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Radial keratotomy (RK)

RK was first described by Sato (Sato *et al.*, 1953) and popularised by Fyodorov in the early 1970's (Fyodorov and Durnev, 1979) and uses a guarded micrometer blade to produce radial cuts in the mid-peripheral and peripheral cornea, through approximately 95% of the corneal thickness, leaving a central untreated area of 3-4mm in diameter (Waring *et al.*, 1985). The disruption of the epithelium that forms the front surface of the cornea results in some pain in the early post-operative period but this subsides within a few days. The incisions substantially weaken the tissue, causing the peripheral cornea to bulge, resulting in a relative flattening of the central cornea and a reduction in myopia. Astigmatism can be treated by placing the radial incisions along just one of the principle meridians. Permanent radial corneal scars are visible following .this procedure (figure 7)

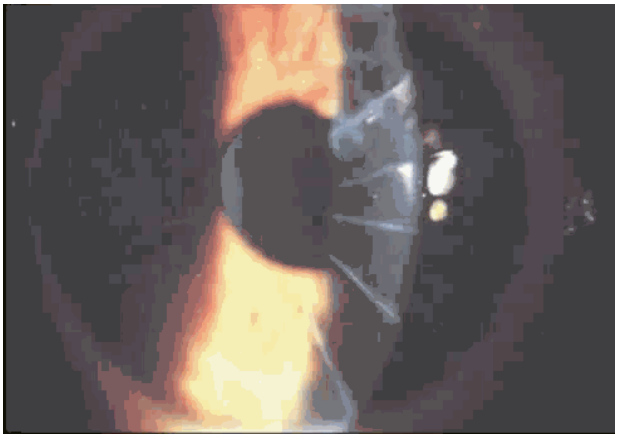

Figure 7: Corneal scars resulting from radial keratotomy (RK)

Surgical outcomes

The Prospective Evaluation of Radial Keratotomy (PERK) study ran in the United States from 1980-1985, and considered the safety, efficacy, predictability and stability of a standardised, 8-incision radial keratotomy procedure. It assessed 793 eyes with a range of pre-operative myopia between -2.00 and -8.75 D with 88% of eyes followed for 10 years (Waring *et al.*, 1994). The PERK study found that 53% of eyes achieved 6/6 unaided vision or better and 85% achieved 6/12 or better at the end of the 10 year period. The procedure is more accurate for treating lower degrees of myopia with 84% of the -2.00 to -3.12D group and 62% of the -3.25 to -4.37D group, achieving a refractive result between +1.00D and –1.00D at 1 year post-surgery in the PERK study, but only 38% of the -4.50 to -8.00D group fall in to this category (Waring *et al.*, 1985). However, the long-term stability of the refractive result has been questioned following the detection of a drift towards hyperopia in up to one third of patients after 4 years (Waring *et al.*, 1991). The 10 year follow up of the PERK study revealed an alarming 43% of eyes with a hyperopic shift greater than 1.00D from the refractive result measured at 6 months post-RK (Waring *et al.*, 1994). Large shifts in direction of long sight have been noted at high altitude (Butler, 1999). Post-RK eyes appear to be stable at increased levels of atmospheric pressure such as that found when scuba diving (Peters *et al.*, 1999).

Ocular integrity

A serious but rare complication of radial keratotomy is a 2.2% risk of sight-threatening corneal perforation (Waring *et al.*, 1985) due to structural weakening of the cornea. One study reported three cases of corneal rupture more than 10 years after RK, resulting from an assault (1 case), a sports injury (1 case) and "daily living" (Panda *et al.*, 1999). Another study considering 28 eyes that had ruptured after RK attributed 7 cases to assault, 4 to sport injuries, 5 to car crashes and 12 to "daily living" (Vinger *et al.*, 1996). Wound leakage resulting from blunt trauma has been reported up to 91 months post-RK. The continuity of collagen fibrils is not restored following RK and so the tensile strength of the cornea is reduced. Many surgeons believe that the radial wounds never completely heal and corneal infection involving the incisions has been reported many years after surgery.

Visual performance

A common complication is a diurnal fluctuation in refractive error and hence visual acuity due to the structural weakening of the cornea (Bores *et al.*, 1981; Cowden and Bores, 1981; Hoffer *et al.*, 1981; Kwitko *et al.*, 1992). The Prospective Evaluation of Radial Keratotomy (PERK) study encountered an increase in myopia greater than 0.50D in 30% of eyes (Bourque *et al.*, 1986). A study of fire-fighter applicants who had undergone radial keratotomy, found a myopic shift occurring between the morning and afternoon of -0.41± 0.33D compared to +0.06± 0.42D in the control group. The refractive change caused 3 out of 10 subjects to fail to meet the unaided vision standard in the afternoon despite passing in the morning (Bullimore *et al.*, 1994).
Along with other forms of refractive surgery, RK can cause a reduction in the quality of vision due to an increase in forward light scatter and/or corneal aberrations (Applegate*et al.*, 1998). The increase in corneal aberrations (reduction in optical quality) is associated with the flattening of the central cornea in relation to the paracentral area. About 19% of patients in one study showed a shift towards myopia with pupil dilation as a result of increased aberrations, leading to poor night vision (Holladay *et al.*, 1991). For most patients, increased forward light scatter and aberrations rarely cause a reduction in high contrast visual acuity (assessed using the Snellen letter chart), but do influence the ability to resolve real-world targets since they tend to comprise a range of contrast levels. The PERK study noted that following the correction of any residual refractive error, only 13% of cases showed a loss of 1-2 lines of visual acuity on the Snellen letter chart after 1 year and 3% of cases after 10 years. The data on the effects of radial keratotomy on the more subtle aspects of visual performance are inconclusive due to the variety of different measurement techniques employed. Some studies indicate a permanent loss of contrast sensitivity while others report no loss (Krasnov *et al.*, 1988; McDonald *et al.*, 1983; Olsen and Andersen, 1991). Although contrast sensitivity testing should be one of the better ways of assessing visual performance, there is little consistency between the results from commercially available tests (Jones*et al.*, 1994; Reeves *et al.*, 1991; Wilkins *et al.*, 1988). The majority of studies test contrast sensitivity under brightly lit conditions, causing the pupil to constrict so that the influence of the mid-peripheral cornea (where the scars are located), on visual performance remains undetected.

Under low lighting levels, the pupil dilates so that the radial scars and the modified shape of the mid-peripheral cornea influence the quality of the retinal image (figure 8), leading to complaints of glare difficulties and problems with night vision due to starburst effects and halos around lights (Waring *et al.*, 1985). A reduction in visual performance in the presence of a glare source has been reported (Corbe *et al.*, 1993b; Bullimore *et al.*, 1994) although glare sources under clinical conditions often cause pupil constriction masking some of the effects of increased corneal aberrations (Boxer-Wachler B.S. *et al.*, 1999).

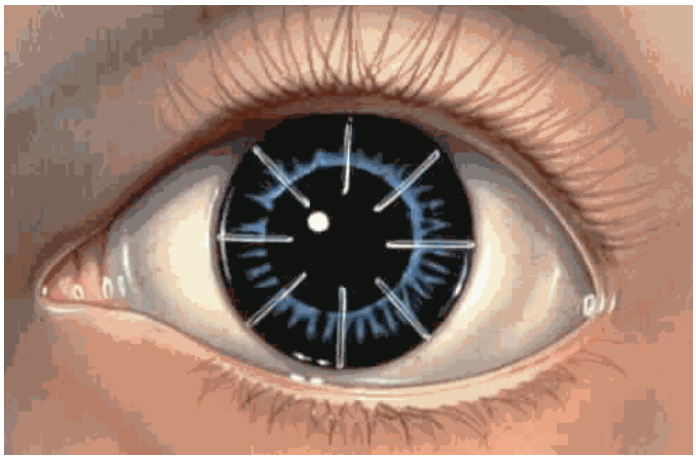

Figure 8: Under low illumination, the pupil dilates such that the radial cuts fall within the pupil. This can cause glare.

Conclusions

Radial keratotomy is rarely performed in the United Kingdom today with most surgeons believing that the risks are too high and that the procedure has been superseded by the advances in excimer laser technology. To our knowledge, only one private centre offers RK in the United Kingdom. Ongoing glare disability is sighted by Corbe and colleagues (Corbe *et al.*, 1993a), as being a significant reason for excluding radial keratotomy patients from the French air force. Enzenauer et al. (Enzenauer *et al.*, 1993) also concluded that radial keratotomy was unsuitable for the Soldier-Aviator. Although plenty of successful cases of RK do occur, it would seem inadvisable to recommend the procedure in view of more recent literature. Any assessment of the suitability of a radial keratotomy patient for a particular profession should include a measurement of the stability of refraction as well as an examination of the visual performance.