LASIK COMBINED WITH OTHER PROCEDURES

JONATHAN D. PRIMACK AND DIMITRI T. AZAR

The excimer laser revolutionized the field of refractive surgery and greatly facilitated its acceptance into mainstream ophthalmology. As techniques evolved, laser-assisted in situ keratomileusis (LASIK) replaced photorefractive keratectomy (PRK) as the procedure of choice given its lack of postoperative pain, quick visual rehabilitation, and ability to treat higher degrees of ametropia. LASIK has been shown to be a safe and efficacious technique for the correction of myopia, hyperopia, and astigmatism, but limitations exist (1–6). These limitations have inspired surgeons to combine LASIK with other ophthalmologic procedures for the correction of both naturally occurring and postsurgical refractive error.

Combining LASIK with other technologies appeals to the refractive surgeon for several reasons. First, it may allow for the successful treatment of high myopia and astigmatism beyond what is generally considered the safe range for LASIK (approximately 10 diopters (D) of myopia and 5 D of astigmatism). Higher levels of myopia cannot be treated with deeper excimer laser ablations because a sufficient amount of corneal stromal tissue must remain to guard against potential keratectasia and refractive instability (7,8). Current recommendations suggest a minimal residual stromal bed thickness of approximately 250 μm. This precludes the application of highly myopic ablations, especially in those patients with thinner corneas. The residual myopia remaining after a maximal LASIK treatment could be corrected by combining LASIK with another refractive procedure that does not involve the removal of stromal tissue.

In eyes with moderate to high myopia and low pachymetry values, concerns over residual stromal bed thickness and potential iatrogenic keratectasia may preclude full LASIK correction or limit retreatment options should regression occur. These patients could also benefit from a combined approach that reduced ablation depth by redistributing part of the LASIK-dependent correction to another procedure. Reports of keratectasia occurring in patients with residual stromal beds greater than 250 μm suggests that less central stromal tissue removal may be safer (9–11). Additionally, decreasing the magnitude of refractive error to be corrected by LASIK may allow for the use of larger optical zones (OZs) with a smaller chance of subjective optical disturbances.

A last theoretical advantage of combining LASIK with another procedure is adjustability. If the additional technology is reversible or adjustable, it could allow for subsequent refractive changes desired by the patient.

COMBINATION OF LASIK WITH OTHER REFRACTIVE SURGERY TECHNIQUES

Combined LASIK and Incisional Keratotomy

Incisional keratotomy refers to procedures that decrease refractive error by means of almost full-thickness corneal incisions. Their effect is a function of incision length and OZ size. Examples include radial keratotomy (RK) and astigmatic or arcuate keratotomy (AK). These techniques are uncommonly performed today given the more predictable outcomes associated with excimer laser surgery (12).

There is one published report of RK enhancements after LASIK to treat residual myopia. Davin and colleagues (13) reported on 60 eyes of 41 patients treated with combined RK and LASIK for a preoperative spherical equivalent (SE) −8.09 ± 2.60 D (range: −4 to −15.25 D). After the initial LASIK procedure, the SE decreased to −2.02 ± 1.02 D (range: −0.50 to −5.50 D). RK was chosen over LASIK retreatment for several reasons including a residual stromal bed of less than 250 μm, insufficient stromal thickness to safely correct the myopia with LASIK alone (planned procedure), and surgeon preference in the presence of a stromal bed thick enough to safely allow a full LASIK re-treatment. RK was performed using four, six, or eight centrifugal incisions with a 3- to 6-mm OZ. AK was performed if astigmatism greater than 1 D was observed. The mean time between LASIK and RK was 7.3 ± 6.5 months. After RK, the SE decreased to −0.43 ± 0.61 D (range: −2 to +0.75 D).
There are multiple theoretical concerns when performing incisional keratotomy on a post-LASIK cornea. First, multiple incisions could potentially lead to epithelial ingrowth under the LASIK flap. Second, it may be difficult to predict the patient’s response given the presence of a thinned cornea. Third, RK incisions could further weaken an already thinned cornea, resulting in iatrogenic keratoclastic. Alternatively, a thinned cornea may develop pronounced flattening with a greater progressive hyperopic shift than has been observed with RK alone (14). Fourth, there may be a risk of the flap separating into fragments if the patient ever sustains corneal trauma or needs to have the flap relifted [i.e., for late diffuse lamellar keratitis (DLK)].

Damiano et al. (13) reported none of these complications after a mean follow-up time of 15.4 months. No eye lost two or more lines of best spectacle-corrected visual acuity (BSCVA), and all eyes had a BSCVA of 20/30 or better. Three patients with sufficient stromal bed thickness desired a LASIK enhancement after the RK procedure and this was performed uneventfully by lifting the original flap. All three eyes had an uncorrected visual acuity (UCVA) of 20/20 after the second LASIK treatment. Postoperative complications included mild glare and halos (23%), diurnal fluctuation (10%), and distorted vision (4%).

AK was most often used in conjunction with LASIK before the United States Food and Drug Administration (FDA) approved astigmatic excimer laser ablation corrections. Surgeons could perform AK to decrease a patient’s astigmatism, followed by LASIK several months afterward to treat the residual spherical error. Some surgeons still combine AK with LASIK for select patients. These include individuals whose astigmatism exceeds that amount for which the laser is approved to correct and those patients with larger pupils who are at risk for optical aberrations with an excimer induced elliptical OZ.

Guell and Vazquez (15) described a staged procedure combining AK and LASIK to treat high astigmatism in 15 eyes. Thirteen of the eyes had naturally occurring astigmatism and two of the eyes had surgically induced astigmatism resulting from a phacoemulsification and a penetrating keratoplasty. AK was performed initially followed by LASIK 3 to 6 months later. The preoperative mean SE and the mean refractive astigmatism were $-2.47 \pm 3.69$ D (range, $-3.25$ to $+1.50$ D) and $-4.59 \pm 1.66$ D (range, $-3.25$ to $-8$ D), respectively. After both procedures, the mean cylinder power decreased to $-1.21 \pm 1.07$ D and the mean SE measured $-0.09 \pm 1.50$ D (12-month follow-up). One eye lost a line of best corrected visual acuity (BCVA) and two eyes gained one and two lines, respectively. No patients experienced epithelial ingrowth through the AK incision sites. No other complications occurred.

Limbal relaxing incisions (LRIs) to reduce astigmatism have also been reported in conjunction with LASIK (16). Unlike AK, LRIs are placed more peripherally near the limbus and are usually only 600 µm in depth. Their location places them outside of the lamellar corneal flap. LRIs are less effective than AK, but have the theoretical advantage of inducing less irregularity.

A role may exist for incisional keratometry after LASIK to treat topographic irregularities. Pulaški (17) reported both AK and combined AK/RK to treat asymmetrical steep island in seven eyes after LASIK. Patients complained of poor UCVA and unwanted optical side effects. After undergoing the incisional secondary procedure, the SE decreased from $-0.94 \pm 0.46$ D to $-0.21 \pm 0.12$ D. Optical aberrations were reduced in all patients and the average UCVA improved from 20/40 to 20/25. Two patients experienced interior steepening, and one microperforation occurred. No eyes lost two or more lines of BSCVA. The author suggested that this technique might be helpful in similar patients until topographically guided custom excimer laser ablations become available for the management of this problem.

The limited data available suggest that combined LASIK and AK/RK may be a safe procedure. Incisional keratotomy is an extracorneal procedure (although microperforations can occur), it can be performed in an office or laser suite setting, and it does not further compromise corneal thickness. Additionally, accommodation is preserved. Disadvantages include its lack of predictability and stability, its inability to treat high myopia, the potential for flap complications, and its lack of adjustability and reversibility. We do not recommend performing RK primarily with a planned secondary LASIK treatment, given the above issues and the potential for healing problems and flap-related complications (18–20).

### Combined LASIK and Phakic Intraocular Lenses

Phakic intraocular lenses (P-IOLs) are designed to correct high ametropia following surgical implantation anterior to the crystalline lens. P-IOLs may be angle fixed (e.g., Nuvita lens, Bausch & Lomb, Irvine, CA), iris fixed (e.g., Artisan lens, Ophthea B.V., Groningen, Netherlands), or located in the posterior chamber (e.g., STAAR, STAAR Surgical, Nidau, Switzerland). P-IOLs have been used for many years in Europe and South America. All models have undergone multiple design refinements to improve safety profiles, and several lenses are currently in FDA trials (21–23).

The practice of combining P-IOLs with LASIK is called biopscias and was first described by Zaldivar et al. (24). The concept's inspiration was the inability of P-IOLs alone to sufficiently correct very high degrees of myopia (greater than 15 to 20 D) and astigmatism. A P-IOL thickens with increasing power; so concerns about lenticular or endothelial touch limit the lens' clinical utility. Decreasing the P-IOL OZ could mitigate this issue, but that could also
result in glare or halos. The solution was biopics—a P-IOL served to reduce the spherical error and a supplementary LASIK procedure corrected the residual sphere and astigmatism, thus extending the range of correction without compromising P-IOL OZ size (25,26).

Biopics is a two-staged surgical procedure. Topical anesthesia may be used, but a retrobulbar block may be preferred to avoid inadvertent lenticular touch with eye movement. In the first stage, a hinged lamellar corneal flap is created using a microkeratome. The flap is inspected and reflated back into position without performing a laser ablation. The surgeon next fashions a scleral tunnel or clear corneal wound, the length of which is determined by the P-IOL size and material [i.e., foldable material vs. polymethylmethacrylate (PMMA)]. The next steps are determined by the intended location of the P-IOL. If the lens is to reside in the anterior chamber, acetylcholine is injected to induce miosis. This protects the crystalline lens from inadvertent contact and allows proper centering over the pupil. The anterior chamber is then filled with a viscoelastic agent. If the lens is to lie in the posterior chamber, the pupil is dilated preoperatively and viscoelastic is injected into the anterior chamber. Once a P-IOL is inserted into the anterior chamber, it must be manipulated into the proper orientation. Paracentesis sites may be helpful to allow for additional instruments. Depending on lens design, it may be tucked under the iris into the posterior chamber or manipulated so that the footplates reside in the angle or are enclaving iris tissue. If fixated in the posterior chamber, acetylcholine is injected to induce miosis and protect against P-IOL dislocation. If not performed preoperatively, a peripheral iridectomy should be created to prevent angle-closure glaucoma. Viscoelastic is then exchanged for balanced salt solution (BSS) and the incision may be sutured closed if necessary. Figure 80-1 illustrates these steps with the Artisan P-IOL. The target SE following P-IOL placement is low to moderate myopia.

The second stage of biopics is the excimer laser ablation, which occurs 3 to 5 months later once the refractive error has stabilized and all sutures have been removed (Fig. 80-2). The flap is reflated and the laser applied to treat the remaining refractive error. The flap is then reflated back onto the stromal bed.

Some authors have deferred creation of the LASIK flap until the second stage of the procedure (24), but theoretical safety concerns suggest that the surgical steps proceed in the aforementioned order. For instance, creating the LASIK flap prior to insertion of the P-IOL may prevent potential intraocular P-IOL movement during the microkeratome pass. This theoretically avoids P-IOL, endothelial touch in the case of anterior chamber lenses and P-IOL, and lenticular contact in the case of posterior chamber lenses. It may also preclude posterior chamber lenses from dislocating during the temporary mydriasis that occurs with suction ring application. The disadvantage of creating the LASIK flap during the first stage is the need to reflt the flap for the second stage, which may increase the risk of epithelial ingrowth (28).

The suggested indications for biopics include myopia greater than 15 to 18 D or myopia greater than 11 D with more than 1.50 to 2 D of astigmatism (24,29,30). A thorough preoperative examination is necessary including an evaluation of the corneal topography, corneal thickness,
cycloplegic refraction, pupil size in scotopic conditions, anterior chamber depth, endothelial cell counts, and retinal periphery. Contraindications include a history of corneal irregularity (i.e., keratoconus), uveitis, glaucoma, shallow anterior chamber (for anterior chamber P-IOLs), low endothelial cell counts (<2,000 cells/mm²), cataract, anterior segment pathology, dry eye, unstable refraction, autoimmune disease, or uncontrolled systemic or eye disease.

The published results of biopics are encouraging and Table 80-1 summarizes the available data. Zaldivar and coauthors (24) reported on 67 eyes that received a posterior chamber STAAR P-IOL followed by LASIK.

### TABLE 80-1. SUMMARY OF VISUAL OUTCOMES FOLLOWING LASIK COMBINED WITH OTHER PROCEDURES

<table>
<thead>
<tr>
<th>Technique</th>
<th>n</th>
<th>Preoperative mean SE (D)</th>
<th>% UCVA ≥ 20/40</th>
<th>% ± 1 D</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>LASIK and RK</td>
<td>54</td>
<td>-8.09</td>
<td>94</td>
<td>NR</td>
<td>Damiano et al. [13]</td>
</tr>
<tr>
<td>LASIK and AK</td>
<td>15</td>
<td>-2.47</td>
<td>53.3</td>
<td>80</td>
<td>Guell et al. [15]</td>
</tr>
<tr>
<td>LASIK and Phakic IOL</td>
<td>67</td>
<td>-20.65</td>
<td>70</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>-23.00</td>
<td>69</td>
<td>85</td>
<td>Zaldivar et al. [24]</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>-18.42</td>
<td>77</td>
<td>100</td>
<td>Guell et al. [30]</td>
</tr>
<tr>
<td></td>
<td>281**</td>
<td>-17.97</td>
<td>89</td>
<td>97</td>
<td>Sanchez-Galeana et al. [31]</td>
</tr>
<tr>
<td>LASIK and ICRS</td>
<td>2</td>
<td>-6.66</td>
<td>67</td>
<td>NR</td>
<td>Zaldivar et al. [32]</td>
</tr>
<tr>
<td>Phacoemulsification and LASIK</td>
<td>34</td>
<td>+4.95</td>
<td>100</td>
<td>100</td>
<td>Primack and Azar [46]</td>
</tr>
<tr>
<td></td>
<td>22***</td>
<td>+5.22</td>
<td>82</td>
<td>83</td>
<td>Pop et al. [52]</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-11.76</td>
<td>82</td>
<td>95</td>
<td>Velarde et al. [54]</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>-15.50</td>
<td>100</td>
<td>100</td>
<td>Probst and Smith [53]</td>
</tr>
</tbody>
</table>

SE, Spherical Equivalent; D, Dipters; UCVA, Uncorrected Visual Acuity; NR, Not Reported; RK, Radial Keratotomy; AK, Astigmatic Keratotomy; IOL, Intraocular lens; ICRS, Intracorneal ring segments; ^, represents number of eyes corrected for distance; *, includes 28 LASIK and 5 PRK patients; ***, may include 67 patients from previously listed study; ****, number of patients myopic vs. hyperopic not reported.
The mean preoperative SE was $-23 \pm 3.60$ D (range, $-18.75$ to $-35$ D). The mean SE decreased to $-6.00 \pm 2.80$ D (range, $-2$ to $-14.38$ D) after implantation of the P-IOL. Mean SE after secondary LASIK (3 months follow-up) was $-0.20 \pm 0.90$ D (range, $+1.75$ to $-5.13$ D). UCVA measured 20/40 or better in 46% of eyes. A gain of two or more lines of BSCVA was observed in 76% of eyes.

Guell et al. (29,30) reported their experience using the iris fixed Artisan P-IOL followed by LASIK 3 to 5 months later. The authors preliminarily reported on eight eyes, which was followed by a paper describing their results in 26 eyes. A $-15$ D PMMA lens with a 60-mm OZ was used in all patients. The mean preoperative SE measured $-18.42 \pm 2.73$ D (range, $-16$ to $-23.50$ D) and, after biopics, decreased to $-0.38 \pm 0.65$ D (range, $+1$ to $-1$). After 24 months of follow-up, 100% of patients were $\pm 1$ D of emmetropia and 77% of eyes had an UCVA of 20/40 or better. Endothelial cell counts decreased by a mean of 0.61% in the first year and 0.60% in the second year. It was unclear if this was the result of the Artisan lens or the operative procedure itself.

Sanchez-Galeana and coauthors (31) followed 37 eyes that received the STAAR posterior chamber P-IOL followed by either LASIK or PKR. The authors did not differentiate the results by type of surgery, but 28 of the eyes underwent LASIK. Mean follow-up time measured 8.1 months. Postoperatively, the mean SE decreased to $-0.18 \pm 0.59$ D (range, $-1$ to $+1$) from a preoperative value of $-17.97 \pm 4.89$ D (range, $-9.75$ to $-28$).

Zaldívar and colleagues (32) also reported on 281 patients with STAAR posterior chamber P-IOLs who subsequently underwent LASIK. Data regarding refractive error prior to P-IOL insertion was not provided. It is unclear if this publication included patients from a previous report (24). The mean SE prior to LASIK was $-5.50$ D (range, $-1.37$ to $-16$ D). One month after LASIK the mean SE decreased to $-0.40$ D. BSCVA measured 20/40 or better in 67% of eyes.

Biopics offers several advantages over existing refractive surgery modalities. The most obvious is the ability to treat very high levels of myopia (approximately 25 to 30 D). The anticipated arrival of toric P-IOLs may also allow for concurrent correction of high astigmatism beyond what is currently treatable by LASIK alone (27). Another advantage of the procedure is adjustability. For instance, purposely undercorrected presbyopic patients may have their LASIK flap refitted and their myopia retreated should they later desire emmetropia. Alternatively, the P-IOL may be exchanged for one of a different power. The procedure also preserves accommodation, which is important in younger patients.

The potential disadvantages of biopics include all of those inherent with P-IOLs and LASIK. The first is the inherent risk of endothelialitis associated with intraocular surgery. One must also consider the risks of cataract formation and endothelial cell compromise that have plagued P-IOLs since their conception. Ongoing engineering refinements continue to address these issues; however, at the current time, no P-IOLs have attained FDA approval. Other known complications of P-IOLs include corneal edema, uveitis, glaucoma, decentration, retinal detachment, endophthalmitis, ischemic optic neuropathy, and pupil ovalization (33–36). Risks associated with LASIK include flap complications, overcorrection, undercorrection, irregular astigmatism, glare and halos, DLK, infection, dry eye, epithelial ingrowth, and loss of BSCVA. In the previously described reports, four patients with the STAAR posterior chamber P-IOL developed cataractous changes in the crystalline lens. LASIK complications included an incomplete flap, free caps, dry eye, flap striae, overcorrection, epithelial ingrowth, irregular stromal bed, traumatic flap dislocation, moderate glare and halos, DLK, and transient corneal edema. Two patients experienced macular hemorrhages thought to result from myopic degeneration and not from the surgical procedure (24,29–32). A theoretical disadvantage of biopics is the creation of two new optical surfaces that could adversely influence optical aberrations. Interestingly, Guell et al. (30) found no difference in preoperative and postoperative assessments of contrast sensitivity. No aberrometry studies, however, have been performed on biopics patients. More prospective studies are needed to assess its long-term safety.

**Combined LASIK and Intracorneal Ring Segments**

Intracorneal ring segments (ICRSs) consist of two 150-degree PMMA spacers that produce a hyperopic shift when implanted in the peripheral corneal stroma. The PMMA segments can correct up to 3 D of myopia by shortening the central corneal arc length. The commercially marketed form of ICRS is called Intacs (KeraVision, Inc., Fremont, CA) and is available in several widths (0.25, 0.30, and 0.35 mm). Segments of progressively greater girth produce more pronounced levels of correction (Table 80-2) (34–36).

In phase III FDA trials, 99% of 90 patients with low myopia

| TABLE 80-2. PREDICTED DIOPTRIC CORRECTION FOR INTRASTROMAL RING SEGMENTS BY THICKNESS: Refined Nomogram phase II study results |
|-----------------|------------------|
| Thickness (mm)  | Predicted Average Correction (D) |
| 0.25            | -1.30             |
| 0.30            | -2.00             |
| 0.35            | -2.70             |
| 0.40            | -3.40             |
| 0.45            | -4.10             |

mm, Millimeters; D, Dioptries (From Schanzlin DJ, Asbell PA, Burris TE, et al. The intrastromal corneal ring segments: phase II results for the correction of myopia. Ophthalmology 1997;104:1067–1078.)
### Table 80-3. Surgical Approaches for Combined LASIK and ICRS for High Myopia

<table>
<thead>
<tr>
<th>Method</th>
<th>Step 1: Form Stromal Channels and LASIK Flap</th>
<th>Step 2: Perform LASIK Ablation (% of maximally safe ablation)</th>
<th>Step 3: Place ICRS Segments into Channels</th>
<th>Expected Residual Error</th>
<th>Secondary Procedure (1-5 Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+</td>
<td>100</td>
<td>+</td>
<td>Minimal</td>
<td>Remove or Exchange ICRS</td>
</tr>
<tr>
<td>B</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>2-3 D less than preoperative refractive error</td>
<td>Perform LASIK Ablation</td>
</tr>
<tr>
<td>C</td>
<td>+</td>
<td>70-80</td>
<td>+</td>
<td>2-3 D</td>
<td>LASIK Ablation to correct residual error</td>
</tr>
</tbody>
</table>


Treated with Intacs had an UCVA of 20/40 or better and 92% of eyes were ±1 D of their intended correction (40). In April 1999, Intacs were FDA approved for the treatment of low myopia (1 to 3 D) with 1 D or less of astigmatism.

ICRSs possess specific qualities that make them a potentially valuable adjunct to LASIK (41). Specifically, the dissimilarity between the underlying mechanisms responsible for the induced corneal flattening suggests that the procedures can be additive. ICRS surgery does not remove central stromal tissue, so one could expect it to safely correct up to 3 D of residual myopia after a maximal LASIK treatment. Combining LASIK and ICRS implantation may provide a means to safely expand the range of high myopic correction without further compromising corneal thickness and stability. A second advantage is that the effect is adjustable and the final refractive result can be titrated by exchanging the ring segments (42). If the patient was dissatisfied, the segments could be removed altogether with an almost complete reversal of the refractive effect (37,40). Potentially, the refractive effect could be adjusted months to years postoperatively. A third advantage is that accommodation is preserved, which is important in younger patients. Additionally, the technique spares the visual axis of surgical manipulation. The PMMA segments are placed deep in the peripheral cornea and would not be expected to interfere with the centrally located corneal flap. ICRSs also maintain the natural prolate shape of the cornea, which may be associated with less optical aberrations than the oblate shaped cornea induced with excimer laser surgery (43-45). Finally, both LASIK and ICRS are extraocular procedures, so intraocular surgery and its attendant risks [e.g., retinal detachment (RD), endophthalmitis, uveitis, cataaract, corneal edema, etc.] are avoided.

In patients with high myopia, LASIK and ICRS treatments may be performed as simultaneous or staged procedures. Table 80-3 describes three different surgical approaches (A to C) from which to choose when performing the techniques together. Figure 80-3 schematically illustrates method A. The implantation of ICRS may be performed in a laser suite setting. Topical anesthetic drops and antibiotics are administered preoperatively. Peri- or retrobulbar anesthesia is unnecessary and could interfere with patient fixation if concomitant LASIK were also planned. Contraindications to the combined surgery include the standard contraindications to LASIK surgery.

#### Step 1:
1A

#### Step 2:
2A

#### Step 3:
3A

**Figure 80-3. A-C: Surgical steps of combined LASIK and intrastromal corneal ring segments (ICRS) procedure. Step 1: Creation of ICRS channels. Step 2: LASIK flap and excimer laser ablation. Step 3: Insertion of ICRS. (From Primack JD, Farah SG, Azar DT. LASIK and intrastromal corneal ring segments (ICRS). In: Azar DT, Koch DD, eds. LASIK—fundamentals, surgical technique, and complications. New York: Marcel Dekker, 2003:335-349, with permission.)**
The surgical procedure is straightforward, but does require some unique instrumentation. The center of the cornea is located and an incision and placement marker (KeraVision, Inc., Fremont, CA) is applied to indicate where the PMMA inserts and superior, radial incision will ultimately lie. Ultrasonic pachymetry is performed at the 12 o'clock incision site and an approximately 1-mm incision of 68% corneal thickness is created using a calibrated diamond knife. A modified Suarez spreader may be used to perform a small lamellar dissection at the base of the incision, so as to create an entry pocket on either side. Next, a Vacuum Centering Guide (KeraVision, Inc., Fremont, CA) is positioned on the globe and stabilized under high suction. Specially designed dissectors measuring 0.9 mm are then introduced through the incision (clockwise and counterclockwise) to create stromal tunnels by blunt dissection. Ideally, the channels are located at two-thirds corneal depth. Suction is then released and the centering guide removed.

Once the channels have been created, a microkeratome is used to create a corneal flap. Based on the patient's intraoperative pachymetry value, the maximal excimer laser ablation considered to be safe is performed. Subsequently, the flap is refloated into place. Using forceps, the PMMA segments are introduced into the channels. In their final position, the segments are located 3 mm apart superiorly. If necessary, the flap could be refloated to eliminate any interstitially induced wrinkles. The incision site may be hydrated, or, alternatively, closed with 10-0 nylon sutures. Postoperatively, if the patient possesses mild anepithelia or later desires undercorrection to ameliorate pre-refractive symptoms, the ICRS may be removed or exchanged.

The presence of empty intralamellar channels in the corneal periphery should not interfere with performing LASIK. This becomes evident when one considers the spatial relationships between the channels, hinged corneal flap, and excimer laser OZ. The Intacs segments lie at two-thirds stromal depth, and have an inner diameter of 6.9 mm and an outer diameter of greater than 8 mm. A hinged corneal flap of 8.5 to 10 mm would cover the tunnels, but its anterior location would make intersection extremely unlikely. The flap could potentially incur a small, full-thickness defect where the microkeratome crosses the superior incision site, but that is of negligible clinical significance.

For illustrative purposes, let us consider a cornea with a peripheral thickness of 700 μm at the Intacs incision site and a central thickness of 550 μm. The empty tunnels (following dissection) are located 466 μm from the surface (two-thirds the depth of 700 μm). An 8.5-mm-wide flap measuring 160 μm thick would leave 306 μm of tissue that would have to be ablated from the stromal bed before the channels were penetrated (466 − 160 μm = 306 μm). This is a not a concern clinically for two reasons. First, most myopic excimer laser ablations have a 6.5-mm OZ that is central to the more peripherally located tunnels (inner diameter 6.9 mm). Second, if larger OZs were used, concerns about adequate residual central corneal thickness would preclude ablations deep enough to encounter the peripherally located tunnels.

Methods B and C (Table 80.3) are similar to method A except that the laser ablation is initially withheld or is partially performed, respectively. The remainder is completed later as a secondary procedure. An advantage of these techniques is that the surgeon can incorporate any ICRS-induced refractive changes (including astigmatism) into the final LASIK ablation.

Patients with a moderate degree of myopia could also benefit from combined LASIK and ICRS surgery (41). Up to 3 D of myopia could be treated with ICRS, sparing precious central stroma and improving corneal stability. Another advantage of this procedure is that surgeons could easily exchange ring segments with a resultant myopic shift if patients decided postoperatively that they wanted to become undercorrected to reduce pre-surgical symptoms. If this change was dissatisfying, the ICRS could be re-exchanged to restore the previous refraction.

As in the previous section, the surgeries could be performed simultaneously using multiple approaches (Table 80-4). In method A, a 70% to 80% LASIK ablation is performed (depending on intended final refraction) fol-

---

**TABLE 80.4. SURGICAL APPROACHES FOR COMBINED LASIK AND ICRS FOR MODERATE MYOPIA**

<table>
<thead>
<tr>
<th>Method</th>
<th>Step 1: Form Stromal Channels and LASIK Flap</th>
<th>Step 2: Perform LASIK Ablation (% of maximally safe ablation)</th>
<th>Step 3: Place ICRS Segments into Channels</th>
<th>Expected Residual Error</th>
<th>Secondary Procedure (1-5 Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+</td>
<td>70-80</td>
<td>+</td>
<td>Minimal</td>
<td>ICRS Exchange or LASIK</td>
</tr>
<tr>
<td>B</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>3 D less than pre-operative refractive error</td>
<td>Perform LASIK Ablation for Remaining Myopia</td>
</tr>
<tr>
<td>C</td>
<td>+</td>
<td>70-80</td>
<td>-</td>
<td>2-3 D</td>
<td>ICRS placement</td>
</tr>
</tbody>
</table>

ollowed by ICRS implantation. Once the refraction has stabilized, either the ring segments can be exchanged or the LASIK treatment enhanced by relifting the flap. Alternatively, in method B, only the ICRSs are put into place initially. The LASIK ablation follows as a secondary procedure after the corneal curvature stabilizes. Another approach (method C) is to perform 70% to 80% of the LASIK ablation initially followed by ICRS implantation 1 week postoperatively to correct residual myopia. This technique may be less desirable as the ring segments may induce astigmatism that could require a third surgical visit for LASIK enhancement.

Primack and Azar (46) reported on two eyes that received combined LASIK and ICRS. Both patients were high myopes with low pachymetry values that precluded full treatment of their refractive error with LASIK. Preoperative examinations revealed no signs of keratoconus. The first patient had a preoperative refraction of $-7 \text{ D}$ and a corneal thickness of $490 \mu\text{m}$. The patient underwent ICRS tunnel formation followed by a $-4 \text{ D}$ LASIK correction. A theoretical residual stromal bed thickness of $309 \mu\text{m}$ remained. Following the LASIK ablation, two $0.25-\text{mm}$-wide PMMA channel inserts were placed into the stromal tunnels. A single 10-0 nylon suture was placed over the ICRS incision and removed after 6 weeks. Three and a half months after surgery the UCVA was 20/30, and the BSCVA measured 20/25 with $+0.50 -1.75 \times 101$. The second patient had a preoperative refraction of $-9.25 -1 \times 180 \text{ OD}$ and an ultrasonic pachymetry measurement of 516 $\mu\text{m}$. Following ICRS tunnel formation, LASIK was performed for a correction of $-5.60 -1.25 \times 175$. A theoretical residual stromal bed thickness of $272 \mu\text{m}$ remained. Following the LASIK ablation, two $0.25-\text{mm}$-wide PMMA channel inserts were placed into the stromal tunnels. A single 10-0 nylon suture was placed over the ICRS incision. Three weeks later the patient had an UCVA was 20/30 and a BSCVA of 20/20+, with $+0.75 -1.50 \times 80$. No complications occurred with either patient. Figure 80-4 illustrates the second patient's corneal topography following each step of the combined surgery.

Combined LASIK and ICRS surgery has some disadvantages and potential risks. A problem sometimes associated with ICRS surgery is corneal flattening in the meridian of the ICRS incision (against-the-rule astigmatic shift). In the two cases cited above, induced astigmatism was also against-the-rule. In patients with high myopia, it may be advantageous to initially perform 60% to 70% of the maximally safe LASIK ablation. This technique allows incorporating ICRS-induced

---

**FIGURE 80-4.** A: Preoperative corneal topography. B: Corneal topography after ICRS tunnel formation and LASIK ablation. C: Corneal topography after segment insertion. (From Primack JD, Farah SG, Azar DT. LASIK and intrastromal corneal ring segments (ICRS). In: Azar DT, Koch DD, eds. LASIK—fundamentals, surgical technique, and complications. New York: Marcel Dekker, 2003:335-349, with permission.)
refractive changes into a later LASIK re-treatment. It also helps avoid an ICRS-induced overcorrection that could result from a greater than expected flattening effect in a thinned stromal bed. Another potential problem is the ICRS incision site. Epithelial ingrowth could occur where it intersects the flap. Additionally, epithelial defects, which occur at the ICRS incision site, could cause DLK. In theory, encountering the stromal tunnels during the microkeratome pass or laser ablation is possible but unlikely. This could occur if the channels were dissected too superficially and with poor centration. Finally, patients with low pachymetry values and high myopia may not be good candidates for the procedure as concerns over residual corneal thickness may preclude LASIK ablations deep enough to provide good UCVA.

The opportunity to implant ICRS in an eye that has previously undergone LASIK may arise if the ablation was deep enough to preclude the safe application of further excimer laser. Patients corresponding to this profile usually include high myopes and patients with thin corneas. Potential candidates should understand that the hyperopic shift expected following ICRS would be no more than approximately 3 D.

It would seem that the technical challenge underlying ICRS implantation following LASIK would be to form the intralamellar channels without disturbing the corneal flap. As discussed earlier, this process requires a suction ring that theoretically could compromise the flap, resulting in wrinkles, dislocation, or potentially avulsion. Preliminary reports of this procedure, however, have been without complications. Fleming and Lorisolo (47) reported a patient who received ICRS 10 months following LASIK that left a residual SE of −3.375 D. Four months after ICRS placement, the patient had an UCVA of 20/20. No flap complications occurred. Lorisolo (48) also presented a series of 15 eyes at the American Society of Cataract and Refractive Surgery (ASCRS) 2000 meeting that underwent Intacs implantation following LASIK. Patients had received their LASIK 6 to 11 months previously and had residual myopia ranging from a SE of −2.75 to −4.75 D. Eight months following ICRS placement, all eyes had an UCVA of 20/25. Once again, no flap complications were observed. ICRS may be a safe procedure following LASIK if enough time is allowed between procedures to ensure adequate corneal flap healing.

Conversely, patients may develop refractive errors after the placement of ICRS. If, over time, a patient with Intacs develops additional nearsightedness, the PMMA spacers may be exchanged for a different thickness to treat up to 3 D of myopia. However, if the error exceeds −3 D or requires cylindrical correction, the patient must consider other refractive modalities. LASIK may be an appropriate option for treating such conditions.

The surgeon must anticipate the potential influence of ICRS when performing LASIK. ICRS and LASIK can coexist on the same cornea without interference; however, the presence of previously placed PMMA spacers could theoretically disrupt proper flap formation. The ICRS could cause tissue distortion that prevents adequate suction or tissue distribution during the microkeratome pass, resulting in an irregular stromal bed surface. At this time it is unclear what effect ICRSs have on LASIK flap formation and which approach is safer, as no reports have yet been published. To avoid potential problems, the surgeon may wish to preoperatively explant the ICRS and then perform LASIK. As discussed in the previous section, the excimer laser ablation should not penetrate deeply enough to affect the channels holding the Intacs segments. Once LASIK has been performed, subsequent changes in refraction could be addressed by simply relifting the flap and ablating further stromal tissue.

**Combined LASIK and Phacoemulsification**

Phacoemulsification is a minimally invasive intraocular surgery that removes the crystalline lens through a small limbal or corneal incision measuring 3 to 4 mm. Axial length, corneal curvature, and desired refractive outcome determine whether the patient is left aphakic or receives an intraocular lens (IOL). IOLs may be minus or plus powered and are sometimes “piggybacked” in order to correct high refractive errors. The success of the procedure is highly dependent on the accuracy of IOL calculation formulas. Although these usually generate accurate estimates of IOL power, undesirable refractive outcomes can occur, especially in patients with high degrees of preoperative ametropia where the formulas tend to be less accurate (49,50). Postoperatively, these patients may complain of poor UCVA from residual refractive error. This may be observed after clear lens extraction (CLE), a procedure in which a clear (noncataractous) crystalline lens is removed (with or without IOL placement) in order to treat high myopia or hyperopia. Historically, postoperative ametropia has been treated with IOL exchange or corrective lenses. Combining phacoemulsification and LASIK, however, provides the refractive surgeon with an improved ability to address residual postoperative refractive error following crystalline lens extraction (51).

The combined LASIK and phacoemulsification procedure is performed in a manner similar to biopsies. First, a hinged corneal flap is created with a microkeratome. After inspection, it is refloated into position without any laser treatment. CLE is performed several weeks later with a postoperative refractive goal of low myopia. After several months, once the refraction has stabilized and all sutures (if present) have been removed, the flap is rellited and the remaining refractive error treated by the LASIK ablation.

It is not absolutely necessary to create the corneal flap prior to CLE. Phacoemulsification wounds are very small and unlikely to compromise flap formation during the microkeratome pass, assuming the incision has had several months to heal. There is, however, a theoretical advantage.
Should the posterior capsule rupture during phacoemulsification necessitating a sulcus fixated posterior chamber IOL, or an anterior chamber IOL, there may be concern over IOL displacement or IOL-endothelial touch during suction ring application. These concerns are negated with the suggested protocol. Interestingly, a study by Zaldivar et al. (32) included three pseudophakic patients who underwent LASIK after neodymium:yttrium-aluminum-garnet (Nd:YAG) capsulotomy. No complications were reported, but these patients all had posterior chamber IOLs with their haptics presumably fibroised inside the capsular bag.

LASIK combined with phacoemulsification (whether for CLE or status postcataract extraction) appears to correct refractive error very well. Pop and coauthors (52) reviewed 34 eyes retreated with LASIK for residual refractive error following CLE for high hyperopia. The mean interval between CLE and LASIK was 69 ± 53 days (range, 30 to 272 days). Postoperatively, 86.9% of patients had an UCVA of 20/40 or better. Probst and Smith (53) reported on two eyes of one patient that underwent combined CLE and LASIK for high myopia. The mean SE decreased from a value of −15.50 D to −0.50 D and the final UCVA measured 20/25 OD and 20/20 OS. Vellarde et al. (54) performed CLE followed by LASIK on 22 eyes with moderate to high myopia and hyperopia. Twelve of the eyes had residual refractive error after phacoemulsification surgery and 10 eyes had both procedures planned preoperatively. The mean SE in the myopic group was −11.76 D and in the hyperopic group +5.22 D. After surgery, the combined mean SE was +0.26 D (range, −0.375 to +1.50 D). Zaldivar and colleagues (32) reported on 64 pseudophakic eyes that subsequently underwent LASIK for residual refractive error. The mean SE decreased from −2.61 D (range, −0.50 to −5.50 D) to −0.07 D.

“Pseudophakic” biopics has several desirable qualities. First, phacoemulsification extends the corrective range of LASIK and does so in a way that spares corneal thickness and is potentially adjustable (IOL exchange). Viscoelastic agents, well-manufactured IOLs, and modern phacoemulsification units with advanced fluids have increased the procedure's safety. Second, the procedure offers many of the advantages of biopics without some of the safety concerns associated with P-IOLs. For instance, there is little concern over progressive endothelial cell loss, and cataractogenesis is no longer an issue. A major disadvantage of the combined procedure is loss of accommodation. Thus, it is usually reserved for patients in the presbyopic age range. The development of accommodating IOLs may eventually overcome this issue.

Three specific patient populations could benefit from combined phacoemulsification and LASIK. The first is those patients with high ametropias who are beyond the range of what can safely be corrected with LASIK alone. CLE could treat the majority of the correction, followed by LASIK. The second group is those patients who have unexpected postoperative refractive error secondary to either inaccurately performed IOL calculations or implantation of the incorrect IOL. The risks of another intraocular surgery to exchange the IOL could potentially be avoided by performing LASIK. The third group of patients is those who are unhappy after uneventful phacoemulsification due to mild to moderate residual refractive error and suboptimal UCVA.

The potential risks associated with combined surgery include all those associated with LASIK (discussed earlier) and phacoemulsification. The latter is an intraocular procedure that carries the risks of endophthalmitis and other sight-threatening complications. Intraoperative concerns include vitreous loss, retained lens fragments, and suprachoroidal hemorrhage. Postoperatively, patients can develop chronic cystoid macular edema or bullous keratopathy. Among the patients reported to have undergone both procedures, none experienced complications related to phacoemulsification. Several patients did develop opacification between piggybacked IOLs (52). Zaldivar and colleagues (32) reported several LASIK complications including an irregular stromal bed, corneal edema, DLK, flap striae, and dry eye. The authors found no increased incidence of complications in older patients.

The risk of retinal detachment is an important concern when performing phacoemulsification on a highly myopic eye. Colin and coauthors (55) observed an 8.1% incidence of retinal detachment over 7 years in high myopes (>−12 D) who had undergone CLE. The incidence was nearly double that estimated for persons with myopia greater than −10 D who did not undergo surgery. Preoperatively, a thorough dilated examination is necessary to evaluate and potentially treat peripheral retinal pathology. An additional risk of retinal detachment exists should the patient develop posterior capsular opacification (PCO) and require a Nd:YAG capsulotomy. These concerns have prevented CLE from becoming a routine option for the correction of high myopia.

CONCLUSION

LASIK, when combined with other procedures, may benefit high and moderate myopes. The combination of two procedures may be especially valuable for patients with relatively thin corneas. Early reports of combined surgeries are promising, but further studies are necessary to establish efficacy, stability, and safety of these surgical procedures.

REFERENCES


