Chapter 2 – TECHNIQUE REVIEW

2.1 CORNEAL REFRACTIVE SURGERY

Corneal refractive surgery owes much to the pioneering work of José Ignacio Barraquer, who coined the term 'keratomileusis' to describe a technique for re-shaping the cornea with a specialised lathe ('microkeratome') to alter the refractive status of the eye [1]. It was recognised in the 1980s that excimer ('excited dimer') laser incisions on the corneal surface were highly precise, and soon this technology was used to ablate the corneal surface for refractive purposes [2]. PRK, as surface ablation became known, was often painful and could result in corneal scarring. A new approach was developed in which a flap of cornea was created with a microkeratome and lifted to expose deeper corneal tissue ('stroma') for excimer laser ablation [3]. This was called LASIK. Other researchers were using new ultra-high frequency lasers (e.g. femtosecond) to cut corneal tissue with increased precision, and eventually, femtosecond lasers were used in place of the microkeratome to create the corneal flap. The concept of refractive surgery as a military application was advanced in the early 1990s after a group of US Navy Seals received PRK to improve their operational effectiveness [4]. Since then, there has been a drive to understand the effects of refractive surgery in military and civilian occupations [5].

2.1.1 Surface Ablation Techniques

Surface ablation techniques include PRK, Epi-LASIK and LASEK. LASEK differs from PRK in that the top layer of cells in the cornea ('epithelium') is removed by ethanol and replaced after the procedure to reduce pain and scarring. In Epi-LASIK, the top layer of cells is removed by a microkeratome. Surface techniques cost less than flap-based techniques, for which reason they are sometimes preferred over LASIK [6]. In military circles, concerns have been raised about the risk of a traumatic flap dislocation after LASIK surgery. Such a complication, although rare, would almost certainly necessitate the repatriation of a soldier from operational duties. These concerns have resulted in a preference for surface ablation techniques in combat troops in many armies. However, more modern techniques of flap creation, specifically with the femtosecond laser, have been shown to significantly reduce the low risk of traumatic flap displacement [7]. In addition, surface ablation techniques can be associated with corneal scarring ('haze'), especially at higher levels of myopia. Newer excimer lasers, the use of mitomycin-C as an adjunctive treatment during the procedure, and improved post-operative management have decreased the incidence and severity of corneal haze. However, haze remains a concern in military aviation and night operations, in which decreased contrast sensitivity may adversely affect visual performance.

2.1.2 LASIK

LASIK has undergone a series of refinements since it was conceived. Microkeratomes have become safer and more precise, and femtosecond laser flaps are now a widespread alternative. Concerns about the risks of LASIK that were raised when it was first made available are now much less evident. For example, flap displacement in the early post-operative period used to be relatively common, but is now considered a very rare complication [7]. Early concerns that high gravitational forces could dislodge the flap no longer seem probable. LASIK produces a thinning of the corneal stroma; therefore, it creates a risk for corneal ectasia. Today, better pre-operative diagnostic tools are available and more is known about the safety parameters necessary to minimise the risk of surgically induced corneal ectasia.

2.1.3 Thermokeratoplasty / Conductive Keratoplasty

Thermokeratoplasty and conductive keratoplasty are non-excimer alternative methods of re-shaping the cornea to treat mild hyperopia. Thermokeratoplasty is the application of heat, delivered via a Holmium YAG laser, to the peripheral cornea. Pulses of energy are applied to spots in a concentric ring. This has the

effect of causing the collagen fibres to shrink, thus steepening the cornea and permitting the correction of mild long sight [8]. Conductive keratoplasty is similar, but entails the use of radiofrequency waves to shorten the peripheral corneal fibres [11]. Regression commonly occurs and neither technique have gained wide acceptance.

2.1.4 Intrastromal Rings

The implantation of Polymethylmethacrylate (PMMA) ring segments into the mid-peripheral corneal stroma is a non-laser alternative treatment for mild myopia. However, glare and night vision problems are of particular operational concern with this procedure [9]. Also extrusion of the rings segments is a post-surgical complication that should be considered prior to implantation in military personnel.

2.1.5 Multi-Focal Corneal Ablations

This technique is designed to treat the age-related loss of accommodation (presbyopia) by applying laser to the cornea in differential contours, enabling multi-focal correcting vision at all distances. This procedure increases optical aberrations, reduces contrast sensitivity and produces night vision problems [10].

2.2 INTRAOCULAR SURGERY

Modification of the shape of the cornea is not the only way of altering the refractive power of the eye. The natural crystalline lens inside the eye may be targeted, even in the absence of cataract formation, to correct refractive error. The risk profile of intraocular procedures is different than corneal surgery. Risks include retinal detachment, intraocular bleeding and infection, all of which may cause blindness. However, these severe complications are rare.

2.2.1 Clear Lens Extraction

Removal of the natural crystalline lens from the eye can be combined with artificial lens implantation to change the refractive power. If the natural lens is not opaque with cataract, this procedure is termed ‘clear lens extraction’. Generally, such surgery is performed to correct large refractive errors. High refractive error is associated with compromised vision and associated pathologic retinal conditions. Since occupational vision standards in most military organisations preclude entry of recruits with high refractive errors, this procedure is rarely performed on military members. Clear lens extraction is seldom carried out on individuals under the age of 45 because the natural lens can accommodate until approximately this age. The natural ability to accommodate is lost after this surgery.

2.2.2 Phakic Intraocular Lenses

In some cases, high refractive errors in younger patients can be treated while preserving the ability of the natural lens to accommodate by placing slim artificial lenses either in the intraocular space between the cornea and the natural lens (“piggy-back”) or by clipping the lens to the front surface of the iris. The risks are similar to other intraocular procedures, with the notable exception of retinal complications, such as retinal detachment and cystoid macular edema. The long-term risk of cataract progression and corneal decompensation (loss of the cornea’s ability to regulate its own water content) has been studied and reported in the literature, but remains a concern. Rare complications exist, such as developing a non-reactive dilated pupil, glaucoma, uveitis and infection [12].

2.2.3 Accommodative Intraocular Lenses

Certain artificial intraocular lenses have a hinge movement that permits, at least in theory, a degree of near accommodation. In practice, this is likely to be relatively small [13].

2.2.4 Multi-Focal Intraocular Lenses

Multi-focal lens implantation aims to preserve vision over a range of distances by including differential focus zones within the lens. These zones enable focusing at near, intermediate and far distance. Many patients complain of halo effects, glare at night and reduced contrast sensitivity. While many patients get used to this kind of vision, a few cannot tolerate the lenses, which must then be removed. A multi-focal contact lens trial beforehand can be helpful. On order to qualify for multi-focal lenses, a patient must have minimal corneal astigmatism (a more powerful axis in one corneal meridian than its perpendicular counterpart), as this will induce aberrations [14].

2.3 ADJUNCTIVE TECHNOLOGY

Since it responds to a widespread need, refractive surgery is an area of medicine in which highly sophisticated technology rapidly becomes incorporated into mainstream practice with the aim of improving quality and increasing profitability. Two important advances have been Wavefront technology and the widespread availability of the femtosecond laser.

2.3.1 Wavefront Measurement

Wavefront measurement allows precise measurement of optical aberrations, and is useful for customising laser surgical procedures in which aberrations are higher than normal by accurately targeting the laser to the source of corneal irregularities. The success of this approach is highly dependent upon precise and accurate positioning of the eye, which can be tracked electronically during the surgery. It has the potential to improve visual outcomes in some patients [17]. It also contributes towards our understanding of visual quality, correlating an objective measure of optical aberrations with the subjective experience of visual stimuli [16].

2.3.2 Femtosecond Laser

A high-precision laser with multiple uses in ophthalmology, femtosecond laser is generally viewed as the most effective, most predictable and safest way of cutting the corneal flap for LASIK. It allows much more precise and accurate control of flap thickness and cutting angle than even the most advanced microkeratomes. Thinner and more precise flaps are thought to be safer, minimising the risk of ectasia and of early flap displacement.