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The development of refractive surgery: a practical perspective

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There is surging public interest in the surgical correction of defective eyesight caused by refractive errors. By my count, the number of refractive lasers in Singapore has soared from six in the year 2000 to 17. I am receiving more calls from fellow medical colleagues asking questions related to refractive surgery on behalf of themselves, their wives, or their patients. The review article by Fong in the current issue of the *Singapore Medical Journal* is thus quite timely in this respect. He has managed to succinctly explain the evolution and development of the major methods of surgical correction, keeping to a historical perspective, in a manner that is comprehensible even for the layperson.[1] In the same vein, I hope to add my two cents worth of opinion from the more practical perspective of someone who is out there in the trenches of the refractive surgery battlefield.

This resurgent interest and boom in the number of refractive surgeries performed is fuelled by multiple factors. Firstly, the patient pool itself is large since defective vision is the epidemic of our generation. Many of our parents did not need to wear glasses when they were young. In contrast, our children are much more likely than we were to require glasses. The motivation to be rid of glasses and contact lens is strong. While wearing glasses remains the safest and most common method of vision correction, it does have its disadvantages. Glasses can be cumbersome, a hindrance in weather and sports, and prone to cause spectacles intolerance in some, especially those with high dioptres. Aesthetically, high-powered glasses are unflattering and the thick lenses they require do not complement the vast variety of stylish eyewear and sunglasses available in the market today. Contact lens wear may mimic closely the natural state of the eye but they are tedious to wear and maintain in today's fast-paced and dynamic society. If the lenses are not appropriately cleaned, medical eye problems are likely to arise. These include giant papillary conjunctivitis, keratitis, pingueculaes, ptosis (droopy eyelids), and the potentially blinding and most feared complication of infective cornea ulcer. Indeed, regarding the latter, there was much recent publicity about a worldwide spike in *Fusarium* (a type of fungus) cornea ulcers that was ultimately linked to contamination of a certain brand of contact lens cleaning solution. Interestingly enough, the existence of a link here was first proposed by our colleagues at the Singapore National Eye Centre. Just recently, there was another similar scare leading to another worldwide recall of cleaning solutions. Certainly, all these scares have prompted many contact lens wearers to seek the surgical alternative.

The refractive surgery boom really only began with the advent of laser-assisted in-situ keratomileusis (LASIK) in the mid-nineties. Just prior to that in the early nineties, photorefractive keratectomy (PRK) was fast replacing radial keratotomy (RK) as the refractive surgery of choice because it was simpler and less risky to perform, and it utilised the laser that has been always a better marketing tool than the use of knives. However, local eye doctors were not enthusiastic advocates of the procedure. While PRK delivered reasonably good results for those suffering from low myopia; in Asian eyes, those with moderate to high myopia had a high chance of developing cornea haze. However, the scenario dramatically changed with the advent of LASIK, which possesses almost all the attributes of an ideal refractive procedure. LASIK is quickly performed as an outpatient procedure with anaesthetic eye drops, without the need for injections. The visual results are almost immediate, possessing what is referred to as the "Wow!" factor. The healing phase is fast and painless, and postoperative care is simple. There exists no risk of cornea haze and the results are not only stable but also predictable early on. Consequently, LASIK quickly established itself as the new surgical procedure of choice for the correction of refractive errors.

Besides patients' word of mouth, the internet has played a major role in promoting the popularity of LASIK. Indeed, "LASIK" is one of the most commonly searched keywords in the major search engines. In the early years of the procedure, ophthalmologists had to spend a considerable amount of time in the counselling process to explain to and reassure patients about the technology. Nowadays, most LASIK candidates are already armed with a wealth of knowledge about the procedure and their confidence bolstered by recommendations from friends or relatives who already have had the procedure done. It also certainly helps that many celebrities have had the procedure performed. A quick glean through the internet throws up names such as Tiger Woods, Vijay Singh, Jennifer Lopez, Reese Witherspoon, Nicole Kidman, Brad Pitt, Carlo Santana, Barry Manilow, Jennifer Capriati, Kenny G, Lorenzo Lamas, Sir Richard Branson, Michael Bolton, Cindy Crawford, among others. It has

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been estimated some three years ago by a leading eye news magazine that some 13 million LASIK procedures have been performed worldwide. I am certain the figure today is much higher. With respect to Singapore alone, my conservative estimate is that to date, some 80,000 patients have had LASIK surgery, and an estimated 13,000 will be added to the list this year.

The public has always placed great faith in the word "laser", equating it with something very technologically advanced. Beyond marketing appeal, laser refractive surgery was developed with the hope of replacing the variable skill of the human hand with the consistency and efficiency of the machine. However, the excimer lasers used when PRK first started were quite simplistic in design and function, as compared to today's technological marvels. They were called "broad beam" lasers as they sculpted the cornea surface via a large diameter laser beam aimed through an adjustable shutter with plastic overlays (masks) to vary the size and energy of the laser beam that hits the cornea. On the other hand, modern lasers are "flying or scanning spot" lasers that sculpt the cornea in a completely different way using small diameter beams that do not shoot in a fixed position as before, but fly or scan rapidly across the treatment surface in a computer-generated randomised pattern with slight overlap that enables much more precise and smoother sculpting. To overcome the problem of involuntary minute eye movements during the treatment period, modern lasers have eye tracking systems to ensure that the laser ablations follow the shifting movements of the eye in the x, y and z axes and even rotational movements. Advancements in software technology allow faster treatment times and removal of less tissue that in turn allow larger treatment zones important for reducing night vision problems. Software algorithms now integrate information obtained from cornea topography and wavefront analysis for true customised wavefront treatments. It is interesting to note that this concept of customised LASIK treatment has stimulated the imagination of those in the optical trade, leading to the invention of customised wavefront glasses and contact lens.

In the early years, most serious problems were related to laser ablation, such as central islands caused by patches of uneven sculpting, de-centred ablation, severe glare and halos. As the lasers improved with time, these problems became increasingly uncommon. Today, the main cause of serious LASIK complications is related to the creation of the cornea flap. The flap may be imperfectly created, resulting in an incompletely or irregularly cut flap. If the patient squeezes or rolls the eye during the cut, a poorly-centred flap may result. The cornea surface is innervated by thousands of nerve endings and cutting the cornea flap severs these, leading to severe dry eyes in some patients that may take months to years to recover. The human eyeball maintains its shape by being under constant positive internal pressure. As cutting the flap weakens the structure of the cornea wall, in patients with thin corneas or severe myopia or a combination thereof, the combination of the cut and sculpt may weaken the cornea wall to such an extent that a condition of progressive thinning and protrusion known as keratectasia may develop. Problems can also occur in the healing of the flap. The most common is an inflammation of the flap interface called diffuse lamellar keratitis (DLK). Most cases are mild sterile inflammations that respond well to a course of steroid eyedrops. Severe cases, however, can cause scarring and lead to loss of best corrected visual acuity. All these beg the question as to the necessity of cutting the cornea flap in the first place? One will recall that its predecessor procedure PRK was plagued by slow painful cornea healing, high risk of scarring and unstable refraction for several weeks. But that was when PRK was done using the first generation lasers that were phased out only after the advent of LASIK. It has been shown that modern PRK surgeries carried out with the new generation of lasers do not suffer as much from these problems and thus there is a call to return to surface ablation. Epi-LASIK is one such procedure that has evolved from this call.

The key to Epi-LASIK is a microkeratome that does not cut into the cornea as in LASIK, but instead mechanically separates or cleaves the superficial layer of epithelial cells from the underlying cornea bed. This is achieved by utilising a blunt blade that vibrates at close to ultrasonic speed and varying the angle of attack of the blade. The result is an atraumatic separation of the epithelial layer from the Bowman's membrane that forms the topmost layer of the underlying cornea bed. The procedure releases less cytokines, a mediator of inflammatory response, and produces less scarring than PRK or laser-assisted subepithelial keratomileusis (LASEK). The subsequent laser sculpting is done on the glassy smooth topmost layer of the cornea bed called the Bowman's membrane. What is different about Epi-LASIK, as compared to the PRK and LASEK, is a fair degree of the "Wow!" factor, faster and less painful wound healing time of three to five days, less risk of cornea haze, and faster stabilisation of vision within a few weeks. More and more doctors are incorporating Epi-LASIK into their surgical repertoire, ever since it was introduced in 2003. Its detractors have derisively call it "glorified PRK", but those who have performed it can testify to a real difference from PRK. Epi-LASIK is slowly but surely shifting the LASIK market place. In the USA, Epi-LASIK is expected to constitute more than 5% of all vision correction procedures this year, up from 1.5% in 2005. In Europe, approximately 10% of laser vision procedures are Epi-LASIK cases. In Singapore,

I have remained a strong advocate of the procedure and am choosing to perform it on an increasing percentage of my patients.

Most people are afraid to have anything come into contact with their eyes, much less knives. The good news for them is that we now have "all-laser LASIK" where the microkeratome is replaced by the femtosecond laser. It makes for a great marketing strategy, but the reality is that regardless of a laser cut or a blade cut, a cornea stromal flap must still be created with all its attendant risks. It is a vastly more expensive piece of hardware as compared to the microkeratome, and a significant number of patients suffer light sensitivity during the early recovery phase. To be objective, the laser does possess certain advantages beyond pure marketing hype, and early studies seem to indicate less flap creation mishaps and greater ease with the creation of thinner flaps. In LASIK surgeries where flap creation mishaps with a blade cut occur leading to abortion of the surgery, the femtosecond laser is especially useful for making an incision into the cornea in the surgeon's second attempt to create a smooth cornea stromal flap. Presently, there exist five such lasers in Singapore.

Intraocular lens implantation surgery is a viable alternative to laser refractive surgery, but it should be considered only if laser vision correction cannot be safely done, as it is a more invasive procedure. In this procedure, an artificial lens is implanted into the eye with its lens power calculated to correspond to the patient's spectacles correction. There are two types of lens implant, based on its location within the eye. The phakic intraocular lens is placed in front of the eye's own natural crystalline lens, either in front of or behind the iris. The aphakic intraocular lens is placed in place of the eye's own crystalline lens after its removal, in a manner akin to that of cataract surgery. In my experience, many patients become wary when lens implant surgery is mentioned, thinking that it is some newfangled procedure. The irony is that lens implant surgery has been in existence even longer than laser refractive surgery and it is still the most commonly performed major surgery in the operating theatre. It provides outstanding results beyond what laser refractive surgery can do in those with extreme refractive errors and thin corneas. There is no definitive rule as to which method of lens implant is best, but I would typically recommend phakic lens implant in the younger patient who has many more years to go before the onset of presbyopia or middle-age farsightedness. For patients who are over the age of 38 years, where there is already loss of ability to auto-focus or where cataract changes are observed, aphakic lens implant would be my preferred choice. Aphakic lens implant with clear lens extraction is preferable for those suffering from high degrees of farsightedness, irrespective of presbyopia onset. As a general rule, I would recommend lens implants as the refractive surgical procedure of choice for those with corneas thinner than 450 microns and those with high myopia exceeding 13 dioptres (i.e. 1,300 degrees). The procedure increases the risk of retinal detachment and patients are advised to come back for urgent review if they experience symptoms of seeing flashing lights or floaters any time in their life. I have a preference of performing bilateral simultaneous eye surgery under general anaesthesia for young patients below 40 years of age and for those who are anxious, or are tight eye squeezers during the retinal examination. Recently, there has been some bad press regarding angle-supported phakic lenses with cornea endothelial cell loss persisting even years after implantation, necessitating the early removal of these lenses.

Refractive surgery is essentially performed for reasons pertaining to lifestyle changes rather than for medical-related reasons. With advancing technology, there are now various options available to correct the patient's vision woes. One can even combine different treatment modalities by performing, for instance, lens implant surgery followed by laser refractive surgery to finetune the residual power, a concept called "bioptics". The onus is on the refractive surgeon to continually upgrade his knowledge and skills so that he is able to provide the best and safest treatment option for his patient. Finally, despite all the technological advances, not all patients are suitable candidates for refractive surgery. Yet, with rising patient expectations and demands, there frequently exists immense pressure on the surgeon to attempt to satisfy a patient's unrealistic demands, in spite of calculated risks. Such temptation must be resisted and considerations of long-term ocular health and safety should remain the top priority in the decision-making process.

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