Surgical Options for the Correction of Hyperopia

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Hyperopia is the refractive condition in which incident light is focused posterior to the retina, causing light to be defocused on the macula and resulting in blurred vision. The surgical correction of hyperopia has lagged behind advances for treatment of myopia. Reasons for this disparity include the tendency that patients in their 20s to 30s with myopia are more likely to seek refractive surgery than their hyperopic counterparts, who can rely on the accommodative power of their crystalline lens for clear vision. Thus, hyperopic patients often present later in life than myopes. Also, surgical correction for hyperopia remains technically more challenging when compared to myopic correction. For example, in corneal refractive surgery, the central cornea must be steepened, as opposed to flattened. Also, the hyperopic eye is often shorter than the myopic eye, with a smaller anterior segment and narrower anatomic angle making phakic intraocular lens implantation more difficult.[1]

Options for the surgical correction of hyperopia include changes at either the corneal or lenticular plane. Corneal refractive procedures include steepening the central cornea with the excimer laser or with collagen shrinkage. Alternatively, a phakic intra-ocular lens can be placed in the anterior or posterior chambers, or the patient's native lens can be exchanged with a monofocal or multifocal posterior chamber intra-ocular lens. This article will focus on these options, with emphasis on techniques and patient selection. Older techniques, such as hexagonal keratoplasty, automated lamellar keratoplasty, epikeratophakia, and keratophakia, are of historical interest only, and will not be discussed.

Excimer Laser Correction of Hyperopia

Keratorefractive procedures with the excimer laser are the most common type of surgery performed for low to moderate hyperopia, and this includes laser assisted in-situ keratomileusis (LASIK) and surface ablations. This article will refer to all forms of sub-epithelial excimer laser treatments, i.e. photorefractive keratectomy (PRK), laser assisted subepithelial keratomileusis (LASEK) or epi-LASIK as surface ablations. The total amount of hyperopia correctable with the excimer laser differs for each of the different platforms, but the maximum range of hyperopia without astigmatism is typically between 4 and 6 diopters.

The central steepening of the cornea in hyperopic LASIK (H-LASIK) is created by a peripheral annular ablation around the center of the cornea **(Figure 1)**. In order to create the new optical zone as well as the transition zone, H-LASIK requires larger flaps than are typically needed for treatment of myopia, generally between 9.5 to 10.0mm. The flap can be created with either a mechanical keratome or the femtosecond laser. If performing conventional H-LASIK, the surgeon should initially use published nomograms, and later personalized nomograms, to achieve the desired refractive result with the excimer laser platform used. If a wavefront-guided treatment is used, no nomogram adjustment is usually needed.

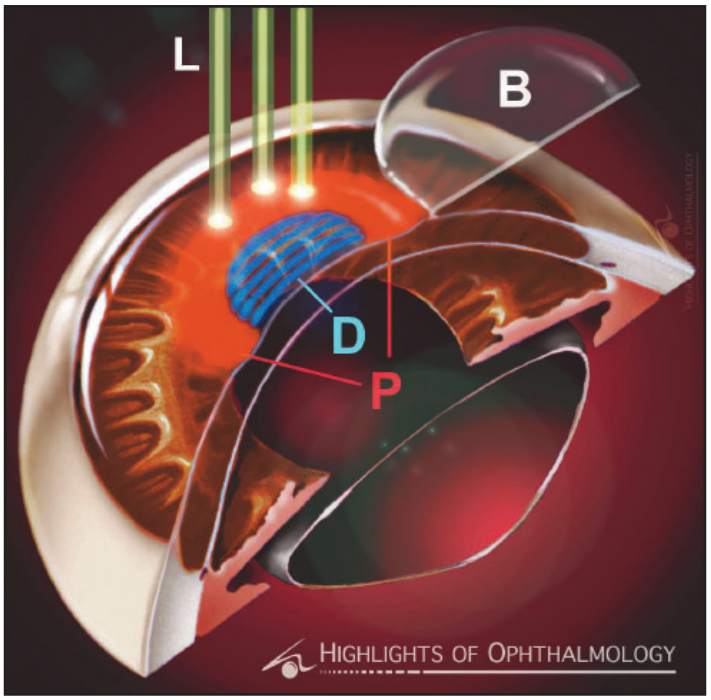

Figure 1: LASIK for Hyperopia - Ablation of Mid-Peripheral Cornea.

The corneal flap (B) with superior hinge is usually larger than myopic LASIK, but not much larger (aproximately 9.0 mm). This is now possible through more sophisticated microkeratomes.

The desired optical zone is aproximately 5.5 mm in diameter. The mid-peripheral zone (P) is the area of stromal ablation where tissue is removed with the excimer laser (L) to produce a different curvature than that of the central cornea. The ablation of the cornea into this area (P) begins where the limiting diameter optical zone is located (D).

It should be noted that the hyperopia nomograms account for the regression normally seen after hyperopic treatment, and the patient will often have initial myopic overcorrection, with an expected regression to emmetropia. For this reason, re-treatments should be delayed until the refraction has stabilized, usually at least 3-6 months after the initial treatment. A low corneal thickness is less likely to preclude treatment of patients with hyperopia compared to myopia, because less central tissue is ablated, and most of the ablation occurs in the mid-periphery, where the cornea is thicker. [2]

Corneal refractive surgery with the excimer laser can also be performed with surface ablation, after removal of the epithelium. Some surgeons prefer surface ablation techniques because of the elimination of the risk of flap complications. Flat corneas are more likely to result in small flaps, which may not be large enough for hyperopic ablations, and steep corneas are at risk for button holes. Also hyperopes can have smaller, deep-set eyes making the creation of adequate suction with the fixation ring difficult. Drawbacks to surface ablation are well known and include pain, delayed epithelial healing, stromal haze and prolonged use of steroids. While both surface ablation and H-LASIK are effective for hyeropia, one study has suggested that H-LASIK has more refractive stability.[3, 4]

Collagen Shrinkage

Steepening of the central cornea through collagen shrinkage can be achieved with laser thermokeratoplasty (LTK) or conductive keratoplasty (CK). Both techniques are reserved for low hyperopic corrections, usually no more than 2.5 or 3 diopters. Refractive results and patient satisfaction in the treatment of low degrees of hyperopia are good, but concerns exist about the stability of the refractive change. Collagen shrinkage techniques may be an alternative for patients with relative contraindications to LASIK such as dry eyes, flat or steep corneas, or narrow palpebral fissues.

In the LTK procedure, spots of laser energy are applied to the midperiphery of the cornea using a holmium laser. Because of initial overcorrection, inability to treat astigmatism, risk of induced astigmatism, and regression of refractive results, this procedure is used infrequently.

CK similarly aims to correct hyperopia through collagen shrinkage using radio frequency energy (350 kHz) delivered through a stainless steel probe. The probe is inserted into the corneal stroma, generating focal spots of collagen shrinkage in a circular pattern in the corneal midperiphery causing steepening of the central cornea.[1, 3] Technique is an important variable in minimizing induced astigmatism. Disadvantages of CK are similar to LTK and include initial overcorrection, inability to treat astigmatism, risk of induced astigmatism, and regression of refractive results.

Phakic Intraocular Lenses

A lens that is placed into the phakic eye without removing the native crystalline lens is termed a phakic intraocular lens (PIOL). There are three types of PIOLs - angle-supported, iris-supported, and posterior chamber PIOLs. PIOLs are more difficult in hyperopic patients compared to myopic patients due to the relatively narrow anterior chamber and the lack of space in the posterior chamber for hyperopic lenses which are thicker centrally. PIOLs offer the advantage of not altering the cornea as in keratorefractive surgery, retention of accommodation in younger patients as opposed to clear lens extraction, and the possibility of lens removal or exchange. The disadvantages include the risks of intraocular surgery, such as infection, inflammation, loss of endothelial cells, and posterior segment complications.[5] The long-term possibility of cataract formation remains an important concern.

1. Angle-supported lenses

Angle-supported lenses have been mostly used for the correction of myopia, and not much clinical data exists for their use in hyperopia. Only a few available angle-supported lenses are available in hyperopic powers. The Phakic [6] lens (Ophthalmic Innovations International, Ontario, CA) has a one-piece PMMA lens is available from +2 to +10 diopters. The I-Care lens (Corneal Laboratoire , Pringy, France) is a single-piece, acrylic injectable lens that is available from +3 to +9 diopters.[6]

Improvements in lens design and sizing have made the use of angle-supported PIOLs safer. New lens designs are being developed such as the Vivarte lens (Ciba Vision, Duluth, GA) which is has a foldable acrylic optic, the Kelman Duet lens (TEKIA Inc., Irvine, CA) which has separate haptics and optic that are inserted separately and merged in the anterior chamber. These lenses, however, are not available in hyperopic powers.[3, 6]

2. Iris-fixated lenses

The Verisyse PIOL, also known as Artisan PIOL (Advanced Medical Optics, Santa Ana, CA, , Ophtec, Groningen, The Netherlands) is the most commonly used type of iris-fixated IOL **(Figure 2)**. A 6 mm corneal incision is created to insert the lens into the anterior chamber, and the peripheral iris is enclavated into the claw-shaped haptics. The lens vaults forward to reduce cataract formation and to allow for the flow of aqueous humor.

The Verisyse is United States FDA approved only for the correction of myopia. In other countries, the Verisyse is available in hyperopic powers from +1 to +12 diopters. Studies have been performed in Europe with the Verisyse for correction of hyperopia with good results. Pre-operative screening is required to identify patients who are not suitable candidates because of convex irides or shallow anterior chambers. Patients with shallow anterior chambers are at higher risk for endothelial cell loss.[7]

3. Posterior chamber lenses

Current options for posterior chamber PIOLs include the Visian Implantable Contact Lens or ICL (STAAR Surgical, Monrovia, CA), and the Phakic Refractive Lens, PRL (Zeiss-Meditec, Jena, Germany). Posterior chamber PIOLs have the advantage that the technique for implantation is similar to that of cataract surgery, thus the skills are familiar to most surgeons. The

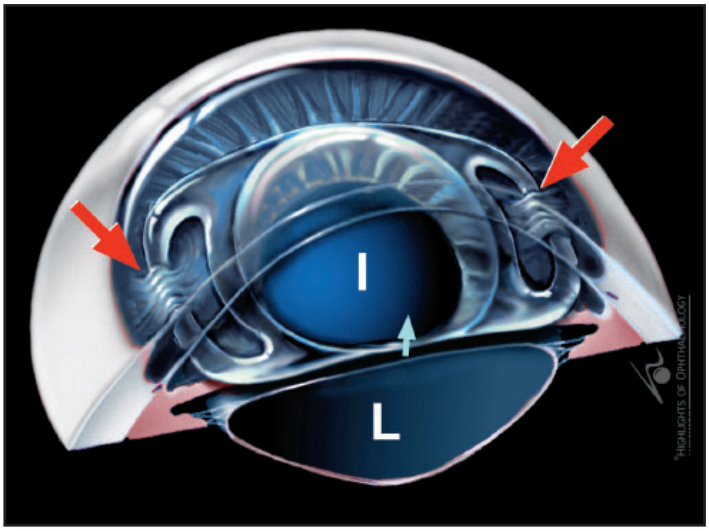

Figure 2. Concept of the Artisan Intraocular Lens
The Artisan IOL is placed in the anterior chamber and is clipped to the iris (arrows) through slots in the peripheral portion of the haptics. Note the relationship of the Artisan Lens (I) vaulted anterior to the natural lens (L).

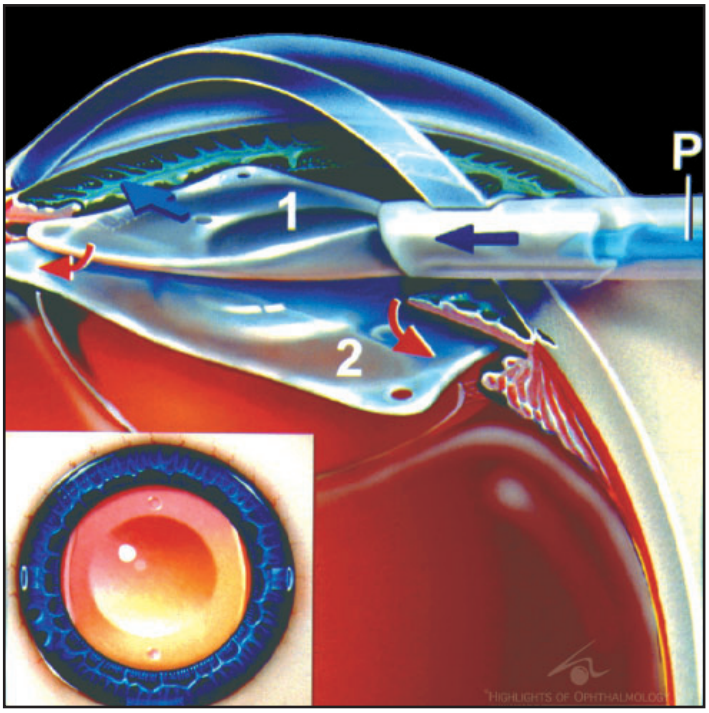

Figure 3: Conceptual Cross Section of All Stages for Implantation of a Foldable Posterior Chamber Phakic Lens (ICL)
This conceptual cross section shows the insertion and unfolding of the (ICL) compared to the final configuration of the ICL in position behind the iris and in front of the crystalline lens. (1) The plunger (P) inside the inserter pushes the distal haptics of the ICL into the anterior chamber (blue arrows) while unfolding as shown. (2) In separate maneuvers, the haptics are then placed (red arrows) into the posterior chamber behind the iris and into the ciliary sulcus. The iris will then be constricted. The inset shows a surgeon's view of this final configuration.
This illustration is a section of the eye taken from 3 to 9 o'clock, as the ICL is inserted through the temporal approach.

drawbacks to the use of posterior chamber PIOLs include all of the usual risks of intraocular surgery as well as the possibility of cataract formation iris chaffing, and pigment dispersion. They also require the creation of peripheral iridectomies to avoid pupillary block.

The ICL **(Figure 3)** is only approved by the United States FDA for the correction of myopia, but elsewhere it is available in hyperopic powers from +3 to +20 diopters. The ICL is foldable and can be inserted through an injector. The lens is designed for placement in the cilary sulcus, and accurate measurements of the diameter of the sulcus is needed to ensure proper positioning. The ICL is composed of collagen, a UV-absorbing chromophore, and a poly-HEMA based copolymer.

The PRL is a silicone PIOL that is also designed for implantation in the ciliary sulcus. The lens is available from +3 to +15 diopters, and the central thickness varies with the hyperopic power.[3]

Refractive Lens Exchange

The replacement of the crystalline lens with a pseudophakic intraocular lens is an option for the correction of hyperopia, especially in patients with lenticular changes. Depending on the status of the crystalline lens, these procedures may be termed refractive lens exchange or clear lens extraction, early cataract surgery, or cataract surgery. Many options exist for lens design, and the main categories of lenses are monofocal, multifocal and so-called "accommodating" lenses. Advantages include rapid visual rehabilitation and predictability of refractive results. Disadvantages include loss of accommodation and the other risks of intraocular surgery.

The proper selection of IOL power is dependent on accurate axial length, corneal power, and use of the latest generation of lens calculation formulas. Monofocal lenses may be best suited for patients who want the best possible clarity of vision without glare or scotopic haloes. Multifocal lenses have the advantage of correcting vision for distance as well as some degree of reading and/or intermediate distance. Other lenses are designed to change position in the eye with accommodative effort. Their mechanism may involve pseudoaccommodation and possibly some degree of lens position shift.

Conclusions

Many options are available for the surgical correction of hyperopia Some of the surgical options and lenses listed in this article are not available in the United States or other areas. The choice of suitable methods for a given patient must be based on individual characteristics such as age, lens clarity, refractive goals, corneal thickness, presence of astigmatism, and others.■

REFERENCES
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