COMMENT

LASIK: KERATOMILEUSIS EVENTUALLY COMES OF AGE?

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INTRODUCTION

Laser *in situ* keratomileusis (LASIK) was born in 1990 [1] and nurtured in the caring hands of the current generation of keratorefractive surgeons. Rapidly heralded as the latest panacea for all or any optical defect, LASIK has already been evaluated by ophthalmologists world-wide and its true niche is becoming established as it is subsumed into mainstream ophthalmology.

BARRAQUER'S KERATOMILEUSIS

LASIK could not have come into existence without the previous development of keratomileusis, first described by José Barraquer in 1949 [2]. The more ponderous evolution of keratomileusis itself speaks of a bygone era, before electronic communications and commercial interests injected increasing impetus into ophthalmic research and development. Keratomileusis – derived from the Greek for 'cornea' and 'chiselling' – was the first effective refractive surgical procedure described and, indeed, represents the initiation of keratorefractive surgery itself. Barraquer devised the first microkeratome with which to resect corneal lamellar buttons. By incorporating cryo elements into a watchmaker's lathe he was able to grind the isolated corneal lamellae to alter their refractive power, in order to correct both myopia and hypermetropia.

In his initial work with corneal tissue resected from the patient's eye (autoplastic keratomileusis) Barraquer was able to correct a range of spherical refractive errors, up to around –15 D of myopia and +8 D of hypermetropia. The limitations in the range of refractive error correctable were not defined by the limitations of the equipment but, on the contrary, by the more fundamental limitation of how much change in corneal profile could be achieved with the raw material of the patient's cornea alone. To overcome this, Barraquer used donor corneal tissue excised by microkeratome from a donor eye (homoplastic keratomileusis) and the additional thickness of tissue derived allowed the refractive range to be extended. Because of the more complex corneal profile required for hyperopic keratomileusis, the procedure had a smaller range than myopic keratomileusis (where the optical zone is effective over a greater proportion of the lamellar button).

In those pre-intraocular implant days, the correction of aphakia was a pressing need, but many aphakic refractions were beyond the range of hyperopic keratomileusis. Barraquer's response was keratophakia – a pre-lathed donor tissue button to implant beneath an unlathed superficial lamellar keratectomy – extending the range of hyperopic correction achievable to around +20 D.

Despite the fact that both homoplastic keratomileusis and keratophakia allowed the lathing of the corneal tissue to be separated from the rest of the operation, these procedures remained complex, the equipment expensive and training in the technique difficult. Keratomileusis was pioneered in England by Derek Ainslie [3], but for 30 years it was carried out by only a handful of ophthalmologists world-wide and it remained an exotic ophthalmic curiosity.

EPIKERATOPHAKIA DEVELOPS FROM KERATOMILEUSIS

TP Werblin conceived of epikeratophakia in 1979, while pondering on the raised burial chambers found above ground level in the cemeteries of New Orleans. The potential of this idea was immediately appreciated and developed by Herb Kaufman [4]. The technology to carry out epikeratophakia had been in existence for many years waiting for this moment! For the first time serious commercial muscle was put behind a keratorefractive procedure, and with support and promotion by American Medical Optics [AMO] epikeratophakia was not only expected to be the cure for severe hypermetropia and myopia, but a new treatment for keratoconus as well [5–8]. With distribution of pre-lathed freeze-dried lenticules, AMO brought keratorefractive surgery to ophthalmologists across the globe. Yet epikeratophakia's heyday and decline was accomplished within a decade and refractive epikeratophakia has now been largely superseded by new technologies. Nevertheless, epikeratoplasty for keratoconus remains a useful technique and indeed continues to be refined and developed [9].

Other directions of development of keratomileusis

In the latter part of the 1980s Barraquer's original microkeratome was re-engineered. The incorporation of a direct translational drive mechanism turned what was previously an extremely difficult instrument into a much more manageable device. This 'automated corneal shaper' was the thrust behind other directions in the development of keratomileusis. To avoid the necessity of the cryolathe, excision of tissue from the bed of a primary lamellar resection could be carried out with the microkeratome alone using an adjustable height suction ring. This so-called automated lamellar keratoplasty (ALK) proved to be a flash in the pan [10]. At around the same time, keratophakia was given a transient resurrection by combining the new microkeratome with manufactured hydrogel inlays, but again this route of development appeared to be a *cul de sac* [11].

Laser keratorefractive surgery

With the advent of the excimer laser and photorefractive keratectomy (PRK) it was natural that this new laser should be used for keratomileusis. Early work was carried out by Lucio Buratto, using the excimer laser as a straight substitute for the cryolathe to reshape the isolated corneal lamella, or alternatively to reshape the corneal bed beneath the excised lamella – the so-called '*in situ* keratomileusis' [12].

The concept of the incomplete superficial lamellar flap on a hinge, originally described by Barraquer [13], was adopted by Pallikaris, who named the technique 'LASIK' [14]. This small technical advance, combined with a simultaneous push by the laser and microkeratome manufacturers, produced an unprecedented growth curve in LASIK, changing it from concept to cure almost overnight.

LASIK: the early days

The path which LASIK was set to follow was that of a useable microkeratome system combined with excimer laser systems in their youthful stages of development. With PRK having already made a significant head start in the keratorefractive market place, LASIK initially had a difficult way to tread, directly in the footsteps of it older sibling. Thus LASIK was seen as a solution for the cases that PRK could not reach [15–17] – the higher levels of myopic correction where significant haze and regression were being encountered [18,19]. There seems no doubt that LASIK does indeed offer relative freedom from axial scarring and regression effects in comparison to PRK [20,21], but the extent to which this is bound up with the excimer laser delivery systems themselves rather than the difference in operative techniques only became apparent as the two procedures evolved.

LASIK and PRK for myopia correction

Where then does LASIK now stand in the family of keratorefractive techniques, in particular in relation to PRK? On the face of it one would expect that comparisons could readily be made between two operations capable of treating identical conditions, and now results of a few direct comparative studies are becoming available. Where the two techniques have been directly compared, LASIK has been shown to give superior results for a number of criteria [20,22–24]. However, one stumbling block to obtaining a simple comparison of the two procedures is the ability to offer LASIK patients re-treatment within a few months of the original treatment. At 3 months postoperatively many cases of PRK are barely half way to reaching a final stable refraction, yet virtually all LASIK patients at this point will have reached a stable endpoint [22]. If one waits until 12 months for an analysis, direct comparisons can be made for patients who have had a single treatment, but this denies patients the major benefit of LASIK, in that any deviant refractive outcome can be quickly re-treated. The problems of analysis are further compounded by the speed of evolution of excimer laser systems, such that in the space of time necessary to recruit and follow-up a reasonable cohort of patients, advances in software or hardware will have made any assessment that of yesterday's technology.

LASIK has now found a place for correction not only of the higher degrees of myopia, but also for the small errors previously treated by radial keratotomy or PRK [25]. Two recently reported prospective comparative studies of PRK and LASIK in low to moderate degrees of myopia have clearly shown the benefit of LASIK for this group, with faster visual rehabilitation and better rates of restoration of normal acuity [26,27]. A further excellent prospective study compared the results of simultaneous and consecutive bilateral LASIK [28]. There was no significant difference in outcomes between the two groups, with the unexplained exception of more frequent epithelial in-growth in the simultaneously treated group.

Optical zone size and hyperopic treatment

Within a short time of evaluation of myopic PRK it became apparent that the optical zone diameters that were achievable with the early laser systems were inadequate [29,30]. Because of the limitations of achieving even energy density over a broad excimer beam, laser manufacturers have moved to various scanning systems whereby large area ablations can be achieved by smaller beams [31]. This has been assisted by the development of associated tracking systems to ensure accurate placement of the treatment.

Because hyperopic excimer laser PRK requires ablation over a zone larger than that in which the optical correction is obtained, the development of hyperopic treatment has lagged behind that of myopic PRK. Early results confirmed the ability to treat low levels of hypermetropia with PRK, but there was a greater tendency to problems with regression and loss of best-corrected acuity compared with similar degrees of myopic treatment [32–34]. LASIK again seems to outperform PRK for hyperopic treatment, although there are only early reports available [35,36]. Initially, the actual laser ablation parameters being used in both PRK and LASIK were identical, and even today some LASIK surgeons are still using the same hardware and software programs interchangeably for the two procedures. By using laser treatment profiles for hyperopic ablation that are specifically tailored for LASIK there is potential for further improvement in the range and quality of results.

Conclusion

Today's laser systems can offer refractive corrections for both myopia and myopic astigmatism that are limited in their range of effect only by the physical constraints of the minimal residual corneal thickness after treatment (up to −10 to −15 D). For hypermetropia and hyperopic astigmatism, treatments are improving but at present are only reliable for the lower degrees (up to around +5 D).

Because of intrinsic biological variability it seems unlikely that any keratorefractive system will ever be able to achieve perfect precision in every case, and LASIK's relative ease of speedy secondary adjustment is a clear benefit in this respect. In addition, the virtually painless postoperative period and rapid visual rehabilitation make the procedure extremely favourable from the patient's perspective. The view that LASIK is PRK performed properly is one now shared by many surgeons.

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