. Larger ablations are possible with special attachments which seem to be either in development or indefinitely tabled in the US due to the FDA. While additional optics to perform hyperopic PRK with larger optical zones are welcome, such ablations will inevitably increase recovery times and perhaps increase the tendency toward superficial haze.
Most recently, the LASIK correction has begun to achieve prominence over the PRK procedure due to a convergence of many factors including rapid visual rehabilitation, less pain, fewer complications particular with respect to superficial haze and the convenience for the process of reoperations. By the nature of the procedure, creating corneal caps larger than 7-8mm has been difficult and hyperopic corrections must be limited by this consideration. In this paper, we present a simple technique which can be utilized with almost any excimer laser to create stable and predictable hyperopic corrections in the five diopter hyperopic range and possibly beyond this range in the future.
PATIENTS AND METHODS

We present 14 eyes of 14 patients having undergone the Hyperopic LASIK procedure. The mean follow-up was 4.7 ± 3.3 months. Patients included in this study had a mean preoperative spherical equivalent was +1.49 ± 0.8 (range, +0.50 to +4.0) diopters. No patients had worse than 20/40 best corrected visual acuity preoperatively. Preoperatively each patient had less than one diopter change in refraction over a two year period as verified by previous medical records.

In this study, 6 patients (43%) were male and 8 patients (57%) were female. The average age was 51 ± 6 years (range, 36 to 60 years).

TECHNIQUE

Each of the cases in the study was performed by a single surgeon (KAB) with the Steinway automated keratome system (#141). Preoperatively we gave each patient 10mg of Valium and an intramuscular injection of 25mg of Demerol. Careful attention was paid to avoiding excess airborne debris in the operating room and all participants wore powderless gloves. The eyes were prepped with betadine, the head was draped with cloth towels and lids retracted with two steristrips. An ioban plastic sheet was placed over the eye, incised linearly between the lids, and an open Barraquer wire lid speculum was used to retract the lids, encasing the lashes within the ioban material. Tetracaine was used to anesthetize the eye. Using a monocular aximeter, the eye was marked in succession with a 3mm and 8mm optical zone, an 8-cut RK marker and a semi radial
mark made superiorly centered on the corneal light reflex and stained with methylene blue (Figure 1). The ocular surface was irrigated in order to present a wet cornea for the interface with the microkeratome.

The microkeratome and suction ring were assembled by the surgeon with a 160um plate and suction ring applied, centered on the previous marks. Intraocular pressure was checked with a Barraquer tonometer and seen to be greater than 60mm Hg. The optical zone of the flap cut was measured to be greater than 7.2mm and the microkeratome was placed in position, held only by the electrical cord. The pass was made, stopped by the mechanical stop device resulting in a flap cut. The ring was removed without displacing the flap.

A disposable soft contact lens (Acuvue, 8.8mm base curve, -0.5 power) was then placed onto a plastic trephine base and a 3.5mm circular trephine knife (Xomed-Treace, Jacksonville, FL) was used to cut out the occluding material. The lamellar flap was pulled back exposing the stromal bed. The new 3.5mm contact lens was then placed on the bed, centered over the visual axis (Figure 1). The patient was then centered under a Star excimer laser. A 6.0 optical zone “PTK” ablation was performed using no transition zone, centered over the contact lens (Figure 2). After the ablation the contact lens was removed revealing a circular, peripheral ablation (Figure 3). The edges of the central elevation were gently scraped with the back side of a Paufige corneal knife to remove any elevated edges (Figure 4).
The bed was dried with a merocel weak sponge and the appearance of the hyperopic correction was noted for centration. The bed was flooded and the flap laid back with the canula without forceps, vigorous irrigation was performed beneath the flap and a "squeegee" motion was performed below the flap to remove excess moisture. The flap was realigned with the marks from the eight cut RK marker using "squeegee" pressure from the irrigating canula without the use of forceps. The edge of the flap was dried with a partially moistened merocel sponge and the center of the flap was moistened with one to two drops of balanced saline. The flap was dried for seven minutes and at the conclusion of drying, adherence was checked by placing gentle pressure just outside the edge of the flap with a dry merocel sponge. Any question concerning adherence of the flap was followed by additional drying time of one to three minutes. A blink test was performed at the conclusion of the procedure to assure flap adherence.

A drop of Ciloxin (Alcon, Fort Worth, TX) ophthalmic drop was placed on the cornea, the lid speculum and drapes were removed and the eye was patched with a non-pressure dressing consisting of crossed segments of ½” 3M Transpore tape with a shield. The patient was sent home with a narcotic pain pill to be taken upon arrival home and taken every three to four hours as needed. The day following surgery the patch was removed only by the surgeon (KAB) and the patient was placed on Pred Forte and Ciloxin drops for three to four weeks.

NOMOGRAM
Table 2.
RESULTS

We present 14 eyes of 14 consecutive patients who underwent hyperopic excimer laser in-situ keratomileusis in chronological sequence. All operated were conducted by one surgeon (KAB).

The mean overall follow-up was $4.7 \pm 3.3$ months (range, 0.3 to 11 months). Follow up was obtained for 10 eyes at one month, 8 eyes at two months, and 4 eyes at 3 months and 7 eyes at greater than 6 months after the initial LASIK.

SPHERICAL EQUIVALENT

The mean preoperative spherical equivalent was $+1.49 \pm 0.8$ diopters (range, $+0.5$D to $+4.0$D)

At one month the study experienced a mean spherical equivalent of $-0.32 \pm 1.2$ diopters (range, $-1.25$ to $+2.63$ diopters). At one month, 7 eyes (70%) of were within one diopter of emmetropia and 10 eyes (100%) were within two diopters of emmetropia.

At last overall follow-up, the study achieved a spherical equivalent of $-0.22 \pm 0.6$ diopters (range, $-1.25$ to $+0.5$ diopters). 11 eyes (79%) were within one diopter of emmetropia and 14 eyes (100%) were within two diopters of emmetropia. 3 eyes (23%)
were myopically overcorrected by more than one diopter and none were hyperopically undercorrected by more than one diopter. (Figure 5)

ASTIGMATISM

The mean preoperative refractive cylinder was $1.05 \pm 0.5$ diopters (range, 0D to 2.0D). At last follow-up the mean refractive cylinder was $0.94 \pm 0.6$ diopters (range, 0.25D to 2.0D).

The mean preoperative keratometric cylinder was $1.89 \pm 1.1$ diopters (range, 0.5D to 4.63D). At last follow-up the mean keratometric cylinder was $1.38 \pm 0.7$ diopters (range, 0.25D to 3.12D).

VISUAL DATA

At one month follow-up, 20/20 uncorrected visual acuity was obtained by 3 eyes (27%). 20/40 or better was obtained by 7 (63%). 20/80 or better was obtained by 11 (100%).

At last overall follow-up 20/20, 20/40 or better and 20/60 or better uncorrected visual acuity was obtained by 3 eyes (21%), 13 eyes (93%) and 14 eyes (100%) respectively.
One eye (7%) lost one line of best corrected visual acuity at last follow-up. No eyes lost more than one line.

ENHANCEMENT PROCEDURES

The enhancement procedure for this study consisted of lifting the lamellar flap in the postoperative period and using an additional laser ablation. This procedure was required for 3 (21%) eyes in the study. Preoperative values for these eyes are on Table 1.

Eye #1 had an initial 4 diopter hyperopia which is the largest correction attempted in the series. As a conservative first treatment the patient was given a 20 micron ablation with the 6.0 toric zone described above and a resulting undercorrection was obtained. An additional 10 micron hyperopic correction was applied for a total of 30 microns resulting in 20/20 uncorrected vision at seven months in close agreement with the predicted result by our nomogram (Figure 6).

Eye #4 required a myopic enhancement one month after the initial LASIK. His pre-enhancement refraction was $-3.25 \pm 3.75 \times 90$ with a best corrected visual acuity of 20/30 and an uncorrected vision of 20/50. At last follow up 7 months after this enhancement, the refraction improved to $-0.75 \pm 0.75 \times 14$ with a best corrected visual acuity of 20/30 and an uncorrected vision of 20/30.
Eye #13 required a myopic enhancement two months after the initial LASIK. Her pre-enhancement refraction was \(-2.25 \pm 3.5 \times 89\) with a best corrected visual acuity of 20/40 and an uncorrected vision of 20/100. At last follow up 5 months after this enhancement, the refraction improved to \(-1.25 \pm 0.25 \times 57\) with a best corrected visual acuity of 20/30 and an uncorrected vision of 20/60.
CONCLUSIONS

These results show that hyperopia up to 5.0 Diopters can be treated successfully, safely and predictably with hyperopic LASIK.

SAFETY

In this study we had no significant complications, no problems with epithelial ingrowth, interface haze, lifted flap or indeed any complications related to the flap. One issue that we feel is of particular importance is the issue of centration and the importance of properly centering the procedure relative to the central axis. In the series reported by Dausch et al,20, decentration of the optical zone created significant complications with respect to best corrected visual acuity. One advantage of our technique is that the patient can visualize the fixation target through the contact lens and the reflection of this light can be seen on the lens facilitating centration of the procedure. No unplanned decentration was observed in any of the cases that we performed by this procedure. In addition, not only did we not lose more than one line of best corrected visual acuity in any case, in fact with respect to BCVA the majority of the patients stayed the same or improved after the procedure. Another significant complication which was avoided in this series was corneal haze which was reported in the midperiphery by Dausch et al. In distinction to that series, none of our patients had significant haze following the procedure and all epithelial defects were healed the next day as opposed to an epithelial defect which took 3-5 days to heal with the PRK.
It is our personal observation that this procedure is much safer than hyperopic ALK, in a small series we had two flaps lift the day after surgery due to the thickness of the flap with hyperopic ALK, one case of a two line loss of BCVA in a well centered HALK correction, and in all of the HALK corrections the ectasia was either slightly decentered and/or irregular inducing either regular or irregular astigmatism. While the publications in this area are limited even the relatively good results reported in this paper needed to be weighed against two cases of epithelial ingrowth, a normally rare complication. In addition, Lindstrom has stated publicly HALK should not be used after RK (personal communication, ASCRS, Seattle, 1996). In distinction to the several cases presented in the series which safely stated hyperopia after RK

Glare appears to be significant problem after hyperopic PRK although the larger corrections attempted may be responsible for this phenomenon. Dausche et al\textsuperscript{20} reported increased glare in almost all patients and subjective symptoms glare within the first 12 months after surgery. In our patients, there were no subjective complaints of glare in any of the patients and glare testing showed no significantly diminished vision after the procedure.

**PREDICTABILITY**

In this low range of hyperopic correction this procedure appears to be very predicable (85% +/- 1 Diopter in addition to one successful case of planned myopia for monovision).
The numbers compare to 80% +/- 1 diopter for hyperopic PRK and only 41% +/- 1 diopter at 6 months for hyperopic ALK. It should be noted however that the range of attempted corrections in both the hyperopic PRK and ALK were generally much larger than the corrections noted in this paper with the exception of case #1 (Figure 6). Nonetheless, the advantages of even relatively small and predictable corrections are immense, allowing more aggressive primary myopic nomograms with a subsequent decrease in the need for secondary operations.

**Efficacy**

The goal of these refractive surgeries is to produce good uncorrected visual acuity and in our series 93% of our patients were able to obtain 20/40 or better uncorrected vision. This compares to 80% 20/40 or better vision for patients with hyperopic PRK, and 76% 20/40 or better at one month for hyperopic ALK with an improvement to 87% 20/40 or better at six months.

**Stability**

We have found this procedure to be very stable with an extremely rapid return of vision within a few days of the procedure. This compares to a fairly slow recovery after hyperopic ALK with spherical refractive error relatively stable at one month and refractive astigmatism stabilizing at three months. Hyperopic PRK results appear to stabilize at one year. Even these results are better than the hyperopic
thermokeratoplasty which tends to regress almost completely over a one year period and as holmium YAG laser data becomes more available, regression appears to be along the same lines.

In summary, this study suggests that for small degrees of hyperopia, predictable, safe and stable corrections can be obtained in a wide variety of patients including patients who have previously undergone lamellar and incisional refractive surgery. The procedure is simple and by its nature, allows good centration avoiding complications reported in previous operations. As we have stated above, the ability to correct even small amounts of hyperopia has wide ramifications with respect to hyperopia after RK, particularly hyperopic shift positively influencing the decision to perform radial keratotomy as a primary procedure. In addition, since overcorrections can be treated equally well as undercorrections after lamellar refractive surgery, construction of nomograms may be directed toward achieving a plano result instead of a deliberate undercorrection improving satisfaction with the primary procedure and improving the number of postoperative enhancements.

While the number of patients with high degrees of hyperopia is limited in this study we are currently investigating the effectiveness of the procedure on this population with a greater number of eyes. At this time we feel that hyperopic correction represents an exiting new procedure in the refractive surgical armamentarium.
LEGEND

Figure 1. A trephined 3.5mm diameter contact lens is placed centrally over the visual axis.

Figure 2. A 6.0 diameter optical zone ablation is performed over the contact lens.

Figure 3. The contact lens is removed after the ablation revealing a circular, peripheral correction.

Figure 4. The edges of the central elevation are scraped with the back side of a Pauflque corneal knife to remove any elevated edges.

Figure 5. Mean spherical equivalent over time. Error bars represent standard deviation.

Figure 6. Videokeratography of eye #1. The preoperative refraction was +4.00 and a two step 30 micron ablation was used to achieve a final uncorrected visual acuity of 20/20.

Table 1. Preoperative characteristics of the 14 eyes involved in this study.

Table 2. Nomogram for hyperopic LASIK correction. Depth is indicated for use with a 6.0mm diameter optical zone ablation with a centrally placed 3.5mm diameter contact lens.


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Table 2.
**Figure S**

**Buzard and Funderland**

**Time**

Months
- Preop
- 1 week
- 1 month
- 2 months
- 3 months

Spherical Equivalent (Diopters)

1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

---

**Spherical Equivalent (Diopters)**
BUZARD AND FUNDINGSLAND

FIGURE 6