Summer 2000
Volume 3, Number 1

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Tribute to Jack Bennett
Profile: Arthur Bradley
The Changing Face of Refractive Surgery
Short History of Keratoscopy and Indiana University Contributions

In This Issue

Profiled in this issue is Arthur Bradley, Ph.D., who has been a faculty member in the IU School of Optometry since 1985. His work on the FDA panel for ophthalmic devices on the efficacy and safety of refractive surgery, along with his expertise in visual function and visual optics, make him uniquely suited to objectively evaluate the current status of the most common refractive surgery procedures. His article, "The Changing Face of Refractive Surgery," is an excellent distillation of a wide variety of published literature and source materials. He touches upon a number of issues often not considered in other discussions of refractive surgery.

Quantification of corneal contour has been a necessary element in the development of keratorefractive surgery. The Indiana University School of Optometry has made contributions to corneal contour assessment and quantification methods. A short history of the IU contributions in this area and of the development of keratoscopy is presented in this issue. Also in this issue are a review of an article on the use of progressive addition lenses for the control of childhood myopia progression and some news items from the IU School of Optometry.

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Journal of

Summer 2000
Volume 3, Number 1

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Cover Photo: Photokeratogram taken with the Keracorneascope, a photokeratoscope which was marketed with an optical device called a comparator for analysis of the pictures; a short history of keratoscopy starts on page 13.

Please contact us with your comments or suggestions by calling 812-855-4440 or emailing us at IndJOpt@indiana.edu.

Jack Winn Bennett, 1932-2000

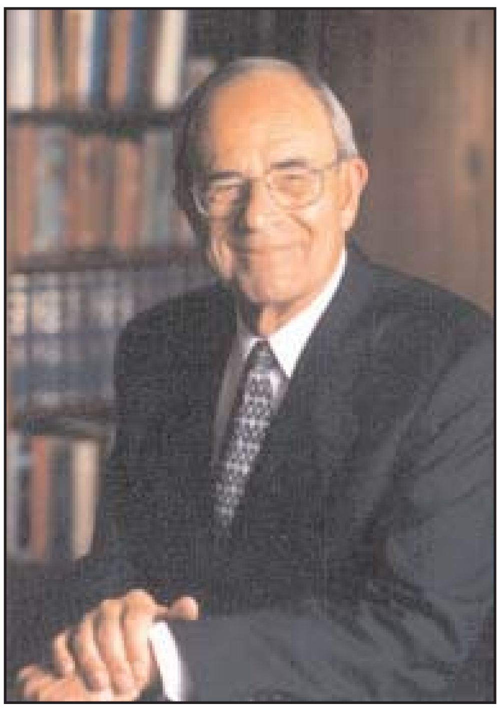
A Tribute

Earlier this year Optometry mourned the loss of one of its most ardent advocates, Jack W. Bennett. Anyone who met him would readily note his friendly and jovial Hoosier manner. But beneath the folksy humor of his Granddaddy Barndollar stories and self-deprecating remarks, there was an man of insight and of commitment to family and profession.

Jack W. Bennett was born on October 23, 1932 in Bloomington, Indiana. He graduated in 1950 from Bloomington High School. Bennett attended Indiana University from 1950 to 1952. In 1952, he married Alice Bauer of Bloomington. Alice became an active helpmate to Jack in optometric activities. For example, she became the president of two state optometric auxiliaries and national president of the American Foundation for Vision Awareness.

Bennett served as an optical technician in the United States Army for three years during the Korean War. He returned to Indiana University in 1955, and completed his Bachelor of Science degree in 1958 and his Master of Optometry degree in 1959.

Bennett practiced optometry in Bloomington from 1959 to 1970. During this period of time he was also a part-time Clinical Associate in the IU Division of Optometry and was very active in the Indiana Optometric Association, serving as its president in 1968-1970. In 1970, he left private practice to become Associate Professor of Optometry at Indiana University, a position he held until 1975. Bennett was Director of Patient Care for the IU Optometry Clinics from 1970 to 1972. While serving on the IU faculty, Bennett received the Distinguished Service to Optometry Award from the Indiana Optometric Association (1974) and Indiana Optometrist of the Year award (1975).



Jack W. Bennett

In 1975 Bennett left Indiana to serve as the Dean for the new College of Optometry at Ferris State University in Big Rapids, Michigan. Despite the challenges of a state economy tied to the auto industry, the school survived and prospered under Bennett's leadership. He served Ferris State in various administrative capacities in addition to being Dean of the College of Optometry, including Executive Assistant to the President in 1986-87 and Vice President for Administrative Affairs in 1987-88. He was president of the Michigan Association of the Professions in 1986-87 and president of the Association of the Schools and Colleges of Optometry in 1987-89. While working in Michigan, Bennett received the Professional Man of the Year Award from the Michigan Association of the Professions (1983) and the Keyman Award from the Michigan Optometric Association (1984).

In August of 1988, Bennett returned to Indiana University to serve as Dean of the School of Optometry. This provided opportunities to return to his roots and to again attend IU basketball and football games regularly, as well as to make new contributions to optometry. In the first issue of the Indiana Journal of Optometry, Bennett looked back on the developments in the IU School of Optometry during his years as Dean.[1] He noted changes such as restructuring of the faculty as a unit rather in a departmental structure, the recognition of the need for clinical rank faculty, the encouragement of practicing optometrists to mentor bright men and women of their communities concerning optometry as a profession, revision and expansion of the curriculum, increases in clinical experience opportunities for students, facility upgrades, increased electronic technology, investments in research, improved relations with alumni, increased activity of faculty in optometric organizations, and equipment improvements.

During his years as Dean at IU, Bennett continued teaching in the classroom, lecturing on such topics as optometric ethics, practice management, and optometric history. These years saw him receive Meritorious Service and Lifetime Achievement Awards from the Indiana Optometric Association, and he was named a Sagamore of the Wabash by Indiana Governor Frank O'Bannon. In 1998, Bennett reached the mandatory retirement age for administrators at Indiana University.

When Bennett stepped down as Dean at IU, he was planning to serve on the IU optometry faculty for some time and then retire. These plans were put on hold when the University of Missouri - St. Louis convinced him to serve as the Dean of their School of Optometry. He was Dean there from January of 1999 to April of 2000, when he became ill. His condition rapidly worsened, and he died at his home in Bloomington on April 28, 2000. A memorial service, held May 20, 2000 at the First United Methodist Church in Bloomington, was reflective of things that mattered to Jack Bennett: one of his nine grandchildren offering a musical prelude, former optometric colleagues giving words of eulogy, and two of his four children making touching and humorous tributes. Memorial contributions can be made to the Jack W. Bennett Endowed Scholarship Fund at Indiana University, the Jack W. Bennett Memorial Fund at Ferris State University, the Jack W. Bennett Scholarship Fund at University of Missouri - St. Louis, or the Creutzfeldt-Jakob's Disease Foundation.

The Editor

Reference
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Dr. Gordon Heath, Dr, Jack Bennett, and Dr. Henry Hofstetter, the first three Deans of the IU School of Optometry.

Dr. Bennett holding the Sagamore of the Wabash awarded to him at his retirement May, 1998

Profile: Arthur Bradley, Ph.D.

After what he describes as the longest hitch-hiking trip of his life, Dr. Bradley arrived in Berkeley, California to join the Ph.D. program in Physiological Optics at the School of Optometry in 1976. Up to that point in time he had never met or spoken with an optometrist, but as an undergraduate at the University of Reading, in England he had developed a deep interest in the human visual system which spurred him to pursue a research degree.

He arrived in Berkeley confident in his own "perfect vision", only to lose a bet with another recently arrived Ph.D. student, Raymond Applegate, an IU School of Optometry graduate who correctly identified Dr. Bradley as a latent hyperope. Dr. Bradley now describes his refraction as the "jock" prescription typical of one who spent most of his youth chasing soccer, rugby or cricket balls when he should have been hitting the books.

At Berkeley, Dr. Bradley studied under numerous IU alumni (Drs. Tony Adams, Ian Bailey, Richard VanSluyters, and Russ and Karen DeValois). He pursued his Ph.D. thesis on human amblyopia with Ralph Freeman in whose lab he also studied the neurophysiology of primary visual cortex and vision in amblyopia.

Dr. Bradley financed most of is graduate career by teaching virtually every physiological optics lab in the curriculum, and lecturing at U.C. Berkeley and U.C. Santa Cruz on visual optics and visual perception. After graduating with a Ph.D., he worked with the DeValois group on color vision, after which he joined the faculty of Indiana University. His decision to come to IU was greatly influenced by his contact with many IU alumni in Berkeley.

Since arriving at IU in 1985, Dr. Bradley has developed a world-renown research laboratory studying visual perception and visual optics. He has specialized in applying the basic science of optics and vision to interesting clinical problems. It was this expertise that led to his "Glenn A Fry" award from the American Optometric Foundation, and his recruitment onto the Federal Drug Administration (FDA) advisory panel on Ophthalmic Devices.

In addition to a research career with over 100 publications, Dr. Bradley has continued his long-standing interest in and commitment to teaching. He teaches the monocular and binocular visual function courses within the O.D. curriculum, and contributes to other courses in visual optics, contact lenses, and environmental optics. He also teaches a wide variety of courses within the Visual Sciences program. His commitment and expertise have been recognized by the students with a "Professor of the Year" award, and by the University with two "Teaching Excellence Recognition Awards".

He was part of a special team put together to advise the Department of Defense on the suitability of PRK for service personnel, and within the FDA, he has advised on numerous refractive devices and procedures. It is primarily his experience within this environment that prompted him to write the article on refractive surgery in the current issue of the Indiana Journal.

Arthur Bradley, Ph.D.

The Changing Face of Refractive Surgery

by Arthur Bradley, Ph.D.

The recent diversification and availability of refractive surgery has initiated the most significant change in refractive technology since the popularization of the contact lens during the 1960s. Just as the contact lens freed the myope from the spectacle, refractive surgery may free the myope from spectacles and contact lenses.

In spite of its coverage in the popular press (e.g., articles in Time magazine and Consumer Reports), it is not easy to keep abreast of the data on and changes in refractive surgery. Optometrists are often provided with pseudo-scholarly publications that are actually promotional literature[1] published by those marketing refractive surgery. It is this environment of biased and difficult to access information, that motivated Dr. Bradley, who is a member of the FDA Ophthalmic Devices panel and Professor of Optometry and Vision Science at Indiana University to write a short summary of the recent history and new developments in this field.

Some prominent ophthalmologists such as George Waring III are concerned about the mismatch between the reality of refractive surgery and the promotional marketing literature[2]: "the patient must have realistic expectations of the procedure based on honest communication from the surgeon and professional staff, regardless of portrayal of the procedure in advertising and the popular media".

There are lingering doubts about the reliability, safety and stability of refractive surgery. For example, Professor of Ophthalmology, Leo Maguire, has referred to patients who have undergone refractive surgery as the "refractive underclass"[3]. Also, there are sufficient numbers of patients dissatisfied in their refractive surgery results that they have their own web page. This web page (http://www.surgicaleyes.org) is full of testimonials and even some computer simulations of post-refractive surgery vision which are worth seeing.

In spite of the lingering concerns about refractive surgery it continues to be promoted and has become a real option for many patients, some of who will seek advice from their Optometrist prior to deciding on surgery. This article is designed as an up-to-date short review of this field to help our readers understand the benefits, shortcomings, and possible future of this approach to correcting ametropia.

1. The optometrists role in laser vision correction: TLC, Laser Eye Centers, 1999.
2. Waring G III, Future developments in LASIK. In: Pallikaris I, Siganos D, eds. LASIK, Thororofare, NJ: Slack , 1998: 367-370.
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Introduction:

Although most spherical refractive errors are caused by anomalous axial length (too long in myopes and too short in hyperopes), there is a long history of correcting for this anatomical defect by introducing optical changes at the anterior eye. For centuries, spectacle lenses were the only option available to make this change, but during the last half of the 20th century, contact lenses became a convenient alternative and are currently worn by over 20 million Americans. These lenses work by changing the curvature at the air-eye interface, where the refractive index difference is large and most of the eye’s optical power exists. A similar and more permanent strategy is to change the curvature of the anterior corneal surface directly.

Although refractive surgery (Keratotomy) was pioneered during the nineteenth century, it was not widely available until the last quarter of the 20th century. Several methods for implementing corneal curvature changes were developed during the last quarter of the 20th century and continue to be developed today. Early methods, e.g., radial keratotomy (RK) in the 1970’s and 80’s and photorefractive keratectomy (PRK) in the 1990’s, had serious shortcomings and they are now being replaced.

For example, RK, in addition to poor predictability, produced eyes with unstable refractive errors that varied diurnally and with altitude and on average shifted towards hyperopia after surgery (e.g., almost 50% shifted by 1 diopter). This article will describe some of the more recent surgical approaches and in particular will examine the refractive success and the safety issues associated with each.

Refractive surgeries designed to reshape the cornea can be grouped by either the site of surgical intervention or the surgical method. For example, in treating myopia, RK and PRK differ in both the site of intervention and the surgical method. RK makes incisions deep into the peripheral cornea, while PRK removes tissue from the anterior central cornea using a high-energy ultraviolet laser.

Photoablative Refractive Surgery

Most photoablative corneal reshaping techniques employ UVB lasers, e.g., an argon fluoride excimer laser (λ=193 nm), to produce high-energy radiation which is highly absorbed by the corneal stroma. This energy is sufficient to break the chemical bonds that form the collagen fibers and effectively remove this tissue from the cornea.

Initial attempts to use UV lasers were based upon the RK radial incision technique. However, the UV laser failed as a "knife" because it created wider incisions than the scalpel and produced more significant scars. More recently, the UV excimer laser has been modified to ablate stromal tissue within the optical zone and thus reshape the optical surface directly. Two manifestations of this approach have been developed, Photorefractive Keratectomy (PRK) and laser in situ keratomileusis (LASIK), and both share a common goal, to reshape the anterior corneal surface by ablating stromal tissue. However, the methods for achieving this goal are quite different.

In PRK, anterior stromal tissue is ablated after the corneal epithelium has been scraped away (although in rare cases transepithelial PRK was performed). Of course, this method also ablates the basement membrane (Bowman's Layer) upon which the epithelium grows, and thus has a number of undesirable complications associated with loss of epithelial function including susceptibility to infection, post-surgical pain, abnormal epithelial growth, and reduced optical transparency. These problems are most pronounced in the period after surgery, and thus patients did not generally have bilateral PRK, but had to maintain one untreated eye during the epithelial recovery period. In spite of this protracted recovery period, PRK surgery has been performed on both eyes simultaneously.

The problems associated with destruction of the epithelium in PRK have been largely eliminated by implementing a different pre-ablation surgical procedure. Instead of scraping off the epithelium, a deep cut into the stromal lamellae is made approximately parallel to the corneal surface using a micro-keratome (LASIK). The cut begins temporally or inferiorly and cuts across the central cornea but leaves the nasal or superior edge uncut (the flap). This method produces an anterior corneal flap (70-160 microns thick), which can be folded back to expose the corneal stroma. At this point a photoablative method, the same in principle to that used in PRK, is employed to remove stromal tissue and thus reshape the corneal stroma without destruction or removal of the epithelium. Once the ablation is complete, the flap can be repositioned over the remaining stroma resulting in a cornea with a mostly functioning epithelium (some sensory nerve damage and associated corneal insensitivity occurs, which remediates after about two weeks). The flap is a non-rigid structure and when repositioned its shape is affected by the underlying stromal re-shaping which is transferred to the anterior corneal surface thus changing the optical power of the cornea.

LASIK is currently the most widely used surgical method for correcting refractive errors and several commercial lasers have received FDA approval.

LASIK Efficacy

If refractive surgery is effective, the post-surgical refractive errors should be the same as the targeted or intended refractive error. The reason to use targeted or intended instead of emmetropia is that sometimes emmetropia is not the target. For example, a patient may elect to have a small amount of myopia to aid in reading.

Many studies report and plot the average post-surgical refractive error, and in general with more recent technology this approaches the target indicating an almost perfect outcome. However, individual eyes do not achieve the mean post-op Rx, and therefore, in order to assess efficacy, the post-surgical refractive errors of individual eyes must be considered.

In order for the FDA to approve a photoablative laser for LASIK, it must be able to demonstrate efficacy by having a high percentage of the post-surgical refractions within some range of the intended or target refraction (e.g., 75% must be within 1 diopter of intended and 50% within 0.50 diopters). Most current systems achieve this goal, with about 60-70% of the eyes ending up within 0.50 D of the target and sometimes more than 90% within 1 diopter. However, some studies still report less than 75% within 1 diopter of target.

In general, the anticipated residual refractive errors increase with the magnitude of the pre-surgical refractive error. However, although approximate emmetropia may not be achieved in some highly myopic eyes, it can be argued that converting a -10 diopter myope into a -2 D myope is an effective procedure since their level of visual disability while uncorrected will be greatly reduced.

It is important, therefore, that patients be fully aware of the likely refractive outcome prior to opting for surgery. Realizing that a patient will typically expect to leave their eye-care practitioner's office seeing "perfectly", clinicians counseling patients about refractive surgery should emphasize that this will probably not happen. Typical results in recent studies indicate about 80% to 90% of patients end up with uncorrected VA (UCVA) of 20/40 or better, and between 40 and 70% with 20/20 or better UCVAs. The FDA requires a new laser system to demonstrate 20/40 UCVA in at least 85% of treated eyes to qualify as effective. That is, perhaps 50% of LASIK patients will have to tolerate uncorrected VAs poorer than 20/20 or wear a spectacle or contact lens to achieve their pre-surgical VA. As many patients with low levels of refractive error now do, these post LASIK patients with small residual refractive errors generally choose to leave them uncorrected making the clear choice of convenience over vision quality.

There is one significant complication associated with efficacy. Since photoablation removes tissue, there will always be some wound healing process, and this can and does lead to post-surgical refractive instability. Since PRK removed the entire epithelium and Bowman's layer, the healing process was very active, and this was the likely cause of much of the post surgical instability. The reduced wound healing response experienced with LASIK results in less post-surgical instability in Rx, most eyes (e.g. 95%) experiencing less than 1 diopter change during the year post surgery. Recent protocols have reduced the population mean change in Rx to almost zero. However, some individual eyes do experience changes during the 6 months post-surgery.

Although LASIK does not require complete re-growth of the corneal epithelium and the wound healing is reduced, recent studies have observed increased epithelial thickness anterior to the ablation indicating some epithelial response to the surgery or the ablation.

Of course, efficacy will be compromised by any change in corneal structure following keratomileusis or photoablation, and the significant reduction in the thickness of the remaining structurally intact cornea does seem to have an effect. For example, bowing of the posterior corneal surface has been reported and this may reflect structural changes caused by the removal of more than 100 microns with the keratome and up to 200 microns with photoablation, reducing the 500 micron thick cornea to approximately only 200 mechanically integrated microns. A significant correlation between bowing and residual stromal thickness has been observed when the thickness is less than 290 microns. The same study concluded that inaccuracies in the refractive outcome stem primarily from a combination of secondary bowing and epithelial thickness changes that develop post-surgically. Leaving less than 250 microns intact is generally felt to be unsafe.

The primary determinant of efficacy is the amount and spatial distribution of tissue ablated. This often depends upon proprietary algorithms, which can be updated to improve efficacy if a procedure has been shown to either under or over correct. Very simply, if the pre-ablation anterior corneal curvature is known, the desired change in refraction determines the required new curvature and the amount of tissue to be removed. Studies have shown how much tissue will be ablated by a given amount of laser energy (e.g. 0.1 microns can be removed by a 50 mJ/cm2 excimer laser pulse), but these values vary slightly from eye to eye depending upon such things as stromal hydration. An additional source of variability is eye position and eye movements during surgery. In response to this concern, some laser systems (e.g. Autonomous flying spot laser) include an eye position tracking system to effectively stabilize the eye with respect to the laser. This system corrects for any eye movements during the procedure, which can last from few seconds to 60 seconds depending on the amount of tissue to be ablated.

One major advantage of PRK over RK is that, unlike RK, it did not suffer from significant diurnal fluctuations or the significant hyperopic shifts associated with high altitudes that plagued RK. Recent studies by the US military at 14,000 ft. have confirmed that LASIK eyes do not suffer from the 1.5 diopter hyperopic shifts seen in RK eyes, but if an eye has had LASIK recently, a hyperopic shift of about 0.5 diopters was observed. However, after six months, no such shift was observed.

Since the mean post-LASIK Rx has approached zero, it appears that the tissue ablation algorithms have been optimized. The fact that the majority of eyes do not end up emmetropic results from the eye-to-eye variability in such factors as epithelial growth, corneal bowing and reaction to the laser. Therefore, in order to improve the efficacy still further, a two step surgery may have to be implemented. The second ablation will fine tune the small errors left after the first LASIK. However, the second procedure is nearly as costly as the first and reduces profit margins. Such an approach is already used to correct "poor outcomes" after the initial LASIK procedure.

LASIK Safety

Evaluation of safety is more complicated than assessing efficacy of refractive surgery. We can consider any change to the eye which compromises vision as a safety problem. There are five general categories of such problems following LASIK: (1) infections and pathology in response to the surgical or/and ablative procedures, (2) undesirable wound healing responses, (3) photoablative changes that cannot be corrected with standard spectacle or contact lenses, (4) effects of the high energy laser on other ocular tissues, and (5) optical problems associated with the pre-ablation surgery (e.g. flap irregularities). Due to the invasive nature of this surgery, it is not surprising to find that problems associated with the flap surgery are the most significant.

1. Post-surgical pathology:

The incidence of infections caused by LASIK is very low, and includes bacterial keratitis due to poor ocular hygiene combined with imperfect epithelial coverage along the flap incision. Vitreous hemorrhage and retinal detachments following corneoscleral perforations resulting from the surgical microkeratome have also been reported, but again, the incidence is very low (e.g., 2 eyes out of 29,916). Other vitreoretinal pathologies in the post-surgical LASIK patients were also very rare and may reflect typical levels experienced by highly myopic eyes. This emphasizes that, although LASIK may correct the myopic refractive error, it does not treat or prevent the other problems associated with and caused by increased axial length in myopic eyes. Dry eye is a very common complaint following LASIK, possibly due to cutting the corneal nerves and decreasing the primary signal that produces normal tear levels. Dry eye complaints persist for a long time and individuals with dry eye prior to surgery should be counseled that LASIK may exacerbate their existing problem. Those without dry eye should be counseled that dry eye complaints are relatively common and can last for several months to a year following surgery.

2. Wound healing response:

Diffuse interface keratitis, with an accumulation of inflammatory cells at the flap interface has been observed presumably due to a wound healing response. Also, unusual epithelial growth has been observed when trauma dislodges the flap. Recent evidence from animal studies indicates that the healing process at the flap interface continues for about 9 months after LASIK. The consequences of this prolonged wound healing are unclear.

3. Optical changes uncorrectable with standard ophthalmic lenses:

There is a genuine concern that photoablative procedures will result in reduced optical quality of the cornea due to either a loss of transparency and optical scatter or irregular changes in the shape of the optical surface. Both of these optical changes are uncorrectable with standard spectacle lenses.

Aberrations exist in an optical system when, even with an optimum sphero-cylindrical correction, the rays forming a point image will not focus to a single point. Increased optical aberrations reported in post-PRK and post-LASIK eyes[4] may reflect the algorithms used to create the ablations, but other factors must also be involved. For example, myopic "islands" are often reported after PRK or LASIK and for some reason these local under-corrected areas seem to disappear over time. The cause of these myopic islands and the mechanisms behind their remediation are not well understood.

As a check for such detrimental changes in the cornea, the FDA requires that post LASIK VAs be determined with the optimum spectacle correction in place (Best Spectacle Corrected Visual Acuity: BSCVA). If an eye can no longer be corrected to its pre-surgery levels of VA, it is likely that one or both of the above optical changes have occurred. The FDA requires that less than 5% of eyes lose more than 2 lines of BSCVA, and less than 1% end up with BSCVA of worse than 20/40. One might argue that any loss of BSCVA is unacceptable since it is essentially an untreatable vision loss. It is, however, disappointing that after centuries of striving to improve retinal image quality, we are now willing to accept reduced retinal image quality and significant loss of vision all in the name of convenience.

Although current standards tolerate reduced retinal image quality and the current LASIK protocols increase the eye’s aberrations, the potential is there to reduce aberrations and actually improve retinal image quality. In principle, photoablative techniques can be used to correct not only the eye’s spherical and cylindrical refractive errors but also higher order aberrations such as spherical aberration and coma, which limit retinal image quality in pre-surgical eyes. Autonomous Technologies is pioneering this concept, which requires measurement of the eye’s aberrations in addition to the refractive error typically measured. We expect to see this approach, referred to as "custom cornea" to develop rapidly in the next few years. Of course, in order to correct for the aberrations, they must first be measured. New technology borrowed from astronomy has been successfully employed to measure ocular aberrations[5] and these can be used to guide photoablative surgeries. The term "wave-guided corneal surgery" was recently coined to describe this procedure.

We shall soon see if wave-guided corneal surgery can succeed. McDonald presented some of the first data earlier this year and showed that the increase in aberrations and thus reduction in retinal image quality associated with the standard LASIK procedure may not occur following a "custom cornea" approach. Currently, it is not clear how successful this approach will be. It may be a way to maintain optical quality at pre-surgical levels, but the potential is there for actual improvement.

Although the ablation algorithms may be perfect and corneal transparency maintained, there is another factor that will lead to significant loss of retinal image quality in LASIK or PRK. In order to maintain a monofocal optical system, the reshaped cornea must be larger than the eye's entrance pupil. However, there are limits to the maximum size of the ablation zone because increased ablation zone size requires deeper ablations. For example, by increasing the ablation zone from 4 mm to 7 mm approximately doubles the necessary ablation depth in the central cornea when correcting myopia. Thus, correction of large refractive errors requires more tissue ablation and larger ablation zones also require deeper ablations. For example, Sher calculated that 300 microns of tissue would have to be removed to correct a -12 diopter myopia over a 7 mm diameter area. Approximate corneal thinning caused by photoablation for myopia is 12, 18 and 25 microns per diopter with 5, 6, and 7 mm ablation zones, respectively.

The problems associated with leaving too little attached stroma after ablation are exaggerated with LASIK since up to 150 microns of the anterior cornea has been removed already in the flap. Ablating significant amounts of the remaining stromal tissue may compromise the structural abilities of the remaining stroma and result in the observed "bowing" of the posterior corneal surface after surgery.

Since there are limits to how much corneal tissue can be safely removed, ablation zone size has typically been smaller than necessary to cover the entire dilated pupil present at night. Current standards try to maintain at least 250 microns of intact stroma after photoablation. Given this type of constraint, the photoablation zone size is limited. Early PRK photoablations were performed with 4 mm and 5 mm zones, but the standard now is about 6 mm with perhaps a 1-2 mm "transition" zone. Because the pupil of many young eyes will be larger than 6 mm under low light conditions, the effective optical system creating the retinal image will be bifocal. The central zone will be near to emmetropic and the marginal zone near to the pre-ablation refractive error. Although this has obvious parallels to simultaneous bifocal contact lenses or IOLs, it is not an effective bifocal correction since the additional add power in the peripheral optics will vary from eye to eye and will be too peripheral to be effectiveat high light levels. This bifocal problem cannot be corrected with a spectacle lens or easily corrected with a contact lens and bifocal optics are known to produce significantly reduced image quality, halos and glare. Data over the last few years indicate that the flattening of the central cornea by LASIK actually leads to steepening of the peripheral cornea potentially exaggerating the simultaneous bifocal effect for larger pupils. Also, by adding transition zones into the surgical procedure, a dilated pupil produces multifocal optics.

The impact of post-surgical simultaneous bifocal or multifocal optics would only be manifest at low light levels, and studies from Europe seem to indicate that night vision can be significantly compromised by PRK and LASIK. Visible halos and glare at night are often reported, and they increase in frequency with increased myopic correction, and cases have been reported in which post LASIK and post PRK night vision is so poor that night driving has to be eliminated. It would be wise therefore, as Applegate[6] has been emphasizing for many years now, to discourage individuals with large night-time pupils from undergoing this procedure. Simulations of these night vision problems can be visualized on the web at http://www.surgicaleyes.org.

4. UV damage to other ocular tissue:

The introduction of a high intensity UV radiation source into the eye produces obvious concerns for other ocular tissue since UV is known to cause cataractogenesis and may be a significant factor in age related maculopathy. However, 193 nm UV radiation does not penetrate more that a few microns. This is why it is so effective at stromal ablation.

5. Problems with the flap.

The major concern with LASIK stems from the radical surgery preceding the photoablation. The entire anterior cornea (epithelium and part of the stroma) is removed across the central cornea exposing the central stroma. Problems develop due to poor quality of the keratome blade, poor control of the cutting speed, failure to complete the cut, leaving tiny metal fragments from the blade on the flap, deposition of other material (e.g., surgical glove powder) within the wound, and movement of the tissue during the cut. Expert use and maintenance of the micro-keratome is essential to reduce the incidence of these vision-compromising complications.

It is important to realize that cutting corneal tissue requires much greater precision and better quality cut surfaces than cutting tissue in other parts of the body. Errors, such as the micro-chatter marks seen post LASIK, on the scale of the wavelength of light, can become significant. Also, since the stroma is avascular, there is little opportunity for debris to be removed by phagocytic inflammatory cells. Reports of tiny metal fragments from the micro-keratome blade, powder from the surgical gloves, small pieces of sponge as well as corneal tissue remnants have been seen under the flap post surgically. All of these reduce transparency, and can require a second procedure in which the flap is opened up and the tissue cleaned.

LASIK has a unique safety issue not present with other refractive surgical procedures, which stems from the structural weakness of the corneal flap and its poor adhesion to the underlying corneal stroma. In some ways it is remarkable that the flap can "reattach" so easily without sutures. Initial reattachment results from hydrostatic pressure due to the hydrophilic nature of the inner cornea. Primary "reattachment" forces may result from capillary surface tension. It is therefore quite easy to remove the flap for additional photoablation, if the initial surgery was not as effective as desired. However, the flap can also become dislodged accidentally. Remarkably, this is very rare, but it can and does happen, usually following some ocular trauma. A notable concern exists for patients with dry eye who may experience adhesion forces between the anterior corneal surface and the lid. This has led to a patient waking to find the flap stuck to the lid. Also, because of the reduced sensitivity following surgery (sensory nerves have been cut) the normal feed-back that controls corneal insult has been seriously compromised which must increase the chances of elevated mechanical forces on the cornea due to trauma or lid friction.

In addition to flap displacement, the structural weakness of the flap and its attachment can lead to structural changes within the flap. Small scale "ripples" or "wrinkles" in the flap have been reported, as have larger folds. Flaps are sometimes detached and reattached to try and remedy flap irregularities. There is also the problem of accurately realigning the flap and replacing it in the correct location. Flap decentration has been reported. As with flap wrinkling, it will lead to reduced optical quality.

The final complication associated with the flap surgery stems from the pre-incision protocol. In order for the keratome to make a precise cut, the corneal tissue must be held firmly by a vacuum ring. During this procedure, the intraocular pressure spikes to above 60 mm of Hg. There is some concern that this IOP spike, particularly if it is maintained for more than a few seconds, can lead to retinal damage. Suction duration depends upon the speed of the procedure and can vary significantly (e.g., from 6 to 80 seconds). Changes in retinal blood flow and visual function following this transient elevated IOP have been reported. In addition to the IOP spike, there is some globe deformation associated with the vacuum ring.

In the March 2000 issue of Biophotonics International, a new technology for producing the flap without a micro-keratome was described. A group at the University of Michigan are developing an infra-red laser to make the flap. This device uses a highly convergent laser beam with very high energy per square cm at its focal plane with sufficient energy to break the collagen fibers. By placing the focal plane within the stroma and scanning across the eye, the anterior cornea can be detached from the remaining posterior stroma and a flap produced. The advantages are that it requires no mechanical shear forces, which tend to move and distort the cornea and lead to variable flap thickness with micro-keratomes. Also, by optically adjusting the laser focal plane, the flap depth can be varied across the cornea and flaps with beveled edges can be produced. The technology is undergoing trials in Europe and may be introduced late in 2000 in the US. Interestingly for optometry, this device removes the necessity for cutting tissue with a blade, or traditional surgery, and may, in the classical sense, make LASIK a non-surgical procedure.

LASIK Summary

The overall picture emerging from the LASIK literature indicates that it is a largely safe and effective treatment for myopia, hyperopia and astigmatism. However, LASIK is not risk free, and with current technology final vision quality will probably be slightly inferior to pre-surgical vision. Night vision may be significantly impaired. There are many stories of post-PRK and post-LASIK patients having to modify their night driving behavior because of seriously reduced vision at night. For the patient, the very small risk of serious complications and the likely small reduction in vision and night driving problems must be balanced against the obvious convenience of never having to worry about contact lenses or spectacles. Perhaps more significantly, highly myopic patients will never have to suffer the serious handicap that exists when their high myopia is uncorrected. For many patients, particularly those who are seriously handicapped by their myopia, and those for whom highest quality vision is not required, this may be the surgical treatment of choice at this time. However, it is imperative that all patients are made aware of the risks, particularly the commonly occurring reduced quality of vision and night driving problems.

Thermokeratoplasty

In addition to the photoablative use of short wavelength UV lasers, corneal irradiation using long wavelength (1.5 - 2.0 micron) lasers has been developed to create thermally induced changes in the corneal stroma. This method, Laser Thermokeratoplasty (LTK), has some obvious parallels to radial keratotomy, and it is sometimes referred to as radial thermokeratoplasty. Unlike RK, which treated myopia by introducing deep incisions to allow the peripheral cornea to stretch and thus reduce central corneal curvature, LTK causes peripheral corneal shrinkage due to thermally induced shrinkage of individual collagen fibers. Thus, LTK has the opposite effect on the peripheral cornea, and therefore induces myopic shifts in the central cornea. It has been suggested and actually tested as a treatment for hyperopia (either naturally occurring or secondary to over-correction by PRK or LASIK), but it is still in the investigational stage and has not received FDA approval. There are major concerns about its ability to produce a stable refractive change since large regressions occur. Also, unlike photoablative techniques which calculate the desired tissue to be removed, LTK must rely on empirically determined nomograms. Predictability with this approach has not been established and dosimetry studies continue to examine the impact of wavelength, temperature, penetration of the radiation, beam profile, and spatial pattern and duration of radiation. There is also concern that the thermal effects cannot be confined to the stroma, and damage to the epithelium and endothelium may occur.

Surgical Implants

In addition to the methods just described in which the cornea is reshaped by removing tissue or reshaping the cornea, two new surgical approaches are being developed that insert foreign bodies into the eye. The first inserts a ring deep into the peripheral corneal stroma and the second involves implanting an intraocular lens (IOL) into a phakic ametropic eye.

1. Intrastromal Corneal Rings

Just as RK and LTK change the curvature of the central cornea by changing the structure of the peripheral cornea, intrastromal corneal rings (ICR) or intrastromal corneal ring segments (ICRS) are inserted into the peripheral cornea to treat myopia. The ring or ring segments are inserted through a small incision and threaded circumferentially into the deep stromal lamellae. The structural changes that are produced translate into curvature changes in the central cornea. Inserting PMMA annular rings into the deep stromal lamellae of the corneal periphery changes the already prolate elliptical cornea into an even more prolate cornea, reducing the overall corneal curvature and thus producing a hyperopic shift. Studies indicate that myopia of up 3 or 4 diopters can be treated with this method. The biggest advantage of this approach is that, unlike PRK, RK or LASIK, it is largely reversible by simply removing the ring (segments). Thicker rings (0.45 mm diameter) introduce large changes and thus can correct for more myopia while thinner rings (0.25 mm) are used to correct lower levels of myopia. BSCVAs seem to remain high and thus the method must not introduce large amounts of aberrations or turbidity in the central cornea. There is some concern that significant refractive instability exists with this method including diurnal variations. Peripheral corneal haze, small lamellae deposits adjacent to the ring, deep stromal neovascularization, and pannus are also associated with the ring insertions. Currently the FDA has approved one ICR (Keravision's Intacs).

2. Phakic Intraocular Lenses

Unlike the previous methods, which all required the development of new technology, IOL implantation has a long and successful history as a treatment for cataract. The major difference with phakic IOL implantation is that the natural lens is left in place. The general principle of using an IOL to correct for ametropia has of course been part of the typical cataract lens replacement regime for many years. By manipulating the curvature, refractive index and thickness of an IOL, significant refractive errors can be corrected by the cataract surgery.

A phakic IOL (PIOL) is placed in either the anterior or the posterior chamber and anchored in a similar way to that of traditional IOLs. PIOLs are made of flexible materials such a silicone and hydrogel-collagen, and can be anchored with nylon haptics or other mechanical anchors. The anterior chamber PIOLs typically anchor in the angle between the cornea and iris while posterior chamber PIOLs anchor around the zonules. One beneficial effect of transferring the myopic correction from the spectacle to the iris plane is that there will be significant image magnification which is responsible for the observed improvements in VA after this procedure.

The primary concerns with phakic IOLs stem from the intrusive nature of the surgery in an eye that does not need to be opened and the introduction of a foreign body into the eye. For example, the acceptably low levels of complications associated with cataract surgery may be unacceptably high for phakic IOL refractive surgeries. Also, recurring problems with lenticular and corneal physiology, the development of cataracts, and reduced endothelial cell counts cast doubt on the acceptability of this approach for routine refractive surgery.

The efficacy of this approach hinges on the application of thick lens optics and accurate biometric data on the eye. There is still some uncertainty in calculating the required PIOL power and therefore the post surgical refractions are not very accurate with residual errors of up to 6 diopters. These inaccuracies are, of course, affected by the precise position of the lens in the eye, and this can vary significantly from eye to eye.

There are two primary safety issues that continue to compromise this approach. First, posterior chamber

PIOLs that are typically in contact with both the lens and the iris, routinely lead to cataract development. Incidence rates of up to 80% have been reported, but other studies report zero incidence of cataract. Anterior chamber PIOLs seem to lead to reduced endothelial cell counts and thus compromise the physiology of the cornea, and in some cases (20% of eyes in one study) have lead to the surgical removal of the PIOL. Also, the posterior chamber PIOLs push the iris forward and thus lead to reduced anterior chamber depth (and volume) and narrower angles with the associated elevated chance of angle closure glaucoma. Also, oval pupils and glare problems have been reported following insertion of anterior chamber PIOLs.

The major advantage of this approach over the corneal reshaping techniques described previously is that it can correct for very large refractive errors, and has been used to correct eyes with up to -30 D of myopia and +10 of hyperopia. One interesting combination therapy for the very high myopes has been to implant a PIOL to correct most of the myopia and then use the more predictable LASIK to further reduce the myopia towards emmetropia.

One solution to the cataract development complication associated with posterior chamber PIOLs is to remove the natural lens and replace it with one that will correct the refractive error.

PIOLs have not received FDA approval although several are in the last phases of FDA approved clinical trials.

Summary:

Refractive surgery has been widely available for about three decades now, and it has undergone many transformations. Overall, the newer techniques have improved accuracy, stability and reliability, but continue to be plagued by biological variability leading to small errors in correction. Although serious problems rarely occur with PRK or LASIK, minor problems associated with reduced optical quality are routinely produced. Eye care practitioners should advise patients of the small risks of serious complications and the high risk of slight daytime vision problems and possible serious night driving problems. These risks must be balanced with the tremendous increase in convenience of reducing or eliminating dependence on spectacle or contact lenses.

The costs associated with excimer lasers and the imperfect results observed with PRK and LASIK are the primary driving forces behind the continued development of novel refractive surgical techniques and products, and we can expect to see more developed in the future.

Post-script

Most of the information reported in this review article comes directly from the primary literature. Refractive surgery has proliferated a large number of publications. For example, 330 articles were published on LASIK during the last five years. I used over 50 such articles identified by searching through the National Library of Medicine's MEDLINE system to write this article. I have not included all of these citations, but a comprehensive bibliography on these topics can be located at http://www.ncbi.nlm.nih.gov/PubMed/ simply by searching for PRK, LASIK, PIOLs, etc. Also, the year 2000 abstract listings from the annual meeting of the Association for Research in Vision and Ophthalmology (ARVO) proved to be a valuable resource (http://www.arvo.org).

Acknowledgements:

Earlier drafts were improved with help from Raymond Applegate, O.D., Ph.D. (Indiana Alumnus), Professor of Ophthalmology, University of Texas, San Antonio; Michael Grimmett, M.D. Assistant Professor of Ophthalmology, University of Miami; and by Carolyn Begley, O.D., M.S., and David Goss, O.D., Ph.D. from the Indiana University Optometry faculty.

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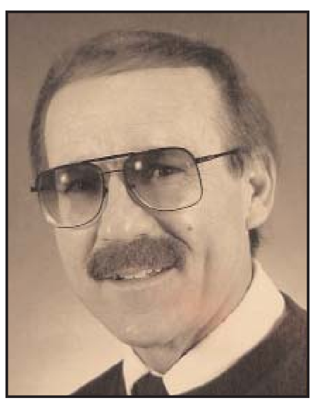
The Optical Science Underlying the Quantification of Corneal Contour: A Short History of Keratoscopy and Indiana University Contributions

David Goss, O.D., Ph.D. and Daniel Gerstman, O.D., M.S.

The Indiana University School of Optometry has been active for a number of years in the optical science underlying the quantification of corneal contour.

The first IU graduate student to earn a Ph.D. degree in physiological optics, Robert B. Mandell, did his dissertation research on instrumentation and measurement of corneal topography. In 1962, Mandell completed his Ph.D. thesis, "Morphometry of the Human Cornea." Mandell has gone on to publish material on corneal topography in books and journals.[1-3] In 1961 at IU, John R. Levene completed an M.S. thesis entitled "An Evaluation of the Hand Keratoscope as a Diagnostic Instrument for Corneal Astigmatism." In 1965, Levene published the definitive work on the history of the invention of keratoscopy.[4] Studies on corneal contour by IU optometry faculty include a subjective evaluation of keratoscopy images.[5]


David A. Goss


Daniel R. Gerstman

The Indiana University School of Optometry got involved early in videokeratoscopy when it obtained a Corneal Modeling System in the late 1980s. Purchase of this videokeratoscopic system was made possible by a grant of $89,900 to Drs. Dan Gerstman, Gordon Heath, Doug Horner, and Sarita Soni from the Indiana Lions Eye Bank, Inc.[6] The Corneal Modeling System captures light information reflected from the cornea in the form of concentric rings, and digitizes this information to produce a color map of corneal dioptric power, thus providing a local radius of curvature.

Indiana University faculty members have published on reliability, validity, and mathematical analysis in keratoscopy,[7-9] as well as on applications of videokeratoscopy in patient care and clinical research.[10-14] IU faculty have also written book chapters on keratoscopy procedures and corneal topography analysis.[15,16] Tom Salmon, a 1999 IU Ph.D. graduate, used videokeratoscopy and other instrumentation to analyze the contributions of the cornea to the aberrations of the eye, culminating in his Ph.D. dissertation entitled "Corneal Contribution to the Wavefront Aberration of the Eye". Recent instrumentation obtained by IU includes the Orbtek, Inc., Orbscan, which yields anterior corneal surface contour measures, corneal thickness maps, and back surface curvature estimates.

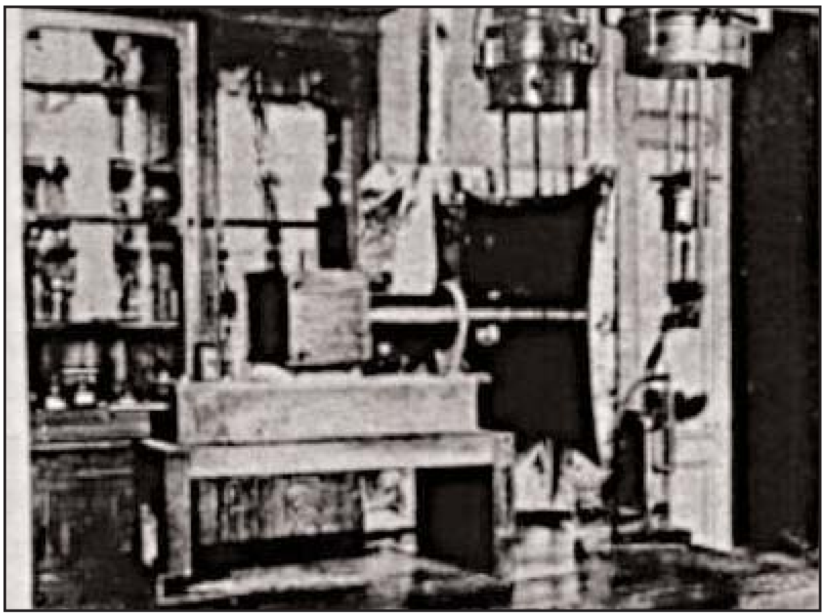
A variety of factors influenced the significant gain in popularity of photokeratoscopy and videokeratoscopy in the 1980s and 1990s. Computers have made the analysis of keratoscopy images quick and simple, thus allowing the use of corneal topography measurements for monitoring keratoconus and various other corneal conditions in a timely fashion. Corneal topography has also been used extensively to study the effects of orthokeratology and keratorefractive surgery. While it may seem that photokeratoscopy is a recent development, the Swedish ophthalmologist, Allvar Gullstrand (1862-1930) worked out the optical concepts of photokeratoscopy over a hundred years ago.

Keratoscopy has its roots in the development of keratometry. Keratometry is based on the principle that the radius of curvature of a convex surface is proportional to the size of an image reflected from that surface. It appears that this principle was first applied in 1619 when Christoph Scheiner measured the radius of curvature of the anterior corneal surface by comparing the sizes of images reflected from the cornea to images reflected from glass balls of known radius.[17,18] The first keratometer was constructed by Jesse Ramsden, an instrument maker, in 1769.[19] Subsequently, in the mid 19th century, Hermann von Helmholtz improved on Ramsden's design and made a keratometer (or ophthalmometer as it was called then) that was similar to the manual keratometers of today. Whereas the optically centered keratometer predicts the radius of curvature across a span of about 3 mm relying on just four localized points (two per meridian), the centered keratoscope provides an assessment of almost the entire corneal surface, utilizing thousands of localized points reflected from the cornea and analyzed for most all meridians.

Levene[4] identified English physician Henry Goode as the first to make a keratoscope. Goode reflected a square object from the patient's cornea and viewed the reflection from the side of the keratoscope target. Goode was influenced by George Biddell Airy's description of astigmatism, and in 1847 Goode reported on his observations of some eyes with astigmatism using his keratoscope.

By studying publications and letters to the editor in 19th century journals, Levene[4] concluded that the Portuguese oculist Antonio PlÆcido independently reinvented a hand keratoscope in 1880, and also invented the photokeratoscope in 1880. PlÆcido's keratoscope had black and white concentric circles and a viewing tube in the center of the keratoscope used for alignment. His pattern of alternating black and white rings is used in modern corneal topographers with the target often referred to as a PlÆcido's disc. French ophthalmologist Emile Javal was the first to suggest using auxiliary lenses to magnify the keratoscope image. Javal talked about attaching a paper disc with concentric circles either to an ophthalmoscope along with a plus lens, or to the Javal-Schiotz ophthalmometer (keratometer), or to a photographic system. Javal was the first to use a keratoscope to evaluate a corneal disease, when he examined an eye with keratoconus.

Gullstrand's contribution came in 1896 in being the first to describe the mathematical analysis of photokeratoscopy.[20] Ludlam and Wittenberg,[20] in their 1966 translation and notes on Gullstrand's photo-keratoscopy system, observed some faults in Gullstrand's work, but stated that Gullstrand's "...work still stands as the best in photo--keratoscopy. Little has been done since then which approaches the insights offered by Gullstrand..." Today computerized photo-keratoscopy and video-keratoscopy units have programs to calculate various parameters of corneal topography. Gullstrand had already worked out a system for these calculations in 1896. But without rapid calculation capability as is made possible today with computers, Gullstrand recognized that the necessary calculations would be too tedious for the typical ophthalmic practice. In talking about measurements of the cornea in his appendices to Helmholtz's Treatise on Physiological Optics published in 1909, Gullstrand stated: " The only way to do this, when the problem consists in ascertaining the radii at different points in one



Gullstrand s photokeratoscopy apparatus, Today s videokeratoscopes look a little different! (Used by permission from: Gullstrand A. Photographic-ophthalmometric and clinical investigations of corneal refraction, translated by Ludlam WM,, with appendix notes by Wittenberg S. American Journal of Optometry and Archives of the American Academy of Optometry, 43(3): 143-214. ©The American Academy of Optometry, 1966.

and the same principal section, is by photographing the reflex image in the cornea. Such measurements, it must be admitted, take much time and require special apparatus made for the purpose. Consequently, they are not suitable for the general run of practice, but on the other hand they give a resultant accuracy that previously could not be obtained in any other way."[21]

Gullstrand's photokeratoscope target was a series of paired concentric circles. Each circle had another paired circle very close to it with a thin dark line between them. To measure radii of curvature in the horizontal and vertical meridians, Gullstrand moved a microscope over the photographic plates by means of a screw mechanism. A "dividing engine"[22] was used to determine the amount of movement of the microscope after it had been moved to align a cross hair in the ocular with the dark line between the paired white circles. These measurements were converted into radii of curvature and then into dioptric powers. In his 1896 paper, Gullstrand gives an example of a photograph taken and analyzed in 1893. He presented an x,y coordinate plot of dioptric power as a function of degrees of eccentricity. This kind of plot had been produced previously with peripheral ophthalmometry (keratometry), but Gullstrand appears to have made the first such plot using keratoscopy. Although today's keratoscopy is often thought of as a recent development, Gullstrand had worked out many of the necessary details over a hundred years ago.

Perhaps because of the lack of rapid calculation methodology for the extensive computations and/or Gullstrand's statement that photokeratoscopy measurements "..are not suitable for the general run of practice...," little work seems to have been done in this area in the first couple decades of the twentieth century. It appears that the first commercial device for photokeratoscopy was manufactured by Zeiss in the 1930s.[23,24] The Zeiss instrument had a flat target so curvature of field would have affected peripheral measurements. Zeiss did not resume manufacture of the instrument after World War II.

The next commercially available device for photokeratoscopy was the Wesley-Jessen Photo-Electronic Keratoscope or PEK.[25,26] It was developed in the 1950s, and was manufactured for about 20 years. Because the target rings were on an elliptical bowl, there were less curvature of field defects than with the Zeiss instrument. Wesley-Jessen marketed the PEK as an aid to contact lens fitting. The practitioner took the keratoscope picture and mailed it to Wesley-Jessen. Wesley-Jessen sent back an analysis of the corneal topography and suggested the appropriate contact lens parameters. Although possibly more accurate than the Zeiss instrument, the PEK did not achieve wide acceptance.

Following the PEK, various photo-keratoscopes were available, including the Corneascope and the Nidek Photo-keratoscope.[15,27] The Corneascope was marketed initially by International Diagnostics Instruments and later by Kera Corporation. The practitioner could analyze photokeratograms taken in the office with a device called a Comparator.[28,29] The Comparator is an optical magnifier with variable magnification. The Comparator projects the Corneascope keratogram onto a screen and allows the practitioner to compare the photokeratogram rings to a calibrated set of concentric rings. Radii of curvature at various points on the photograph can be determined by varying the magnification to match the photograph ring size to the ring size on the comparison pattern.

Allvar Gullstrand (1862-1930) was winner of the Nobel Prize in physiology or medicine in 1911. He made many contributions to the knowledge of optics of the eye and lenses and to instrumentation for ophthalmic clinical practice. This medal, from the collection of Jay M. Galst, was struck by Erik Lindberg in 1935 for the Royal Swedish Academy of Science. (photo courtesy of Jay M. Galst)

The next developments focused on replacing photographs with computer scanning devices coupled with video technology. It appears that the first computerized videokeratoscope was the Corneal Modeling System by Computed Anatomy.[16,30] It was this instrument that was obtained by Indiana University School of Optometry in the late 1980s. IU now has the newer generations of this and other videokeratoscopic instruments. There are a number of videokeratoscopes now on the market. Most use the Placido pattern for the object and an image analysis system similar to that of Gullstrand's. Even though computer technology has allowed keratoscopy to become more widely accepted and more clinically friendly, the basic principles underlying the new technology are the same as those articulated by Gullstrand. Gullstrand's approach developed over a hundred years ago is finally being incorporated into "the general run of practice."

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Article of Interest: Progressive Addition Lenses for Myopia Control

Review by David A. Goss, O.D., Ph.D.

Leung JTM, Brown B. Progression of myopia in Hong Kong Chinese schoolchildren is slowed by wearing progressive lenses. Optom Vis Sci 1999; 76(6): 346-354.

Decades of research on childhood myopia progression still haven't yielded any definitive answers on how progression rates can consistently be controlled. However, it is widely accepted that nearwork plays a role in myopia development, as evidenced by the recent publication of two books on the relationship of myopia and nearwork.[1,2] Laboratory studies with animals have shown that myopia can be induced by the defocus of retinal imagery.[3-6] The physiological correlate in humans to these animal models of defocus-induced myopia may be large lag of accommodation during nearwork. Myopic children and young adults tend to have lower accommodative response levels than emmetropes and hyperopes.[1,2,7,8] If defocus associated with high accommodative lag plays a role in the etiology of human myopia, then the prescription of added plus for near becomes a logical approach to myopia control.

A recent paper by Leung and Brown[9] reports progressive addition lenses to have a significant effect in reducing childhood myopia progression rates. The study was conducted at The Hong Kong Polytechnic University Optometry Clinic where potential subjects were selected by review of the clinic records. Subject inclusion criteria were: nine to twelve years of age, one to five diopters of myopia, astigmatism less than or equal to 1.50 D, anisometropia less than or equal to 1.25 D, intraocular pressure less than 20 mm Hg, monocular visual acuities better than 6/9, stereoacuity better than 100 seconds of arc, and myopia progression greater than -0.4 diopters per year. None of the subjects had strabismus or had a correction for large phorias. All subjects wore spectacles prior to the study. Seventy-nine subjects started the study, and 68 completed the full two years of the study. Subjects were examined at six month intervals during the investigation.

The control group wore single vision spectacle lenses. There were two progressive addition lens treatment groups: one with +1.50 D reading additions and one with +2.00 D reading additions. Subjects were advised to wear their glasses full-time. When subjects had a change in spherical equivalent refraction of 0.37 D or greater, they received new lenses with the new prescription. The examiner was not masked to the treatment group or to the previous prescription.

Study Findings

Refractive error measurements were made by manifest subjective refraction, and the right eye spherical equivalent was used for analysis. The mean increase in myopia in two years for the single vision lens wearing control group was -1.23 D (n=32; SD=0.51). The subjects who wore +1.50 D adds had a mean change in refractive error of -0.76 D (n=22; SD=0.43). This was significantly different from the mean change for the control group (p=0.0007). The subjects with the +2.00 D add treatment had a mean two year progression of myopia equal to -0.66 D (n=14; SD=0.44). This was also significantly different from the mean for the control group (p=0.0007). The means for the +1.50 D and +2.00 D add groups were not significantly different (p=0.505).

The depth of the vitreous chamber was measured by ultrasonography. The enlargement of eyes of control group subjects was greater than that for subjects who wore progressive addition lenses. The mean increases in vitreous chamber depth were 0.63 mm (SD=0.40) in the single vision lens group, 0.46 mm (SD=0.34) for the +1.50 D add group, and 0.41 mm (SD=0.41) in the group wearing +2.00 D adds.

Comments

This appears to be the first published paper on the use of progressive addition lenses for slowing childhood myopia progression. In the extensive literature on bifocals for myopia control, study outcomes have been variable. One consistent result in four studies is that mean progression rates were about 0.2 diopters per year less with bifocals than with single vision lenses in children with esophoria at near on the von Graefe test.[10,11] Phorias were not reported in this paper.

The examiner was not masked to subject treatment group in this study, so it could be argued that inadvertent examiner bias could have affected the refractive error results. However, the vitreous depth increases show the same trend of less change in the progressive addition lens groups than in the single vision lens group.

The amount of reduction in myopia progression rates with progressives in this study (about a quarter diopter per year) is greater than that found in most of the bifocal studies without division by phoria status.[10,11] It is unknown whether this was due to the population studied or unrecognized variables or whether progressives may be more effective in myopia control than bifocals. One possible advantage of progressive addition lenses in this regard is that parents may more readily accept progressives than bifocals. Most children adapt successfully to progressive addition lenses.

Nearpoint plus can be beneficial in non-presbyopes with conditions such as convergence excess and accommodative insufficiency. This study suggests that nearpoint plus in the form of progressive addition lenses can also be useful in myopia control.

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News from the IU School of Optometry

Dr. Victor Malinovsky recently received the Indiana University's President's Award for Excellence in Teaching during the Founder's Day ceremony. He was the only recipient from the Bloomington campus. This is a very competitive University system award and the first time that an Optometry School faculty member has received it. The award is a tribute to Dr. Malinovsky's many years of hard work in the classroom, his development of the ocular disease clinic, and his national reputation in professional continuing education.

U.S. Surgeon General David Satcher, Dr.Norma Bowyer, HHS Secretary Donna Shalala, and Dr. Ed Marshall.

Dr. Ed Marshall was recently chosen by the U.S. Public Health Service to receive the prestigious 2000 Primary Care Policy Fellow. He is one of 32 individuals from around the country and world chosen for this fellowship. This is a very competitive process and Dr. Marshall is the second optometrist to ever be chosen for this program. This is a great honor for him, the School of Optometry, and the optometry profession. The program brings together a multi-disciplinary group of primary health care leaders to work with top government, congressional, and private sector health care officials in Washington, D.C. Dr. Marshall will be making a number of additional visits to Washington in conjunction with this program.

Dr. Sarita Soni was recently appointed to the National Advisory Eye Council. This group advises the Secretary of Health and Human Services; the Director, NIH; and the Director, NEI, on all policies and activities relating to the conduct and support of vision research, research training, facilities development, and other programs of the Institute.

Thomas Stickel, a fourth year optometry student, was recently named a recipient of the Indiana University John H. Edwards Fellowship. There were only five recipients from the entire Indiana University. The amount of the fellowship was approximately $14,000. Tom also was recently named the Chancellor's Scholar from the School of Optometry.

Tom Stickel

The Family Health Center of Clark County, IN, site of the optometry exam room funded by Dr. Marshall s grant.

Dr. Ed Marshall recently received a $99,000 grant from the Indiana State Department of Health under the Preventive Health and Health Services Block Grant program. The application is to equip an examination room in the Family Health Center of Clark County, the Patoka Family Healthcare Center in Crawford County, and the Martin County Health Clinic in Shoals. These facilities target the under-served, low-income residents.

Dr. Doug Horner was an invited lecturer at the B.P Koviala Lions Centre for Opthalmic Studies' optometry program in Kathmandu, Nepal recently. Since the library at the Centre had very few optometric publications, the faculty of IU School of Optometry, under Dr. Horner's guidance, is now contributing publications to the Centre in Nepal.

An official ribbon cutting ceremony was held on March 8 at the opening of the new Indiana University optometry clinic at the Hospital General in Guanajuato, Mexico. The event was presided over by Mrs. Maria Esther Montes de Martin, President of the Department of Infants and Family (DIF); Professor Martha Aguilar Gomez, Director General of DIF; and Dr. Carlos Tena Tamayo, Secretary of Health.

Mrs. Maria Esther Montes de Martin, President of DIF and Dr. Carlos Tena Tamayo, Guanajuato s Secretary of Health and Medical Director of DIF cut the ribbon to the new Eye Care Center in Guanajuato.

Representing the IU School of Optometry at the ceremony were Dr. Cyndee Foster who is the faculty member in charge of the clinic, and Dr. Doug Horner, who has been instrumental in establishing the clinic. This clinic will be a rotation site for fourth year interns from Indiana University as well as for interns from The Ohio State University.

Hospital General, Guanajuato, Mexico where our Eye clinic is located.

Drs. Joe Bonanno, Susana Chung, and Larry Thibos were recipients of sizeable grants from National Institute of Health (NIH) recently.

Drs. Jerry Lowther and Sarita Soni lectured at the American Academy of Optometry International meeting in Madrid, Spain in April.

Dr. Sarita Soni will present at the Essilor 200 Presbyopia Conference in Portugal n June and also at the International Society of Contact Lens Specialists meeting in Switzerland in September.

Approximately 30 of our faculty and students presented papers, posters, and continuing education at the American Academy of Optometry in Seattle this past December. In addition, Dr. Sarita Soni and Dr. Jerry Lowther served on the Executive Council, Dr. Vic Malinovsky was the chairperson of the Ellerbrock Continuing Education program, and Dr. Larry Thibos was in charge of the AAO web site. Indiana University was, indeed, well represented at the AAO.

Approximately 20 of our faculty and students will present papers and posters at the Association for Research in Vision and Ophthalmology (ARVO) annual meeting in Fort Lauderdale the end of April.

Indiana Journal of Optometry
Indiana University School of Optometry
800 East Atwater Avenue
Bloomington, IN 47405

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