Blockbusters
Successful management of chronic rhinosinusitis

Motion sickness
Shaking up therapies for essential tremor

Advances in corneal refractive surgery
Rapid developments in technology have contributed to a resurgence of interest in enhancements, modifications and alternatives to corneal refractive surgery. The aim of this article is to give an overview of current and emerging techniques, instruments and technologies that are shaping the future of this highly dynamic field.

Excimer laser procedures
Photorefractive keratectomy (PRK), laser-assisted in-situ keratomileusis (LASIK) and laser epithelial keratomileusis (LASEK) currently use an ultraviolet argon fluoride (193nm) gas discharge excimer laser to remove minute layers of superficial corneal tissue under computer control. The computer controlling the laser is programmed to generate a specific algorithm relating to the diameter and depth required for a given refractive change, based on the average amount of tissue removed per pulse. To treat myopia, more tissue must be removed from the centre of the cornea than the periphery to produce a flatter refracting surface. The treatment of astigmatism involves greater ablation of one principle meridian than the other. Hypermetropic treatments attempt to steepen the optically significant central cornea by producing a smoothly transitioned annular ablation in the stroma at the periphery of the optical zone. The central cornea often remains relatively untouched.

Creating corneal flaps
Microkeratome is a precision surgical instrument with an oscillating blade designed for creating the corneal flap in LASIK surgery. These can be selected to cut the cornea at various depths. The most commonly used microkeratomes in the United Kingdom are the Hansatome (Bausch & Lomb) and the Moria M2.

The Femtosecond laser is the latest addition to the refractive surgeon’s armamentum that offers the option of dissecting the cornea without the use of a blade. The Intralase FS laser introduces new high precision femtosecond laser technology to ophthalmology; a potentially safer computer-controlled alternative to a microkeratome for creating the corneal flap. A femtosecond laser is an infrared laser (1030nm) that works with ultra-short impulses of light (10-15 seconds) that last only a quadrillionth of a second to create a spot as tiny as 1/100nm. To illustrate the extremely short pulse time; light travels 7.5 times around the earth in one second; however, it only travels one half of the thickness of a hair in a femtosecond.

Contrary to traditional lasers, the energy of the laser beam from a femtosecond laser doesn’t affect the tissue on the surface of the cornea, but instead reaches a specific predetermined depth inside the cornea. Very high energy levels can be achieved through intense focusing of the laser beam. The point of focus of the laser beam allows material to be divided at the molecular level so that tissue is gently separated. The surrounding corneal tissue remains relatively undisturbed without significant damage. The femtosecond laser beam produces a layer of tiny bubbles at the desired depth of the cornea. This enables the corneal flap to be opened and lifted to the side as in traditional LASIK. The newer
generation femtosecond lasers can create a flap within 10μm of the desired thickness whereas the traditional microkeratomies are often only accurate within 20-40μm.

**Corneal refractive procedures**

- **Photorefractive keratectomy (PRK)**
  The first PRK procedure was performed on a human cornea in November 1989 by Mr David Gartly at St Thomas' Hospital, London. Topical anesthetic drops are instilled into the eye and the epithelium is scraped away over an area approximately 1 mm larger in diameter than the intended treatment zone to expose Bowman's layer. The excimer laser is then employed to remold the anterior corneal surface by the ablation of stromal tissue for a period between 5 and 90 seconds. The postoperative pain can occasionally be quite severe for the first 24 hours but is now better controlled by medication such as topical non-steroidal drops, oral anaesthesia and the use of bandage contact lenses. More recently, the use of chilled balanced salt solution or ice application to the treated area has been found to reduce early postoperative pain. Some pain may persist and the vision remains hazy until the epithelium heals over the treated area, over approximately three to six days.

A recent Cochrane review found that PRK is of comparable effectiveness to LASIK. There is some evidence to suggest, however, that LASIK may be less likely than PRK to result in loss of best spectacle-corrected visual acuity. This is often due to formation of scarring sub-epithelial haze following PRK that mostly occurs when treating higher refractive errors.

- **Laser-assisted in-situ keratomileusis (LASIK)**
  LASIK was developed in 1990 and involves the use of a microkeratome to cut a thin flap of corneal tissue followed by ablation of the underlying stromal tissue using an excimer laser. The flap is then repositioned and is held in place by strong osmotic forces until the epithelium heals over to cover the wound margins. The aggressive wound healing that occurs following PRK is not seen post-LASIK because of limited disruption of the corneal epithelium. This allows much higher refractive errors to be treated without inducing significant postoperative haze or pain. As a result, the period of visual rehabilitation is very short compared to PRK, and useful vision can often return within a matter of hours.

  - **Laser epithelial keratomileusis (LASEK)**
  LASEK is a relatively new technique used for low myopia and hyperopia combining some principles from both PRK and LASIK. It involves the production of an epithelial flap using a solution of 18% alcohol. The underlying anterior stroma is ablated, as in PRK, but the epithelial flap is then replaced, acting as a bandage lens to minimise post-surgical inflammation. However, the epithelial layer is often nonviable beyond the immediate post-operative period due to alcohol toxicity. Apart from the intraoperative benefits of not requiring suction to create the flap, LASEK produces less haze than PRK and therefore can result in improved best-corrected visual acuity, whilst avoiding the potential stromal flap complications of LASIK.

  - **Epi-Lasik**
  Epi-Lasik is a relatively new adaptation of surface ablation, such as PRK, that also has marked similarities to LASEK with some potentially distinct advantages over LASIK and intralASIK. This technique was developed by Professor I. Pallikaris in Crete and utilises a microkeratome with a blunt blade to mechanically cleave the epithelium from the Bowman's membrane, leaving an exposed area for excimer laser ablation. Unlike LASEK, however, epi-LASIK aims to produce a viable epithelial flap with an intact basement membrane. Long-term studies are currently underway, evaluating the outcomes, safety and efficacy of this procedure with promising preliminary results, at least for myopia.

  - **Femtosecond assisted LASIK (IntraLasik)**
  IntraLase, also called 'all laser Lasik', is similar to traditional conventional or custom wavefront LASIK, except the corneal flap is created with a femtosecond laser rather than a mechanical microkeratome with a metal blade. The IntraLase name comes from a combination of the name of a femtosecond laser manufacturer, Intralase, and LASIK. There are several distinct potential advantages to IntraLasik that lend themselves to a more predictable and safer surgical process then seen in traditional LASIK with a mechanical microkeratome. These advantages include more precise positioning of the flap, more accurate thickness of the flap, more even thickness of the flap throughout, and a lower probability of intraoperative complications such as buttonhole flaps, thin/thick flaps, or epithelial defects. Further review of the current literature is still required to assess whether femtosecond laser truly delivers better outcomes compared to traditional microkeratome LASIK.

  This procedure is restricted by the safe limits of residual corneal stromal bed thickness due to the potential long-term concerns of ectasia. These safe limits are evolving as more long-term data emerges and a minimum residual stromal thickness of 250 microns is generally accepted at present. Thinner flaps with newer microkeratomies, as thin as 90 microns, allow for a thicker residual stromal bed, potentially improving the long-term safety profile of this technique.

  - **Conductive Keratoplasty (CK)**
  CK uses mild heat from radio waves to shrink the glue-like connective tissue (collagen) in the periphery of the cornea. This steepens the cornea, giving farsighted patients with presbyopia better near and distance vision, while improving near vision for patients with presbyopia alone.

  The procedure remains plagued with the risk of recurrence of hyperopia (regression), although this seems to be less likely to occur, following recent advances in the technique.

- **Refractive corneal incisions**
  Limbal relaxing incisions (LRI) and Arcuate Keratotomies (AK) are incisions performed in the cornea to flatten the corneal curvature along the steepest meridian in order to reduce the degree of astigmatism. LRRs are often combined with cataract surgery, although they can be performed independently, whilst AKs are predominately reserved for corneal graft patients.

**Recent advances**

- **Wavefront-guided lasers**
  These lasers use advanced laser delivery systems in which a specialised computer maps specific corrections for each individual eye. Refraction evaluates myopia, hyperopia and astigmatism, which are called low order aberrations (LOA). Wavefront technology has the ability to detect and measure high order
aberrations (HOA). HOA are represented in mathematical calculations and are therefore infinite. The more common of these mathematical calculations are Zernike polynomials and have names like spherical aberration, coma, trefoil, and quadtrefoil. Ophthalmology only deals with about the first eight levels of HOA as represented in Zernike. Wavefront technology tends to improve the quality of night vision by addressing these aberrations.

Iris registration is the newest add-on to wavefront LASIK. Traditional lasers track the patient’s eye moving left, right or up, down. Iris registration tracks rotational, forward and backward movements and communicates it with the laser so that the eye tracking coordinates are better matched with the laser during surgery.

- Topographic supported customised ablation: Orbsoft topographic images are obtained before surgery and used as the source for planning the customised ablations (TOSCA, Meditec, Germany). The programme calculates as standard the ablation pattern necessary to change the corneal surface into a spherical shape within a 6 mm optical zone, without altering the spherical equivalent refraction. Correction of the full refractive error can also be performed, occasionally at a second sitting. This technology is particularly useful for highly irregular corneas, complex re-treatments or post-keratoplasty cases.

- Mitomycin-C: Mitomycin-C (MMC), with its antibiotic and antineoplastic properties, is intended to inhibit wound-healing mechanisms. Topical MMC 0.02% for one to two minutes enables one to treat high refractive errors without inducing stromal haze. MMC has been used successfully with PRK procedures to reduce the incidence of post-operative haze formation. However, further evaluation of the long-term implications of corneal MMC usage is still awaited.

- Custom Contoured Ablation Pattern: C-CAP uses a liquid material that is applied to the outside of the eye. In some cases, a contact lens is applied over the liquid to give a smoother surface. The liquid becomes firmer, and the contact (if used) is removed. A broadband laser applies energy to the entire treatment area with each pulse. The liquid ablates at the same rate as corneal tissue. As the laser removes tissue and the liquid, the high areas of the cornea are exposed and ablated down to the lowest areas. C-CAP has been shown to resolve many topographical imperfections caused by disease, trauma, or surgery.

- Intra-corneal ring segments: ICORS allow the correction of low myopia and astigmatism. Half-ring segments of PeriGel are inserted into channels created in the corneal stroma, causing the central cornea to flatten. The channels can be created mechanically using specially designed surgical instruments or by using a femtosecond laser. They possess a number of advantages over PRK and LASIK in that they do not involve the central cornea and are positioned outside the pupil margin. They also maintain the prolate shape of the cornea and are relatively reversible. Only low degrees of myopia can be treated (<4.50D) but they are also useful for treating some cases of keratoconus, and LASIK-induced ectasia where the cornea has become abnormally thin.

- Femtosecond Lenticule Extraction (FLEX): FLEX is a new form of refractive corneal surgery similar that creates a lenticule for removal and a corneal flap, all with a femtosecond laser. This investigatory, “all-in-one” refractive procedure that reshapes the cornea without excimer laser ablation. Further outcome and safety data is awaited for this exciting new procedure.

- Presbyopic Corneal Implant: A presbyopia-correcting corneal inlay, such as the AcI 7000 developed by Bausch and Lomb, is a thin, opaque ring that is implanted under a corneal flap in the presbyope’s nondominant eye. This device claims to improve the patient’s depth of focus by preventing unfocused light from reaching the retina. The device can be removed at any time if the patient is dissatisfied with the results. Trials are currently underway on such implants to evaluate their role in presbyopic refractive surgery.

Customised Treatments

It is known that certain corneal refractive procedures are more suitable for particular patients, implying that truly customised refractive surgery includes tailoring the technique of flap dissection along with laser delivery. Careful and meticulous patient selection still remains the cornerstone of an ethical and successful refractive service. Although there is a marked variety in the surgical options listed in this article, it is becoming increasingly apparent that today’s refractive surgeon must familiarize themselves with all available techniques to ensure that they deliver the highest standard of ethical care to their patients with the best available technology.

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At a glance: techniques of corneal flap creation procedures

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