

MYOPES AT ALTITUDE: SURGICAL AND NON-SURGICAL ALTERNATIVES

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Over the last few decades, numerous devices and surgical procedures have become available for the correction of myopia. Many have been accompanied by huge marketing campaigns, which at times have been rather misleading. In this correspondence, I will briefly review the surgical and non-surgical options currently available for myopes, who may be exposed to high altitude during mountaineering excursions. I will attempt to objectively discuss both the positive and negative aspects of each.

Section I - Glasses

Glasses are the time-honored method of correcting myopia. The advantages of glasses are well known to all, but merit discussion because of comparisons to other devices and surgical procedures later in this text. Glasses can provide excellent vision for most myopes, UV light protection, protection from small flying foreign bodies, and are relatively inexpensive. Prescription, tinted glacier goggles can be made for nearly any myope. The disadvantages of glasses are obvious. Losing or breaking prescription sunglasses in the backcountry could be disastrous to even a moderately myopic climber. They can fog with high humidity and become scratched if not properly cared for. Certainly an extra pair of prescription glacier goggles in a rigid case should always accompany a climber.

The use of glasses for a myope offers one additional advantage. As the normal eye ages beyond the early 40's, this is accompanied by the loss of accommodation and the need for reading glasses. Thus, the normal (non-myopic) eye can see clearly far away, but the vision becomes fuzzy up close. This loss of near vision can be extremely annoying when an attempt is made to perform near visual tasks. However, for a myopic climber in the presbyopic age group, reasonably good near vision can usually be achieved by simply removing the glasses and reading with the naked eye. If one uses any device or procedure that transforms the myopic eye into an emmetropic eye (normal vision at distance), one pays the price of losing near vision with age.

Section II - Contact Lenses

Various types of contact lenses have been available to the public for nearly half a century. The two most common basic types of contact lenses available today include rigid gas permeable (RGP), and soft contact lenses. The RGP lenses are approximately 8-10 mm in diameter and very closely resemble the old polymethyl-methacrylate lenses (PMMA) which contact lens wearers used extensively in the 1950's, 60's, and 70's. However, RGP's are more gas permeable than PMMA lenses, allowing more oxygen diffusion through the contact lens to the cornea. Also, the lens moves a few millimeters with each blink, thus exposing a larger portion of the corneal surface to ambient oxygen. When properly fitted, these lenses offer excellent visual acuity. The advantages of RGP contact lenses compared to soft lenses are their

relative ease to clean and maintain their lower rate of corneal ulcers, and their ability to offer many people with astigmatism very crisp vision because they create a very spherical anterior corneal surface. They can be cleaned on a daily basis for a year or more without replacement. They have several disadvantages which include a profound foreign body sensation with dust or other particles in contact with the lens. As with any contact lens, maintaining proper lens hygiene may be difficult in a remote mountain environment. They are not designed for overnight use. Also, they are generally more easily dislodged than soft contact lenses and are subject to the sensation of dryness and grittiness at high altitude.

Several types of daily use soft contact lenses are available. All are approximately 14 mm in diameter and cover the entire cornea. Conventional soft contact lenses can be cleaned and reinserted for daily use over a period of many months. It is important that a rather precise cleaning procedure be used in order to avoid lens contamination. Another variety is the individually packaged, sterile disposable soft contact lens. There are two types of daily use disposable soft contact lenses. One type is used once for one day only, and then simply discarded. This form of daily use may simplify lens care but may prove cumbersome on a long trip since dozens of such lenses must accompany the climber. The second type of disposable soft contact lens is cleaned nightly and reinserted daily for a week or more, then discarded. Daily use soft contact lenses of both varieties have been used successfully by mountaineers. As with RGP's, extreme dryness at high altitude may lead to rather annoying discomfort in some individuals.

Disposable and conventional soft extended wear contact lenses are also commonly used by mountaineers since the cold, rather unsanitary environment of high altitude climbing does not lend itself well to daily manipulation of contact lenses. They offer the great advantage of not having to remove, clean, and reinsert a lens on a daily basis and have been used by climbers for days, or even weeks without removal. They offer one major disadvantage. Overnight use of conventional or disposable extended wear contact lenses confers at least a 10-fold greater risk of ulcerative keratitis (corneal ulcer) than strict daily wear use [1-3]. Ulcerative keratitis refers to a breakdown of the corneal epithelium with underlying bacterial infection of the corneal stroma. These ulcers may be extremely painful and cause a profound and sometimes permanent decrease in vision. Their occurrence in a remote setting could prove disastrous for the climber. Eye pain in extended wear contact lens subjects traveling in a remote environment should be assumed to be a bacterial corneal ulcer until proven otherwise. The contact lens should be removed and broad-spectrum antibiotic drops started at once.

Section III - Surgical procedures

A. Radial keratotomy

Radial keratotomy has been performed on millions of active young myopic patients. Radial keratotomy usually consists of 4-8 radial incisions made at approximately 90% depth in the periphery of the cornea. These incisions are normally made with a diamond blade and the visual axis of the cornea remains untouched. These wounds may never completely heal and remain weak even years after this procedure [4].

Diurnal changes in vision are well documented at sea level following radial keratotomy [4] also, several reports have documented visual changes at altitudes in

excess of 9,000 feet following this procedure [5-8]. Any cornea thickens with exposure to hypoxia. However, research suggests that when the normal corneal architecture is weakened by radial incisions, the hypoxic cornea may preferentially expand circumferentially in the periphery, leading to central corneal flattening and a resultant hyperopic (farsighted) shift [9]. One study performed on RK subjects documented a progressive increase in hyperopia and corneal flattening when measurements were made at sea level, 12,000 and 17,000 feet. [7]. In this same study a 46 year old RK subject with excellent uncorrected vision at sea level observed a hyperopic shift with a pronounced decrement in near and far vision at 17,000 feet. After 24 hours at this elevation, he could not read his watch or assemble a cook stove. Another RK climber experienced a profound visual loss while attempting to ascend to the summit of Mt. Everest. [10] This visual loss led to his inability to safely ascend or descend, which resulted in severe frostbite to his hands and face. One further study, performed at 14,000 feet on 11 RK eyes, documented that approximately 24 hours of altitude exposure were necessary to produce the hyperopic shift, and the shift increased in magnitude over three days at this altitude [8]. All studies have documented that the hyperopic shift was reversible with re-exposure to sea level [6-8].

Several points regarding RK and mountain climbers should be emphasized. First, all reports have documented that approximately 24 hours of altitude exposure is necessary to cause the hyperopic shift and associated visual changes. This 24-hour delay could be potentially dangerous for high altitude RK climbers. Upon arrival at high camp, following a day hike, an RK climber's vision may be unchanged from that which existed at low camp. However, following a night's sleep with the additional hypoxic stress of lid closure, this same individual may experience pronounced visual acuity changes upon awakening the next morning.

Postoperative refractive error is an important factor in predicting potential visual acuity difficulties at high altitude. An RK climber with residual myopia at sea level may note improved distant visual acuity at high altitude because of the hyperopic shift. However, an RK climber with 20/20 uncorrected vision at sea level may notice a prominent shift toward farsightedness. Additionally, younger subjects with larger amounts of accommodative amplitude may experience less of a decrement in visual acuity as compared to older subjects with less amplitude, who may note more prominent visual difficulties. Climbers who have undergone RK may be aided by plus lenses at high altitude. One RK climber who is slightly myopic at sea level has ascended to 20,000 feet without difficulty using +1.5 glacier goggles (Larry White, M.D. personal communication). Unfortunately it is difficult to predict the exact lens power needed at a given altitude. Thus, if travel to extreme altitude is planned, multiple spectacles with increasing plus power must be considered.

B. Photorefractive Keratectomy

Photorefractive keratectomy (PRK) is another surgical procedure designed for the correction of myopia. It involves a laser ablation of the anterior cornea with a resultant resculpturing of the corneal surface. This procedure ablates the central 6 mm or so of the cornea to a maximum depth of about 100 microns. Although this procedure has been used to correct very high degrees of myopia, it has been most successful for low to moderate myopia (up to 6.0 Diopters). Mild optical aberrations

following PRK may occur because this procedure does not always uniformly ablate the entire corneal surface. When a corneal surface irregularity persists following PRK, the image produced may lack edge definition and contrast [11-14] Numerous studies have documented glare and ghost images following PRK, which may become more prominent with increased pupil size [15-19] This was particularly true of early PRK procedures, which only ablated 4-5.5mm of the central cornea. Optical zone diameters must be at least as large as the entrance pupil to preclude glare at the fovea, and larger than the entrance pupil to preclude perifoveal glare [20] More modern lasers which ablate the optical zone to 6 mm or greater have decreased the incidence of these complaints. Also, temporary corneal haze within the optical zone can occur following PRK, and become more prominent with deeper ablations for higher degrees of myopia [21-26] On the positive side, visual results from PRK have been very well accepted by most patients and it exhibits no diurnal variations in refraction. Also, PRK subjects studied during 72 hour exposure to 14,000 feet demonstrated no significant change in refractive error [8]. Thus, it appears that those individuals who have undergone PRK for myopia are not susceptible to altitude-related refractive shifts.

C. LASIK

Another new procedure for the correction of myopia is Laser in situ keratomileusis (LASIK). During the LASIK procedure, a plano-lamellar corneal flap incising the anterior stroma is created with a microkeratome. A refract Zive ablation using an excimer laser is then performed in the corneal anterior stromal bed. The flap is then replaced without sutures or adhesives. This procedure preserves the central epithelium, basement membrane, and Bowman's membrane and is frequently used to correct up to about 12 Diopters of myopia. Although no long term studies are available, early reports suggest acceptable visual acuity and stable results with this procedure [27] There is one case report in the literature describing LASIK at high altitude [28] This report documented a stable refraction and near point of accommodation in one 29 year old climber at 16,000 feet following this procedure. No cycloplegic refraction was performed on this subject at high altitude. To date no hypoxic studies have been done on LASIK subjects and its performance at high altitude is largely speculative [29]

D. Intrastromal Rings

Another new device for the surgical correction of myopia, in its final FDA trials, is the intrastromal corneal ring [30]. This is a ring device, made of a clear polymer (PMMA), that is surgically inserted through a single, small radial incision in the peripheral stroma of the cornea, outside the central optical zone. This intracorneal inlay mechanically flattens the central cornea, and can correct myopia in the range of -.50 to -5.00 Diopters. This procedure does not involve disruption of the optical zone, multiple incisions, or the removal of large amounts of corneal tissue as occurs with other surgical procedures for the correction of myopia. Also, by varying the size of the implanted rings, there is the potential for adjusting the surgical outcome through exchange procedures. In theory, this procedure may be reversed by removing the ring. There are no long term studies of patients who have undergone this procedure.

The effects of altitude on this procedure are unknown.

E. Intraocular Lenses

Perhaps the most common ocular surgical procedure performed worldwide is the surgical removal of a cataract lens, and its replacement with an intraocular lens. This is also a refractive procedure. Prior to performing this procedure, the surgeon calculates the power of the intraocular lens, based on measurements of the curvature of the cornea and the axial length of the eye. With this information, the surgeon can choose an intraocular lens power to create any refractive error desired by the patient. For example, a patient with a lifelong history of severe myopia or hyperopia can be made emmetropic (no glasses needed for distant vision) by inserting an intraocular lens of the proper power. Modern intraocular lens surgery has very successfully withstood the test of time. A variety of intraocular lenses, most with UV protection, can be inserted through incisions as small as 2.5 mm. Although no published studies have been performed in a high altitude mountain environment, their successful use in aviators is very well documented. In fact, these lenses are now waiverable in all three U.S. military services, the Federal Aviation Administration, and even the astronaut corps [31-35]. As with any surgical procedure, intraoperatively and postoperative complications may occur, such as infection, lens dislocation, or macular edema. It does have the disadvantage of a postoperative fixed focal length, because the eye is no longer able to accommodate.

In summary, numerous surgical and non-surgical alternatives are available for the correction of myopia. Their practical use in a mountain environment is strongly dependent upon the individual needs of the climber. With the exception of glasses, any alternative has risks and side effects which must be carefully considered when weighing the options.

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