What is the Future in Refractive Technology?

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Introduction
Refractive technology is advancing in all aspects of ophthalmic treatment and opening up many customized options for patients. We are able to offer our patients the widest array of options for optimal, crisp twenty-twenty vision at distance, intermediate, and near. We are able to offer patients comfortable clear vision at all distances with multi-focal contact lenses, progressive addition lenses, and many new options with refractive surgery. As the primary ophthalmic eye care providers we are the gate keepers to educating patients on the options and ultimately the best solution to their vision needs. As our patient population is growing in age with the Baby Boomer generation there are advancements to meet the diverse needs of this patient population. The percentage of patients in the presbyopic age range (forty-five plus) is estimated to continue growing to around forty-one percent of the population of the United States by 2020 and continue to grow in projections to 2050.

Visual demands of patients are becoming greater than in past generation. An example is the wide spread use of hand held electronic devices such as smart phones. With these inventions patients are demanding more options for multifocal ophthalmic corrections with the ease of ophthalmic corrections they have had available for their previous distance only needs. Patients also want the convenience of twenty-four hour visual correction. The future of refractive technology will be based on the advancement of previous treatment modalities with modern technology applied to improve the optics and materials. The future will also embrace brand new modalities for treating ametropia.

There are many roads to provide patients with refractive correction. Historically we have had glasses and contacts as the primary means of visual correction. In the last decade the range of improved visual correction and availability of these options has been
multiplied many times by advances in lens fabrication, optical materials, as well as advanced refractive testing. Refractive surgeries have become a popular option over the last decade as well with about one million Lasik procedures done in 2008 \(^2\). Better technology and financing options have made refractive surgery a more attractive option for more patients. Refractive technology also is also drastically changing the typical treatment of cataracts in the aging population. Recent advancements in IOL technology and operative techniques is allowing for correction of corneal astigmatism or the correction of near vision along with distance for more freedom from spectacles or contact lenses. Practitioners have the greatest number of possible corrective lenses and procedures than ever before to individualize the custom treatment of their patients.

The current visual treatment options for ametropia patients are spectacles, contact lenses, or refractive surgery. A patient’s visual demands can be met by a contemporary practicing optometrist who would only be limited by a patient’s budget. Options are continuously evolving and providing more options to the ametropic population.

**Spectacle Lenses**

The oldest option of visual correction available to a patient is a pair of spectacles. This can be the most cost effective option if the most basic pair is ordered. The current scope of treatment with glasses is not antiquated such as its historical roots. Treatment of ametropia with a wearable pair of spectacles can be traced back to the 11\(^{th}\) century. Lenses in spectacles historically were made from glass with the best material being crown glass with a refractive index of 1.523. Glass lenses provided great optics with an Abbe value of 58, but had a downside of a heavy weight with a specific gravity of 2.54. Higher prescriptions produced heavy lenses which created a demand for lighter weight lenses due to the weight of the glasses on a patient’s nose. CR-39 (Colombia Resin- 39)
was the answer to the weight issue. It was a technology from airplanes in World War II which had optical properties. Lenses had the refractive index of 1.499 with a specific gravity of 1.28-1.32 which provided a lighter lens. Abbe distortion of 52 was greater than crown glass. CR-39 lenses are thicker than a comparable glass lens. Polycarbonate was the next lens material introduced in the 1980’s. It is lighter with a specific gravity of 1.20. Polycarbonate has a refractive index of 1.59 and an Abbe value of 32. The thinner lens capability of polycarbonate had the downside of more distortions due to a lower Abbe value (primarily chromatic). Polycarbonate is an impact resistant material which is prescribed for all children and monocular patients.

More recent advancements in the lens material industry have led to the use of high index plastic lenses and Trivex materials. High index plastic is available up to an index of 1.74 depending upon manufacturer parameters. The higher index lenses provide thinner and lighter lenses for higher ametropias. Trivex is a newer polymer material which gives a mix of the best properties of both plastic and polycarbonate lenses. Trivex is impact resistant like polycarbonate and has the scratch resistance and higher Abbe value (43-46) of plastic.

Options for optimal vision with glasses are diverse depending upon patient needs and budget. These options extend beyond the lens material and include the coatings which can be included on the lenses. Anti-reflective (AR) coating can be applied to a lens for both a cosmetic and optical reasons. AR coating helps cut down on glare and increases light transmission by 8%.

Photochromatic options have been available for lenses since 1964 but limited to glass lenses until 1991 when Transitions introduced the product to plastic (CR-39) and then later to the rest of available lens materials.
Photochromatic technology is continuing to be modified with modern technology and improved material for darker lenses in sunlight and clearer lenses indoors with a quicker change between clear and tinted lenses.

The future of ophthalmic spectacle lenses will allow maximum vision under all visual conditions. Patients will be able to have computer designed, digitally customized lenses made for them via measurements taken off wavefront imaging systems such as the iZon\(^7\) progressive lens currently does. Glasses will be customized for patients beyond the typical pupillary distance, optical center, and segment height measurements. Patients will have digitalized measurements taken with the use of new technology such as the iZon z- aberrometer. Higher order aberrations can be minimized by these custom lenses with use of patient specific corneal aberrations of each eye. Every eye has a unique corneal map such as a fingerprint, in which digitally customized and grounded lenses can cancel out the individual corneal error. Manufacturing of iZon lenses combines the refraction findings with the wavefront readings of the Z- aberrometer to customize the manufacture of the spectacle lens to produce a truly custom ophthalmic lens just like in custom wavefront LASIK. Clinical research has shown the correction of higher order optical aberrations by iZon lenses improved night time driving conditions allowing iZon patients to spot objects in the road allowing them to stop twenty feet shorter than patients with standard manufactured lenses\(^8\). Essilor has been using W.A.V.E. (Wavefront Advanced Vision Enhancement) technology to decrease optical distortions in the production of progressive addition lenses (PALs) since 2005\(^9\). W.A.V.E. technology uses computer technology to reduce distortions typically occurring with standard lens surfacing techniques. Recently released (February 2010) the second generation of W.A.V.E.
technology promises to minimize higher order aberrations and increase a patient’s ability for clear and comfortable vision in both high and low lighting conditions. Studies have shown an increase in contrast sensitivity by thirty percent and an increased field of view. The W.A.V.E. technology is applied to both the front and back surfaces of lenses for maximum effect. Essilor has been working on using W.A.V.E. technology for single vision lenses which is currently available in the Essilor 360 line in high index of 1.67 or 1.74 and polycarbonate 10.

Progressive addition lenses have been around since 1959 when Essilor produced the first no-lined trifocal lens 11. The smooth transition of vision through the no-lined trifocal had many down sides. Due to a minimum segment height of around eighteen millimeters it was necessary to have a larger B-size frame. The first decades of PALs had down sides such as induced distortions. The lens design had an hour glass shape corridor of the optically corrected zone which would cause a “swimming” effect if patients looked even slightly out of this corridor. Patients who are more of “eye-movers” than “head turners” would often complain of the bad distortions and normally not adapt to the lenses, thus needing a lined bifocal or trifocal. The distortions have since been minimized by manufacturers with advanced designs, but still exist to a lesser extent. As previously mentioned designs such as the iZon and W.A.V.E. technology are coming forth to meet the demand of decreased distortions and more usable vision in these lenses. This technology is also allowing for a shorter segment height to allow no line bifocals in smaller and more fashionable spectacle frames.

**Contact Lenses**  
Technological advances have brought about an arsenal of options for contact lens desiring patients. Material options are at an all time high. Materials can be chosen based
upon the patient needs and lifestyle. Materials are currently available to give the cornea
the best health with high oxygen permeability in gas-permeable and soft lenses as well as
hybrid combinations\textsuperscript{12}. Lens designs are at a complementary all time high with a massive
arsenal available to the astute clinician for the treatment of almost any ametropia and
given ocular health combination.

Contact lenses allow a patient to have corrected vision without the need for
spectacles or refractive surgery. The earliest versions of contact lenses can be traced back
to the invention of scleral lenses by Fick and Kalt in 1888\textsuperscript{13}. Modern mass treatment of
ametropia with contact lenses began with the first rigid corneal lenses produced by Kevin
Touhy in 1948\textsuperscript{13,14}. These initial lenses were made from Polymethylmethacrolate
(PMMA). PMMA was a nice rigid material that provided a stable lens with a refractive
index of roughly 1.489. PMMA had a downside of poor oxygen permeability but since
1948 many lens materials have come out to give better oxygen permeability for a
healthier cornea.

A healthy corneal surface will provide a patient with the highest possible vision
with the healthy refractive surface. The use of higher oxygen permeability lenses allow
for patients to have the healthiest corneas as possible. Oxygen permeability is an
important factor for best vision because corneal hypoxia induces corneal edema which
can have effects on a patient’s visual acuity if beyond five percent when stromal striae
start to appear and at ten percent with stromal folds appearing\textsuperscript{15}. Corneal hypoxia can
also cause neovascularization of the cornea if severely hypoxic. Neovascularization will
decrease corneal health and compromise vision if encroaching on the visual axis. Limbal
hyperemia is another complication from hypoxic corneal conditions.
Designs in gas-permeable lenses started with basic spherical corneal lenses for correction of distance ametropia. Given the tear layer power, standard spherical gas permeable lenses can correct corneal astigmatism up to about two and a half diopters. Advancements have allowed for toric lenses to correct higher astigmatic powers above two and a half diopters. Front toric, back toric, and bi-toric lens designs are available to correct a patient with high corneal astigmatism. Further refinement of these designs will allow for more stable vision and increasing comfort. The newest of designs are toric hybrid lenses\(^\text{16}\). The lens combines a spherical central corneal gas permeable lens with soft skirt. This allows for better comfort and lens stability.

Twenty four hour continuous vision is possible with gas-permeable lenses with the use of orthokeratology lenses. Using reverse geometry design orthokeratology lenses reshape the cornea while the patient wears the lenses overnight. The reverse geometry design causes a shift in the corneal epithelial cells centrally to the peripheral cornea. Orthokeratology is also being investigated as a treatment to prevent myopia progression in children. If research proves this as a viable option, we might see a great reduction in the number of high myopes. This would provide parents with an option to treat their children to allow the best vision for life without the demands of thick glasses or contacts. The main benefit of orthokeratology is the freedom from spectacles or contact lenses during daytime hours. The patient wears the lenses for a minimum of six hours overnight while sleeping. The reverse geometry design flattens the central cornea in myopic patients. It is approved for patients of up to six diopters myopia with up to -1.75 diopters astigmatism\(^\text{17}\). The patient will need to wear the contacts during the day, or later in the day for up to fourteen days until the full effect of the therapy takes place and from then
on only while sleeping. If a patient would ever like to discontinue the therapy, it is fully reversible to the initial correction after a few days of discontinuation. This treatment option should continue to grow due to the FDA approval for any age group with it being a great option for children, especially of high myopes. Thanks to the availability of highly oxygen permeable materials available, this treatment option should continue to grow through its safe and reversible treatment.

Expanded treatment options have come forward for multifocal gas-permeable lenses with a continuous release of new designs. Multifocal designs and aspheric designs have been available for many years for the correction of presbyopic patients. A new addition to the traditional aspheric and segmented lenses is the recent introduction of hybrid multifocal lenses by SynergEyes. The GP lens uses a corneal lens with a concentric center near and distance surround with the attached soft skirt for enhanced comfort and stability.

Recently high index materials in the 1.50 index range have come out to provide a thinner gas permeable lens. These lenses should be more comfortable for patients due to thinner edge thickness and less movement. High index materials will allow for better correction in multifocal lenses. The necessary higher add powers can be put into lenses and keep the overall weight and thickness less than that in older materials. Pushing advances of higher index and aberration cancellation of gas-permeable lenses will allow for a highly effective method of visual correction for our presbyopic patients.

Semi scleral lenses are an attractive option for post-refractive surgery patients whom are suffering from aberrations and an irregular surface. This midsized lens (~9.5-16mm) has become a quickly growing category in the last few years with designs
such as the msd\textsubscript{m} (mini scleral design) and the RSS (Refractive Surgery Specific) by Blanchard. The RSS allows a clinician to alter the base curve for central corneal correction and a separate peripheral fitting curve. This class of lenses looks to remain a strong option for practitioners for years to come as the number of designs and popularity increases. Semi scleral lenses work well on patients with keratoconus, pellucid marginal degeneration, irregular corneas, and post-Penetrating Keratoplasty\textsuperscript{20}.

Scleral lenses are the oldest form of contact lenses. This is the design which Fick and Kalt originally used\textsuperscript{13}. They have had a widespread resurgence in clinical popularity in the last few years. This has been due to wider availability of the lenses as well as an increase in pathology to treat\textsuperscript{21}. Modern materials with higher oxygen permeability allows for healthier corneal tissue. Sclerals work well for fitting keratoconic patients as its design has the lightest apical touch by vaulting over the corneal ectasia. The use of scleral lenses is a new treatment modality for severe dry eye and neurotrophic keratitis patients. The large fluid reservoir under the lens is a constant supply of lubrication to the cornea and creates a healthy refractive surface and allows for healing of the epithelium. This lens design works well on patients who had a penetrating keratoplasty (PKP) as it lands well peripheral to the corneal graft tissue interface with the host cornea. Other post surgical patients who may benefit from a scleral lens include those with irregular corneal surfaces such as post- Radial Keratometry and post-Lasik induced ectasias. Overall comfort and ease of use make this increasing resurgence a strong lens choice for the future treatment of these difficult corneas.

Soft contact lenses have been available since Bausch and Lomb commercially introduced the lens in 1971\textsuperscript{13}. Since the initial launch of soft contacts many materials and
applications have been developed. There is a multitude of soft lens materials with designs based on everything from a daily disposable to monthly replacement continuous wear lenses. Conventional lenses such as those introduced in 1971 have lost popularity to newer materials and designs. The conventional lenses were designed to last a patient for at least a year of wear. Currently popular lens modalities are the daily, two week, and monthly replacement lenses. These lenses are designed thinner and work well for patients with allergies and protein build up. Planned replacement lenses of 2 week or monthly intervals are available in almost any lens material. Silicon hydrogel (SiHy) lenses have been out for several years and provide a high amount of oxygen for the cornea. Several SiHy lens designs are approved for up to thirty days of continuous wear. This is convenient to treat patients whom are non-compliant in daily wear lenses by sleeping in them and over wearing them. This non-compliance can put the cornea at risk due to hypoxia, neovascularization, edema, and bacterial ulceration (Pseudomonas risk with an increased anaerobic environment). Corneal hypoxia is less common with the use of SiHy lenses and thus any induced neovascularization and edema.

An increasingly popular lens modality in the United States has been the use of daily disposable lenses. European and Asian studies have shown up to seventy percent of the soft contact lens wearing population using daily disposables. The use of daily disposables is postulated to decrease the amount of contact lens complications such as lens over wear (beyond the two week or monthly replacement schedule), bacterial infections, CLARE (Contact Lens Acute Red Eye), protein build up, etc. Daily disposables are great for patients whom have ocular allergies and dry eyes. A healthier
corneal surface and a fresh lens daily will provide patients with the best possible visual and comfort outcome.

Toric soft contact lenses have been a treatment option for patients with astigmatism of three quarters of a diopter and up to as much as three diopters in mass produced planned replacement lenses and up to ten diopters in conventional custom ordered lenses. Soft toric designs have been improved over the last several years in many ways. Stability and thickness were some longstanding problems for patients, especially if their astigmatism reached the three diopter range. New designs with a wider spread balance design have come forward as well as thinner edge thickness. Better stability and better comfort means more patients can be treated with this option.

Multifocal lenses are a rapidly changing category of soft contact lenses. Companies are continuously perfecting multifocal lens designs. Historically multifocal contacts have not had the highest success rates in patients when compared to single vision contact lenses or PAL spectacles. From the current base of lens materials and lens design the future of multifocal contact lenses will continue to be improved with better vision, comfort, and health. As dry eye is a big problem in the presbyopic population, the use of newer materials for better comfort and a lower patient drop out rate. The continued advancements will aid patients in clear, comfortable vision at all demands of distance, intermediate, and near. The ability of a doctor to give a patient more than single vision or monovision contact lens correction is a great enhancement to the patient’s life. Many patients work on computers and need the intermediate zone of clarity which can be created by using multifocals in the treatment of the ametropia and presbyopia. Given the unique different designs put forward by each company there is a lens that can be fit to
almost every patient’s specific prescription and visual demands. This category will continue to grow as the population ages and expects options to keep them out of spectacle dependence. An area which will continue to grow in the future is toric multifocal lenses designs, as there are not many currently available.

Hybrid lenses are a newer technology which fuses a central corneal gas permeable lens with a soft lens skirt on the perimeter. It is becoming available in many modalities to treat many vision and health conditions. It is ideal for keratoconus patients, allowing for better comfort such as the older “piggyback” (a gas permeable lens on top of a soft lens) fitting system with combining the two types of lenses. Currently the soft skirt material is a hydrogel which has low oxygen permeability and could cause corneal hypoxia and neovascularization in the peripheral cornea. The future use of this lens treatment option will only expand when a higher oxygen permeable soft skirt material can be combined with the highly oxygen permeable central gas permeable lens and more practitioners will embrace the healthier option. The expanding treatment line of the hybrid lens has been made for keratoconus, torics, multifocal, and post refractive surgery. It is an ideal design for many patients due to the excellent optics of the gp lens and the comfort of the soft skirt. This hybrid design will undoubtedly grow in popularity as the aging population demands crisp, clear, and comfortable vision.

**Keratoconus Refractive Options**

The mainstay for the treatment of keratoconus has been the use of gas-permeable contact lenses. This continues to be the foundation of improving the vision of patients suffering from the corneal ectasia which occurs from keratoconus. The use of gas permeable contact lenses cause a smoother refracting surface on the anterior aspect of the cornea by using the tear layer to fill in the irregular refracting surface from the ectasia.
Traditionally corneal gas permeable lenses were the primary option in the treatment of keratoconus. Recently there has been an increase in the options of lenses outside this category. Semi-scleral and scleral lenses have had a recent rise in usage and increase in available lens designs and materials. Hybrid lenses are another type of lens which is growing in popularity for the refractive treatment of keratoconus. Hybrids, semi-scleral, and sclerals all claim to have improved comfort than the traditional corneal gp lens. The sclerals and semi-sclerals lenses can provide apical clearance and less touch, providing more comfortable vision and less chance of corneal scarring.

Keratoconus Intacs are a non-FDA approved (has a FDA Humanitarian Device Exemption) option for patients with severe keratoconus who can no longer tolerate contacts and might only have penetrating keratoplasty (PKP) as the only treatment to improve vision.\(^\text{24}\) The Intacts are similar as those used for corneal manipulation for myopic correction. Intacs is an FDA approved device/operation for the correction of only myopia between one and three diopters and one or less diopters of astigmatism.\(^\text{25}\) Intacs surgery uses a small incision to enter the peripheral cornea. Through the incision a channel is made for the placement of two half rings. The rings reshape the peripheral cornea and flatten out the surface reducing the refractive power of the cornea. The thin rings are inserted into the cornea to relieve the corneal ectasia and make a more spherical corneal surface in the treatment of keratoconus.

Another treatment for keratoconus is a penetrating keratoplasty (PKP). This is not totally a refractive surgery but rather to give the patient better vision and a more stable corneal surface. This surgical procedure is performed as a last option to improve a patient’s vision. It is undertaken once a patient’s cornea is excessively scarred due to
incidents of corneal hydrops and advanced ectasia. It is not a new “future” treatment for keratoconus, but there are some advances in the PKP technology to allow for better outcomes. Recent advancements allow for the trephination of a corneal button from donor tissue and an exact matching host cornea with a femtosecond laser. This provides a very accurate alignment of both the donor tissue and the patient cornea. Using this type of accuracy and tighter fitting incisions, a surgeon will not need to have as tight of corneal sutures and will have an increased amount of alignment accuracy. Both of these will provide patients with better post-operative outcomes with a smoother refractive surface with less induced astigmatism (early reports of one diopter less than conventional PKP). Overall a quicker healing of the cornea can occur with the increased surface area the treatment is spread across \(^{26,27,28}\).

Collagen cross linking is a promising newer treatment for improving the refractive status and ocular health of keratoconus patients. Collagen cross linking involves a surgeon removing the epithelium and placing one drop of riboflavin on the exposed stroma every two minutes for thirty minutes. The cornea is then exposed to UV A of 370nm for thirty minutes \(^{29,30}\). Collagen cross linking stabilizes the cornea and can minimize the advancement of the ectasia and stabilize the refracting surface. Many studies have even had a flattening of the cornea and decrease in refracting power \(^{29}\). Not all keratoconus patients may benefit from this procedure. Patients who may be excluded include those with severe scarring, steeper than sixty diopters of ectasia, or a history of herpetic eye disease (viral activation from UV A). This procedure has been used for several years outside the United States and shows promising results which may yield its inclusion as an option for keratoconus patients someday soon. Many keratoconus patients
need refitting of lenses as soon as a few months after getting new lenses dispensed during acute proliferation of the corneal disease process. Collagen cross linking can ease the burden of constant refits and continuous deteriorating vision. It can prevent the furthering disease process before visually significant corneal scarring occurs and predominantly steep ectasias and hopefully provide less disease proliferation to needing a PKP.

**Surgical Options**

**Cataract Options**

The earliest versions of refractive surgery can be traced back to the practice of couching thousands of years ago. Couching involves probing a blunt object into the eye to knock a mature lens off of the visual axis in a very visually reduced individual. This provided access of significantly more light and images to the retina. This was in practice thousands of years before the advent of optically correcting spectacle lenses. Patients undoubtedly benefited from increased illumination even though a large hyperopic shift of around sixteen diopters in vision occurred. This technique is still practiced in very remote parts of the world today.

Phakic intraocular lens (IOL) implantation was invented by Harold Riley with the first implantation occurring in 1949. Ridley invented the first lens as well as method of implantation of the posterior chamber IOL through extra capsular cataract extraction. These first lenses were made from PMMA. During World War II Ridley noticed that pilots who had penetrating intraocular injuries from shattered PMMA cockpit canopies did not have ocular inflammation or rejection of the foreign body. He chose PMMA as his material for the IOL based off these clinical observations. A large scleral incision was necessary to slide the rigid lens into the posterior chamber. Thus, large silk sutures were necessary to close up the incisions. Complications could be high with this large of
an incision. Patients required over a week long stay in the hospital and were bed ridden for the duration. IOL research and development led to use of a silicon lens material which allowed for a folding of the lens and a smaller micro-incision surgery. The smaller incisions allowed for the discontinuation of sutures. Both forms of IOLS had a very high rate of posterior capsule opacification (PCO). This was due to both the design and the material the lenses were made of. A high incidence of YAG capsulotomies were performed on the pseudophakic population (>50%). The invention of acrylic IOLs decreased the incidents of PCO to around 10-20% of the pseudophakes. Better patient acuity and quality of vision could be maintained with the lower incidence of PCO. The acrylic lens is today’s lens of choice.

The modern treatment of cataracts with removal by phaco-emulsification was invented in 1967 by Charles Kelman. The method involved cutting up the crystalline lens via ultrasound and removing it through vacuum line. Up until the late 1970’s both IOLs and phacoemulsification was not used in regular clinical practice, due to low acceptance from the medical community of both the procedure and of implanting a foreign body (IOL) in the eye.

Until the acceptance of IOLs by the medical community in the late 1970’s and early 1980’s, operations left the patient aphakic. It was necessary to prescribe a highly hyperopic “coke-bottle” pair of lenses for the patient to correct for the residual ametropia. This post-operative treatment gave the patient clear vision compared to the reduced vision with the cataract. Due to the high powered lenses there were many down sides to the treatment. If only one eye was treated, a very large difference in the two spectacle lenses would produce different retinal images, anisekonia. This could produce depth
perception problems, dizziness, and diplopia with image jump at near. Even if both eyes were operated on and were corrected with similar powered spectacle lenses there were still many visual problems patients could experience. Patient would experience a reduced visual field due to the very high hyperopic prescription. The glasses were very thick and cosmetically displeasing lenses, known as “coke-bottle” lenses. Other optical errors induced by the high prescription included pincushion distortion and image jump. Slab off prism was common to correct the image jump patients would experience with transitioning from the distance to bifocal portion of the lens. Typical lens materials available for optical lenses were crown glass (Refractive Index = 1.523) or CR-39 (1.499). The glass lenses made for this high hyperopic correction would be very heavy with a specific gravity of 2.54. Visual optics would be the best out of the glass as well as a cheaper option for the patient. Glass would offer the lowest amount of aberrations such as chromatic, due to its Abbe value of 58. The CR-39 lenses would provide the patient with a lighter pair of glasses, with a specific gravity of 1.28-1.32. The lenses would be thicker and have more chromatic aberration, due to an Abbe value of 52.

A new step forward in the refractive treatment of cataracts is the recent use of multifocal IOLs. These new IOLs allow patients to have no need for glasses at distance, intermediate, and near or at least a large reduction in needing near correction for most near visual demands. There are many lens designs in the multifocal IOL category. There are several versions of spherical lenses which have concentric rings of differing optical powers. The Fresnel-like rings project multiple images towards the retina with differing focal lengths. Images are projected for distance, intermediate, and near. The technology is similar to that of several multifocal soft contact lenses. An example of one such lens is
the ReSTOR PCIOL (Alcon) which uses apodized diffractive optics for correction of all three distances.

Another popular multifocal IOL option is the use of accommodating IOLs. The IOL sits in the capsular bag and is able to flex via a hinged system. The lens uses the fact that convergence activates ciliary body contraction to cause flexure of the lens. It is based upon mimicking the movement of the natural lens. The Crystalens PCIOL (Bausch and Lomb) is an example of one of these new accommodating lenses.

Toric IOLs are a newer option in the premium IOL category. It is available for patients with greater than one and a quarter diopters of corneal astigmatism. Toric IOLs can finally liberate patients who have been stuck with glasses or difficult to fit contact lenses through their cataract surgery. Careful pre-operative topographies are used to determine the placement of the toric lens in the capsular bag. Each lens is ordered based off the pre-operative corneal topography, keratometry, and A-scan. Lenses are marked with some sort of a brand specific marking on the power meridian to allow for proper alignment. The lens arrives for the surgeon with a guide for proper lens placement. This guide is then placed in the patient’s permanent chart to aid the practitioner who is providing post-operative follow up care and long term care. Current lens design provides a stable foundation for precise positioning and long term placement of the lens. The future of toric IOLs will expand when multifocal toric IOLs are clinically available.

Light adaptable lenses might be the future of IOL technology. It is currently being used internationally in countries such as Mexico and more recently it has launched in England. A photosensitive silicone lens is implanted as a three piece PCIOL to the pre-determined power needed, as a typical cataract surgery. Once the patient is in the post
operative period any residual refractive error can be corrected by exposing the IOL to a specific wavelength of light. This procedure is done in office with slit lamp mounted device such as the YAG laser procedure for PCO. The light wave helps reshape the molecular alignment to correct the residual ametropia. The current model is has been clinically tested to correct for spherical errors in both hyperopic and myopic under or over correction up to three diopters following cataract surgery. The design has the researchers postulating that multifocal and cylindrical correction will be capable in the future based off of an expansion of the current technology and techniques. A day in which patients can have residual ametropia fixed with a simple treatment of light energy to the IOL may not be to far off for practitioners in the United States. The technology and lens is currently in Phase I FDA trials.

Limbal relaxation incisions are a surgical technique which cataract surgeons have been using for many years to treat corneal astigmatism. Surgeons apply two incisions to the prelimbal area of the cornea during the cataract surgery. Some surgeons use the same incision sites for their phaco tunnel to lessen the insult to the cornea and have a better surgical outcome due to any induced corneal astigmatism. The incisions are placed one hundred eighty degrees apart on the steep axis. Limbal relaxation incisions can correct astigmatic values up to one and a quarter diopters and skilled surgeons claim to have success treating up to one and three quarter diopters. Astigmatic values of greater than one and a quarter diopters can be treated best with toric IOLs. A combination of limbal relaxation incisions and toric IOLs can be the best treatment for patients with high corneal astigmatism. Limbal relaxation is based off of careful pre-operative measurements. Corneal topography on a healthy cornea gives the surgeon the most
information for the placement of the incisions. There are various resources for calculating placement, size, and depth of the incisions. Surgeons can use resources such as the limbal relaxation incision calculator which is provided by Abbott Medical on their website.

A newer surgical technique being explored by cataract surgeons is use of the Femtosecond laser for performing the capsulorrhexis. Use of the Femtosecond laser has created higher accuracy for even a very skilled surgeon. Use of the laser has decreased the incidence of PCO. It allows for a quicker procedure time as well. The Femtosecond laser can be used to make the phaco-tunnel incisions and even limbal relaxation incisions. This can decrease the amount of surgical devices needed and increase the accuracy and repeatability of these procedures. It is also being researched on the option of using the Femtosecond laser for partial or complete lens fragmentation. In the not to distant future we may see a different type of cataract surgery, with a heavier reliance on the Femtosecond laser for quicker surgical time with highly accurate and repeatable outcomes.

**Refractive Surgery Options**

LASIK continues to evolve to produce better results and happier patient outcomes. Recent use of Femtosecond laser for creation of the corneal flap has led to better surgical outcomes. Laser flap creation has reduced the damage to corneal nerves and decreased dry eye complaints. There has been a significant decreased incident of epithelial ingrowth due to no microkeratome slicing through the stroma while possibly implanting loose epithelial cells. Pupil tracking technology allows for the exact treatment zones to be applied to the pre-determined areas. The recent use of wave front technology allows for the cancellation of higher order optical aberrations such as coma, trefoil, and spherical aberrations.
Photorefractive Keratectomy (PRK) continues to be the best refractive surgery option for patients with epithelial membrane dystrophies. Wavefront technology is available for reduction of higher order aberrations in PRK, such as with LASIK.

**Phakic Lens Options**

The use of an anterior chamber intraocular lens (ACIOL) is an option to traditional refractive surgery for higher phakic myopes. The procedure involves placing an ACIOL in the anterior chamber either in front of the iris or just posterior to the iris. A prophylactic iridotomy is performed prior to the procedure in order to avoid a potential pupillary block. Advantages of this option are for high myopes who are unable to have LASIK due to lack of enough central corneal thickness (stroma) to ablate or patients with large pupils. The Verisyse (Abbott Medical Optics) ACIOL attaches to the iris with iris hooks and centers the PMMA lens over the optical axis. The device is approved in the United States for patients with myopia from five to twenty diopters and two and a half or less diopters of astigmatism, all at the spectacle plane. The Visian ICL (Staar Surgical Company) is another option of phakic IOL. The Visian is made of a collagen polymer and placed in the posterior chamber between the iris and anterior capsule of the crystalline lens.

**Corneal Implants**

A less popular treatment option for refractive procedure is the reshaping of the cornea with a type of ring shaped device or an injectable material. The devices are termed corneal inlays or onlays depending upon how they are surgically added to the cornea. This class of devices/procedures is an alternative to traditional refractive surgeries.
Intacs (as mentioned earlier) are one example of this type of surgical alternative to traditional refractive surgeries. Intacs is an FDA approved device/operation for the correction of myopia between one and three diopters and one or less diopters of astigmatism. Intacs surgery uses a small incision to enter the peripheral cornea. Through the incision a channel is made for the placement of two half rings. The rings reshape the peripheral cornea and flatten out the surface reducing the refractive power of the cornea. Intacs claim to be reversible and can be removed at anytime in the future, such as with the development of presbyopia allowing for other treatment options.

Another class of correction is currently in clinical trials. This related series of treatments in the corneal device/procedure is for the correction of both presbyopia and distance ametropia. We may see the use of these devices in the near future. Some examples are the ACI 7000 (AcuFocus), PresbyLens (ReVision Optics), and Presbia Flexivue System (Presbia Coöperatief U.A., Amsterdam). All three of these are devices which are implanted in the cornea to manipulate light rays for an increase in near and intermediate vision. The ACI 7000 uses the basic principles of the pinhole effect for an increased depth of focus. The PresbyLens is placed below a corneal flap and uses concentric rings to refract light such as a multifocal contact lens or IOL. The Presbia Flexivue System works similar to the PresbyLens with a similar surgical manipulation of the cornea.

**Conclusion**

Today many options are available for patients who desire the best possible ophthalmic visual correction. Evolving technology allows for spectacles, contacts, and many surgical options. Patients are demanding better vision and expect to have the latest and greatest “high-definition” vision. They are willing to pay a premium price for the
best options and this will continue to drive the ophthalmic industry to produce higher quality ophthalmic correction and outcomes. As the primary care ophthalmic practitioners we must stay up to date on all possible options in order to offer our patients the best possible vision.
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References:


3. TRIVEX® Lens Material: The Technology Behind the Triple Benefit; Phillip Yu, PhD; http://corporateportal.ppg.com/NR/rdonlyres/509109FE-93D4-4852-9408-3D88E4493E9D/0/PhilipYu_Lens Technology.pdf; accessed 2/10/10

Accessed 2/20/10

Accessed 2/20/10

Accessed 2/20/10

Accessed 1/24/10

8. Visual Performance In A Night Driving Simulator using Spectacles With Wavefront 'Guided' Correction. Navy Refractive Surgery Center, Ophthalmology Department, Naval Medical Center
http://ophthonix.izonlens.com/reviews/sci-papers.php
Accessed 1/24/10

Accessed 3/10/10


11. http://www.essilor.com/Varilux; accessed 1/24/10

Bruce, A; Hom, M; Wood, C. Pgs 203-214; 313-321


17. http://www.paragoncrt.com/ecp/faqs.asp; accessed 2/10/10


20. CLE 365.2 Contact Lenses, Class Notes Fall 2008. Jurkas, J. Illinois College of Optometry


Accessed 2/12/10


29. Corneal Collagen Cross-linking; Cataract and Refractive Surgery Today, Trattler, W; Rubinfeld, R; Vol 9 (9): 53-55


33. Limbal Relaxation Incisions. *Cataract and Refractive Surgery Today*; Cionni, R; Grabow, H; Katzen, B; Miller, K; Vol 9: No 9: 27-30

34. [http://www.lricalculator.com](http://www.lricalculator.com); accessed 1/26/10


41. [http://presbia.com/flexivue/index.html](http://presbia.com/flexivue/index.html); accessed 1/25/10