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LASIK

LASIK has revolutionised refractive surgery and is a quantum improvement over previous methods. This article will explain why.

Indications

Laser in-situ keratomilieusis (LASIK) is indicated to treat myopia and myopic astigmatism, hyperopia and hyperopic astigmatism[1,2]. It also has a role in treating presbyopia by inducing monovision. The precise level of ametropia that LASIK treats is a matter of debate within the refractive community, and to some extent depends on individual surgeon preference, idiosyncrasies of the different laser systems available and clinical features specific to individual patients. I take a somewhat conservative approach and prefer not to treat more than about 11 dioptres of combined sphere and cylindrical correction for myopia, and about 5 dioptres of sphere and 3 dioptres of cylindrical correction for hyperopia. Other approaches are necessary for patients who fall outside these approximate guidelines. For example, for a patient with 20 dioptres of myopia, the choice lies between a phakic intraocular lens and a clear lensectomy.

The majority of patients undergoing LASIK have refractive error but perfectly normal eyes. However, an important and burgeoning group consists of those who have a 'medical' justification for undergoing refractive surgery. Such circumstances include old style, extracapsular cataract surgery with an unsatisfactory refractive outcome, penetrating keratoplasty, high myopes (within the LASIK range) who have become contact lens intolerant, previous radial keratotomy and previous retinal detachment with myopia induced by the encircling band used to compress the retina. Of all the patients in this group, perhaps the most satisfying to treat are those whose extracapsular cataract surgery has resulted in disabling ametropia. Such patients are often very aware of the fact that their friends who received phacoemulsification cataract surgery have virtually no refractive error. The use of LASIK to resolve the problem brings relief to both the patient and the original cataract surgeon.

LASIK vs PRK
Why patients prefer LASIK

The relationship between these two techniques in the treatment of refractive error is currently in flux. A comprehensive description of PRK by David O'Brart appeared in the previous instalment in this series (*OT* 21/04/00). It is, however, probably true that PRK has become very much the minority procedure compared to LASIK in the last two or three years. This is because LASIK is generally preferred by both refractive surgeons and patients. The proof of this is the phenomenal growth in the volume of LASIK surgery around the world but especially in North America where it is estimated that between 1 and 1.5 million LASIK procedures will be performed this year (**Figure 1**).

Figure 1
A happy LASIK patient

For many refractive surgeons, the list of indications for PRK is steadily shrinking as that for LASIK simultaneously expands. Often, PRK is used mostly as a phototherapeutic keratectomy (PTK) rather than for refractive reasons. PTK is the treatment of choice for stabilising the corneal epithelium in situations such as recurrent corneal epithelial erosion syndrome and for treating superficial corneal scars.

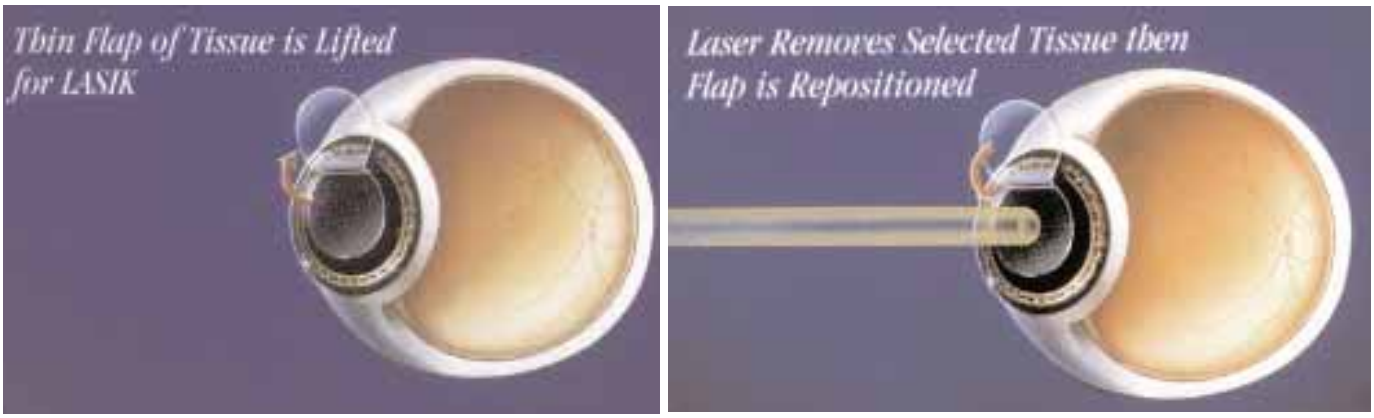
The superiority of LASIK over PRK becomes evident when the performance of the two techniques is compared. LASIK causes no pain, whereas PRK is exquisitely painful post-operatively for two or three days, notwithstanding the use of unpreserved topical analgesics. Vision returns to near normal within a day or so after LASIK, whereas in PRK vision is very blurred for one to two weeks. Furthermore, whilst there is virtually no regression (loss of refractive effect) with LASIK, regression may be a major problem after PRK.

Six months is an average period for on-going regression after PRK and it may be as long as 18 months before the patient and surgeon know where they stand vis-à-vis the need for enhancement. An enhancement is a relatively patient-friendly event in the context of LASIK. The flap is lifted (this requires special instrumentation – the patient is not able to inadvertently shift the flap except within a short period of the original surgery by rubbing very hard) and further laser is applied. This may be done as soon as a month after the original procedure and, as previously, causes no pain. Compare this enhancement experience with the situation pertaining to PRK. It is necessary to wait at least six months for the refraction to stabilise. The patient must then endure the 'normal' post-operative PRK experience, namely a period of pain followed by a period of blurred vision and the possibility that regression will once again occur. The risk of haze (corneal scarring) is very low after myopic LASIK, whereas this is by no means the case with PRK. Furthermore, although haze is more likely to occur after PRK for higher corrections, its onset is unpredictable, probably because some patients mount a fierce healing response. There is no way of predicting who such patients will be other than by operating on one eye. The need to treat haze and reduce regression in patients who have had PRK may necessitate the use of a topical steroid for six months or even longer with all the attendant risks and unpleasantness, not the least of which is its bad taste. By contrast, LASIK patients rarely require post-operative medication for longer than one week.

The disadvantages of LASIK are, of course, that it is a much more sophisticated surgical technique and that the making of the LASIK flap is an extra step in the procedure during which complications may occur. The main lesson to draw from this is that LASIK is a highly surgical technique and should be performed only by an experienced ophthalmologist with substantial surgical training[3].

Why LASIK and PRK are different

The enormous difference in the post-operative behaviour of the two techniques stems from the fact that in LASIK there is virtually no disturbance to the corneal epithelium and Bowman's membrane. Instead, after making the flap, the laser is applied to the, physiologically



Figures 2 and 3
Graphic showing the technique of LASIK *(by courtesy of the Gimbel Eye Centre, Calgary, Canada)*

speaking, almost inert corneal stroma (**Figures 2 and 3**). In PRK the laser is applied directly to the epithelium, one of the two most biologically active regions of the cornea (the other being the endothelium). Whilst one can laser the corneal stroma almost with impunity, any trauma to the epithelium stimulates an immediate and fierce healing response with the resultant difficulties already described. The exquisite sensitivity of the epithelium to pain when it is disturbed is also in marked contrast to the complete insensitivity of the stroma.

Pre-operative consultation

1. Clinical assessment
LASIK is preceded by a thorough assessment of the patient's optical and ocular status. The required tests included manifest and cycloplegic refraction, measurement of pupil diameter in bright and dim light, recording of ocular dominance, a cover/uncover test and keratometry. Keratometry is necessary both to detect corneal ectasias and to programme the laser's computer prior to ablation. Corneal topography is essential to exclude ectasias. Contact lens wear must be discontinued before these measurements for a sufficient period for the cornea to resume its true shape. This instruction must be tempered with realism. Many units ask for one week out of soft lenses, two weeks for gas permeable lenses and three for PMMA lenses. Others insist on serial measurements of corneal topography or keratometry. Corneal pachymetry is essential because the ablation depth depends on the required dioptric change and enough stroma must be left behind after treatment to prevent iatrogenic ectasia (see later).

A careful history should identify problems such as amblyopia, previous corneal disorders such as herpetic keratitis which may be reactivated by laser treatment, previous retinal surgery, which makes LASIK more difficult to perform because the suction ring may not adhere properly to previously disturbed conjunctiva, and systemic diseases such as rheumatoid arthritis which may impair corneal wound healing post-operatively. Ocular examination is directed toward identifying corneal pathology, such as keratoconus, which precludes treatment because the ectasia will worsen if the already thin cornea is thinned further. Blepharitis and dry eye will both be temporarily worse after LASIK, although they are not contraindications to surgery as long as the patient is forewarned. Disorders such as glaucoma and peripheral retinal pathology obviously take precedent over refractive surgery. Retinal examination must be performed after mydriasis.

Figure 4
The suction ring holds the eye still to allow the microkeratome to cut

2. Discussion
The pre-operative consultation has typically lasted for 45 minutes or longer by the time this phase begins. In some ways, it is the most important pre-operative event. The patient must be made aware of exactly what refractive surgery can and cannot achieve and of the choices that he or she must make. It is crucial that the patient leaves the consultation with a realistic understanding of what is on offer and with sufficient time to contemplate whether this is a course of action that he or she wishes to pursue. Unfortunately, common sense advice to avoid making the patient feel pressured to go ahead with surgery and to allow a 'cooling-off' period after the consultation is not universal practice. The consultation should be a dialogue not a monologue delivered by the surgeon and it is important that the patient has ample opportunity to ask questions. It goes without saying that the patient should expect the doctor to have sufficient seniority to both diagnose any disorders precluding treatment and give accurate answers to any questions asked.

Specific aspects of refractive correction discussed are the difference between distance and near vision, the fact that low myopes may prefer to retain myopia in at least one eye after the age of 40 or so, the possibility of an enhancement being required for under or over correction and risks (see later). In general, my approach is to read chapter and verse to the patients so that they are aware that complications, although statistically uncommon, do sometimes occur. I put it to them that their desire for refractive surgery must be sufficiently great for them to undertake some risk. I advise patients who are completely risk averse not to proceed.

How LASIK works

The microkeratome used to make the LASIK flap is assembled and checked. The intended refractive change is entered on the laser's computer. The patient lies on a comfortable couch and anaesthetic drops are applied. General or injection anaesthesia are never required in LASIK. The eye is cleaned in the same way as before cataract surgery. An eyelid speculum is applied to prevent blinking. Radial marks are placed on the cornea so that the flap can be aligned accurately when it is replaced after the ablation.

A suction ring is applied to hold the eye still (**Figure 4**) and the microkeratome is then engaged (**Figure 5**). This sophisticated surgical device splits the cornea into two lamellae. The outer lamella is (depending on the model of microkeratome) about 180um thick and attached by a hinge to the remainder of the cornea. I use the Chiron Hansatome which produces a superiorally-placed hinge which is constantly massaged by blinking ('down-up LASIK'). The flap is then turned back on itself exposing the stromal bed. At this point, the patient is enjoined to look at the laser's aiming beam and the ablation is performed (**Figures 2, 3, 6 and 7**).

The laser is applied to the exposed stromal bed, not to the flap itself. The exposed stromal surface is appropriately reshaped, by flattening in myopia and steepening in hyperopia. This typically takes a minute or less so that fixation is not required for very long. The flap is then replaced and floated on to a bubble of fluid. This is a delicate moment since it must be precisely realigned in its original orientation and treated with appropriate respect or it will stretch and wrinkle. The flap adheres spontaneously to the underlying ablated tissue without needing sutures to keep it in place. The flap being thin will adopt the new shape given to the underlying stromal bed. Therefore, the contour of the surface of the flap will become flatter in myopes whose stromal beds have been flattened by the laser. Flattening of the cornea surface lessens corneal refractive power and so corrects myopia. Conversely, in a hyperope whose stromal bed has been steepened, the surface of the flap will become steeper when it is replaced. This increases corneal refractive power and corrects hyperopia. A combination antibiotic and steroid is then applied followed by a pad. The procedure takes about 15 minutes in total.

Post-operative care

The post-operative phase is minified by LASIK. Patients use a combination antibiotic and steroid drop QID for one week. Vision is sufficiently clear after a day or so for the patient to resume normal activity and even return to work. There is no pain. Patients are seen at one week, one month and three months post-operatively.

One or both eyes?

The reader should be aware that abroad, bilateral simultaneous refractive surgery is almost universal. The practice of operating on one eye at a time that is prevalent in the UK, is very much the exception not the rule. The unilateral approach is based on a desire to reduce risk by allowing delayed post-operative complications time to manifest. However, anisometropia, the need for two operations rather than one and the inconvenience of two sets of post-operative visits make unilateral surgery unpopular with patients. The attitude to risk taken abroad is basically that the complication rate of LASIK is sufficiently low to justify the bilateral approach[4].

Figure 5
The microkeratome fixed to the suction ring. The cutting blade is covered by the assembly and is not visible in this Figure
(by courtesy of Bausch & Lomb)

Figure 6
The excimer laser *(by courtesy of Bausch & Lomb)*

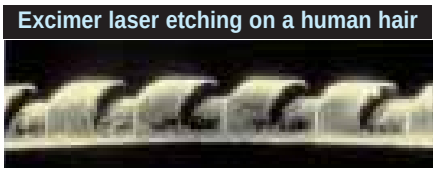


Figure 7
The computer-controlled excimer laser ablation is highly precise *(by courtesy of IBM)*

"Will it hurt doctor?" - How to improve the patient's experience of LASIK

It is perhaps too much to expect that patients will enjoy undergoing refractive surgery, but various steps can be taken to make the event more gentle. These include the provision of accurate and informative brochures which patients can read before the consultation and re-read in the light of the discussion afterwards, free access to advice from a trained counsellor to whom questions can be directed, an unhurried discussion during the consultation, preferably with the surgeon who will carry out the treatment since this allows the doctor-patient relationship to form, and the option of discussing refractive surgery with patients who have undergone it previously. It is true of all surgery that the better prepared the patient is beforehand, the less traumatising the experience will be.

There are several ways to allay inevitable anxiety during the procedure. These include the availability of a sedative and sitting with the patient prior to the procedure and explaining each step so that the patient knows exactly what to expect. During the procedure, one can talk to the patient and reassure him/her that everything is going well. Finally, in some units abroad, relatives are invited to hold the patient's hand during the procedure.

LASIK trouble-shooting

Part of the art of refractive surgery is to identify situations prior to surgery that will lead to a poor outcome. Such circumstances include unrealistic patient expectation of the surgery, for example unwillingness to wear reading glasses afterward. Large pupils' (greater than 8mm) mean glare is to be anticipated post-operatively. Corneal pathology such as keratoconus will be worsened disastrously by further thinning of the cornea. Blepharitis and dry eye are worsened, albeit temporarily, after LASIK and patients need to be prepared for this. Cornea thickness measured by pachymetry and the expected ablation depth for a given degree of myopia must be correlated so that sufficient stroma remains post-operatively or the patient is at risk of developing iatrogenic keratoconus. Certain corneal geometries make a complication whilst cutting the flap with the microkeratome more likely, including those with unusually flat (40 dioptres or less) or steep (49 dioptres or more) curvature. Very deep-set eyes make the surgery more difficult. Finally, the surgeon must identify patients in whom there is a large disparity between the cylinder axis measured by the manifest refraction and the corneal cylinder measured by keratometry or corneal

Figure 8
A damaged cornea flap after LASIK
(by courtesy of the Gimbel Eye Centre, Calgary, Canada)

topography. It is now believed that such a discrepancy arises as much from the posterior corneal surface as from the lens (lenticular astigmatism). Patients with high ocular residual astigmatism may have poor contrast sensitivity after surgery if the cylinder axis of the manifest refraction is sculpted on to an anterior corneal surface in which the cylinder is orientated completely differently. There are now sophisticated software programs available to guide the surgeon in dealing with this situation, e.g. the ASSORT program written by Dr Noel Alpins.

Results

The recovery time from LASIK is usually brief with a high percentage of patients achieving 6/6 or similar vision the day after surgery. This 'wow' factor is in no small part responsible for the popularity of LASIK. One of my patients, an oral surgeon, returned to operating on his own patients the day after bilateral simultaneous LASIK for a 5 dioptre myopic correction. However, it is necessary to warn patients that recovery may not always be so rapid.

LASIK results are generally excellent with a high percentage of patients achieving close to emmetropia. For example, in one series, 83.4% of patients were within 1 dioptre of emmetropia after the initial LASIK procedure for myopia ranging from 1 to more than 10 dioptres[5]. Similarly, excellent outcomes are now expected from hyperopic treatments following technical improvements in the LASIK procedure. For example, about 97% of patients with hyperopia of up to 3 dioptres were within 1 dioptre of emmetropia following LASIK[6]. In general, there is a strong trend in the published literature for improved outcomes. This change is obvious when comparing data published in 1999 with, for example, 1996. This reflects the rapid evolution of hardware design (lasers and microkeratomes), the software used to drive them and greatly increased surgical experience.

Presbyopic and pre-presbyopic patients are well advised to consider monovision with under correction (assuming they are myopic) in their non-dominant eye. Monovision produces the same excellent results as in the context of contact lens wear[7]. Patients are sometimes uncertain whether monovision will work for them. It is helpful for patients to undergo a trial of monovision with contact lenses before the monovision is sculpted on to their cornea. Nevertheless, the penalty for monovision-failure is low since it is straightforward to enhance the patient from under correction to emmetropia if necessary.

Enhancement

The term 'enhancement' means performing a top-up procedure to amend the initial LASIK correction. The ability to amend an initially unsatisfactory ablation is one of the most appealing aspects of modern laser refractive surgery. It is not necessary to recut the LASIK flap. Using appropriate instrumentation and technique, it is possible to lift the original flap for many months after the procedure. This inevitably raises the question of whether the flap has healed safely. The answer is that it is virtually impossible for a patient to inadvertently displace the flap except by vigorous rubbing and even then only within a month or so of the procedure. The flap is then to all intents and purposes healed but fortunately, can still be lifted when necessary by the surgeon. Further laser is then applied to the stromal bed and the flap is replaced and heals in the same way as previously. Multiple enhancements can be performed if necessary. The main impediments to enhancement are an understandable reluctance on the part of the patient to undergo any further surgery and the fact that only a limited amount of corneal stroma can be removed without a danger of inducing iatrogenic ectasia. Refractive stability in myopic LASIK occurs quickly so that enhancement in these patients can be performed as early as one month after the initial procedure[8]. However, in hyperopes, complete stability can take as long as three months to occur so enhancement should wait until this period has passed.

Complications

The long list of potential complications associated with LASIK contrasts sharply with the small percentage of patients who suffer them. This is a tribute to the excellence of the technology but also serves as a reminder of the high level of surgical skill and training necessary to be a successful LASIK surgeon. This is not an activity that can be safely performed on an occasional basis by an insufficiently trained surgeon[3]. It should also be appreciated that complications may follow any type of ocular surgery including cataract extraction. However, patients are frequently not told about such risks because their ophthalmologist considers that the operation is 'essential' and that there is therefore little point in worrying the patient about the inevitable risk. This contrasts with the situation in refractive surgery where most surgeons are punctilious in discussing this subject. This may create the impression that refractive surgery is riskier than, for example, cataract surgery when in reality the opposite is probably true.

Selected LASIK complications, their cause and management include the following:

- The flap may be abnormally shaped – thin, hingeless, irregular or buttonholed (**Figure 8**). This usually results from poor surgical technique. For example, failure to achieve sufficient suction prior to cutting the flap or allowing an obstruction such as the eyelashes or surgical drape to get in the way of the cutting blade. This complication is infrequent with modern microkeratomes. It is often possible to replace the inadequate flap in its original orientation, allow it to heal fully which takes three months and then recut the flap with no adverse affect on the outcome;
- The corneal epithelium occasionally detaches from the flap whilst it is being cut, an event followed by the antithesis of the normal LASIK experience, i.e. post-operative pain. One cause of this is the application of too much pre-operative anaesthetic which can weaken epithelial adherence. The solution is sympathy, a bandage contact lens and unpreserved topical lubricants;
- As discussed previously, inadvertent vigorous rubbing of the flap, usually at night when the patient is sleeping, can displace it up to about a month post-operatively. The reader will be reassured to learn that this is a very uncommon event. The patient is immediately aware of an unpleasant foreign body sensation. The flap is generally easily replaced by the surgeon without untoward affect;
- Dry eye and blepharitis are temporarily worsened by LASIK probably because of the loss of neural supply to the cornea surface occasioned by the slicing action of the microkeratome. Fortunately, neural regrowth occurs after about three months;
- Haze (scarring) and regression are unusual after myopic LASIK but occasionally occur following hyperopic corrections. Prevention is better than cure, in this case by avoiding high hyperopic corrections;
- Halos around oncoming car headlights at

night result from a mismatch between pupil size and the ablation zone. Once again, the problem is easier to avoid than treat, in this case by advising against surgery when scotopic pupils are large; Loss of two lines of best corrected visual acuity occurs in about 0.9% of recent publications[2] but frequently this occurs in circumstances such as a 10 dioptre myope who is 6/6 uncorrected following LASIK having been 6/4 in contact lenses. Such patients are usually happy to swap marginally decreased acuity for vastly enhanced unaided vision.

When all is said and done, the most common 'complication' is simple under or over correction which can generally be dealt with by enhancement.

Forthcoming developments

The tools used to perform LASIK, both hardware and software, are improving quickly. Improvements on the horizon include microkeratomes which cut with a laser instead of a metal blade and so-called customised ablation. The latter refers to an ablation designed to precisely mirror the contours of an individual patient's cornea rather than one based on the manifest refraction. This work has reached an exciting stage of development and will probably soon be in routine clinical use. For example Bausch & Lomb recently launched its latest customised laser vision correction procedure, Zyoptix™, which utilises wavefront technology, and similar systems are under development by other companies. Customised ablation profiles will improve contrast sensitivity and probably ultimately lead to the creation of myopic ablation profiles that are prolate (rather than oblate as at present) so maintaining normal corneal geometry.

LASIK and optometrists

Refractive surgery is here to stay although in a country as conservative as the UK, it seems unlikely to become as popular as elsewhere. Optometrists are ideally placed to act as gatekeepers, directing patients who enquire about it to surgeons whose outcomes they know to be good. Co-management of the pre-and post-operative phases is the norm abroad and will doubtless become so here. Refractive surgery co-management, direct referral of cataract to ophthalmologists, greater involvement with diabetic and glaucoma screening and other aspects of primary eyecare will perhaps combine to create 'medical optometry' as an exciting new avenue of optometric practice.

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His Internet information service for refractive surgery patients is at **www.eyesite.org**.

Multiple choice questions - Please note there is only one correct answer

LASIK

1. Which is true about the indications for LASIK?
a. It has no role in the management of hyperopia
b. It can treat almost any degree of myopia
c. It can treat about 11 dioptres of combined sphere and cylindrical correction in myopia
d. It can treat up to 11 dioptres of combined sphere and cylindrical correction for hyperopia

2. When comparing LASIK and PRK, which of the following is true?
a. PRK is currently performed much more frequently then LASIK
b. LASIK is currently performed much more frequently then PRK
c. PRK causes little post-operative discomfort
d. Vision generally takes several weeks to recover after LASIK

3. When comparing LASIK and PRK, which of the following is false?
a. Regression rarely occurs after myopic LASIK
b. Regression frequently occurs after PRK
c. Haze is more likely to occur following LASIK than PRK
d. LASIK is a more sophisticated surgical technique then PRK

4. Which of the following is false about LASIK?
a. The ablation is applied directly to the corneal epithelium
b. A flap of tissue is made with a microkeratome
c. The healing response is less than after PRK
d. Laser is not applied to the corneal endothelium

5. Which of the following is true concerning the pre-operative LASIK consultation?
a. Corneal topography is essential
b. Corneal pachymetry is only necessary in selected cases
c. Recent contact lens wear does not affect the measurements made
d. Keratoconus is not a contra-indication to LASIK

6. Which of the following is false about LASIK?
a. Blepharitis is likely to be temporarily worsened post-operatively
b. Dry eye is likely to be temporarily worsened post-operatively
c. The depth of the laser ablation and the degree of myopia are not directly related to each other
d. Patients with high 'ocular residual astigmatism' may have poor contrast sensitivity post-operatively

7. Which of the following is true about the surgery of LASIK?
a. General anaesthesia is preferred
b. Topical anaesthesia (eyedrops) is preferred
c. The flap is cut by hand
d. The flap needs to be sutured into place

8. Which of the following is false about the post-operative management of LASIK?
a. There is no pain
b. Patients may return to work quickly.
c. Prolonged (up to six months) use of steroid eyedrops is required
d. A combination antibiotic and steroid drop is used QID for one week

9. When considering monovision in the context of LASIK which of the following is true?
a. Monovision generally produces unsatisfactory results
b. It is difficult to change monovision once it has been created
c. Results are similar to those achieved with contact lenses
d. Monovision cannot be created by LASIK

10. Which of the following are true about LASIK enhancement?
a. It is necessary to recut the flap
b. It is impossible to lift the flap after a month post-operatively
c. Several enhancements can be performed if necessary
d. It is always possible to perform an enhancement

11. Which of the following is false about LASIK complications?
a. A high degree of training is required to minimise the likelihood of complications
b. The risk of complications is no higher than in the context of cataract surgery
c. The flap may be abnormally shaped, making it impossible to apply the laser ablation
d. There is virtually no chance of epithelial trauma

12. Which of the following is true about LASIK complications?
a. The flap may easily detach up to several months following the procedure
b. Halos when driving at night sometimes occur post-operatively
c. Haze (scarring) commonly occurs after myopic LASIK
d. Under or over correction are very rare events

An answer return form is included in this issue. It should be completed and returned to: CPD Initiatives (RS5), OT, Victoria House, 178-180 Fleet Road, Fleet, Hampshire, GU13 8DA by June 14.