Emerging Trends for Procedure Selection in Contemporary Refractive Surgery: Consecutive Review of 200 Cases From a Single Center

George O. Waring IV, MD; Daniel S. Durrie, MD

ABSTRACT

PURPOSE: To quantify emerging refractive surgery trends in a single refractive surgery practice.

METHODS: A retrospective chart review was performed of 200 consecutive candidates (377 eyes) for refractive surgery from July 20, 2007 to October 31, 2007. Patient age, manifest refraction spherical equivalent, pachymetry at the thinnest location (CCT), topographic symmetry patterns, and corneal apex location were analyzed. Patients were recommended sub-Bowman’s keratomileusis (SBK), photorefractive keratectomy (PRK), conductive keratoplasty (CK), phakic intraocular lens implants (PIOL) or refractive lens exchange (RLE). Corneal excimer procedures were either wavefront-optimized or wavefront-guided ablations.

RESULTS: Mean patient age for refractive surgery was 44±12 years (range: 18 to 68 years). The mean MRSE was −2.78±3.37 diopters (D) (range: −12.75 to +6.25 D). Of the 200 patients, 75% (n=151, 288 eyes) were recommended corneal excimer procedures. Of these, the mean CCT was 548±36 µm (range: 466 to 628 µm). Symmetric topographic patterns were observed in 54% (n=155) of eyes, whereas 32% (n=92) were borderline and 14% (n=41) were asymmetric. The corneal apex was centered in 79% (n=226) of eyes, whereas 18% (n=51) were borderline and 3% (n=10) were decentered (>2.5 mm from the center). Overall, 69% (n=139) of patients were recommended SBK, 16% (n=32) RLE, 6% (n=12) PRK, 5% (n=9) CK, and 4% (n=8) PIOL. Of the corneal excimer group, 88% (n=132) were scheduled for wavefront-optimized ablation and 12% (n=18) for wavefront-guided ablation.

CONCLUSIONS: Sub-Bowman’s keratomileusis was the predominant refractive surgical procedure offered in this practice, followed by RLE, PRK, CK, and finally PIOL. Of the corneal excimer procedures recommended, the majority of patients were scheduled for a wavefront-optimized ablation. [J Refract Surg. 2008;24:S419-S423.]

Refractive surgery is a rapidly evolving subspecialty. Advances in research and technology have spawned new trends in refractive surgery. From the widespread acceptance of LASIK in the late 1990s, to the resurgence and development of a variety of surface ablation procedures, corneal excimer laser procedures remain the cornerstone of non-cataract refractive surgery.1-6 In recent years, thin flap LASIK (referred to as sub-Bowman’s keratomileusis [SBK]) has gained popularity. Our center has demonstrated that SBK offers the benefit of rapid visual recovery while providing a biomechanical outcome, within the limits of current assessment, similar to surface ablation.7 Improvements in implantable lens technology, techniques, and the aging population have led to presbyopic procedures such as refractive lens exchange and conductive keratoplasty (CK), practically creating a subspecialty of its own.

We performed a retrospective case review of 200 consecutive refractive patients to quantify the refractive surgery trends taking place in our practice. This study was conducted at a private practice in the Midwest (Durrie Vision, Overland Park, Kan) sub-specializing in corneal-, lens-, and presbyopic-based refractive surgery. The practice is self-pay, invests in presbyopic and refractive surgery marketing, and functions independent of an optometric referral system.

PATIENTS AND METHODS

Charts of new refractive patients who qualified for refractive surgery were reviewed retrospectively by the fellow (G.O.W.) in cornea and refractive surgery. Age and manifest refraction spherical equivalent (MRSE) were examined for all patients. Pachymetry at the thinnest location (referred to as CCT), topographic symmetry patterns, and corneal apex...
location were examined for all corneal excimer laser candidates. Topographic symmetry patterns were subjectively determined to be either symmetric, borderline, or asymmetric based on the four-map Pentacam (Oculus Inc, Lynnwood, Wash) (anterior elevation map, posterior elevation map, axial topography map, and corneal thickness map). Corneal apex location was subjectively determined to be centered, borderline, or decentered (>2.5mm from center) based on Pentacam images. The CCT measurement was obtained from the corneal thickness map on the Pentacam. The recommended procedure for each patient was also examined. Patients were offered one of the following procedures: SBK, photorefractive keratectomy (PRK), CK, phakic intraocular lens (PIOL) implants, or refractive lens exchange (RLE).

Corneal refractive laser procedures were performed with one of two excimer laser profiles: wavefront-optimized (ALLEGRETTO WaveLight; WaveLight Laser Technologie, Sterling, Va) or wavefront-guided (Alcon LADARVision4000 CustomCornea; Alcon Laboratories, Ft Worth, Tex). All SBK flaps were created with the 60-kHz IntraLase femtosecond laser (Advanced Medical Optics, Irvine, Calif) with a planned flap diameter of 8.5 mm and an intended mean flap thickness of 100 µm. A raster pattern was used with a superiorly located hinge position, planned raster energy of 1.0 µJ/spot and planned spot/line separation of 9×9 µm. The hinge angle was set at 50° and the side-cut angle was 75°. The “pocket” software was enabled to decrease the occurrence of dense bubbles in the flap interface. Data were entered into a spreadsheet, statistically analyzed with Microsoft Excel (Microsoft Corp, Redmond, Wash) and trends were reported.

RESULTS

Of the 200 patients evaluated, 69% (n=139) were recommended SBK, 16% (n=32) RLE, 6% (n=12) PRK, 5% (n=9) CK, and 4% (n=8) PIOL (Fig 1). Both eyes were treated with the same procedure in 100% of bilateral surgeries, and in no case was a recommendation made for two different procedures in the same person. Of the 200 candidates for refractive surgery, 49% (n=97) were males and 51% (n=103) were females.

The mean age for patients recommended refractive surgery was 44±12 years (range: 18 to 68 years), 42±12 years (range: 18 to 62 years) for corneal excimer procedures, 57±8 years (range: 39 to 68 years) for RLE, 52±5 years (range: 46 to 60 years) for CK, and 37±7 years (range: 27 to 46 years) for PIOL. Mean MRSE for the entire group was $-2.78±3.37$ diopters (D) (range: $-12.75$ to $+6.25$ D), $-2.97±2.58$ (range: $-9.63$ to $+3.00$ D) for corneal excimer procedures, $-0.54±4.40$ D (range: $-11.88$ to $+6.25$ D) for RLE, $-0.09±0.70$ D (range: $-1.00$ to $+0.88$ D) for CK, and $-9.54±1.61$ D (range: $-12.75$ to $-6.63$ D) for PIOL. The Table shows the preoperative mean age, spherical equivalent, and cylindrical magnitude for all recommended surgeries.

 Seventy-five percent (n=151) of patients (288 eyes) evaluated were considered candidates for corneal excimer laser procedures. This was based on a number of factors, but most strongly on the refractive error, age, corneal thickness, and pattern of topographic symmetry. Of these, the mean CCT based on Pentacam was 548±36 µm (range: 466 to 628 µm). Of the eyes recommended for corneal excimer laser procedures, 54% (n=155) were considered to have symmetric topographic patterns, whereas 32% (n=92) were borderline and 14% (n=41) were asymmetric. The corneal apex was considered to be centered in 79% (n=226) of eyes, whereas 18% (n=51) were borderline and 3% (n=10) were decentered (>2.5 mm from the center).

Of the 151 patients selected for corneal excimer laser surgery, 88% (n=132) were scheduled for wavefront-optimized (ALLEGRETTO WaveLight) and 12% (n=18) for wavefront-guided (Alcon CustomCornea) ablation. Of these, 92% (n=139) were offered SBK and 8% (n=12) PRK.

Among the eyes recommended for SBK, 55% (n=144) had symmetric topographic patterns, 33% (n=88) were borderline, and 12% (n=33) asymmetric. Of these, 79% (n=209) had a central corneal apex, whereas 19% (n=49) were borderline and 2% (n=6) were decentered. A wavefront-optimized ablation was recommended in 90% (n=125) of SBK patients because of minimal preoperative asymmetry and irregular astigmatism. Wavefront-guided ablation was recommended for the 10% (n=14) of patients with higher preoperative aberrations. Among the eyes recommended for PRK, 48% (n=11) of eyes had symmetric topographic patterns, 17% (n=4) were borderline, and 35% (n=8) asymmetric. Of these,
74% (n=12) had a central corneal apex, whereas 9% (n=2) were borderline and 17% (n=4) decentered. A wavefront-optimized ablation was recommended in 64% (n=7) of PRK patients and wavefront-guided in 36% (n=4). Of the patients with bilateral symmetric topographic patterns and with bilateral central corneal apices (n=53), 91% (n=48) underwent SBK and 9% (n=5) PRK. In the same group, 98% (n=52) of patients were recommended a wavefront-optimized procedure and 2% (n=1) were recommended a wavefront-guided procedure. Of the patients where either eye displayed borderline or asymmetric topographic patterns or borderline or decentered corneal apices (n=70), 91% (n=64) were recommended SBK and 9% (n=6) were recommended PRK. In this same group, 81% (n=56) of patients were recommended a wavefront-optimized ablation and 19% (n=13) were recommended a wavefront-guided ablation.

For patients with bilateral CCT >500 µm, 96% (n=126) were recommended SBK and 4% (n=5) were recommended PRK. Of this group, 89% (n=116) were recommended a wavefront-optimized ablation and 11% (n=14) a wavefront-guided ablation. For the subset of patients with a CCT <500 µm in at least one eye, 63% (n=12) were recommended SBK and 37% (n=7) were recommended PRK. Of this group, 79% (n=15) were recommended a wavefront-optimized ablation, and 21% (n=4) a wavefront-guided ablation.

**DISCUSSION**

Sub-Bowman’s keratomileusis with wavefront-optimization is the predominant refractive surgical procedure offered in this practice. We have demonstrated in a multicenter prospective, contralateral study that patients who receive SBK benefit from the quick visual recovery of LASIK, and biomechanical outcomes equivalent to PRK, within the limits of current evaluation.7 As a result, we are performing an increasing number of SBK procedures on borderline cases that we may have previously suggested a surface procedure, prior to the advent of SBK.

**SUB-BOWMAN’S KERATOMILEUSIS VS SURFACE ABLATION**

When determining whether to perform a flap-based corneal refractive procedure, we screen for signs of ectatic corneal disorders or evidence of anterior basement membrane dystrophy. We evaluate the global clinical picture, including but not limited to: slit-lamp microscopy, anterior and posterior elevation maps, global and relative corneal thickness, and Placido-based keratometry values with attention to inferior steepening. This decision-making process is often multifactorial and factors are often interrelated. For the purposes of this article, we analyzed and reported pachymetry at the thinnest location, topographic symmetry patterns, and corneal apex locations.

Typically, patients with CCT <500 µm or a planned residual stromal bed <300 µm, are recommended PRK with a careful consent, or are considered non-candidates for corneal excimer surgery depending on concomitant ectasia risk factors. Although optical pachymetry maps are useful for corneal thickness location and estimation, measurements are typically lower when compared to ultrasonic pachymetry.8 We measure preoperative manual ultrasound pachymetry on patients with a spherical equivalent >−6.00 D or with optical pachymetry of <500 µm. Abnormally thick corneas (>620 µm) raise suspicion of endothelial dysfunction and warrant further investigation.

Patients with topographic patterns demonstrating inferior elevation, inferior steepening with superior flattening, or asymmetric dumbbell or “crab-claw”

### TABLE

**Preoperative Mean Age and Mean Refractive Error by Recommended Surgery in 200 Patients From a Single Center**

<table>
<thead>
<tr>
<th>Recommended Surgery (N)</th>
<th>Mean Age (±SD) (Range)</th>
<th>Spherical Equivalent (±SD) (Range)</th>
<th>Cylindrical Magnitude (±SD) (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Bowman’s keratomileusis (139)</td>
<td>42±12 (18 to 62)</td>
<td>−2.83±0.54 (−9.63 to +3.00)</td>
<td>−0.76±0.69 (−3.50 to 0.00)</td>
</tr>
<tr>
<td>Photorefractive keratectomy (12)</td>
<td>36±9 (23 to 49)</td>
<td>−4.60±2.58 (−9.25 to +0.50)</td>
<td>−0.95±1.08 (−3.50 to 0.00)</td>
</tr>
<tr>
<td>Conductive keratoplasty (9)</td>
<td>52±5 (46 to 60)</td>
<td>−0.09±0.70 (−1.00 to +0.88)</td>
<td>−0.13±0.19 (−0.50 to 0.00)</td>
</tr>
<tr>
<td>Refractive lens exchange (32)</td>
<td>57±8 (39 to 68)</td>
<td>−0.54±4.40 (−11.88 to +6.25)</td>
<td>−0.72±0.71 (−3.50 to 0.00)</td>
</tr>
<tr>
<td>Phakic IOL (8)</td>
<td>37±7 (27 to 46)</td>
<td>−9.54±1.61 (−12.75 to −6.63)</td>
<td>−0.92±0.92 (−3.25 to 0.00)</td>
</tr>
<tr>
<td>All patients (200)</td>
<td>44±12 (18 to 68)</td>
<td>−2.78±3.37 (−12.75 to +6.25)</td>
<td>−0.76±0.73 (−3.50 to 0.00)</td>
</tr>
</tbody>
</table>

SD = standard deviation, IOL = intraocular lens
patterns were either considered non-candidates for corneal excimer refractive surgery or were recommended PRK with careful informed consent, depending on the severity of irregularity and other risk factors.

If a patient has a single clear risk factor, or a constellation of borderline risk factors, we may elect to perform a surface procedure with careful informed consent. In our study, PRK was recommended to less than 10% of patients qualifying for a corneal excimer laser procedure (Fig 2). If a patient has a single borderline risk factor, we may consider SBK with a detailed informed consent. Patients with clinical keratectasia are not considered candidates for corneal excimer laser procedures and were not included in this study. Finally, we are likely to recommend PRK for patients with anterior basement membrane dystrophy.

**Wavefront Optimized vs Wavefront Guided**

Corneal refractive laser procedures were performed with one of two excimer lasers platforms: wavefront-optimized (ALLEGRETTO WaveLight) or wavefront-guided (Alcon LADAR4000 CustomCornea). Approximately 90% of our excimer procedures were performed with the wavefront-optimized ALLEGRETTO WaveLight laser (Fig 3). There are many reasons for this—speed, a non-dilating eye tracking system, and a wavefront-optimized treatment. With a pulse frequency of 400 Hz, treatments are noticeably faster compared to the Alcon LADAR4000 operating at 60 Hz. The non-dilated eye tracking improves patient flow, increases the potential daily case volume, and allows for a non-mydriatic procedure. Most importantly, we have been impressed with the results of the wavefront-optimized platform. This algorithm, based on pre- and postoperative wavefront data taken from the literature, precompensates for the expected amount of spherical aberration and astigmatism of the higher order usually observed after classic spherocylindrical corrections. Radial ablation efficiency is achieved by placing more pulses in the midperiphery of the optical zone, minimizing the tangential energy loss. This results in a more prolate treatment with less induced spherical aberration.

We have demonstrated in other studies that outcomes for hyperopic treatments with the wavefront-optimized ALLEGRETTO WaveLight were superior at all time points up to 6 months postoperatively when compared to conventional treatments with the Alcon LADARWave 4000. Further analysis revealed less induced negative spherical aberration with the wavefront-optimized platform (Fig 4). It is important to note that the suggested wavefront-optimized algorithm treatment is based directly on the preoperative manifest refractions; as a result, serial accurate refractions are critical.

For new refractive patients who are candidates for corneal excimer laser surgery, we typically reserve...
the wavefront-guided CustomCornea treatments for asymmetric corneas, decentered apices, or corneas with large amounts of irregular astigmatism. Our study showed that this criterion is met approximately 10% of the time, illustrating the fact that we are comfortable using wavefront optimization in the majority of cases. However, we believe a true wavefront-guided platform is a critical tool for this minority of cases.

**Refractive Lens Exchange, Conductive Keratoplasty, and Phakic IOLs**

The number of lens-based procedures has dramatically increased in the recent history of our practice. In addition, the mean age of patients receiving RLE procedures has decreased over the past few years. In this series, the mean age was 57 years, with the youngest at 39 years. Based on our experience and the improving technology in presbyopic IOLs, we expect to see the mean age of patients receiving RLE to continue to decrease. Factors that influence our decision to recommend RLE over corneal refractive surgery include age, lenticular changes correlated with the Scheimpflug densitometry, and optical quality analysis “optical scatter index.” In addition, we carefully consider cases with hyperopia (to avoid the induced negative spherical aberration resulting from paracentral hyperopic laser ablations), presbyopia, relatively steep keratometry, or signs of forme fruste keratoconus.

We currently use presbyopic, aspheric, or toric lenses for our RLE patients. For the broadest range of vision, we routinely combine the AcrySof ReSTOR (Alcon Laboratories Inc) in the nondominant eye and Crystalens (eyeonics Inc, Aliso Viejo, Calif) for the dominant eye. We use the Alcon AcrySof Toric IOL for up to 2.00 D of astigmatism and will combine limbal relaxing incisions with the Acrysof Toric for larger degrees of astigmatism. Limbal relaxing incisions are performed for astigmatism ≥0.75 D with presbyopic IOL implantation. If optimizing distance vision and contrast sensitivity is the primary surgical goal, we use the Tecnis (Advanced Medical Optics) or the Alcon AcrySof IQ.

We recommend CK for plano or near plano (≤+0.50 D) presbyopes. Phakic IOLs are reserved for patients with moderate to large amounts of myopia who are not otherwise structurally or optically candidates for corneal refractive surgery. We use both the Verisyse iris-fixated PIOL (Advanced Medical Optics) and the Visian posterior chamber ICL (STARR Surgical Co, Monrovia, Calif). Patients must have adequate endothelial cell counts to qualify for a PIOL implantation.

Although this study based on 200 patients demonstrates that wavefront-optimized SBK is the predominant procedure offered in this practice, trends may vary with a larger sample size. In addition, our results may differ from practices that are not purely refractive. Future analysis should also include additional keratometric information, and all patients should be fully analyzed, not only the subset of patients referred for corneal excimer laser procedures.

**REFERENCES**


