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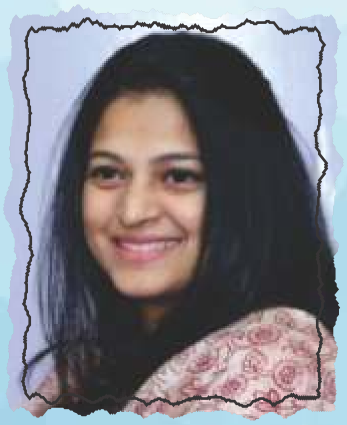

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"The only thing worse than being blind is having sight but no vision."

- Hellen Keller

FROM THE DESK OF PRESIDENT

Dear Colleagues and Friends,

I am honored to address you as the President of the Indore Divisional Ophthalmological Society (IDOS) in this inaugural issue of our journal. As we embark on this new journey, I am reminded to the power ot collaboration, innovation and continuous learning in our pursuit of excellence in ophthamology.

Our society has always been at the forefront of promoting quality eye care, advacing research, and fostering camaraderie among opthalmologists. The journal is a teastament to our commitment to sharing knowledge, best practices and cutting edge research in our field.

I would like to extend my heartfelt congratulations to our Chief Editor, Dr. Urvija Choudhary, for her tremendous efforts in publishing this journal. Her dedication and hard work have been instrumental in bringing this issue to life.

I also warmly welcome our guest, Dr. Rohit Shetty, atalwart in ophthalmology, whose presence graces our journal. His expertise and insights are a valuable addition to our community.

In this issue, we feature insightful articles, case studies, and expert opinions that showcase the diversity and depth of our community's expertise. I invite you to engage with the content, share your thoughts, and contribute to future issues.

As we move forward, I am to explore new opportunities, address challenges, and celebrate our successes together. Thanks for your support and I look forward to your valuable contributions.

Best regards,

Dr. Mahesh Garg

President, IDOS

EDITOR'S NOTE

Advancing Refractive Surgery Patterns

Dear Readers,

We are excited and privileged to feature in this edition a guest editorial on the Role of Artificial Intelligence (AI) in Refractive Surgery. AI is rapidly transforming the field of ophthalmology, offering new ways to enhance diagnostic accuracy, personalize treatment plans, and predict surgical outcomes. This editorial delves into how AI technologies are shaping the future of refractive surgery.

In this edition, we explore the evolving field of refractive surgery, which offers transformative solutions for vision correction. From LASIK to SMILE, advancements have made these procedures safer and more effective, but careful patient selection and thorough understanding remain crucial.

We present several articles that offer valuable insights for clinicians. First, understanding corneal topography is key in planning surgery, and our guide simplifies its interpretation. We also discuss upon how to choose the best refractive surgery option based on different factors ensuring tailored treatment for each patient. We regularly face problems with residual errors and calculating IOL power post refractive surgery, our articles on managing post-refractive surgery refractive errors & IOL power calculation post Laser vision correction provides strategies for optimal corrections.

Journal also gives an insight on PRK, lenticule extraction procedures, Contoura treatments and managing Flap related complications, offering a clear view of their respective advantages and limitations. Further increasing the dimension of refractive surgery to corneal biomechanics & emphasizing its role in predicting surgical outcomes, helping minimize complications. Lastly, we address presbyopia management with the latest options to meet the growing demand for treatments in today's aging population.

Together, these topics provide a comprehensive overview of current refractive surgery practices. Whether you're an experienced surgeon or new to the field, these insights will enhance your ability to deliver exceptional care.

Refractive surgery not only improves vision but also enhances lives. I hope this issue inspires and informs your practice, helping you continue to make a meaningful impact in patient care.

Warm regards,

Dr. Rohit Agrawal
Dr. Nikunj Tank
Co-Editor

Dr. Urvija Choudhary
Chief Editor

GUEST EDITORIAL

Impact of Artificial Intelligence on Refractive Surgery

Rohit Shetty[1], Anushree[2]

Artificial intelligence (AI) has revolutionized eye care and research involving AI has expanded rapidly in recent years. Although an ophthalmologist's role is unlikely to be replaced by AI, it is likely to assist enhancement of diagnostic performance and predict possible outcomes thereby augmenting improvement in patient care.[1] There is a significant impact of AI on refractive surgery by improving preoperative assessment, surgical planning, surgical precision, post-operative monitoring and outcomes of procedures.[1] AI provides enhanced preoperative assessment by advanced imaging where AI algorithms analyze high-resolution images from devices like OCT (Optical Coherence Tomography) and topographers with greater accuracy, detect subtle abnormalities that may be missed by manual analysis.[1] AI can help predict the outcome of different types of refractive surgeries in a patient based on their refraction and scans. Improved surgical planning by using AI will be possible by customized treatment by analyzing vast amounts of data and tailoring surgical plans accordingly determining the best approach for each patient.[1,2] AI systems measure subtle intraoperative changes and make real-time adjustments during surgery to optimize the outcomes. AI can also increase precision by lasers to reduce the risk of over- or under-correction by extreme precision in ablating the cornea. Automated measurements of fine corneal parameters by AI will ensure consistency and accuracy.[2] AI also provides enhanced postoperative monitoring by prediction of outcome using tools that analyze data from previous refractive procedures and patient records, which are then used to predict potential postoperative outcomes and complications which can also help monitor long-term results and identify any issues that might require intervention.[2]

AI can comprehensively analyze data from corneal tomogpraphers such as pentacam HR(OCULUS Optikgerate Gmbh, Germany), anterior segment optical coherence tomography (AS-OCT), corneal visualization Scheimpflug technology (Corvis ST) for corneal biomechanics, thereby reducing the likelihood of errors and providing assistance to surgeons in decision-making.[3]

Clinical applications of AI in refractive surgery :

Post-refractive surgery ectasia :

Unidentified pre-existing subclinical keratoconus or biomechanical weakening due to refractive surgical procedure can cause ectasia of the cornea following LASIK. Hence, pre-operative screening to identify candidates at high risk of iatrogenic ectasia is crucial. Certain algorithms developed using AI can predict eyes that are risk for post-LASIK ectasia. Few such algorithms are the Pentacam Random Forest Index (PRFI), Saad and Gatinel Orbscan II based linear discriminant model, 'SCORE' Analyzer and Pentacam InceptionResNetV2 Screening System by Xie and co-workers.[4]

Corneal biomechanics has emerged as a significant determinant of planning and management of laser vision correction (LVC) surgery in recent years.[5-7] A study by Francis et al.[8] validated a software for preoperative prediction of postoperative corneal stiffness after LVC where they analysed 529 eyes from 529 patients from three eye centres and 10 post-SMILE ectasia eyes .The software (called AcuSimX™) derived the anisotropic, fibril and extracellular matrix biomechanical properties (using finite element calculation) of the cornea using the preoperative Corvis-ST, Pentacam (OCULUS Optikgerate Gmbh, Germany) and AI and predicted the postoperative corneal stiffness relative to the preoperative corneal stiffness derived from the Corvis-ST.[8]

Prediction of vision correction method :

AI has been used in recommending the appropriate refractive surgery based on nomograms. Machine learning (ML) based algorithms have been developed to select refractive surgery options appropriate for each eye based on comprehensive analysis of the scans and refractive status of the eye. ML model nomograms have been developed to achieve the desired visual outcome with SMILE surgery.[9] A ML model was developed to suggest a nomogram for SMILE surgery to achieve the desired visual outcome which reported that 93% eyes in ML group and 83% eyes in surgeon group had post-operative refractive error within ±0.50D.[9]

A study with a data set comprising of preoperative data of 10,561 eyes was used to design a multi-class machine learning model to predict suitability for refractive surgery with an accuracy of 93.4%, including laser-assisted epithelial keratomileusis (LASIK) and small incision lenticular extraction (SMILE).[10] Another study looked at patients' registration records and role of AI in predicting definitive endpoints such as the probability of patients signing up for refractive surgery and predicted with over 93% accuracy which patients would undergo refractive surgery.[11]

Prediction of subjective refraction :

Prescription for refractive error by an automated system rather than a subjective refraction has become an important goal due to alarmingly rising number of persons with refractive errors. LD/HD (Low Degree/High Degree) polynomial has been used to challenge the current use of Zernike Polynomials for wavefronts.[12,13] AI has been utilized in predicting refractive errors from imaging analysis including fundus images and thus AI using these polynomial decompositions beta-software installed on a wavefront aberrometer has shown accurate prediction of results achieved by subjective refraction.[12,13]

Effect of biology and modern diagnostics on refractive surgery :

The intersection of biology and modern diagnostics has significantly advanced refractive surgery, leading to more precise, personalized, and effective treatments for vision correction.

Understanding of corneal biology including corneal biomechanics has led to better assessment of corneal strength and stability, crucial for determining eligibility for various refractive surgeries like LASIK and PRK. Advances in techniques such as corneal topography and corneal wavefront analysis help in mapping thousands on individual points on the corneal surface and understanding individual variations. Knowledge of corneal healing processes and adaptation after refractive procedures has improved postoperative care allowing for better management of complications and improved recovery protocols.[14,15]

At the cellular and molecular biology level understanding tissue regeneration through advances in stem cell research and regenerative medicine are paving the way for new treatments that could potentially enhance the corneal repair process or even reverse certain types of vision impairment like the ones caused by central corneal scar. The density of corneal epithelial cells can be assessed using techniques like confocal microscopy.[16] Reduced density may indicate poorer epithelial health post refractive surgery. Epithelial Growth Factor (EGF) is a biomarker involved in the repair and regeneration of epithelial cells. Abnormal levels can affect corneal healing after surgery. Inflammatory biomarkers like Matrix Metalloproteinases (MMPs), in particular, MMP-9 can indicate inflammation and tissue degradation. MMPs are involved in the remodelling of extracellular matrix and can be elevated in dry eye conditions. Pro-inflammatory cytokines such as IL-1â and TNF-á can be elevated in inflammatory conditions of the ocular surface, impacting healing and surgical outcomes.[17] These impact post-operative healing and remodelling of the cornea. The lipid layer composition of the tear film is crucial for preventing evaporation. Imbalances in lipid composition can contribute to dry eye symptoms and affect surgical outcomes. Biomarkers predict post refractive surgery response of the cornea and ocular surface, allowing for tailored postoperative care plans. Monitoring biomarkers post-surgery can help in the early detection of inflammation or dry eye, enabling prompt intervention and management.[17,18]

As the understanding of ocular surface biomarkers advances, they are likely to become integral in clinical practice for preoperative evaluations and personalized treatment plans. Future biomarker-based therapeutics might include treatments targeting specific biomarkers to enhance ocular surface health and improve surgical outcomes. In summary, ocular surface biomarkers play a crucial role in the management and success of refractive surgery. By providing detailed information about the health and function of the ocular surface, these biomarkers help in tailoring preoperative assessments, customizing surgical approaches, and managing postoperative care effectively.

Modern Diagnostic Technologies in refractive surgery :

- High-Resolution - Optical Coherence Tomography (OCT) provides detailed cross-sectional images of the cornea, allowing for precise measurement and analysis of corneal thickness and structure.
- Corneal Topography maps the surface curvature of the cornea, identifying irregularities and helping to plan the surgical approach with high precision.
- Wavefront aberrometry measures how light waves travel through the eye, identifying aberrations that affect vision quality paving the way for customized treatments that address specific visual distortions rather than just correcting basic refractive errors.
- Advanced Biometry techniques measure the accurate corneal and ocular dimensions with high accuracy, including the length of the eyeball and the curvature of the cornea. This information is critical for planning surgeries like phakic intraocular lens implantation.
- Preoperative assessment using advanced diagnostic tools like MS-39 and corvis-ST provide a thorough assessment of the corneal anatomy and strength before refractive surgery.

Modern diagnostics allow for highly precise refractive surgical interventions tailored to the unique characteristics of each eye. This precision reduces the risk of complications and improves the overall visual outcome of the surgery. By integrating biological insights and advanced diagnostic tools, surgeons can better anticipate and manage potential risks, leading to improved outcomes and fewer postoperative issues. Personalized treatment plans, driven by detailed diagnostics and biological understanding, lead to better visual acuity, greater patient satisfaction, and longer-lasting results. The synergy between advancements in biological sciences and modern diagnostic technologies has revolutionized refractive surgery, making it more precise, personalized, and effective. These developments not only improve the safety and outcomes of the procedures but also throw light for future innovations in laser vision correction (LVC).

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Refractive Surgery
Past, Present & Future

Sharadini Vyas

Refractive surgery means surgery to correct the low order refractive errors like myopia, hyperopia and astigmatism which can be refracted and optically corrected with the available methods. But there is another component of refraction known as higher order aberrations which determines the quality of vision, this also can be modified with the present day refractive surgery options.

Refractive error by definition is the error which can be refracted. By definition presbyopia is not a refractive error but as it can be corrected by optical means, it also has a potential to be corrected with refractive surgery.

Evolution of refractive surgery :

Refractive surgery started way back when the popular form was incisional surgery, which was later given up due to unpredictable outcome.

Main refractive components in the eye are cornea, lens and the overall axial length of the eye and hence refractive surgery can be classified according to the tissue handled into

- Corneal surgeries
- Lens based surgeries
- Scleral surgeries

Principle of corneal surgeries is to modify the anterior curvature to flatten or steepen the cornea to change the focus. These surgeries are then further classified as Incisional surgeries and photorefractive procedures. The beginning of the corneal refractive surgery started with incisional procedures in the form of Radial keratotomy, astigmatic cuts and combined procedure like Ruitz. These all procedures corrected myopia and astigmatism. Hexagonal keratotomy was evolved for correcting hyperopia. Initial results of these incisional procedures were quite promising but in long term PERK study demonstrated a continuous hyperopic shift which continued for significant time. In absence of corneal mapping methods and algorithms to correct different magnitude of myopia the results were unpredictable which lead reduce popularity of the procedures and except a few rest all were abandoned.

Next was the era of Photorefractive surgery. With the advent of Excimer LASER there was a complete revolution in the field.

The various LASER which evolved for refractive surgery include

- Excimer LASER (193 nm)
- Picosecond LASER
- Femtosecond LASER (solid state LASER)

Picosecond LASER was tried for intrastromal ablations but could not show promising results hence could not make its presence in clinical practice

The most popular LASERSwhich are available today are

- Excimer LASER
- Femtosecnd LASER

Both the laser works as photorefractive laser.

Table 1 : Types of refractive surgeries

Corneal surgeries

1. Incisional surgeries :
   RK,
   Astigmatic cuts,
   Mixed procedures like Ruitz
   Hexagonal keratotomy for Hyperopia
   Opposite clear corneal incisions (OSSI)
2. Photorefractive procedures
   PRK
   LASEK
   LASIK with Microkeratome
   Femto LASER assisted LASIK
3. Corneal lenticular Procedures
4. Thermokeratoplasty for Hyperopia
5. Corneal rings
6. Corneal Inlays

Excimer LASER Procedure :

This laser works on Photoablative principle where the laser removes calculated amount of tissue from cornea to correct the refraction. Biggest advantage of lasers is that they came

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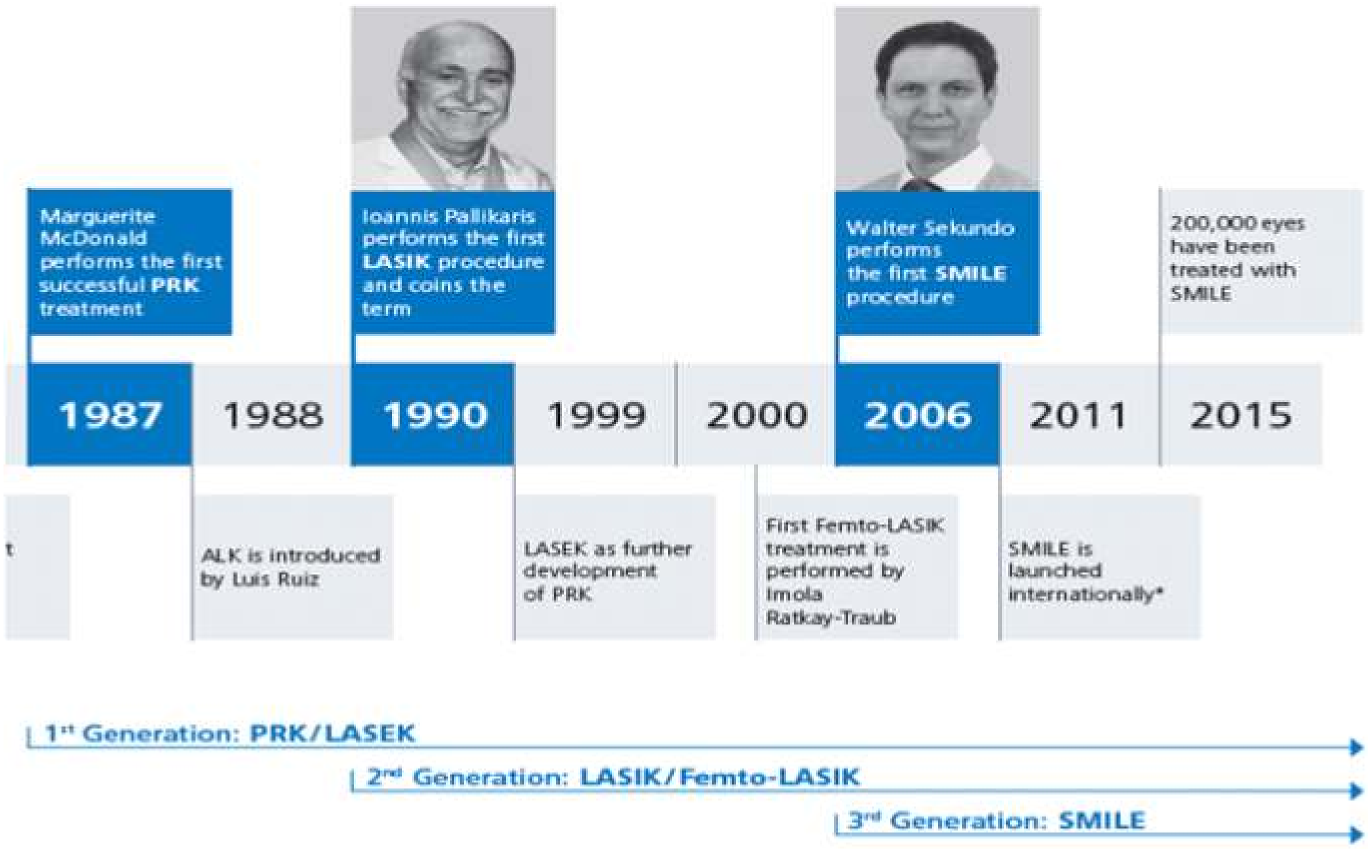

Table 2 : Evolution Of LASERS

into clinical practice with lot of pre operative evaluation techniques which helps the surgeon to assess the fitness, predictability and safety and long term stability data before doing the procedure. This has tremendously improved the outcome which in turn improves the patient satisfaction. These pre operative exams include corneal topography, corneal tomography and assessment of pachymetry, which improves not only the predictability but also reduce the post operative complication rate.

Table 3 : Excimer LASER procedures :

1. Photorefractive Keratectomy (PRK)
2. Photothrapeutic keratectomy (PTK)
3. Laser assisted subepethelial keratectomy (LASEK)
4. LASER insitu keratomeliusis (LASIK)

Photorefractive keratotomy (PRK) :

Also known as surface ablation. Procedure involve removal of epithelium by various means and than the surface is ablated to change central 6.5 mm of cornea from prolate to oblate shape.This effective flattening of central cornea is done in precise way by creating a computer calculated profile generated by taking into account the pre operative refractive error,corneal topography and pachymetry of the given patient .Final effect of precise flattening corrects the refractive error and improves uncorrected vision. Epithelial removal causes discomfort in early postoperative period and surface modulation takes time leading to slow visual recovery. It's a procedure of choice for low myopia. In higher refractive errors haze formation and regression makes it a poor choice for refractive correction. Immunomodulatory drugs though have reduced the incidence of haze and regression. PRK variants include surface ablation with epithelial removal, no touch or Trans PRK, LASEK and Epilasik

LASIK :

LASIK stands for LASER insitu keratomeiliusis. In this procedure a partial thickness anterior corneal flap is made either with a mechanical microkeratome or a femtosecond LASER. This flap is then reflected and a laser ablation is carried out under the flap. The excimer LASER used here works on the principle of photo ablation.The tissue ablated here is removed at an ultra micron speed with the device attached making it a smooth surface. Because the epithelium is intact ,patient achieve early comfort and visual recovery is fast. Like any other procedure Lasik is also not free of complications and hens pre operative selection of case and intraoperative factors need to monitored carefully. In mechanical microkeratome the tissue is cut to make the corneal flap and hence biomechnical strength of the cornea is affected which may predispose the cornea to post procedural ectasia. Also the microkeratome flaps are meniscus flaps and so too steep or too flat corneas can lead to intraoperative complicatios.

The femto lasik works on the principle of Photo disruption.This creates cavitational bubbles intra stromally. The bubbles then collapse to form a layer of separation making very precise and smooth flap .This also preserves the biomechanical strength of cornea and hens reduces the risk of ectasia to a large extent.

Third Generation Refractive procedures

Corneal lenticular procedure

Aslo known as Klex, Lelex , or lenticular corneal surgery is the most advanced femto laser procedure . Performed with the help of only femtolaser. No excimer is required,no ablative part is required. With the help of femto laser an intrastromal lenticule is dissected of desired shape and depth as calculated by the refractive error, corneal topography and pachymetry. With proper dissection the lenticule is removed making the central cornea flatter to correct the refractive error.

To start with only one platform was available for this procedure by the name of SMILE which stands for Small incision lenticular extraction. Now several platforms are available which work on same principle with minor differences in the way the laser operates. They are CLEAR ,SILK and ATOS smart sight.

The biggest advantage of lenticular procedures is minimal or no post procedural dry eye, reason being no cuts in cornea so no cutting of nerve plexus. The lenticules are at a deeper plane than corneal nerve plexus , preventing any trauma to these.

Thus evolution of refractive procedure from incisional surgeries via PRK ,LASIK and now Lenticular procedures is a long journey towards better predictability ,safety , efficacy and outcome. Simultaneous development of pre procedural high quality diagnostic modalities with high efficacy and predictability make refractive procedures a treatment of choice. Equipment to measure the biomechanical strength of the cornea helps in proper selection of the procedure and prevents the most dreadful complication of post procedural ectasia.

New Horizons of Refractive Surgery :

As discussed Trans PRK and FEMTO second procedures have already revolutionized the safety, predictability and efficacy of the refractive surgery.

Lenticular corneal surgery has made it a safe procedure with fast recovery.

Customization of ablation in the form of topography guided ablations (Contoura vision), newer wave front guided ablations (I design) have contributed to improved quality of vision with reduced night vision problems.

Presbyopia for a long time was not considered to be a refractive error because it is an age related loss of accommodation which was corrected with spectacles and hence sought least attention in surgical correction. With growing popularity of LASER refractive surgery demand from this group of population have led to a number of surgical procedures to correct it.The preby LASIK include central presby lasik, CustomVue(VISXAMO), Supracor(Technolas), PresbyMAX (SCHWIND), Peripheral preby LASIK and the most popular LASER blended vision Prebyond (Carl Zeiss Meditec).

Table 5 : Presbyopia correcting surgeries

1. Corneal Procedures :
   - Monovision
   - Presby LASIK
   - Corneal Inlays
   - Conductive Keratoplasty
2. Lenticular Procedures
   - Multifocal IOLs
   - Extended depth of focus IOLs (EDOF)
3. Dynamic Methods
   - Scleral Implants
   - Accomodative IOLs

Artificial Intelligence In Refractive Surgery :

The biggest advantage of AI in photo refractive procedures is to improve the pre procedural selection of cases in terms of safety and predictability. Calculation of ectasia risk probability helps in improving the safety and outcome.

Decoding Topography Maps
Key Considerations & Red Flags

Arushi Garg[1], Urvija Choudhary[2]

Introduction :

Topography maps are essential tools in the preoperative assessment for refractive surgery. These maps provide a detailed view of the corneal surface, offering critical insights into its curvature, thickness, elevation and overall health. Correct interpretation of these maps is crucial for selecting appropriate candidates for surgery and for planning the most appropriate surgical procedure for the patient. This article explores the fundamental aspects of reading topography maps correctly and highlights the red flags that may indicate underlying disease processes requiring careful consideration.

Topography and tomography are two different imaging modalities, but both are usually referred to as topography. Topography maps only the anterior corneal surface, using Placido disc system, such as Orbscan (Bausch n Lomb), NIDEK OPDscan and Atlas. Corneal tomography maps a 3-D model of both the anterior and posterior corneal surfaces. Pentacam (Oculus) captures 25000 true elevation points on the cornea, usingthe Scheimpflug principle (mapping the complete corneal data using a rotating camera), and converts this data to keratometric data (1). Sirius (Schwind) and Galilei (Zeimer) combine both Scheimpflug and Placido based systems to generate topography maps.

Understanding Topography Maps :

Topography maps represent the corneal surface in a 3-D format, typically using color-coded maps or contour lines to indicate variations in curvature and pachymetry. The most common types of maps include:

1. Curvature Maps : These show a colour coded display of the keratometry valuesof the measured cornea. These are of 2 kinds;axial or sagittal maps provide an average of adjacent curvature values, and give a global view of the corneal curvature, but tends to ignore the minor irregularities. Tangential maps are more sensitive in detecting localized curvature changes and are helpful to evaluate focal irregularities such as ectasias. Figure 1 shows the various topographical patterns on an axial curvature map, described by Rabinowitz et al.

2. Elevation Maps : The surface of the cornea is like the surface of the earth, with some elevations and some depressions. The way that earth has a reference surface (the sea level), to which all elevations and depressions are related, the cornea is fitted with an imaginaryreference plane with features most resembling it(best fit sphere or BFS).Anterior and posterior elevation maps show the height of the respective corneal surface relative to the BFS.

3. Corneal Thickness Maps : These display the distribution of pachymetry values across the measured cornea, from centre

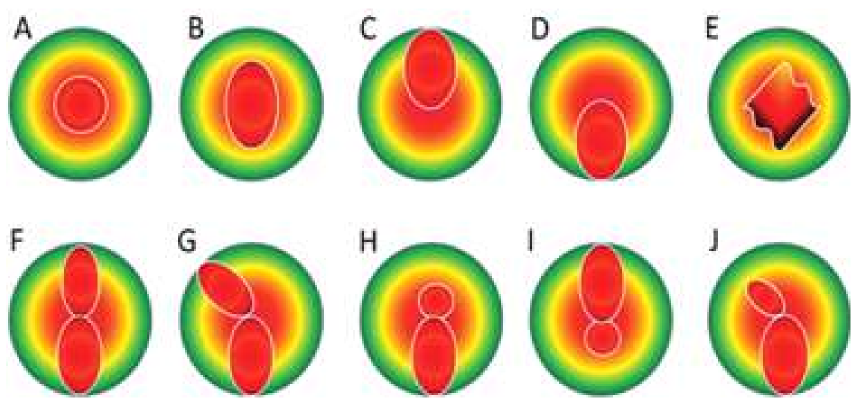

Fig 1. Topographical patterns. Top A, round; B, oval; C, superior steepening; D,inferior steepening; E, irregular; F, symmetric bow tie; G, symmetricbow tie with skewed radial axes; H, asymmetric bow tie with inferiorsteepening (AB/IS); I, asymmetric bow tie with superior steepening; J,asymmetric bow tie with skewed radial axes (AB/SRAX). (2)

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to periphery. They portray the thinnest area on the cornea, and its location with respect to the steepest area.

Table 1 summarizes the colour coding, units of display, the normal and abnormal patterns of the various maps on topography scans.

Interpreting a Topography Map :

Most topography map outputs have the corneal parametric readings on one side and the color-coded maps on other side. (Figure 2).Usually,the red flags are depicted in warm colours as a warning! Table 2 outlines the normal values and the abnormal values to look out for in a Pentacam topography scan (3, 4).

Belin-Ambrosio Enhanced ectasia Display : Presents 3 sets of anterior and posterior elevation maps. The first set are relative

Table 1. Summary of the various maps on a topography scan and their utility.

	Curvature Maps	Anterior Elevation Maps	Posterior Elevation Maps	Pachymetry Maps
Colour code	Warm = steep cornea Cool = flat cornea	Warm = elevated above BFS Cool = Depressed below BFS	Warm = elevated above BFS Cool = Depressed below BFS	Warm = thin Cool = Thick
Unit of measurement	Dioptres (D)	Microns (µ)	Microns (µ)	Microns (µ)
Significance	Assessingoverall shape and detecting irregular astigmatism	Assess the regularity of astigmatism and its location	To look out for forme fruste keratoconus.	To rule out thin corneas, ectasia
Normal	Steepest area in the centre, with progressive flattening towards the periphery. Regular astigmatism has 'bowtie' or 'figure-of-eight' appearance	Maximum anterior elevation in the centre, values within normal limits	Maximum anterior elevation in the centre, values within normal limits	Thinnest at the corneal centre and progressively becomes thicker towards the periphery
Abnormal	Steepest area outside the corneal centre, or progressive steepening in an irregular fashion. Irregular astigmatism has a tilted bow-tie or the steep and flat axes are not 90° apart	High values outside normal limits, decentred location of maximum elevation	High values outside normal limits, decentred location of maximum elevation	Low thickness and location of thinnest area in paracentral zone may suggest ectasia.

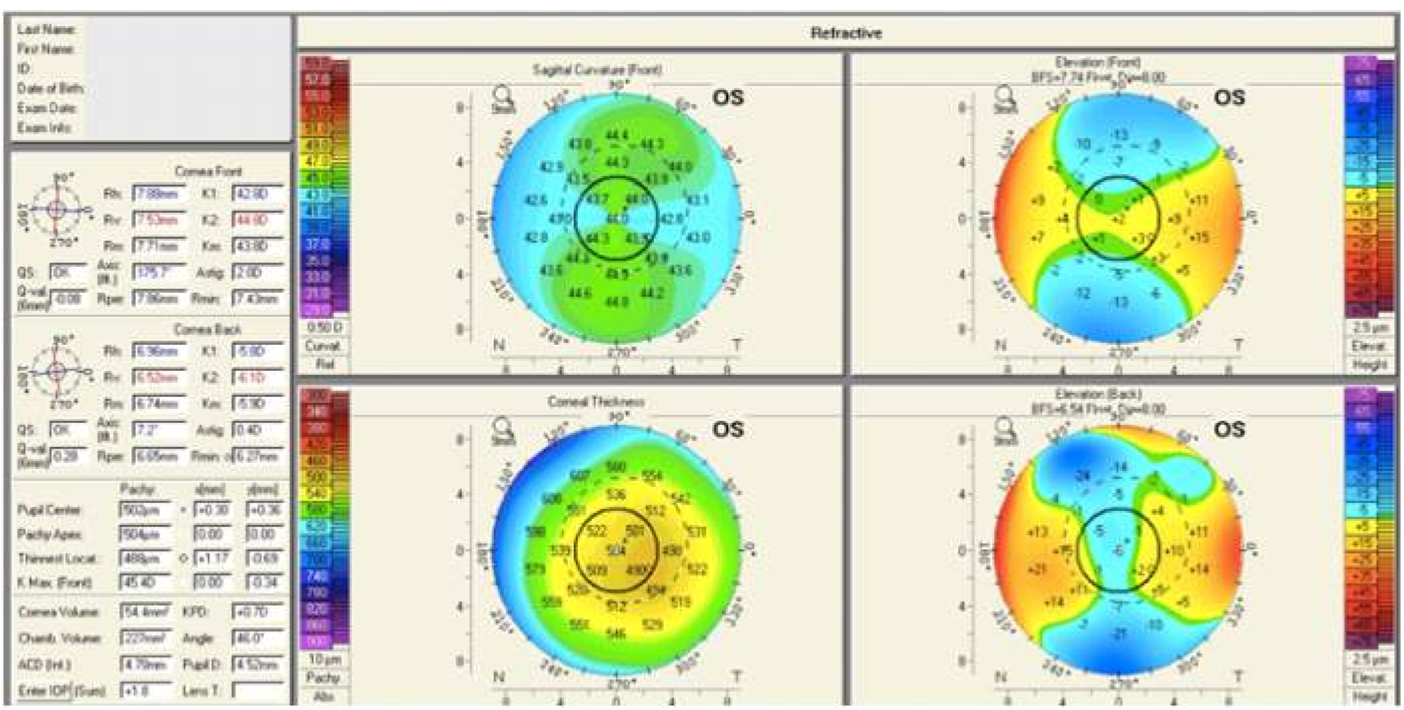

Fig 2. Topography map output from Pentacam of a regular cornea. Fig courtesy Dr. Urvija Choudhary, Rajas Eye Hospital,Indore.

to the standard BFS calculated at 8 mm zone. For the second set, first a 3.5-4 mm mm zone is demarcated centred on the thinnest point of cornea, then all the points in 8 mm zone after excluding this 4mm zone are used to derive an 'enhanced BFS', and the second set of elevation maps is calculated based on this enhanced BFS. The third set of elevations is the difference between the standard BFS (first set) and the enhanced BFS (second set). This final set highlights the ectatic corneas (5). It also calculates 5 parameters that denote the change in anterior elevation from standard to enhanced BFS (Df), change in posterior elevation (Db), pachymetry progression (Dp), Thinnest value (Dt) and Thinnest point displacement (Da). The final D value is calculated by considering all these 5 parameters (4).

Red Flags to Watch For :

1. Keratoconus : A condition characterized by progressive thinning and conical deformation of the cornea. Signs on a topography map include:

o Inferior-Superior (I-S) Difference : A significant difference between the inferior and superior corneal curvature (> 1.5 D) with skewing of the radial axes of superior and inferior curvature.

o Steepening of Cornea : A localized area of steepening, particularly in the central orinferotemporal zone, with irregular astigmatism, increased central corneal power, corresponding thinning at the steepest point, and increased anterior and posterior elevation.

o Increased difference between power at corneal apex and periphery.

o Difference between pachymetry at the thinnest point and the periphery is >100 µ. Difference between pachymetry at thinnest point and centre is >27 µ (6).

Indices onOrbscan : Ratio of anterior: Posterior BFS >1.21, Power of posterior BFS >55D, Corneal thickness Index >1.16, Irregularity in 3 mm zone >1.15D and Irregularity in 5 mm zone >2.5D are suspect for keratoconus (7).

Indices onPentacam: (8,9)

o Index of surface variance (ISV) : Deviation of the corneal radius as compared to the mean radius. It indicates the corneal

Table 2. Normal and abnormal values of various parameters in a topography scan from Pentacam.

	Normal values	**Abnormal values**	**Significance**
Qs(quality specifications)	OK	Data gaps, Fixation, blink, Model Dev	Indicates the reliability of scan acquisition
Asphericity (Q value):	Avg -0.20	>0 or <-1.0	Plus (>0) in oblate corneas (such as post myopic LASIK) and <-1.0 in hyperprolatecornea (such as keratoconus or post hyperopic LASIK)
Keratometry	-Central K= 40- 47.2D -Astigmatism upto 2.5D	- 47.2-48.7D forme fruste KC >48.7 keratoconus -Astigmatism >2.5D	Flat K <41D and K >46D to be avoided for microkeratome-based LASIK due to higher risk of free flap and incomplete flap
Axial Curvature map	- Inf- sup K <1.2D (I-S asymmetry) -Regular astigmatism	-Inf- sup K >1.2D suggests KC - Irregular/skewed astigmatism	With-the-rule astigmatism: steeper along vertical axis Against -the-rule astigmatism: Steeper along the horizontal meridian
Pachymetry	>500µ	<500µ	Low pachymetrysuggestsreduced corneal biomechanical strength and increased risk of post-surgical ectasia
Anterior elevation	-Orbscan: <15µ -Pentacam: <12µ	-Orbscan: >19µ -Pentacam: >15 µ	Increased values along with increased posterior elevation indicate keratoconus, however isolated anterior elevation may mean tear film abnormalities
Posterior elevation	-Orbscan: <34µ -Pentacam: <17 µ	-Orbscan: >51µ -Pentacam: >20 µ	Detect sub-clinical keratoconus, even when anterior elevation is normal
Belin-Ambrosio enhanced ectasia display (BADD)	Total deviation value <1.6 SD	Total deviation value >2.6 SD	Combines multiple parameters to indicate the probability of keratoconus
Corneal Thickness Spatial Profile (CTSP) and Percentage Thickness Index (PTI) from centre to periphery	Measured corneal line in red liesbetween upper and lower black lines	Measured corneal line in red lies below or above the upper and lower black lines	Red line below the lower black line denotes ectasia, and above the upper line denotes endothelial dystrophy

surface irregularity and is highly sensitive in detecting KC from normal eyes.

o **Keratoconus Index (KI) :** Ratio of mean radius of curvature values between upper and lower segments of cornea. Useful to differentiate normal from KC.

o **Central keratoconus Index (CKI):** Valuable in diagnosing frank KC but not so much useful in pre-KC.

o **Index of height decentration (IHD) :** The degree of vertical decentration of elevation at 3mm radius ring. It can help pick up early KC.

o **Minimal sagittal curvature (R min) :** Corresponds to the maximum anterior curvature

o **Index of vertical asymmetry (IVA) :** Mean difference between superior and inferior corneal curvature, highly specific for pre-KC corneas.

2.Post-Surgical Corneal Ectasia : This iatrogenic ectasia occurs when the cornea becomes progressively more irregular after surgery. Red flags include :

· Significant astigmatism that is not regular, not achieving full BCVA with refraction

· **Topography:** Significant steepening, usually in inferior cornea, with corresponding thinning and increased anterior and posterior elevation.

3.Pellucid Marginal Degeneration: Characterized by thinning of the cornea in the inferior peripheral zone. Indicators include:

- Inferior Peripheral Steepening: A notable steepening in the corneal periphery, particularly inferiorly., with high degree of flattening in vertical meridian and horizontal steepening.

- **Irregular Topography:** A typical 'Crab claw' or 'butterfly' pattern on axial map.

4. Contact lens warpage : Chronic use of contact lens may sometimes induce an irregularity over the anterior surface of the cornea which manifests as irregular astigmatism, superior steepening, or increased anterior elevation, without corresponding thinning or increased posterior elevation.

Lastly, we must not forget that any machine is only as reliable as its operator. Hence, the technicians acquiring the scan must pay adequate attention to the centration of scan, patient positioning, instructing the patient correctly during the procedure, prior contact lens use or preexisting dry eye, all of which affect the quality of the scan.

Conclusion :

Interpreting topography maps is a vital skill for ophthalmologists performing refractive surgery. By thoroughly understanding the normal variations and recognizing the abnormal patterns, clinicians can make informed decisions, minimize surgical risks, and optimize outcomes.

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TransPRK: A Modern Approach to Refractive Surgery

Palak Agarwal

Photorefractive keratectomy (PRK) is a well-known method to treat refractive errors. The goal of PRK is to remove the corneal epithelium either mechanically, chemicallyor via excimer laser and then ablate the stroma with the excimer laser. In single-step transepithelial PRK, the excimer laser removes the corneal epithelium and ablates the stroma in a single step. Because the epithelium is removed by the laser, the corneal epithelial defect (CED) has regular, precisely defined edges and a smooth surface, resulting in faster healing time, less haze, and less painpostoperatively than other procedures.[1]

Several studies compared visual, clinical, and refractive outcomes between different single-step transepithelial PRK techniques and other laser-assisted keratorefractive techniques, including alcohol-assisted PRK, mechanical PRK, laser in situ keratomileusis (LASIK), femtosecond-assisted LASIK, and laser epithelial keratomileusis. Most of these studies showed similar efficacy between transepithelial PRK and the other procedure. Few studies showed better visual acuity (VA) and refractive results in the transepithelial PRK patients than patients receiving alcohol-assisted PRK and LASIK with faster visual rehabilitation and less pain and haze for transepithelial PRK patients. Other non-comparative studies showed a promising and acceptable outcome of single-step transepithelial PRK.

TransPRK (Transepithelial Photorefractive Keratectomy) represents a significant advancement in refractive surgery, offering a safer, bladeless alternative to traditional methods such as LASIK and PRK.

TransPRK is a single-step, all-laser procedure that corrects vision by reshaping the cornea without the need for physical contact. The WaveLight laser system, with its advanced eye-tracking and corneal mapping technology allows for precise ablation of the corneal epithelium and stroma.

Procedure for Trans PRK :

1. Pre-operative Assessment : Comprehensive ocular examination and corneal mapping are conducted to tailor the treatment.

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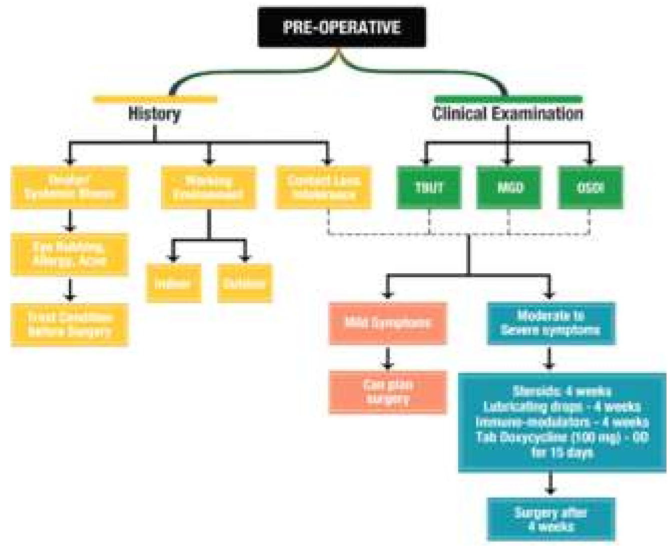
Preop tree chart (2)



2. Epithelial Removal and Corneal Reshaping : The laser removes the epithelial layer and then reshapes the cornea based on the pre-determined treatment plan.

3. Recovery : Recovery is slightly delayed in PRK compared to other refractive procedures but sooner in Trans PRK. All follow up schedules should be strictly adhered to by the patient and detailed assessment carried out at every visit. Role of UV protection glasses should be emphasized to the patient at all visits. [3]

Advantages :

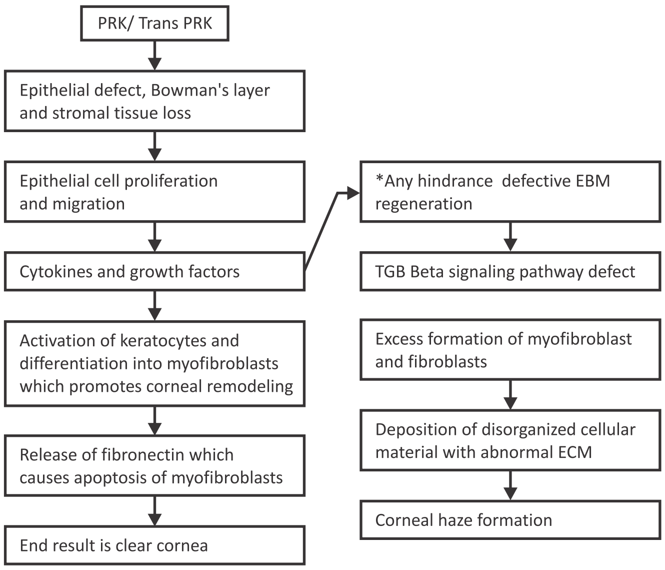
TransPRK offers multiple benefits over traditional refractive surgeries, including reduced risk of complications, enhanced precision, and suitability for a wider range of patients, particularly those with thin corneas, subtle topographic irregularities or other contraindications for LASIK. The advantages of Trans PRK in particular has already been mentioned above.

It has been shown to cause less biomechanical weakening than other corneal refractive procedures.[1,4]

Limitations :

1. This procedure can also have side effects early or late-onset corneal haze[1] which may cause a significant reduction in the postoperative vision.It is therefore important to find methods to minimize post-PRK haze to optimize outcomes.

Pathophysiology of haze post PRK (1)



*A number of factors have been implicated in post-PRK haze including tissue ablation for high refractive errors, laser energy used, size of ablation zones, methods of epithelium removal, amount of postoperative UV exposure and even autoimmune conditions. A subset of patients develops significant post-PRK haze even without these known risk factors. Mitomycin-C (MMC) is an antimetabolite which is used intraoperatively in the concentration of 0.02% to reduce the incidence of post PRK haze. It acts by modulating wound healing by inhibiting myofibroblast formation and keratocyte activation implicated in formation of subepithelial haze.[5] The duration of its application depends on the amount of refractive error of the patient. We generally apply it for 10 seconds per diopter of SEQ of refractive error.

Topical corticosteroids post-PRK inhibit the activation of fibrocytes and thus, play an important role in controlling corneal haze.[6] Longer use of topical steroids with monitoring for complications like rise in intraocular pressure is advisable. Preoperative management inflammation is essential to improve postoperative outcomes. Topical immuno-modulators like cyclosporine 0.05% or 0.09% eye drops for 6 months have a lower risk profile, steroid-sparing effect and help in controlling chronic inflammation post-PRK.Nutritional supplements with Vitamin Dand vitamin C beneficial.

2. Pain management :

- Thorough irrigation with cold BSS helps to dampen the the thermal effect of the laser and reduces the release of inflammatory mediators.
- Ketorolac soaked BCL reduces pro-inflammatory mediators and aids in controlling severity.
- Cold BCL dampens the initial pain response and reduces the pain overall
- Topical NSAIDs in the postoperative period
- Oral post-op painkillers

Conclusion :

TransPRK is a safe, effective and advanced option for the correction of refractive errors. Treatment measures at each step of the surgery can lead to improved outcomes post PRK and decrease the incidence of post PRK haze.Pain mitigation is carried out by curbing the cascade of events at various levels. Its non-invasive nature, coupled with the precision offers significant advantages over traditional methods making it a preferred choice for many patients and clinicians alike.It represents a leap forward in refractive surgery, offering patients a safer, more precise, and less invasive option for correcting vision. Its innovative approach to epithelial removal and corneal reshaping not only enhances the accuracy of the procedure but also improves the overall patient experience and recovery process.

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Contoura LASIK : Unraveling the Enigma

Zain Khatib

INTRODUCTION:

When the name Contoura LASIK comes up, a variety of adjectives come to mind; enigma, puzzle, conundrum etc. And for good reason, because ever since Contoura LASIK acquired FDA approval in 2016(1) as a form of topography LASIK for virgin eyes, there has been much debate about its true utility. Many surgeons claimed it to be a marketing gimmick by a multinational company, while some claimed it to significantly improve their outcomes. Moreover, there have been at least 5 6 different protocols / methods for doing Contoura LASIK, each claiming to have better results than the other. Some of them are the 3Z protocol(2), the LYRA protocol(3), the TMR and modified TMR protocol(4,5), Phorcides software(68), iSMART software(9) etc. The purpose of this article is not to dictate which method of Contoura is superior to the other, but rather to provide a good understanding of how the technology works with some relevant case examples.

UNDERSTANDING THE TECHNOLOGY :

"Contoura" is the name given for topography guided LASIK being done on the Alcon Wavelight EX500 excimer laser platform. Pre-operatively, corneal images are captured using the "Wavelight VARIO Topolyzer" placido disc based topographer. The machine calculates the Higher Order Aberrations(HOAs) from the anterior corneal surface which is imported to the excimer machine(10,11). The software then adds the HOA ablation to the refractive ablation to give a combined treatment. The removal of surface HOAs along with the refractive error is presumed to give a better quality and quantity of vision(12). However, many believe that the biggest argument to this technology is that the virgin cornea barely has any HOAs to begin with, so whether they need to be removed or not is questionable. That, along with the fact that doing Contoura adds a significant amount of time in preoperative planning, to an otherwise simple and already successful LASIK surgery.

What I have learnt in my years of experience with Contoura LASIK is that there is more than what meets the eye. There are 2 main benefits that Contoura provides overconventional LASIK, which I have explained below:

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1. HIGHER ORDER ABERRATIONS :

Firstly, about HOAs; yes, it is true that most virgin corneas do not have too many HOAs, but some eyes do have a significant coma. This is more so seen in patients with higher corneal astigmatism and bowtie patterns on topography. Rarely is a bowtie perfectly aligned without being skewed, and a skewed bowtie always induces some coma. These eyes benefit from Contoura over conventional LASIK (refer to case examples ahead).

It is also important to note that even an eye that does not have HOAs pre-op, will end up having surgically induced HOAs by the LASIK treatment itself. This is more seen in higher magnitudes of refractive errors.Contoura, with its visual axis treatment (eliminating angle kappa effect) helps reduce or in some cases even eliminate the surgically induced HOAs. Overall, Contoura is surely beneficial in this aspect of reducing preexisting and ioatrogenic HOAs, which may have a visually significant impact on most eyes.

2. MODIFYING MANIFEST ASTIGMATISM :

This is a less understood aspect, which many surgeons practicing Contoura struggle to comprehend even today. Astigmatism itself is a complex entity, but it is important to know that there are multiple components contributing to it. In some eyes, most of the refractive astigmatism comes from the anterior corneal surface; these eyes tend to do well even with conventional LASIK. But a significant proportion of eyes have refractive astigmatism which varies significantly from the anterior corneal cylinder, in magnitude or axis or both (Refer to case examples 2 and 3). These are the eyes where there is a cylinder component coming from inside the eye as well (Posterior Corneal Astigmatism and Lenticular Astigmatism). In these eyes, doing a conventional treatment tends to leave behind an unexpected residual cylinder post-op. Contoura helps to delink the corneal cylinder from the manifest cylinder by modifying the final treatment to be entered in the excimer machine. There are many ways to do this, but discussing details on these techniques is not within the scope of this article.

I use my own software, "iSMARTContoura LASIK"(freely available on request), which uses vector mathematics to automatically modify the final refraction, after calculating the cylinder coming from all components of the eye.

Below I am sharing some case examples highlighting the benefit of using Contoura in LASIK surgery:

CASE 1 :

A 20 year old female had a left eye pre-op refraction of -6DS / -0.50DC at 155.Two weeks post Contoura LASIK she was plano with unaided 6/5 vision. Figure 1 shows the comparison of pre-op and post-op sagittal corneal topography as well as the HOA maps. What is important to note is that a -6D correction is quite large and can cause a significant increase in HOAs. However, as seen in figure 1, a beautifully centred large optic zone in post-op the sagittal curvature map is seen after

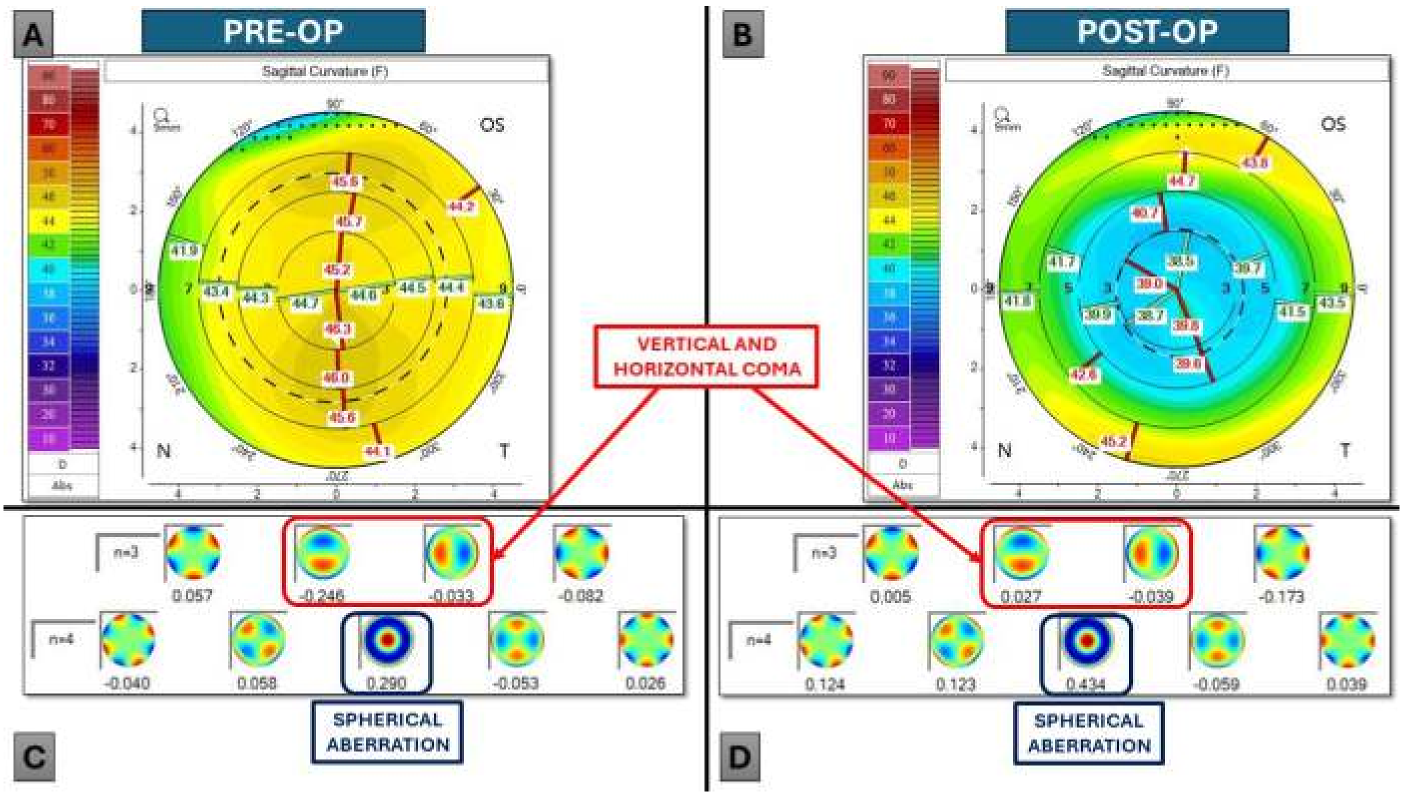

Figure 1: Comparison maps pre-op and post-op for Case 1. A: Pre-op sagittal anterior corneal topography. B: Post-op sagittal anterior corneal topography. C: Pre-op HOAs. D: Post-op HOAs.

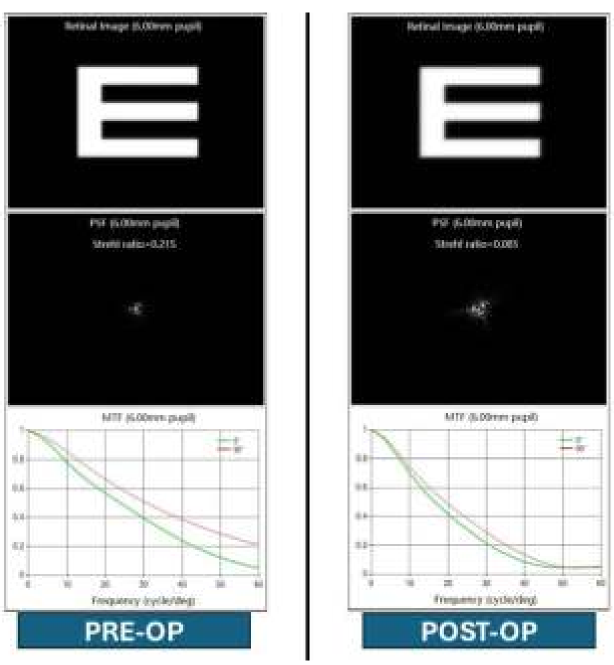

Figure 2: Case 1, pre-op and post-op comparison of HOA simulated retinal image, Strehl's ratio and MTF graph.

Contoura LASIK. Further, in the aberration maps note how both the vertical and horizontal comas have reduced significantly following treatment. The spherical aberration has marginally increased from 0.29 to 0.41, which is very less for a -6D treatment. Figure 2 shows the comparison of some objective corneal parameters related to HOAs: retinal image simulation at 6mm pupil, Strehl's ratio and Modulation Transfer Function(MTF) graph. All these parameters are only slightly worse after a -6D treatment, which shows how Contoura curtails the surgically induced HOAs.

CASE 2 :

This 24-year-old female had BCVA improving to 6/6p in her left eye with a manifest refraction of only -2.5DS, without any cylinder acceptance. However, her anterior corneal topography revealed acylinder of -1.87DC at 1(Figure 3A), which was significantly different from the manifest. This means that she would be having high internal astigmatism to compensate for the difference in manifest and topography cylinder. Her topography map in figure 3A, shows quite an

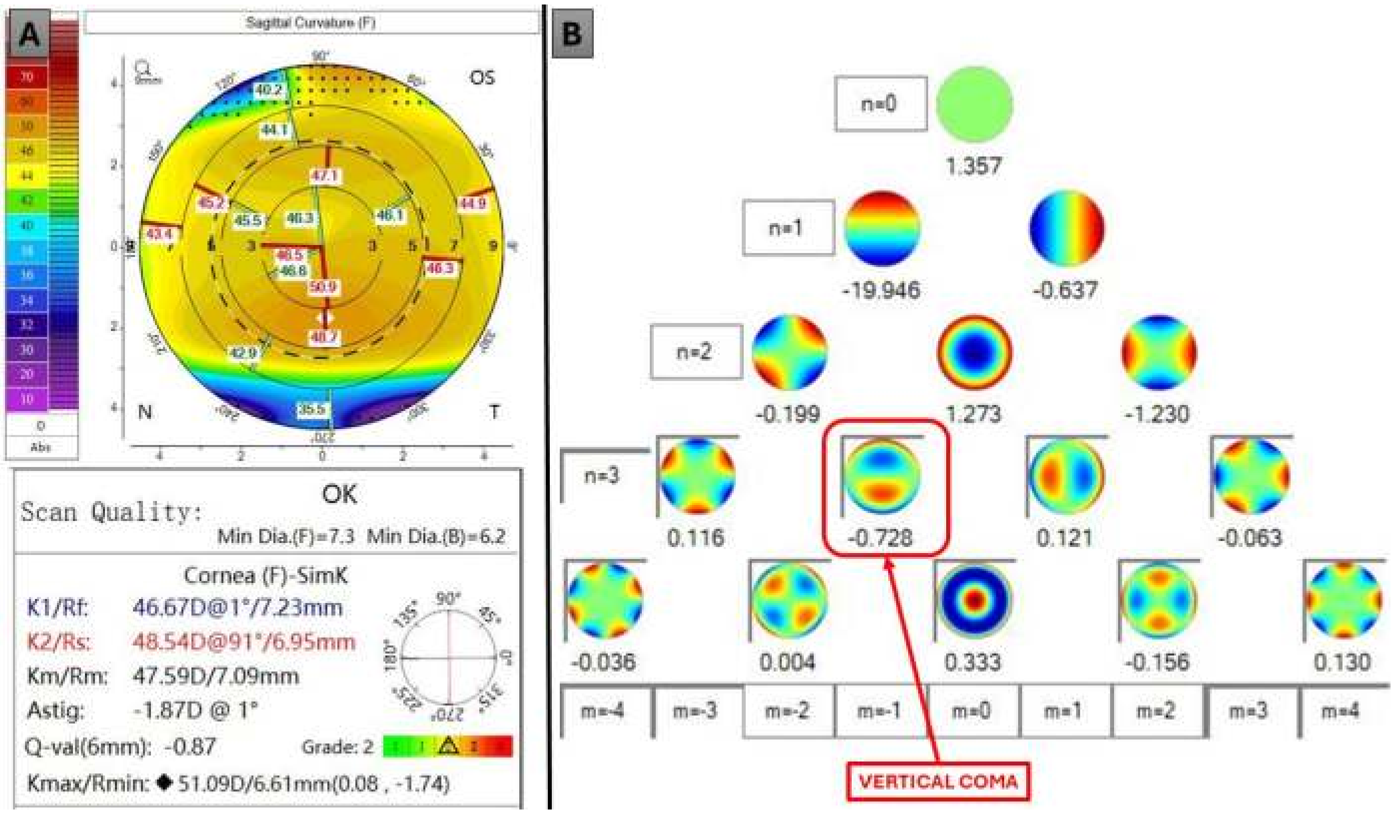

Figure 3: Case 2 Pre-op scans. A: Pre-op sagittal anterior corneal topography. B: Pre-op HOAs.

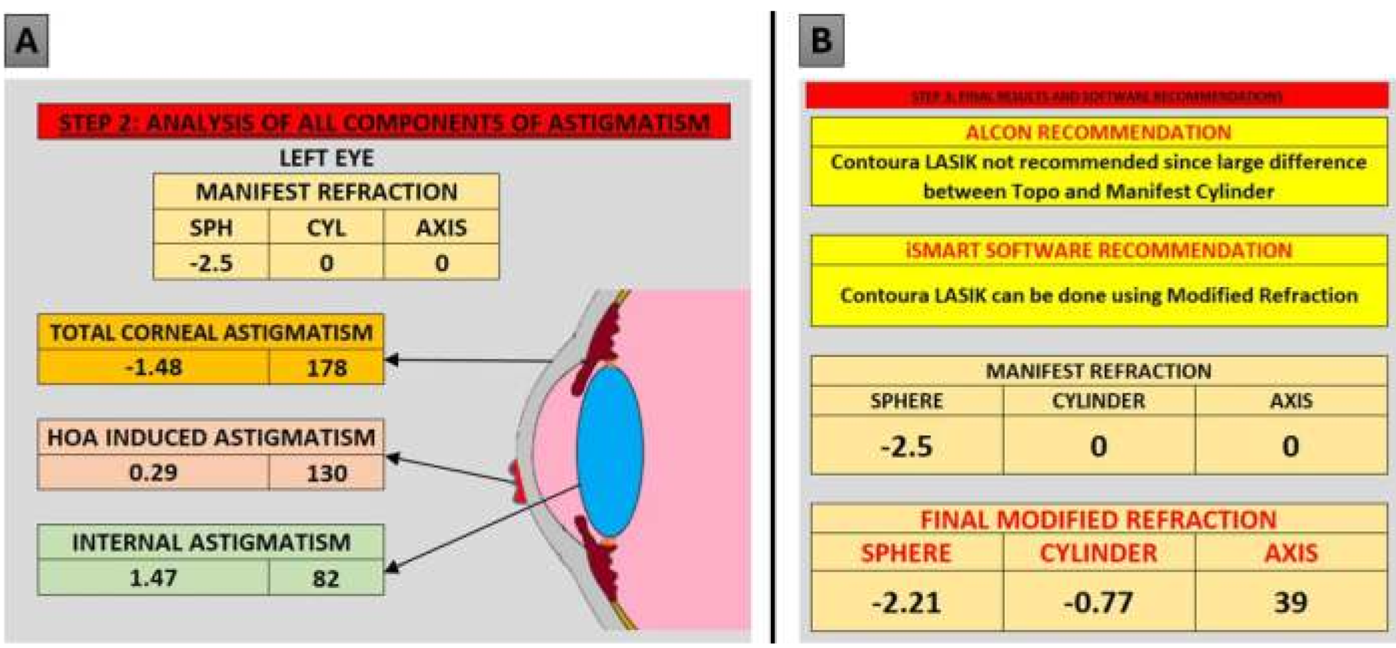

Figure 4: Case 2 iSMART software screen. A: Software screen showing all the individual components of Astigmatism. B: Software screen showing final modified refraction that needs to be entered for treatment.

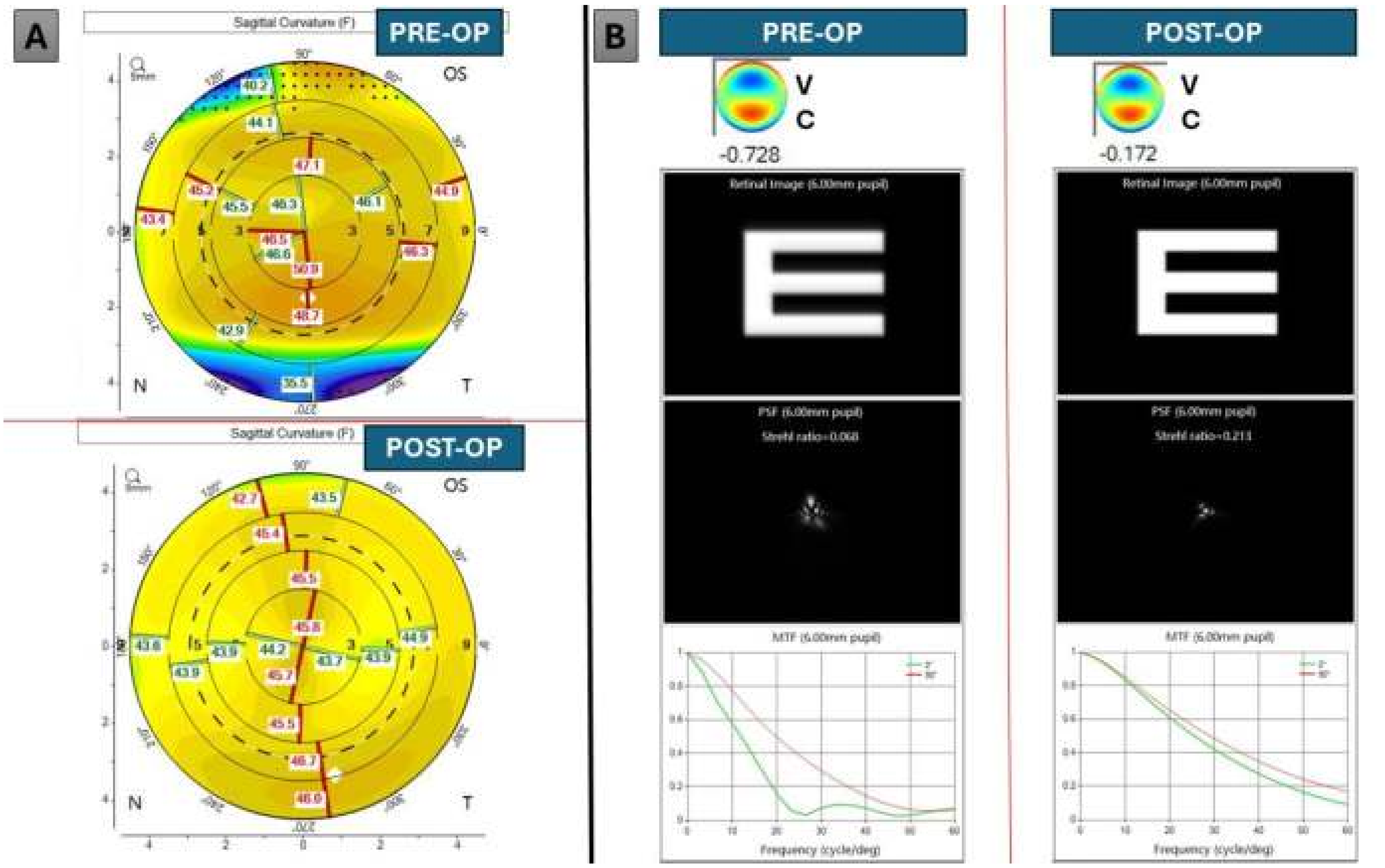

Figure 5: Case 2 pre-op vs post-op comparison. A: Pre-op vs post-op sagittal anterior corneal topography comparison. B: Pre-op vs post-op vertical coma, HOA simulated retinal image, Strehl's ratio and MTF graph comparison.

irregular surface with steep keratometry. Figure 3B shows a high vertical coma value of -0.72, indicating that her overall HOAswere quite high. Figure 4A shows theiSMART software screen for this eye, demonstrating the astigmatism coming from all the components of the eye, which is automatically calculated. Figure 4B shows the final modified refraction recommended by the softwarewhich needs to be treated, after considering all the components of astigmatism(-2.21DS / -0.77DC at 39). The treatment was done with the same software recommended refraction, and 2 weeks post-op the patient improved by one line to 6/5. Figure 5Ashows the comparison of pre-op vs post-op sagittal anterior corneal topography demonstrating a very nice regularization of the surface. Figure 5B shows the comparison of aberration parameters, where the pre-op high vertical coma has reduced drastically, along with a significant improvement of HOA retinal image simulation, Strehl's ratio and MTF. It is quite evident that in the above case, the HOA reduction and accurate cylinder correction which was only possible with Contoura, helped thepatient gain one line of visual acuity. This case is a classic example of the extent to which this technology can benefit LASIK surgery.

CASE 3 :

This 24 year old female had a right eye manifest refraction of -4DS / -1.25DC at 30. In spite of counselling for Contoura, she opted for a non Contoura treatment. The sagittal topography seen in figure 6A shows a slightly skewed bowtie pattern, which could indicate presence of a coma. Also, there is a difference in axis between manifest (30 degrees) and topography (16 degrees) cylinder. The surgery was done andpost-op the patient had an unexpected refractive surprise of +0.75DS / -1.25DC at 150 (unaided vision 6/18 improving to 6/5). The post-op topography seen in figure 6B shows a residual cylinder from anterior cornea. This is not very unusual, as refractive cylinder surprises are sometimes seen in non Contoura treatments, when pre-op themanifest refraction is not compartmentalized. This is classic example of an eye needing Contoura treatment, due to skewed bowtie and axis difference between topo and manifest cylinder. 1 month postoperatively, a flap lift with Contouratopo guided enhacement of the residual number was done, and post the 2nd treatment the patient improved to 6/5 vision unaided. The regularization and removal of cylinder is seen inthe final topography(Figure 6C).

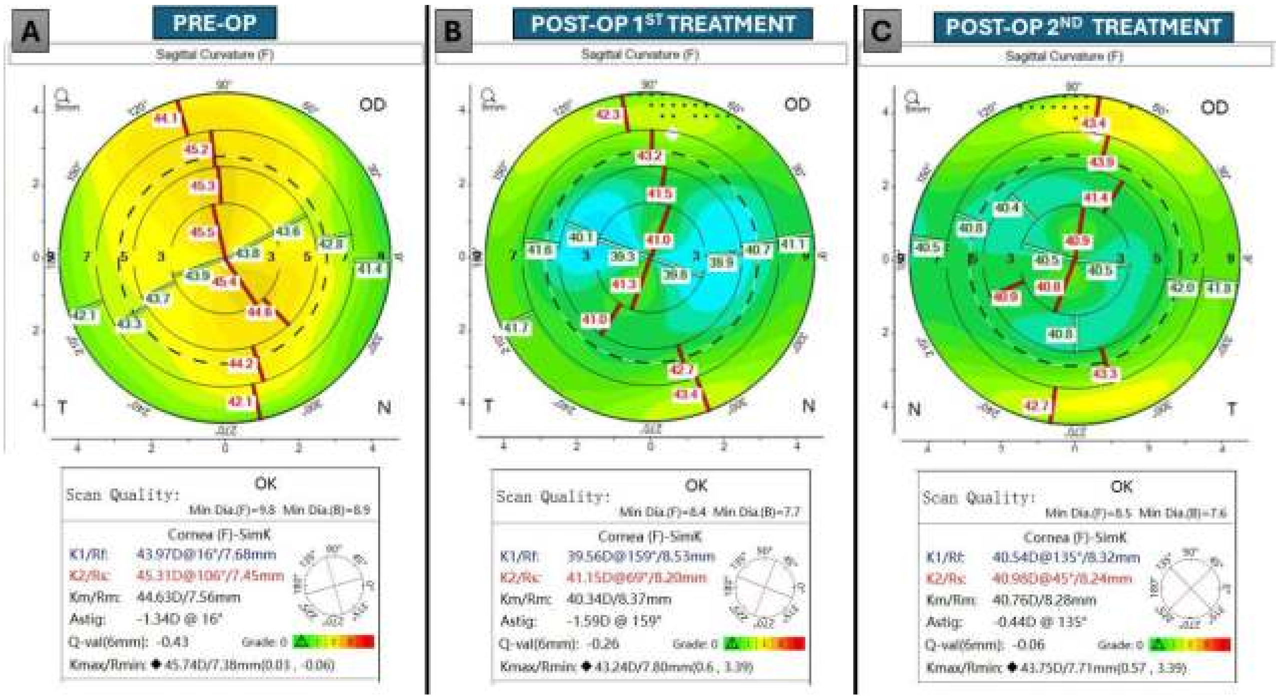

Figure 6: Case 3 comparison of sagittal anterior corneal topography maps.
A: Pre-op. B: Post-op after 1st treatment. C: Post-op after 2nd treatment.

CONCLUSION :

There is enough evidence today to prove that topography guided LASIK for refractive correction in virgin eyes has an added benefit over conventional LASIK. Yes, more effort and time are required for planning, but then if it can improve outcomes then why not. Of course, some eyes will benefit more than others, and some may do equally well even without Contoura, but there are no fixed criteria to highlight or quantify which eyes will do better and which will not. A good take home point is that as long as it is not worsening outcomes, there should be no reason as to why Contoura LASIK should not be offered for all patients undergoing refractive surgery.

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Keratorefractive Lenticule Extraction

Rushad Shroff

Refractive surgery through laser vision correction (LVC) has evolved significantly within the past few decades. From the first generation techniques involving surface ablation to Laser in situkeratomileusis (LASIK), refractive surgery has now become intrastromal with the advent of refractive lenticule extraction (ReLEx) technology.

Small incision lenticule extraction (SMILE) procedure was launched by Zeiss in 2009 was the first lenticular extraction procedure. It uses a femtosecond laser to cut a lenticule in the cornea, followed by a 3-mm-long cap opening incision for lenticule extraction.

Today, the Kerato-refractive Lenticule Extraction (KLEX) procedure can be performed using femtosecond lasers from four different companies.(Table 1)

To accomplish the procedure, first the patient's eye needs to be docked to the contact glass of the femtosecond laser.

Once the centration is confirmed, the suction is activated to fixate the eye in this position. After adequate suction is established, the patient is instructed to hold still.

The refractive procedure involves a series of corneal lamellar resections. The goal of the procedure is to create an intrastromal lenticule that is manually removed through a small incision to achieve the desired refractive outcome.

The first lamellar cut, the refractive cut, defines the posterior surface of the lenticule and is the most important step as it creates the desired final refraction with the programmed depth. The second cut, a side cut, defines the lenticular diameter. The third cut is a lamellar cut and defines the anterior surface of the lenticule and the posterior surface of an attached cap. The final cut creates a 60°-90° superior incision to allow for the removal of the lenticule. This is followed by lenticule separation and extraction which is done under the surgical microscope.

	Johnson-Johnson	**Zeiss**	**Zeiss**	**Ziemer**	**Schwind**
System	ELITA	VisuMax 500	VisuMax 800	Femto LDV Z8	ATOS
KLEX	SILK	SMILE	SMILE	CLEAR	SmartSight
Laser pulse duration	~150 fs	220580 fs	220580 fs	200500 fs	<295 fs
Pulse repetition rate	10 MHz	0.5 MHz	2 MHz	<10 MHz	<295 fs
Pulse energy	4050 nJ	125170 nJ	125170 nJ	<100 nJ	80125 nJ
Spot separation	~1 ìm	34.5 ìm	34.5 ìm	No data	34.5 ìm
Laser cut time	~16 s	~30 s	~10 s	~30 s	~30 s
Patient interface	Flat	Curved	Curved	Flat	Curved
Postdocking centration	Allowed	No	No	Allowed	No
Postdocking cyclotorsion	Allowed	No	Allowed	Allowed	Allowed
Lenticule shape	Biconvex	Plano-convex	Plano-convex	Plano-convex	Plano-convex

Advantages of lenticule surgery over LASIK include better preservation of corneal biomechanical stability and corneal nerves. This results in reduced risk of corneal ectasia and dry eye.

Smooth Incision Lenticule Keratomileusis (SILK) is a new lenticule extraction procedure that uses the ELITA femtosecond laser (Johnson and Johnson Surgical Vision, Inc. Milpitas CA, USA) and is designed for the treatment of myopia and myopic astigmatism.

For removal of the lenticule, the small incision is opened and the upper and lower interfaces of the lenticule are identified to define the tissue planes. The upper interface is usually separated first using a blunt dissector, the movement of the instrument being in a windshield wiper like fashion. The lower layer is then dissected in a similar fashion. During separation,

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the eye may be stabilized with a fixation forceps to have better control while separating the surgical planes. Once both interfaces are separated, and the lenticule is free, it is grasped with a pair of micro-forceps and extracted. At the end of the procedure, some surgeons prefer to flush/wash the interface with saline while others do not perform this step for the concerns of corneal hydration and introduction of infection.

SILK procedure has a unique biconvex lenticule shape, which gives ELITA two major advantages.

First, it provides mirror symmetric posterior and anterior lenticular surfaces that are expected to match perfectly after lenticule removal, leading to fewer wrinkles in Bowman's membrane, therefore less light scattering.

Second, since the corneal stiffness, collagen fiber density and nerve density decrease from anterior to posterior, the biconvex shape is expected to better preserve corneal strength, leading to fast regeneration of corneal nerves.

Both biconvex and plano-convex lenticule shapes follow the same Munnerlyn formula for refractive vision correction, and they remove the same amount of tissue for a given refractive correction.

The ELITA system uses a combination of small focus spot size, ultrashort pulse duration and ultrafast pulse frequency to deliver lower energy to the cornea. The spots are almost contiguous leading to continuous tissue resection and easier lenticule dissection.

LIMITATIONS OF SILK :

While the majority of patients are considered candidates for SILK, certain prescriptions fall outside the current indications. Similar to other lenticular extraction procedures SILK is appropriate for myopic astigmatism but is not indicated for hyperopia or myopic astigmatism SE greater than -12 D.

A complication unique to KLEX is a lenticule remnant being left in the interface due to inadvertent tearing of the lenticule causing irregular astigmatism.

The excimer laser is still used for refractive enhancements after KLEX; therefore it continues to play a vital role in the refractive surgery platform.

CONCLUSION :

KLEX is a revolutionary technology that combines the advantages of LASIK and PRK with a quick LASIK-like recovery and the advantageous PRK-like flapless procedure.

Other advantages include preservation of biomechanical corneal integrity, low enhancement rates, lower induction of higher order aberrations and attenuation of side effects such as dry eye.

Comprehensive Review of Surgical Procedures for Presbyopia Correction

Shruti Kochar

Introduction :

Presbyopia, a common age-related condition affecting near vision, has sparked significant advancements in vision correction procedures. Alongside traditional approaches like eyeglasses and contact lenses, advanced techniques have emerged, offering diverse options for addressing presbyopia. This comprehensive review explores cutting-edge procedures, including corneal-based techniques and intraocular lens (IOL) implants, shedding light on their efficacy, outcomes, and patient satisfaction.

Corneal-based Procedures :

Corneal inlays have emerged as a promising solution for improving near and intermediate vision. The Kamra inlay (Figure 1), FDA-approved in April 2015, operates by creating a small central aperture, akin to a pinhole effect, enhancing depth-of- focus without compromising distance vision. [1][2] Studies have reported significant improvements in uncorrected near visual acuity (UNVA) and uncorrected intermediate visual acuity (UIVA) post-implantation, along with enhanced reading performance.[3] Another notable option, the Raindrop Near Vision inlay (Figure 2), reshapes the corneal surface to achieve a multifocal effect. Despite initial success, concerns regarding corneal haze development have led to a recommendation to discontinue its use. [4]

Refractive corneal inlays, such as the Flexivue Micro-Lens (Figure 3) and the Invue Lens, aim to alter the corneal refractive index to create a multifocal effect. While studies have shown improvements in UNVA, some patients experienced a slight decline in uncorrected distance visual acuity (UDVA). [5][6]

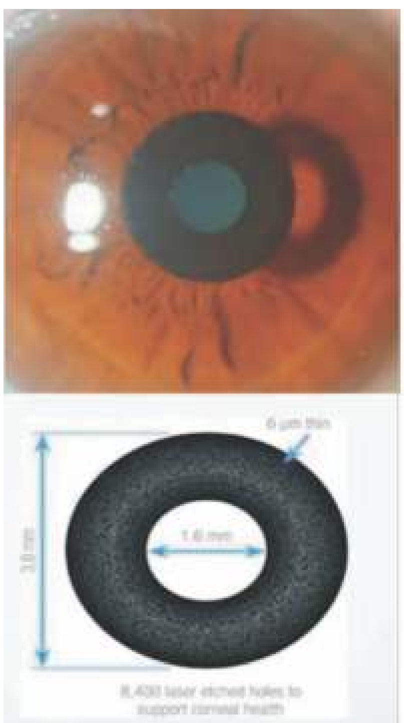

Figure 1- Kamra Inlay

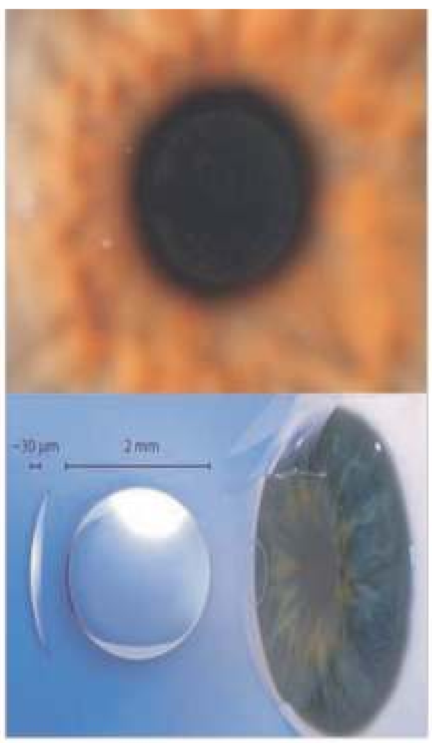

Figure 2- Raindrop Inlay

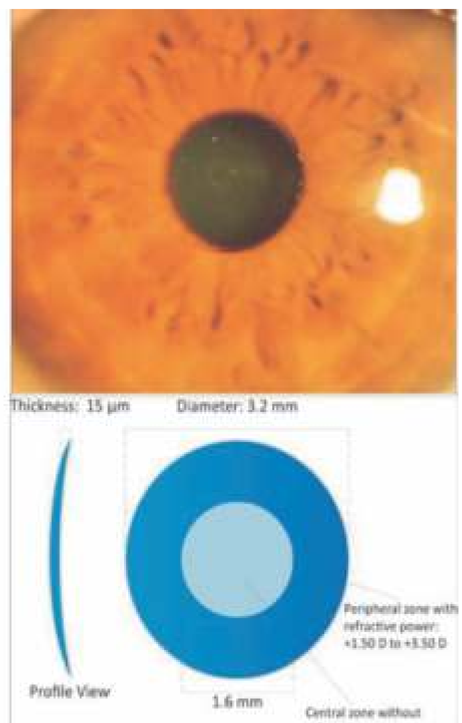

Figure 3- Flexivue Inlay

Conductive keratoplasty (CK) is the successor of laser thermokeratoplasty. CK uses the application of low frequency radio waves to 'shrink' collagen fibrils within the mid-

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peripheral cornea. This causes a net steepening on the central cornea and thus increases the positive power of the eye. Radiofrequency energy is typically 0.6 W with a 0.6-s treatment time, delivered through a fine tip inserted into the peripheral corneal stroma in a ring pattern outside of the visual axis. Although this has shown to be a relatively safe technique and may present theoretical advantages over flap creation techniques (less invasive and no flap-related complications), long-term studies report high rate of regression and hence this is not a popular technique at present.

Laser Refractive Surgery :

Monovision LASIK and Photorefractive Keratectomy (PRK) remains a popular strategy for presbyopia correction, correcting one eye for near and the other for distance vision. Although effective, it may lead to reduced stereopsis and contrast sensitivity. [7][8]

PresbyLASIK offers a multifocal approach by reshaping the cornea to enhance both near and far vision. However, it may result in decreased contrast sensitivity and visual disturbances. [9]

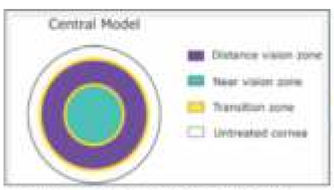


Figure 4- Central PresbyLASIK

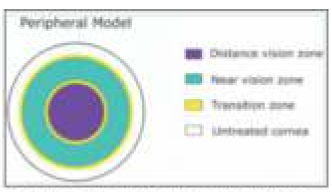


Figure 5- Peripheral PresbyLASIK

Central PresbyLASIK :

Central PresbyLASIK produces a small central optical area with higher curvature (hyperpositive area) for near vision, surrounded by a flatter area for far vision (Figure 4). It is pupil dependent and can be applied at the centre of the cornea in myopic and hyperopic profiles. It is also possible to use after initial myopic or hyperopic laser treatment for far vision. The most important technical limitation is establishing the most adequate axis: the visual or optical axis, or the cornea vertex. A lack of adequate alignment will induce coma aberrations. It is the most used PresbyLASIK technique. There are mainly three different technologies available, all of them with published outcomes in hyperopic patients:CustomVue™ VISX (AMO Development LLC, Milpitas, California, USA)

Combines the wavefront-guided hyperopic treatment with a presbyopic shape - steepens the central cornea for near vision while treating the periphery for distance.

Supracor™ (Technolas Perfect Vision GmbH, München, Germany)

Creates a hyperpositive area in the central 3.0mm zone, giving an addition of approximately two diopters. It may be used symmetrically (for patients that demand good near vision) or asymmetrically (for patients that demand good near and distance vision).

PresbyMAX™ (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany)

Creates a biaspheric multifocal corneal surface with a central hyperpositive area (to achieve +0,75 to +2,50D near correction) surrounded by an area in which the ablation is calculated to correct the distance refractive error. It is the only technology of central PresbyLASIK with published results in myopic and emmetropic eyes.

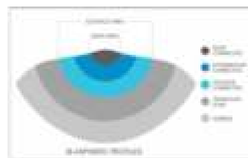


Figure 6- Supracor

Figure 7- PresbyMax

Peripheral PresbyLASIK :

In Peripheral PresbyLASIK the peripheral cornea is ablated to create negative asphericity. (Figure 5) The centre of the corneais left for far vision and the middle periphery for near vision (for example, Nidek Advanced Vision, Nidek co. LTD, Gamagori, Japan)

The major limitation of this technique is in myopic correction because it is necessary to remove a significant amount of corneal tissue to create a hyperprolate shape. For this reason, it is more adequate for hyperopic eyes. Moreover, this method also requires an efficient excimer laser beam profile capable of compensating the loss of energy that happens while ablating the peripheral cornea. As central PresbyLASIK, it is pupil dependent too and has the same technical limitation related to establishment of the axis.

Laser Blended Vision - Presbyond :

Laser Blended Vision - Presbyond(Carl Zeiss Meditec, Inc., Jena, Germany) approach induces a certain amount of spherical aberration to each eye, increasing the depth of focus within a

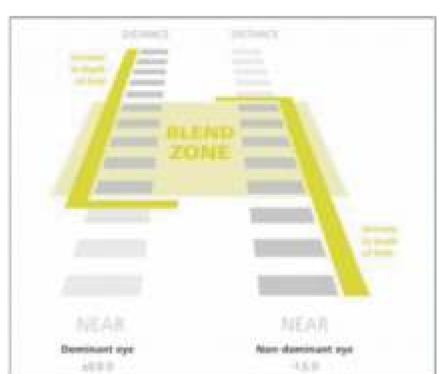


Figure 8- LASER blended vision

limited range to avoid visual quality degradation and makes the nondominant eye slightly myopic (-1,50D) - micro-monovision. It can be performed on emmetropic, myopic and hyperopic presbyopes.

INTRACOR presents an alternative procedure focusing on intrastromal rings for corneal steepening, primarily beneficial forpresbyopic and hyperopic individuals. Nonetheless, it may lead to a loss of corrected distance visual acuity (CDVA) and a myopic shift. PRK provides a flapless alternative to LASIK, offering advantages such as better wound healing and reduced risk of flap-related complications. Despite potential postoperative pain and complications like corneal haze, PRK maintains positive outcomes for presbyopic patients.

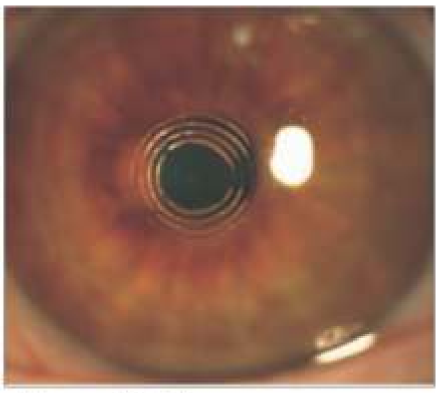


Figure 9

Sclera-based Procedures :

Scleral implants and scleral laser micro-excision offer innovative approaches to restore accommodation. While showing promise in improving near and intermediate vision, these procedures come with concerns such as scleral perforation and long-term risks that require further study [12][13]

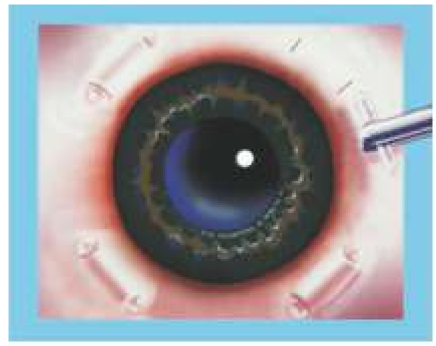
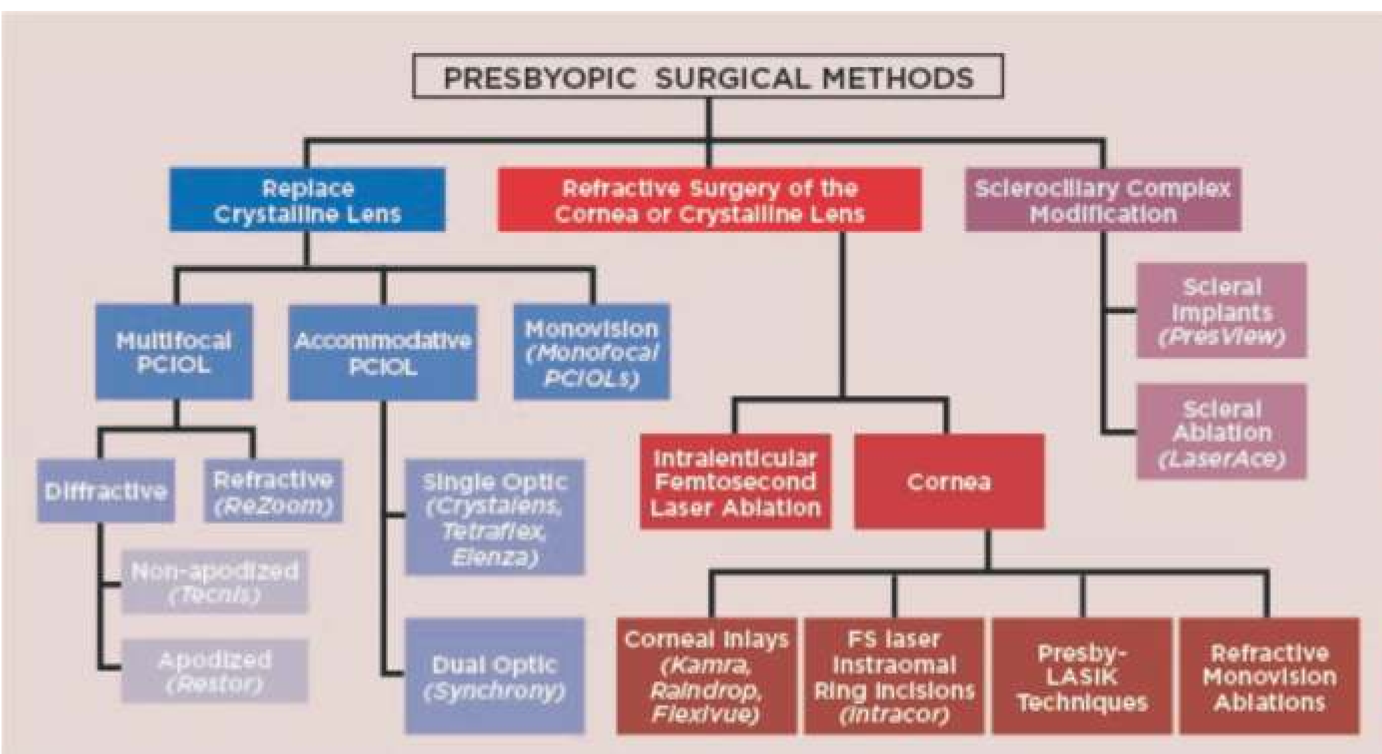


Figure 10

Laser-assisted presbyopia reversal :

Laser assisted presbyopia reversal aims to restore dynamic accommodation increasing pliability in the sclera and net forces of the ciliary muscles on the lens facilitating accommodation. The postulated mechanism of action of laser assisted presbyopia reversal is to decrease ocular rigidity. The procedure isperformed using a handheld fibre-optic handpiece that delivers pulses of an erbium-YAG laser ablating a diamond matrix pattern of nine laser spots into each oblique quadrant of the sclera. These are presumed to decrease the distance between the ora serrata and the scleral spur, restore the anatomical relationships of the system and free the ciliary muscle to contract normally. The spots delivered in a diamond



matrix pattern of nine laser spots into each oblique quadrant.

Intraocular Lens (IOL) Implants :

Intraocular lens implants have revolutionized vision correction, offering solutions for refractive lens exchange and cataract surgery. Presbyopia-correcting IOLs can be broadly classified into multifocal IOLs, extended depth of focus (EDOF) IOLs, and accommodative IOLs.

Multifocal IOLs feature multiple zones of lens power, enabling vision enhancement at various distances. They are further categorized into diffractive and refractive lenses. Diffractive IOLs, such as Tecnis and ReSTOR, generate two distinct imagesfor near and far vision. Trifocal diffractive IOLs introduce a third focal point to improve intermediate vision. Refractive IOLs like ReZoom and Array create multiple focal points for comprehensive vision. Extended Depth of Focus (EDF) IOLs, exemplified by the Symfony and Vivity IOLs, aim to elongate the range of vision without compromising distance acuity. Ametropia and presbyopia can also be corrected using an anterior chamber phakic MIOL. Accommodative IOLs, represented by the Crystalens, mimic natural accommodation by changing power with ciliary muscle contraction.

Conclusion :

Advanced vision correction procedures, ranging from corneal-based techniques to intraocular lens implants, offer diverse options for addressing presbyopia and other refractive errors. While each approach has its advantages and limitations, ongoing research aims to enhance efficacy and safety, paving the way for improved vision correction outcomes.

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Choosing the best option for Corneal Refractive Surgery

Prateek Gujar

Before we get started, I'd like to pose a question! How often have patients in your refractive practice expressed a preference for a specific refractive procedure? Even when the patient has absolutely no clue about the procedure. Sadly, we live in an era where patients' decisions are influenced by 'social media influencers' rather than doctors. Our role as refractive surgeons becomes even more important in the current scenario.

Refractive Surgery Overview :

The goal of refractive surgery is seemingly simple: to reduce a person's reliance on contact lenses and glasses. The ideal outcome post-surgery is for the patient to have 20/20 vision at all distances, under any lighting conditions, with no visual experiences that degrade vision quality, and with no risk to the long-term health and performance of the eye. Ideally, this outcome could be achieved regardless of the patient's pre-surgery refractive status or pre-existing eye conditions.

Due to current limitations in technology, this simple goal appears impractical. In a real-case scenario, refractive surgery might require trade-offs and compromises. It's important to understand the patient's visual preferences and effectively communicate what to expect post-surgery to set realistic expectations for the outcome.

To understand different types of corneal refractive surgeries, it's important to understand the basics of the cornea as a refractive surface. The human cornea has a prolate shape, which means the central portion is steeper (i.e., has a shorter radius of curvature) than the peripheral portion. On average, the central cornea is 3-4 diopters steeper than the periphery. The anterior corneal surface adds about 49 diopters of convergence to incoming light. However, the posterior corneal surface adds about 6 diopters of divergence as light passes through it into the anterior chamber. The net result across the cornea is an overall power of approximately +43D. Of course, these are only averages. To perform keratorefractive surgery, one must have accurate measurements of central corneal powerideally, at both its anterior and posterior surfaces. Most corneal refractive surgeries involve altering the shape of the cornea in a way that impacts the vergence(convergence or divergence) it imparts to incoming light. For e.g. in myopic keratoablative surgery, the central cornea is flattened to reduce its converging power, and in hyperopic keratoablative surgery it's the opposite the central cornea is steepened to increase its converging power.

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Among the popular corneal refractive procedures available, there are two broad types: those with flaps (Microkeratome, Femtosecond laser Lasik) and those without flaps (Photo refractive keratectomy, Transepithelial PRK, Lenticular extraction-based procedures). In addition, presbyopic treatment options have also expanded to include new ablation profiles, intracorneal implants, and phakic intraocular implants.

Decision-making in Corneal refractive surgeries :

When evaluating a patient for refractive surgery, factors that guide decision-making include refractive error, age, patient lifestyle, specific activities, corneal tomography, aberrometry, and biomechanics.

Age-It's important to consider that as patients approach pre-presbyopic/presbyopic age, there are multiple options available beyond corneal refractive surgery(Phakic IOL's, refractive lens exchange). As a refractive surgeon, it's crucial to understand that our responsibility extends beyond immediate corrections and to also plan for patients' visual needs throughout their lifetime.

Corneal topography- It assesses the shape of the corneal surface, while wavefront analysis assesses the overall image formation by the eye's optical system. These assessments have traditionally been used routinely in preoperative evaluations for refractive surgery. Placido-based curvature topographic systems are valuable for measuring corneal curvature and refractive status but do not directly show the actual shape of the cornea(1). On the other hand, Scheimpflug corneal tomography is a 3-D imaging technique that characterizes the anterior and posterior corneal surfaces, as well as corneal thickness distribution(2). Preoperative assessment is important to rule out any conditions that may contradict surgery, and it's crucial to detect subclinical keratoconus suspects to prevent iatrogenic post-surgical ectasia.

Recently, the addition of corneal biomechanics to cornealtopography has been studied as a potential adjunct to preoperativeevaluation for keratorefractive procedures. Thecorneal visualization tonometer (Corvis ST, Oculus Optikgeräte

GmbH; Wetzlar, Germany) uses an ultra-high speedScheimpflug camera that visualizes corneal changes duringdeformation to produce various parameters(3). A combined tomographic and biomechanical data may provide greater accuracy for detectingsubclinical keratoconus among eyes clinically deemed tohave 'normal topography'(4). High-resolution swept-source optical coherence tomography (SS-OCT) allows for imaging and measurements of the anterior segment in a single platform. Additionally, it can provide corneal epithelial thickness maps, which may be useful for planning refractive surgery or identifying early keratoconus by pinpointing areas of focal epithelial thinning typically associated with corneal steepening(5).

Surface ablation versus Laser in situ keratomileusis (LASIK): The evolution of keratorefractive surgery began with surface ablation techniquessuch as photorefractive keratectomy (PRK) that involves epithelial removal[6], or laser epithelial keratomileusis(LASEK) where 20% alcohol is used to displacethe corneal epithelium[7].More recently, excimer laserablation has been used to remove the corneal epitheliumdirectly i.e. transepithelial PRK(TransPRK)[8]. One advantage oftransepithelial PRK is the epithelial layer removal andexcimer is performed at the same timealthough mostreports suggest that healing time and visual outcomesresults do not vary greatly amongst various techniques ofepithelium removal(9,10).Surface ablation has regainedpopularity over the past few years due to the safety of thesurgery and better biomechanics[11], especially in patientswith moderate-high myopia and thin corneas [12,13].In addition, patients involved in high-impact activities such as boxing or martial arts are better candidates for surface ablation compared to flap-based procedures. If the patient's lifestyle involves high UV exposure, such as outdoor construction work, one can consider alternatives to standard surface ablation treatments. TransPRK can be safely performed with intraoperative use of mitomycin C and postoperative UV protection, to reduce the chances of postoperative haze.

LASIK gives the advantage of a 'wow factor' to the patients but involves the formation of corneal flaps either with an oscillating microkeratome or using a femtosecond laser. The addition of femtosecondlasers greatly reduced the risk of some of the moresignificant flap complications such as buttonhole, free cap,and irregular cuts, and increased the reproducibility of flap thickness(14).Post-operative flap relatedcomplications in LASIK include flap displacement, diffuselamellar keratitis (DLK), or epithelial ingrowth. Patients should be counseled about the potential for increased glare and halos. Dry eye is a common side effect, but it is usually temporary and can often be managed with topical lubricants. Preoperative assessment of dry eye is crucial when planning for LASIK. One should also exercise caution with patients who have used isotretinoin therapy and have compromised meibomian gland function.

With the advancements in corneal imaging and aberrometry measurements, corneal topography-guided laser ablation has gained popularity. Corneal topography-guided laser ablation ismost useful where the refractive error of the eye matches itscorneal topography i.e. most of the aberration is producedby the cornea [15].

Small incision lenticule extraction (SMILE): The SMILE procedure involves using a femtosecond laser to delineate a refractive lenticule withinthe stroma connected to the surface by a small incision. The femtosecond interfaces are surgically separated and the refractive lenticule is removed through the small incision. SMILE brings two main advantages overLASIK: faster dry eye symptom recovery and better sphericalaberration control[16-18]. Both of these advantagesstem from the minimally invasive pocket incision thatresults in maximal retention of anterior corneal innervationand structural integrity. The evidence for reduced dryeye is supported by studies on corneal nerve regeneration[19], and recovery of corneal sensitivity[20]. Biomechanically, SMILE offers a theoretical advantage over LASIK by preservation of the stronger anterior stromal lamellae. As the anterior stroma remainsuncut, the strongest part of the stroma continues to contributeto the strength of the cornea postoperatively.The refinements into the energy level and spot/track spacinghas significantly improved visual recovery, withoutcompromising the ease of lenticule separation.Most published results suggest that SMILE is safe, effective,and predictable for treating moderate myopia andmodest levels of astigmatism, with postoperativevisual outcomes comparable with femtosecond LASIK(21).

Refractive correction for hypermetropia : Hypermetropia can be categorized into low (= 2.00 D), moderate (2.00-4.00 D), and high (> 4.00 D). The surgical correction of high hyperopia can be challenging given the tendency for regression and the lack of predictability of excimer laser treatments. Factors to consider when deciding between available options include the degree of hyperopia, the patient's age, lens status, accommodative ability, keratometry (K), corneal topography, and endothelial status.LASIK for patients with low degrees of hyperopia has been shown in numerous studies to be safe, effective, and predictable. In patients with higher degrees of hyperopia, the results are less predictable, and regression is more common(22). Typically presbyopic individuals with more than 4.00 diopters of hyperopia are good candidates for refractive lens exchange. Young patients with less than 4.00 diopters of hyperopia, normal corneal topography, and expected postoperative K values of less than 50.00 diopters can be safely considered for corneal refractive surgery.

An alternative to corneal surgery in correcting hypermetropia is the implantation of an intraocular lens into a phakic eye(phakic IOL) with a healthy crystalline lens. The use of such a phakic IOL allows the accommodative function of the crystalline lens to be retained. However careful measurement of white to white diameter and anterior chamber depth is required to get optimal vaulting of the phakic IOL.

To conclude, the field of refractive surgery is rapidly evolving.Advances in technology and innovation have now increased therange of refractive surgical options available to patients. Preoperative assessments now allow for customized laserablations to further achieve better visual quality. Keratorefractive surgery is now established as a safe and effective treatment option for refractive errors, with excellent visual outcomes, improvementin quality of life and achieves high patient satisfaction. Recent surgical advancements in the form of lenticular extraction procedures and presbyopia treatments have added new tools to our armamentarium. Despite technological advancements, the burden of delivering a perfect outcome still lies on the shoulders of the refractive surgeon. Additionally, each advancement brings an added financial burden that cannot be ignored. In times like these, where technology is changing quickly, it's important not to forget the importance of a thorough pre-operative evaluation. This is necessary to develop customized treatment plans for each patient, educate patients, manage their expectations, and keep their long-term vision goals in mind.

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A Systematic Approach to Post LASIK Refractive Error

***Himanshu Matalia*[1]*, Nandini C*[2]**

Introduction :

Refractive error following LASIK surgery causes dissatisfaction to the patient andthe surgeon as well. As the causes of postLASIK refractive errors are multifactorial, it is important for the treating physician to know the same and treat the patient accordingly. This chapter aims bringing in the scientific approach and rational thinking to identify the cause of refractive error in a postLASIK patient. We will also briefly discuss the recommended treatment of each cause.

Amongst the refractive errors myopia and hyperopia, the later being dynamic in natureposes a different challenge. Correct estimation of refractive error itself is debatable in hyperopia as accommodation component keeps altering the manifested error. Similarly, hyperopic LASIK has its own issues with regards to the outcome. However, to avoid any confusion, in this article we will limit ourselves to the myopic laser vision correction only.

Causes :

Following are 6-most important causes of refractive error post LASIK surgery based on timing of presentation.

Causes of post LASIK refractive error

1. Deliberate/non-deliberate under/overcorrection
2. Spasm of accommodation
3. Progression of myopia
4. Long term regression
5. Cataract
6. Post LASIK ectasia

1. Deliberate/non-deliberate under/overcorrection : Deliberate under correction is not unknown in cases of high myopic refractive error with lower corneal thickness. In order to keep adequate residual stromal bed thickness (RSBT), surgeon may plan a deliberate under correction. Non-deliberate under correction can be related to improper refraction, human error during the data entry or poorly calibrated laser machine. This can also occur if the surgeon fails to uniformly dry the bed before firing the excimer laser. Similarly, non-deliberate under correction can be caused by flap related complications such as irregular flap or partial button hole, giving rise to uneven bed before firing the excimer laser. Over correction may happen mostly commonly if there is dehydration of the cornea during the procedure and improper algorithm planning during data entry.[1]

Diagnosis

Presentation : Patient complains of suboptimal uncorrected vision (UCVA) on first postoperative day. We can enquire patient about vision in immediate postoperative period if we are not the primary surgeon and about any preoperative and surgical data availability.

Treatment :

- Rule out deliberate under correction. Find out from the primary surgeonthe reason for under correction.
- Confirm the refractive error by cycloplegic refraction.
- Do anterior segment OCT (ASOCT) to know flap and residual bed thickness (RSBT) to know the limit of correction we can plan on the patient.
- Enhancement can be planned after stability of refraction and topography: 2 stable refraction and topography done 6 weeks apart are mandatory prior to enhancement.

2. Spasm of accommodation : Also referred to as pseudo myopia. In this condition, there is extended contraction of ciliary muscle after prolonged near activities. The etiology is multifactorial and more often is associated with anxious personalities. Clinically, accommodative spasm may give symptoms of distance blurring or fluctuations of vision, frequent headaches, eye pain, and intermittent diplopia. This condition is most commonly seen after hyperopic laser vision correction.[2,3] However, not uncommon with myopia too.

Diagnosis :

Presentation : Patient may present with blurring of vision after few days to months after laser surgery. Patient may have blurred distance vision with good near vision. Dry refraction

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and retinoscopymay show myopia, however complete cycloplegia reveals emmetropia. Which maycoincidewith start of extended hours of near work. It is important to note that uncorrected vision documented on day first postoperative day is good and normal.It is typically seen in type A, anxious personality.

Usually presents when patient starts working for near activities like

- Increased near work
- Reading
- Computer usage
- Mobile phone

Treatment :

It is important to reassure the patient about their state of excess accommodation and available management strategies. Counsel the patient regarding the reduction in the screen time, de-stress and regular breaks during work. Cycloplegic refraction with 0.1 % cyclopentolate needs to be done to relieve the spasm and must see for any cycloplegic subjective acceptance. In severe case patient may need atropinisation (once atnight-time for a week) if spasm persists especially in post hyperopic LASIK treatment.[2,3]

Accommodation lag : As myopes donot require use of significant accommodation for near work, many of them would not have used their accommodation for their day-to-dayactivities. After refractive laser vision correction, we expect their accommodation to start normally, which may happen in most cases butsometimes it maynot start functioning immediately and it may take some time. This is called lag of accommodation. These cases have good distance vision but near vision may not be clear. Reassuring the patient that it would take a while for accommodation to act would relax the patient and reassures them.

3. Progression of myopia : Commonest cause of post LASIK refractive error and least commonly diagnosed by refractive surgeons is progression of myopia. This has nothing to do with the surgery or surgical technique but depends upon the natural progression of axial myopia in the patient.

Diagnosis :

Presentation : Patient would have good vision documented on postoperative day one, at one month and 3 months but would present with gradual decreased vision months to years after laser surgery. Presentation depends upon the growth of axial length. This can only be diagnosed if we have pre-operative axial length measurement to compare with and therefore axial length measurement must be part of preoperative LASIK work up.

Treatment :

Indications for refractive surgery enhancement

- Treat only if needed: If the residual refractive error post laser ablation is affecting the routine activity of the patient and there is significant reduction in uncorrected vision, then onlythe refractive surgeon shouldconsider an enhancement procedure.1
- First make sure refractive error/progressive myopiais stable for at least 3-6 months documented by stable refraction and axial length measurement. Once refractive error is stable, check the RSBT, flap thickness with anterior segment OCT and if adequate, plan enhancement surgery (figure 1).

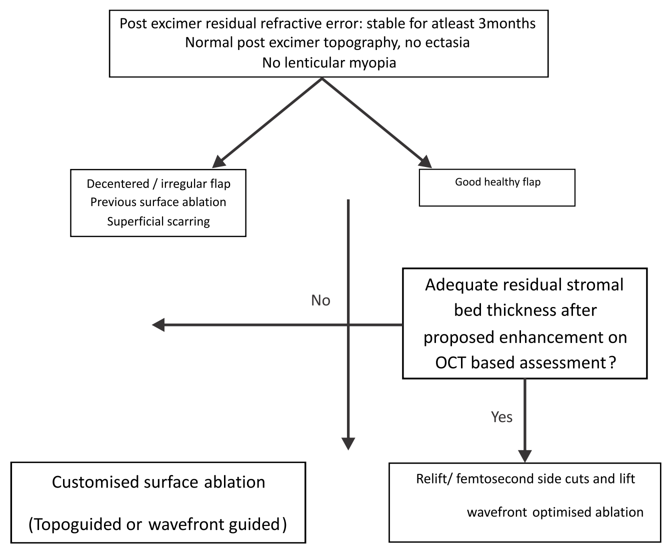

Figure 1 : Post laser refractive correction enhancement algorithm (Source: EyeWiki AAO website)[1]

If patient is not suitable for enhancement procedure, then other options like glasses, contact lenses and phakic IOL (if adequate internal ACD and endothelial counts>2500 cells/mm2)can be considered.

4. Long term regression : Regression is the highly misusedterminology and not to be confused with progression of myopia.

The term LASIK regression suggests the loss or reduction of effect from the LASIK ablation performed to correct an amount of myopic refractive error.[4]

Regression can also bedue to stromal &epithelial remodeling post laser ablation both in myopia and hyperopic LAISK,[5,6] and it is mostly commonly reported in high myopic LASIK surgery.[7,8,9] As the LASIK is based on the principle to alter the anterior corneal surface alone, any myopic regression should show reversal of the flattening achieved during primary treatment. This would be evident in increased corneal curvature or keratometry (K values) following LASIK. Alio JL in their long term outcome of LASIK of 40 eyes, reported increase in mean K value by 0.90 ±1.71 D in 15 years, which corresponded to a mean annual increase in the mean K value by a clinically insignificant value of 0.06 D.10 Similarly, Kim G et al published their long term outcome of more than 8 year follow-up of 475 eyes which underwent Lasik and the change in K values ranged from -0.06 to 0.53. There was no significant clinical difference between type of surgery such as PRK or LASIK, age of the patients or amount of correction.[11] Both studies suggest that change in corneal curvature is not clinically significant and thus would not be as important factor. One of the important causes proposed for regression is abnormal epithelial healing. Reinstein DZ et al using Artemis very high-frequency digital ultrasound studied epithelial thickness changes following LASIK in 11 eyes and found that most notable changes occurred in first 3-months.[12] However, clinically we do experience stable refractive error for few months to years in most of the case as evident in long term studies.[10,11] Thus in most of the regular cases, regression it may not be a major issue.

Predisposing factors[8]

1. **Age of the patient :** younger the patient ,higher is the risk of regression.
2. **Type of excimer laser machines :** Broad beam and scanning slit excimer laser machine have higher chance of regression compared tothe flying spot laser machines. Fortunately, most of the current generation machines are based on flying spot principle only.
3. **Diameter of optical zone :** Largerthe diameter, more the ablation of corneal bed during excimer laser ablationand hence higher the chances of regression.

Diagnosis :

Presentation : It may take months to years for the stromal remodeling leading to myopic regression. There would be good vision documented on post-operative day oneand at even at one month. Regression needs to bediagnosed by change in topography leading to increased curvature (can be recognized as a change in curvature or K values).7 Anterior segment OCT with epithelial profile may help to recognize any irregularity in epithelial healing, which may be responsible in some cases. As evident from the literature it is very slow process andpractically does not exist. More commonly we over diagnose this condition in absence of data regarding myopic progression. Highlighting the importance of axial length measurement as an important parameter to document preoperatively.

5. Cataract : Cataract can also be a most common cause of myopic refractive error post laser vision correction at long run. Age related nuclear sclerosis commonly seen in high myopes and likely seen much earlier than normal age-matched persons.[8]

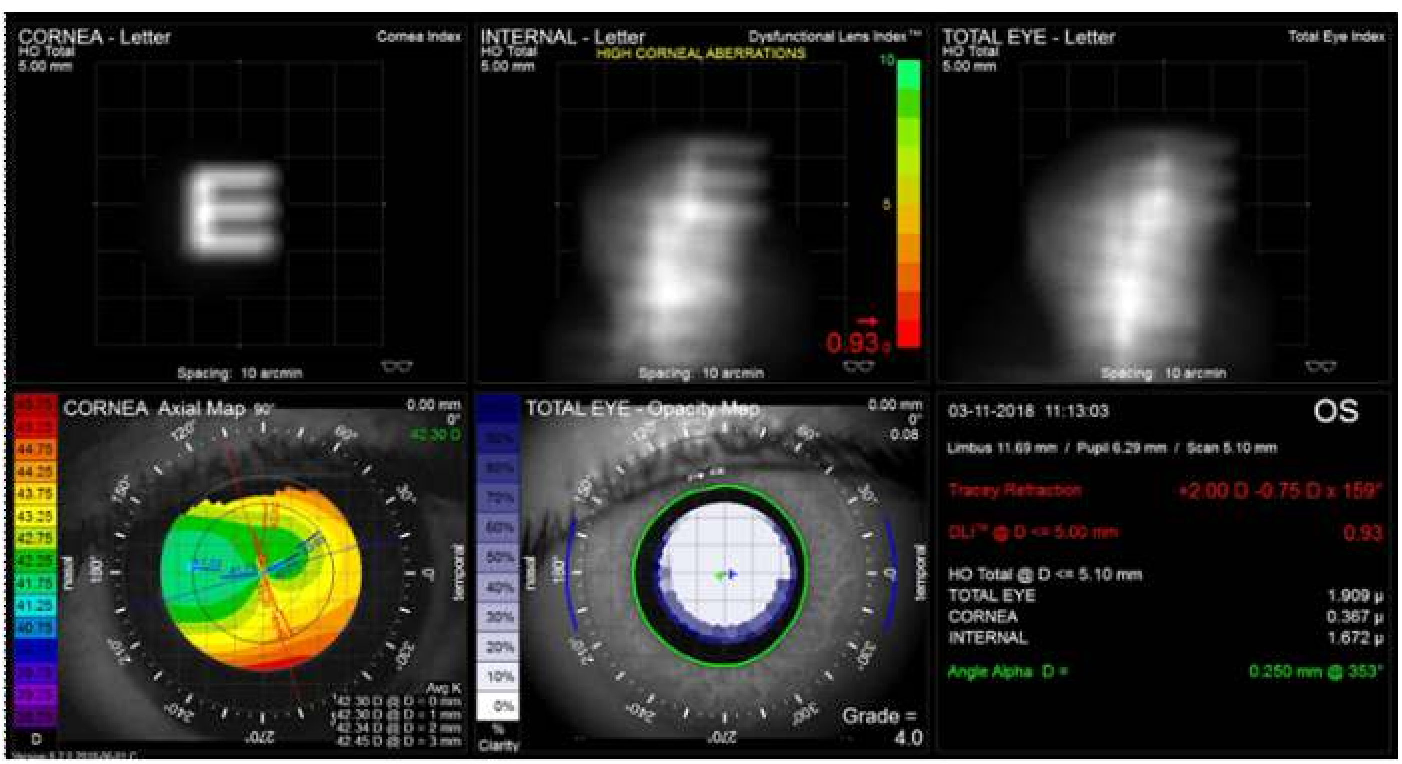

Figure 2 : Showing increased internal aberration arising from the lens evidenced by low Dyfunctional Lens Index (DLI) values: 0.93 (top center) and increased opacity in opacity map (bottom center).

Diagnosis

Presentation : Patients may present after many years following a successful laser surgery. There would be good vision documented on post-operative day one, at one month and until cataract formation. Like any other nuclear cataract, myopic shift is related to change in refractive index of the lens.

There would be no change in topography between post-operative period and axial length would be similar to pre-operative values. Patients may experience increased aberrations and poor quality of vision. Symptoms of glare and night driving issue may increase. An aberrometry would show increased internal aberration and iTrace (Tracey Technologies, TX) would show low dysfunctional index(DLI).[13] (figure 2) Pentacam would show increased densitometry values13of natural crystalline lens.

Management :

Post-LASIK cataract surgery can pose a chance of refractive surprise due to error in calculations. Post LASIKsurgery IOL power calculation can be challenging to any ophthalmologist.[14] However, newer IOL formulae along with American Society of Cataract and Refractive Surgery (ASCRS) online calculator has given confidence to the refractive surgeon to get a predictable,reliable good visual outcomes in these cases.[15]

6. Post LASIK ectasia : Post LASIK Ectasia (PLE)is the likely cause when there is late onset of sphero cylindrical refractive error post laser ablative surgery. PLE is not only the important concern for the patient as it reduces quality of vision but also to the treating surgeon as it can be a medicolegal issue.[16] Reported incidence range from 0.02 to0.22%[17,18]

Risk factors for post-LASIK ectasia[17,18,19]

1. Low preoperative corneal thickness: the most common risk factor
2. High myopic refractive error correction.
3. Abnormal preoperative corneal topography/tomography

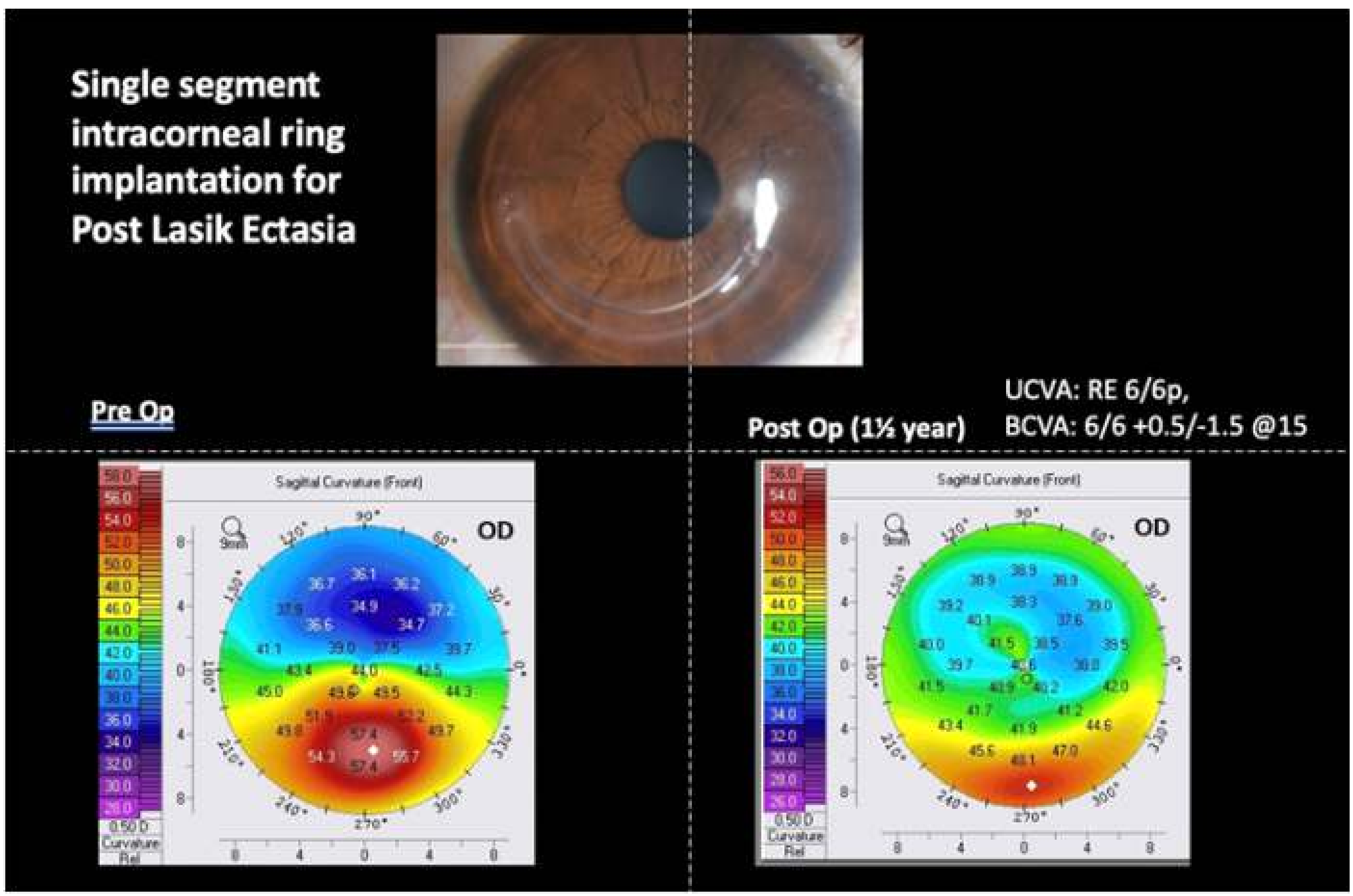

Figure 3 : Single segment intracorneal ring implantation for post-LASIK ectasia: Top slit-lamp photo shows single segment of intracorneal ring implant placed inferiorly. Preop map (bottom left): shows area of ectasia inferior paracentral regions marked by red color and relatively normal and flat area above that marked in blue color. Postop map (bottom right): shows significant improvement in overall curvature of the cornea, which looks more uniform and similar to a post-LASIK case leading to significant improvement in vision.

(e.g., anterior map irregularities, posterior elevation > + 15µm)

4. Low residual stromal bed thickness RSBT(<250 microns)
5. Percentage Tissue Ablation (PTA) = 40%
6. Multiple enhancements
7. Young age
8. Direct and indirect eye rubbing

Diagnosis :

Presentation : Patients may present after many months to years. There would be good vision documented on postoperative day one, one month and later on till ectasia manifests. It presents as compound myopic astigmatism (usually irregular astigmatism) with reduction in quality of vision due to increased higher order aberrations such as coma/ trefoil. Overall, reducing best corrected vision. May present uniocular or binocularly.

Pentacam shows posterior elevation usuallyin inferior paracentral region.[20] As the laser refractive surgery only affects anterior surface, any posterior elevation seen postoperatively should be seen with suspicion of PLE.

Treatment :

Unlike keratoconus, there is no need to wait and watch to document progression of PLE. Once diagnosed we must treat the condition immediately. Management of PLE involves two parts:

1) Prevention of progression of PLE by collagen cross-linking (CXL)

   CXL remains the corner stone of the treatment to halt the progression of PLE. Studies have shownsafety and efficacy even on long term follow upsup to 80 months.[21,22]

2) Visual rehabilitation by correcting the distorted vision in PLE.

a. Glasses : May not beable to achieve good visual acuity due to higher order aberrations.

b. Scleral contact lens : Would offer best visual outcome.

c. Intra-Corneal Ring Segments (ICRS) : Can be performed along with CXL or sequentially. As PLE manifests in localized area(usually inferior paracentral region), the unaffected cornea still maintains the flattening effect of myopic LASIK. Thus, a single segment implanted inferiorly may give better visual outcome by maintaining the shape of the cornea to its original post-LASIK contour.[23] When combined with CXL, ICRS can arrest the disease process safely, improve the uncorrected and best corrected vision,[24] by reducing refractive error and providing topographically better corneas.[25] (figure 3).

d. Topo-guided PRK (T-PRK) : A topography guided limited PRK can be combined with the CXL treatment on the same day to improve the shape of the cornea and thus improving overall quality of vision. Keeping in mind the safety our treatment depth should not go beyond 50 microns of the stromal ablation. The goal here should be to reduce the surface irregularity and to achieve emmetropia.[26]

In severe cases of post LASIK ectasia where it is not possible to perform CXL, deep anterior lamellar keratoplasty (DALK) can be considered.

Conclusions :

Post LASIK refractive error is a common but multifactorial problem. A careful systematic approach is needed find out the root cause and treat accordingly.

Causes of post LASIK refractive error

1. Deliberate/non-deliberate under/overcorrection : Immediate presentation, check for data entry error, careful before touching up if done elsewhere.

2. Spasm of accommodation : 1 week to 1 month presentation, cycloplegic refraction

3. Progression of myopia : Late presentation, check Axial length preop, touch up only if safe for RSBT after stabilization, phakic IOL can be considered.

4. Long term regression : Late onset, rare cause, change in anterior curvature on topography, AS-OCT to check epithelial profile.

5. Cataract : Late onset, visual quality disturbance, good clinical examination & check aberrometry for early changes, be careful about IOL power calculation.

6. Post LASIK ectasia : Late onset, irregular refraction, early changes are seen on the posterior surface on tomography, cross-linking with or without adjunctive treatment.

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Flap Related Complications

Prashant Bhartiya

Refractive surgery has evolved from surface ablation with its associated healing and recovery issues to flap or intra corneal procedures like LASIK, SMILE or SILK, which give nearly instantaneous recovery due to the absence of a large epithelial defect. But, this in-situ removal of corneal tissue needs additional manoeuvres and creates an interface which can convert an obvious advantage to a potential disadvantage.

Flap related complications are the most common complications of LASIK surgery. Most flap related complications are similar in either the Microkeratome (MK) or the Femtosecond (FS) Laser assisted LASIK. This article lists the various intraoperative and postoperative flap related complications with their risk factors and probable etiology, prevention and their management.

Flap Decentration :

Probable causes and risk factors :

- Rotation of eyeball during suction application
- Incorrect placement of the suction ring along with a large angle kappa.

Prevention and Management : Pre-emptive decentration of the suction ring in the opposite direction to get a final hold in the centred position can be tried. Also, if this does not prevent decentration of the globe, a large flap size can be chosen to include the whole ablation zone within the decentred flap.

Incomplete, Irregular Flaps :

Probable causes or risk factors :

- Sudden Suction loss (MK motor is designed to stop automatically if suction is lost)
- movement of eye or head
- incorrect assembly
- obstruction by lid, lash or drapes

Prevention and Management : Detection of an incomplete flap is most important. Do not lift the flap, evaluate the configuration under high magnification and assess availability of adequate area to accommodate the ablation zone. Lift the flap only if there is enough area available otherwise it is best to postpone surgery for at least 3 months and then plan a surface ablation.

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Flap Buttonhole :

Buttonholing of the flap mostly happens in the centre of the flap with MK or in the periphery with a FS laser where the gas breaks through vertically.

Probable causes and risk factors :

- Inadequate or excess suction
- Steep Corneas (keratometry above 46D)

Prevention and management : Preoperative high keratometry values should alert the surgeon regarding the risk of buttonholing. Many a times a central button hole may be mistaken for a central epithelial defect and this should be differentiated intraoperatively under high magnification to avoid flap lift in case of button hole. Laser ablation must not be done and it is most advisable to not lift the flap. A contact lens is placed to allow for healing and a surface ablation resorted to later. Any ablation if done (although not advisable) under a button holed flap, increases the risk of haze due to ablation of Bowmans membrane similar to PRK and hence MMC application may be resorted to intraoperatively.

Free Cap :

This occurs when the MK cut includes the hinge and the flap is free. It may be lost or stuck in the MK head.

Probable causes and risk factors :

- Flat keratometry

Prevention and management : Preoperative anticipation is essential in patients with flat keratometry readings. The free flap must be replaced in the best possible orientation. Stay sutures to prevent postoperative flap loss along with a BCL are placed. Ablation may be done before flap replacement if the area is wide enough, otherwise a surface ablation is done after 3 months.

Epithelial Defect :

Probable causes and risk factors :

- Excessive pressure during MK movements

- Preexisting Diabetes Mellitus
- Basement Membrane dystrophies with history of recurrent corneal erosions (RCES)

Prevention and management : Preoperatve screening for dry eye, basement membrane irregularities or history of RCES along with evaluation for diabetes nust be done. Intraoperatively, it must be differentiated from a button hole at times. Flap lift and ablation may be continued. After flap repositioning, loose epithelium must be carefully removed and a BCL should be placed. Postoperative watch for any epithelial ingrowth or diffuse lamellar keratitis should be done. Post operative lubrication may have to be intensified to prevent recurrent corneal erosions.

Flap Dislocation :

Probable causes and risk factors :

- Heavy Blinking
- Rubbing
- Trauma
- Anxiety
- Dry Eye
- Thick Flap
- Shallow sidecut

Prevention and management : Postoperative counselling is essential to avoid rubbing and trauma. A nap immediately after reaching home helps in improving the adhesion. Once the flap is not attached, the patient starts feeling a foreign body sensation and the vision gets blurred. Epithelium may regrow on the bed in the exposed area. Management includes refloating, unfolding and repositioning of the flap after removal of any new epithelial growth. Presentations more than 24 hours later may need deepithelization over the flap also to allow unfolding of the flap. A BCL for at least 4 days is placed. Watch for any evidence of infections and epithelial ingrowth.

Flap Striae :

Probable causes and risk factors :

- Excessive eye movements during flap repositioning
- Improper flap repositioning
- Excessive irrigation
- Flap Bed mismatch due to large stromal ablations or thin flaps

Prevention and management : Meticulous repositioning, patient instructions during procedure and use of BCL at end of procedure are useful to prevent striae. Striae may be left untreated if they do not affect the vision or cause excessive glare. When necessary, it is important to intervene at the earliest possible. Good pupillary dilation during surgery helps in identifying the striae during the procedure also. Alcohol deepithelization is a must before refloating the flap and the flap may be swollen by use of hypotonic solutions like distilled water. The flap is massaged in an outward direction and 2 or 3 sutures may be placed perpendicular to the striae for stretching and to hold the flap during healing. A BCL is placed at the end.

Epithelial Ingrowth :

Probable causes and risk factors :

- Improper flap repositioning and adhesion at the edges
- Improper technique of inserting instruments
- Inadequate irrigation
- Resurgery
- Epithelial defects especially at edges of the flap
- Button holes, free caps

Prevention and management : It is one of the most common postoperative complications after LASIK and usually presents many weeks later postoperatively. It is best prevented by the use of meticulous surgical technique during surgery. It may be in the form of isolated pearls/islands or diffuse sheets. It can cause irregular astigmatism or stromal melting with decrease in vision. It is best treated by complete removal from both the undersurface of the flap and the stromal bed after flap lift and aggressive irrigation. The flap edges may have to be sutured to prevent further ingrowth and a BCL placed for quick healing of any epithelial defect. YAG laser disruption of epithelial ingrowth has also been reported and may be tried initially.

Diffuse Lamellar Keratitis (DLK) :

Probable causes and risk factors :

- Excessive surgical manoeuvres
- Epithelial Defects
- Presence of fine fibres, red blood cells or meibomian secretions in the interface.

Prevention and management : DLK is usually a sterile inflammation in the stroma or interface occurring as early as first day postoperatively. It is associated with decreased vision, redness and photophobia. It typically manifests as fine granular haze with diffuse margins in the interface and called "Sands of Sahara syndrome". The infiltrates usually start on day 1 or 2 in the periphery and reach the centre by day 3 or day 4 (stage 1 and stage 2). The Further in the course of the progression, central scarring and permanent decrease in vision can occur (stage 3). If left untreated, stromal melting and further scarring (stage 4) can cause loss of best corrected visual acuity and a hyperopic shift. Early detection and intensive steroids are the mainstay of the treatment. Rarely a flap lift and wash may be necessary. It needs to be differentiated from other rarer conditions like infectious keratitis, Central Toxic keratopathy (CTK) and Pressure Induced Stromal Keratitis (PISK).

Infectious Keratitis :

Probable causes and risk factors :

- Preexisting blepharitis, meibomitis, dry eye
- Poor personal hygiene
- Presence of skin conditions like psoriasis, eczema, recurrent folliculitis etc
- Excessive surgical manipulation, operative time
- Resurgery for any complication
- Improper flap repositioning

Prevention and management : Meticulous surgical technique and proper sterilization of equipment along with preoperative management of meibomitis and dry eye helps in preventing infections. Unlike DLK, infectious keratitis is usually unilateral and starts 3 to 4 days postoperatively. Pseudomonas infections can be bilateral and start early with devastating results. Any interface or corneal infiltrate needs immediate flap lift and scrapping for microbiological evaluation. Initial empirical therapy is with a combination of a fluroquinolone with an aminoglycoside antibiotic. Specific organism like nocardia, mycobacterium or fungus need to be identified early and treated accordingly to prevent vision loss.

Other Rare Complications :

Pressure induced interlamellar stromal keratitis (PISK) : This is a rare form of interface opacity usually associated with a water cleft in the interface caused by the steroid induced increase in IOP. It starts later as compared to DLK and is best treated by tapering steroids and adding antiglaucoma medications.

Central toxic keratopathy (CTK) : A very rare form of predominantly central opacification starting around 7 to 14 days postoperatively. There are usually no signs of inflammation like redness, photophobia or pain. It does not respond to steroids and may linger on for around 18 months to finally lead to a hyperopic shift with residual opacification. It has been treated with oral Doxycycline, Ascorbic Acid and topical lubrication.

The overall incidence of flap related complications has been reported from 0.3% to as high as 10%. Complication rates are nearly similar in MK or FS LASIK. Intrastromal procedures like SILK/SMILE also have an interface and have a potental for similar complications. Reports have suggested that the incidence of flap related complications reduces to less than 2% as the learning curve advances. This learning curve along with the possibility of sub optimal visual outcomes or need for additional manoeuvres has led to the resurgence of surface ablations like transepithelial PRK. However, most cases if detected early and managed appropriately do not lead to significant visual loss.

Phantom Folds : Addressing the Why, When & How in LASIK Striae

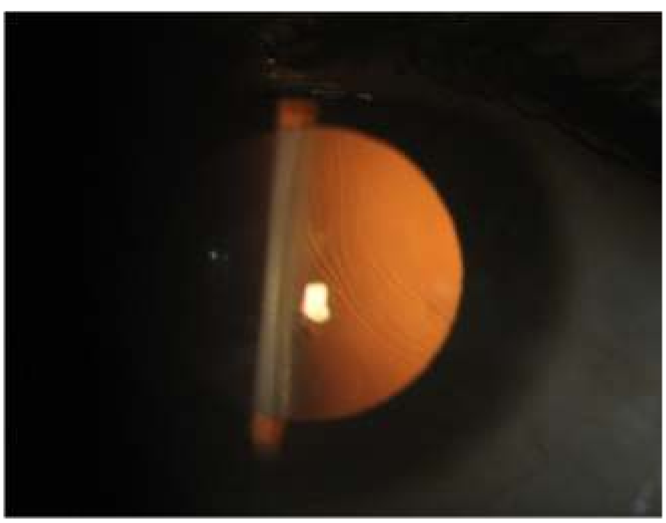
Reshma Raghunath Ranade[1], Sangeeta Wagh[2]

Introduction :

Laser-assisted in situ keratomileusis (LASIK) as a laser ablative procedure to correct refractive errors has gained popularity on account of its early post operative recovery and relatively lower risk of intra and post operative complications.[1] Inspite of the technological advancements and instrumentation, it is still associated with a few challenges, flap related complications being one of them. To name a few, microstriae, macrostriae, buttonhole flap, incomplete cap, free cap, cap dislodgement, and epithelial ingrowth, though low-risk events, stand significant with 0.1-4% of patients reporting some form of complication.[2,3]

Flap striae can be small and asymptomatic, but can lead to visual disturbances if the folds are large and involve the visual axis. Early onset striae can be managed by flap relift, ironing etc. However, late onset striae or those which remain persistent months after surgery causing significant visual debilitation may need aggressive management.

LASIK striae are broadly classified as Microstriae and Macrostriae. Microstriae are fine microscopic, superficial wrinkles mostly commonly involvingthe Bowman's layer and/or the corneal epithelial basement membrane.[4] They are generally asymptomatic and most often detectable on microscopic examination of the cornea.Macrostriae are larger, full thickness folds in the cornea that lead to visual disturbances and may need surgical intervention.[4]



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Knowing the Why :

Flap folds result from uneven alignment of the flap edge and the peripheral epithelial ring. Striae are more common in thinner and larger flaps since they are more prone to shift easily. Similarly so, they are more likely in high myopes and hypermetropes. This is due to the change in the central convexity and stromal support resulting in a redundant flap also known as the tenting effect.[5] Uneven sponge smoothing can result in radial (with centrifugal movement) or circumferential folds (with centripetal movement).

Diagnosis of Flap Striae :

1. Visual acuity assessment and Subjective Refraction :

Decrease in the best corrected visual acuity (BCVA) may be noted with new onset irregular astigmatism, hyperopic shift and increase in higher order aberrations, specially in macrofolds involving the visual axis.[6]

2. Slit Lamp Examination :

Macrostriae appear as linear full thickness stromal folds showing "tenting"[6] and are usually perpendicular to the flap hinge.[7] On fluorescein staining, they appear as negative staining lines.85 types of folds and striae in LASIK flaps have published in literature, these include loose epithelium, hinge ridge, hinge fold, deep stromal striae, deep epithelial/ Bowman's striae.[7]

3. Confocal Microscopy :

On Confocal imaging, striae are visible as linear distortions in the corneal flap and can serve as a supplementary tool to identify the depth of the striae and aid classification. It can give information regarding longitudinal orientation (vertical, horizontal, and oblique) and morphological characteristics of the folds.[9]

Management :

a) Early Management :

In the early postoperative period between 1-2 weeks, symptomatic striae can be managed by a flap lift, hydration and ironing the flap in position.[1012] Methylcellulose or Merocel sponges can be used for flattening and ironing out the folds.[13] Instruments such as the Pineda LASIK Flap Iron (Asico, Westmont, IL) can also be used to flatten isolated flaps at the slit-lamp or under the operating microscope by gently pressing on them. Debridement of the epithelium overlying the flap has also been recommended.[14] Earlier the intervention, greater are the chances of complete resolution.

b) Late Management :

Fixed folds develop when epithelium proliferates in the crevices formed by the folds. Persistent fixed folds may need exhaustive treatment options in comparison to early striae.

1. Suturing :

Recalcitrant fixed folds can be treated with placement of sutures at the flap edge attempting to provideprolonged mechanical stretching of the flap.[13] Irregular astigmatism and development of striae in the direction opposite to the pulling force of the suture are the possible side effects of the procedure.

2. Phototherapeutic Keratectomy (PTK) :

A standardized protocol for PTK was described by Steinert et al15 where transpithelial excimer laser was used to deliver 200 pulses (utilizing the pupil tracker) and a maximum limit of 100 further pulses with masking fluids (with the tracker necessarily turned off), not exceeding 300 pulses. This is followed by the second phase of PTK wherein 5-8 pulses are delivered after wiping a thin film of a medium-viscosity preservative-free artificial tear from the bed and repeating the process again.

Prevention :

- Preplaced surgical landmarks can help accurate repositioning of the flap.
- Immediate post operative examination on slit lamp can help prompt diagnosis and gives time for redressal.
- It is essential to ensure an even distribution of the “gutter” between the flap edge and the peripheral epithelial ring. The gutteris assumed to be due to biomechanical retraction of the collagen lamellae or to flap dehydration and subsequent retraction.[6]
- Precise repositioning of the flap and early evaluation may help achieve good positioning of the flap.

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Intra Ocular Lens Power Calculation After LASIK and PRK

Nikunj Tank

Intraocular lens (IOL) implantation after refractive surgery is challenging because standard IOL power formulae can lead to significant unintended postoperative refractive errors. Special methods of IOL calculations should be used in these cases.

Current standard IOL formulae are the 3rd and 4th generation theoretic formulae such as the Hoffer Q, SRK/T, Holladay II, as well as the Barrett Universal II and Hill RBF formulas. The formulae use the corneal power in two ways. First, corneal power is directly used in the vergence calculation to predict the postoperative refraction. Second, corneal power is used in the prediction of effective lens position (ELP), which is the depth of the IOL relative to the cornea. Refractive surgery alters the corneal curvature and introduces error into both the measurement of corneal power and the prediction of ELP. Both types of error lead to an underestimation of the required IOL power in eyes that had previous myopic refractive surgery and an overestimation of the required IOL power in eyes that had previous hyperopic refractive surgery.Laser vision correction (LVC) and radial keratotomy (RK) both affect corneal power in such a way that standard keratometry underestimates the refractive correction.

Change in Keratometry after Laser vision correction :

Laser vision correction includes LASIK, PRK and SMILE or SILK. These procedures modify only the anterior corneal curvature but leave the posterior curvature unchanged, thereby altering the normal anterior/posterior curvature ratio. Because standard keratometry measures only the anterior corneal curvature, the posterior curvature is extrapolated based on the normal anterior/posterior curvature ratio. This extrapolation is no longer valid after LVC. Therefore, one potential strategy for determining post-LVC keratometry is to directly measure both anterior and posterior corneal curvature and thereby calculate the net corneal power.

Error in Effective Lens Position Calculation after Refractive Surgery :

Standard IOL power formulae use the axial length and corneal power to predict the position of the IOL postoperatively. Refractive surgery changes the corneal power but not the depth of the lens, leading to an error in ELP prediction in the standard formulae. After RK and myopic LVC, the corneal power is decreased and the ELP estimates become too low. This leads to an underestimation of the IOL power that is required. Overestimation of IOL power occurs after hyperopic LVC. Special methods must be used to reduce this error.

Methods to obtain true corneal power after refractive surgery :

There are various methods to obtain true corneal power after refractive surgery.

Many of them are of historical importance as they are not used in the clinical practice in current times but for the purpose of this article it is mentioned below for the readers.

Clinical History Method :

This method was firstly introduced by Holladay [1] in 1989. The corneal power is calculated by subtracting the change in manifest refraction at the corneal plane induced by the refractive surgical procedure from the corneal power values obtained before refractive surgery.

K=KPRE-RCC

K: calculated corneal power

KPRE : corneal power before refractive surgery

RCC : Change in manifest refraction at corneal plane

This method theoretically yields the actual corneal power and is easy to calculate if the relevant data are available. Problems with this method include unavailability or inaccuracy of these data and interval changes in the corneal curvature or lens power and clarity (if the postoperative refraction is not available).

Contact lens over refraction method :

The contact lens method was first described by Ridley [2] in 1948. Corneal power is calculated as the sum of the contact lens base curve, power, and over-refraction minus the spherical equivalent of the manifest refraction without a contact lens. The advantage of this method is that the necessary equipment is inexpensive and readily available. The only additional step is to place the contact lens on the eye and repeat the refraction. This method is suitable for both post LASIK and RK corneas.The accuracy of this method worsens with poorer best corrected visual acuity (BCVA). Therefore it is not suitable for cases of dense cataracts.

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Topography based post LASIK adjusted keratometry :

These regression formulas are based on analysis of post-LASIK corneal topography central Ks (TK) in LASIK eyes. True corneal power is predicted using only the single central postoperative reading TK. There are two regression formula for this adjustment Koch and wang formula [3] and Shammas Formula [4]

Koch and wang formula :

K= 1.1141 *TK -6.1

Shammas formula :

K= 1.14 * TK - 6.8

K: calculated corneal power, TK : Post LASIK corneal topography central K

Net Corneal power measurement :

The fundamental solution to obtaining accurate post-LVC corneal power is to directly measure both anterior and posterior corneal curvature and thereby calculate the net corneal power. Several instruments can directly measurement of both anterior and posterior corneal surfaces. These methods include slit-scanning tomography, Scheimpflug tomography, and optical coherence tomography.

Orbscan :

The Orbscan II videokeratography system (Bausch & Lomb, USA) combines Placido disk and slit-scanning technology to directly measure elevation and curvature of both the anterior and posterior corneal surfaces.[5] A limitation of Orbscan elevation maps is that intracorneal opacities may obscure imaging of the posterior cornea and introduce artifacts into total corneal power calculations. Additionally, the reliability of posterior corneal measurements with the Orbscan has not been fully established.

Pentacam :

Pentacam (Oculus, Germany) is a rotating Scheimpflug photography system that can provide a topographic analysis of the corneal front and back surfaces as well as central corneal thickness. It generates a TrueNetPower map of the cornea as well as calculates an equivalent K called the Holladay Report. The equivalent K (at the recommended 4.5 mm zone) of the postoperative cornea has been proposed as an accurate measure of the true corneal power. [6] [Image 1] When clinical historical refractive data are not available, Pentacam provides an alternative method of measuring the central corneal power. It is recommended to look at the centration of the ablation pattern , decentered ablation changes the corneal curvature and these are not good candidates for multifocal or trifocal IOLs.

Optical coherence tomography :

Optical coherence tomography (OCT) can be used to measure both anterior and posterior corneal power. It is particularly valuable when preoperative refractive surgery data are not available. Tang reported good repeatability and accuracy when using OCT to measure total corneal power[7] and IOL power calculation[8][9].

IOL power Formula for post refractive surgery eyes :

The following IOL power formulae and nomogram adjustments have been developed or tested in post-refractive surgery cases. The reader should note whether they are designed to take standard keratometry or true corneal power (see above) as input (Table 1). The reader should also note that some methods are suitable for post-LVC eyes, some for post-RK eyes, and some are applicable to both situations (Table 1).

Formula	Input
Double K Formula	True K
Hoffer Q formula	True K
Haigis L formula	Standard K
Masket formula	True K
Koch & Wang nomogram	True L
Barrate True K	True K

Table 1 - Intraocular lens power formula or nomogram suitable for post refractive surgery eyes.

Double K method :

In "double-K" version of IOL formula, the post-refractive surgery corneal power reading is used in the vergence calculation while the pre-refractive surgery corneal power (or an estimate of it) is used in the ELP prediction formula. is reduces the error in post-refractive surgery ELP calculation. Double-K versions of SRK/T[10], Hoffer Q[11] and Holladay II formulae are available.

Hoffer Q Formula :

The Hoffer Q formula estimates a method of ELP calculation that is less sensitive to corneal power variation. Therefore it introduces less error in post-refractive surgery eyes than other single-K formulae [12] If double-K formulae are not available, the single-K Hoffer-Q formula may be useful.

Haigis L formula :

This formula is part of the built-in software of IOLMaster. Corneal power is calculated by inputting IOL-Master biometry as follows : axial length (AL), anterior chamber depth (ACD), and keratometry (corneal radii). This formula is a regression formula based on statistics. Accuracy may decrease if the eye is on the edge of normal distribution (high myopic or high hyperopic eyes). It is based on LASIK data and only suitable for post-LVC cases.

Masket Formula :

P=PTARG-0.326×RCC -0.101

PTARG: IOL power calculated by standard IOL formulas

RCC: surgically induced refractive change

This method adjusts the power of the IOL, calculated using the postoperative measured data using the knowledge of the surgically induced refractive change. They recommend using the SRK/T formula for myopic ALs and the Hoffer Q for hyperopic ALs[13]

Barrett True K Formula :

Barrett True K formula is also integral part of optical biometers like Zeiss IOL master 700. Its latest version is version 3.0 which is thought to be more accurate for post MYOPIC or Hyperopic LASIK patients. Recent study by Ferguson et al [14] compared outcomes of barrett true ka formula in myopic and hyperopic LASIK eyes and compared with ASCRS online calculator and found that it performed equivalently to ASCRS mean formula.

American Society of Cataract & Refractive Surgery (ASCRS) online calculator for post LASIK eyes (www.ascrs.org)

One of the most convenient and easily accessible online calculator is ASCRS post LASIK calculator which gives IOL

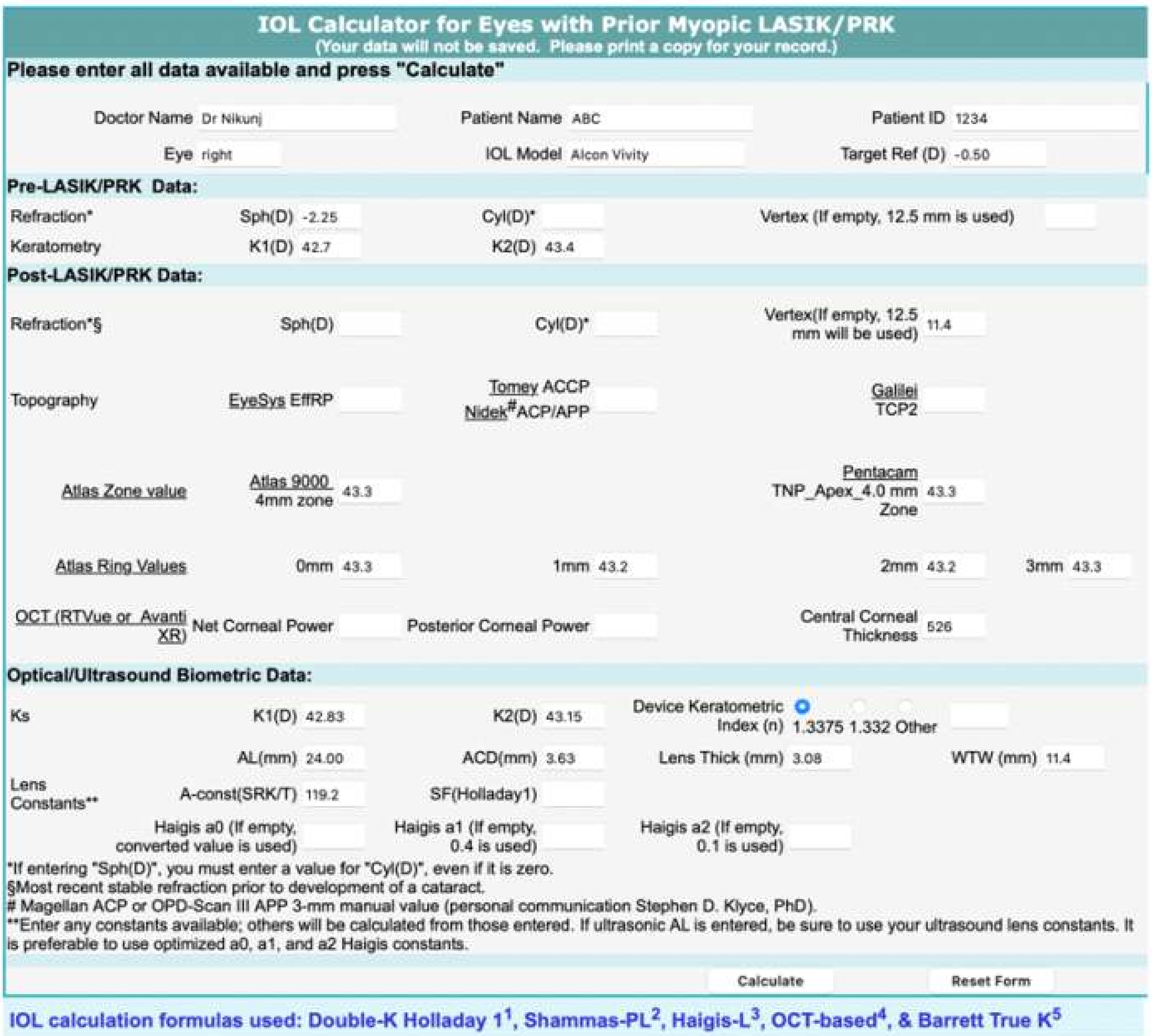

Figure 1

calculations by multiple formulas and mean average IOL power of all the formulas at the ed of calculations. Surgeon needs to enter the necessary done in to the calculator which includes pre LASIK refraction and keratometry data if available, Post LASIK refraction data, keratometry from different machines and different zones of the cornea based on topography, corneal thickness in the center, biometry values like axial length, anterior chamber depth, white to white measurement, lens thickness, IOL A constant provided by the company. [Image 1] Equivalent keratometry values from different zones of the cornea can be obtained by corneal topography EKR map [Image 2] where EKR values are showed from central 1 mm to peripheral 7mm zone of cornea. 3-4.5 mm zone values are more important to consider while doing the calculation and they need to be more or less similar to each other. At the end of the calculation display, the ASCRS online calculator will give IOL calculation values by multiple formulas and also minimum, maximum and average IOL power by all formulae are also given. [Image 3] It is personally by far one of the most accurate method for IOL calculations in post LASIK patients.

Conclusion :

It is always advisable to look at the corneal topography along with biometry values while planning cataract surgery in post LASIK patient. Always look out for decentered ablation pattern which can cause irregular astigmatism , any flap related issues like flap folds also consider post refractive surgery dry eyes while taking the measurements. Till date there is not consensus to follow only one formula but you need to look at the multiple formula and then decide about which IOL power to be implanted. In all cases patient needs to be explained about post operative possible refractive surprise and need to glasses for same as these patients have inherent need of not need to use glasses. In current times with more and more date about cornea using advanced topography machines and newer Non-defractive technology IOLs like extended depth of focus (EDOF) category, we are able to offer better and almost spectacle independent visual outcomes to our patients. In future we will have even better IOLs and better way to calculate IOL power in post refractive surgery patients but till that time comes it is advisable to take all calculations with pinch of salt and never to overpromise about visual outcomes

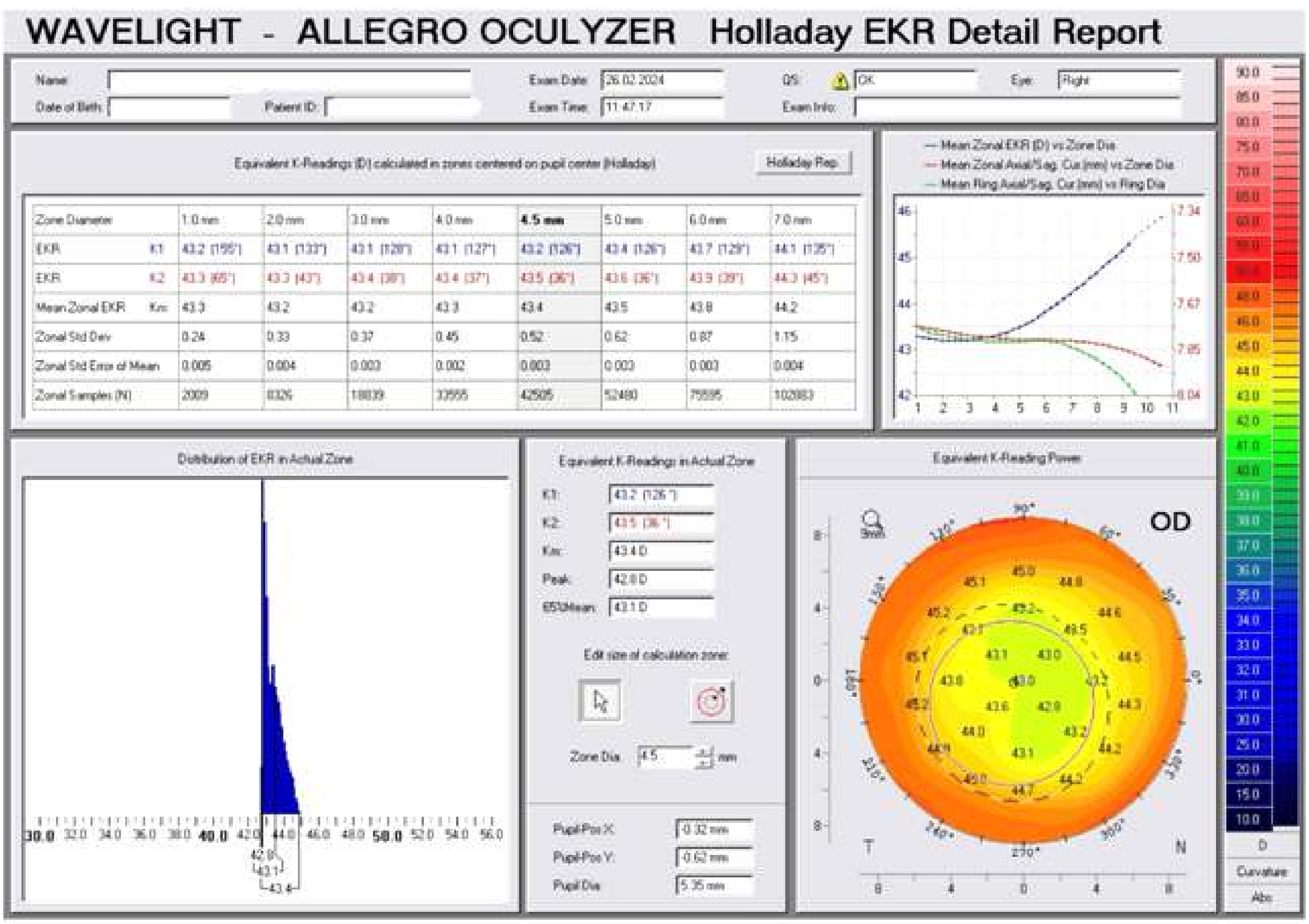

Figure 2

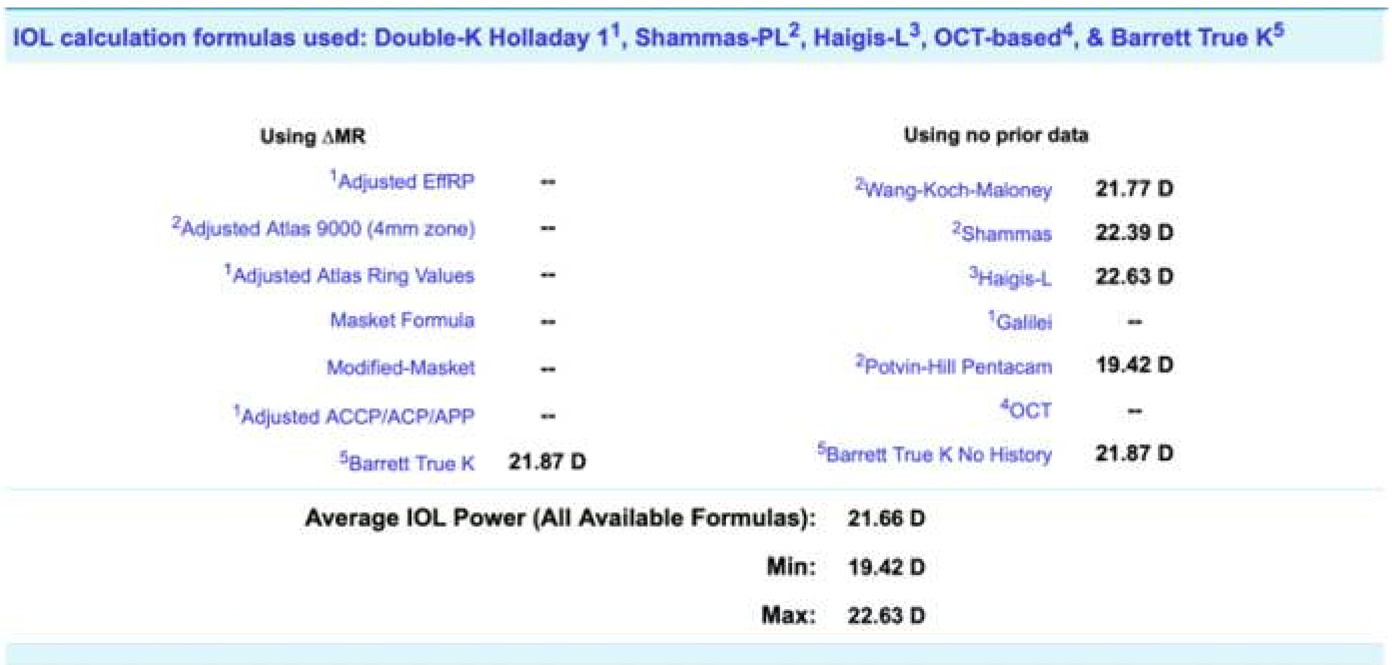

Figure 3

in such cases.

Image 1- ASCRS online calculator with filled data of a post myopic LASIK patient

Image 2 - Corneal topography EKR map showing K values from different zones of cornea from centre to periphery

Image 3 - ASCRS online calculator showing IOL power with different formulae and average IOL power at end below.

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CORNEAL BIOMECHANICS

Divya Trivedi

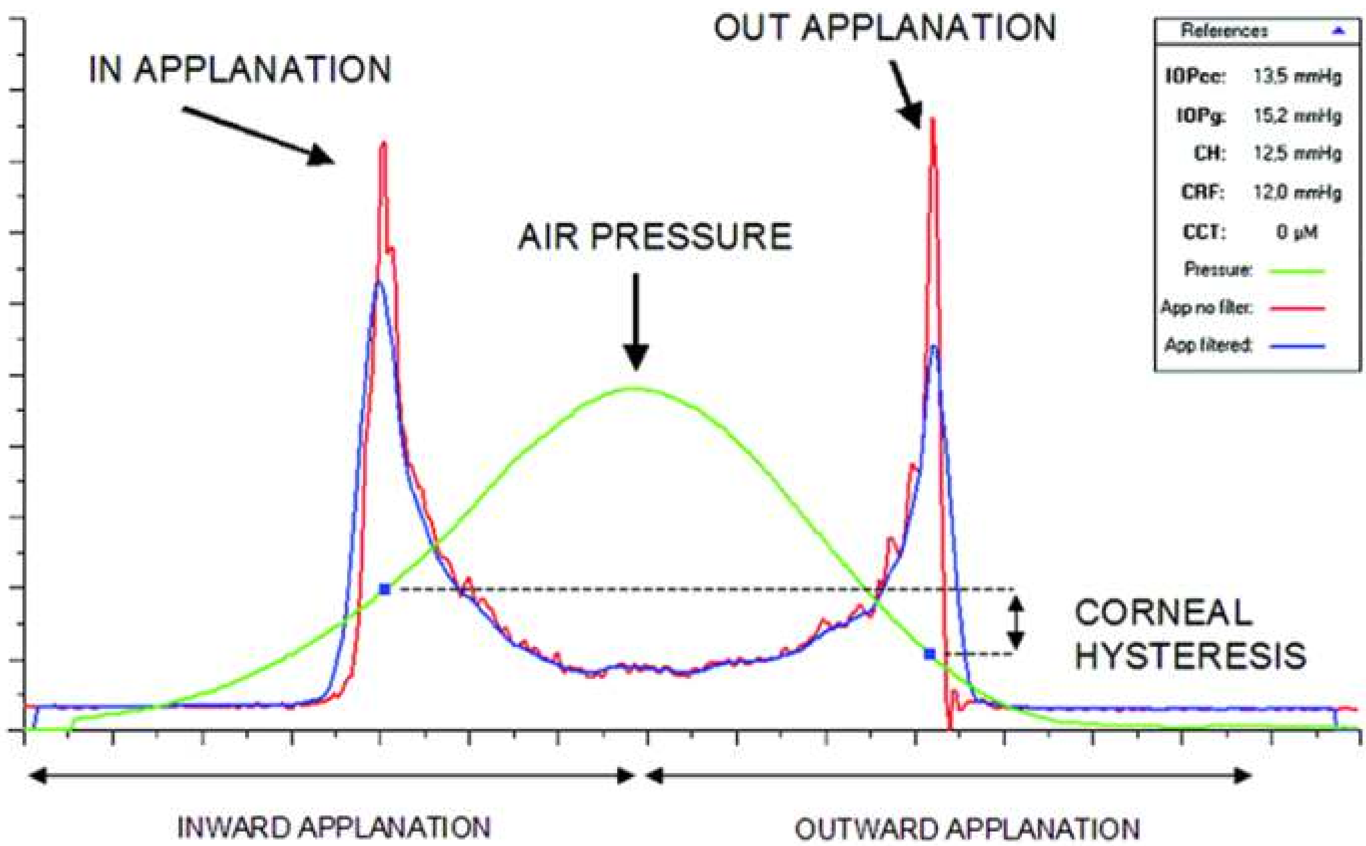
INTRODUCTION :

Biomechanics can be simply defined as mechanics applied to biology. It is the development, extension and application of mechanics for the purposes of understanding the physiology and pathophysiology of disease processes. In the context of the cornea, the cornea needs to be soft enough to bulge out in an aspheric half-sphere, yet, stiff enough to maintain its shape and resist the intraocular pressure. The stroma contributes most to the overall corneal biomechanics, followed by the Bowman's and the Descemet's membrane accounting for 20% of the bending rigidity of the cornea. The endothelium indirectly affects corneal stiffness by regulating corneal hydration.

PHYSIOLOGY OF CORNEAL BIOMECHANICS :

Factors that affect the biomechanics of the cornea are

1. Components of the extracellular matrix - Glycosaminoglycans (GAGs) form polymers, which associate with protein cores to form megamolecular complexes in the ground substance, which in turn, increase the viscosity. Proteoglycans (PGs) act as an interfibrillar glue, that is crucial for the arrangement of collagen fibres, and maintenance of a cohesive force between the lamellae. In corneal ectatic conditions such as keratoconus and pellucid marginal degeneration, the amount of keratan sulfate and dermatan sulfate (PGs) are reduced or absent. This accounts for the biomechanically weaker corneas in ectatic diseases.



2. Organization of the collagen lamellae - Collagen fibres approximately 22-32nm in diameter appear to run uninterrupted from limbus to limbus in flat sheaths or lamellae. A uniform centre-to-centre spacing of

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approximately 55nm is maintained by the intramolecular forces in the surrounding matrix. Orthogonal orientation provides the highest visual acuity and best maintains the corneal shape. This collagen organisation is disrupted in corneal ectatic conditions like keratoconus.

3. Hydration/osmotic pressure - Corneal hydration affects not only the transparency, but also the elastic modulus of the corneal tissue more hydrated the corneal tissue, the lower is its elastic modulus.

Clinical Assessment Of Corneal Biomechanics :

1. Ocular Response Analyzer (ORA) : The first commercially available device capable of evaluating the cornea's biomechanical features was the Ocular Response Analyzer (ORA, Reichert, Inc., Depew, NY), 9 which utilizes a high-speed air-puff to quantify the dynamics of corneal deformation and recovery as an indicator of corneal hysteresis (CH). The following figure illustrates a typical response waveform. CH is the difference between the ingoing and outgoing applanation pressures (P1 P2) and represents the energy loss due to viscous damping in the cornea and extra-corneal structures. This difference would be equal to zero in an isotropic material and is always positive in a viscoelastic tissue: as mentioned before, pressure is always greater at the first applanation event ("loading") than the second ("unloading"). A higher CH indicates a greater capacity for absorption and dissipation of kinetic energy in the tissue. Eyes with a higher CH (i.e. greater viscoelastic damping) present a signal analysis which shifts the applanation peaks to the right, resulting in a higher P1, a lower P2, and an increased CH.

2. Corvis-ST : The Corvis ST (Oculus Optikgeräte GmbH, Wetzlar, Germany) is a non-contact tonometer that employs a similar air puff perturbation and has been commercially available since 2011. It employs an ultra-high-speed Scheimpflug camera that records the deformation process at 4330 frames/second along an 8 mm horizontal corneal cross-section during corneal deformation.Analysis of the images provides insight into the infrared signal behavior observed with the ORA, and because direct analysis of shape is possible, provides additional opportunities for a more direct derivation of biomechanical response. Contrary to the ORA, the Corvis ST does not vary the air puff pressure from measurement to measurement. Differences in applied force might confound attempts to directly compare results obtained with these two instruments.

3. Optical Coherence Elastography (OCE) : Optical coherence tomography (OCT) is a well-established low coherence interferometric imaging technique, providing great resolution and is completely non-invasive. In principle, elastography imaging has several ideal elements, such as high-resolution imaging, the application of a mechanical force to cause tissue distortion, re-imaging of the resulting tissue deformation response, and mathematical modelling and analysis to link the observed tissue response to the biomechanical properties of the tissue, e.g. the elastic modulus.

4. Brillouin Microscopy : Brillouin microscopy is an optical approach to quantification of material properties. In principle, when objects are interrogated with monochromatic light, photons will experience a slight frequency shift that can be related to the material properties of the object and its density. This non-invasive optical technique based on analyzing the Brillouin frequency shift is capable of generating depth-resolved elasticity distribution maps of the cornea and lens with micrometer-scale spatial resolution. Brillouin microscopy has been used to investigate the depth-resolved Brillouin shift in human corneal buttons with and without keratoconus, in ex vivo porcine corneas before and after CXL, and in human eyes in vivo. Current limitations include high acquisition time and the system expense, but like OCE, the method is being developed for commercial translation.

Clinical Relevance Of Corneal Biomechanics :

The biomechanics of the cornea govern its shape and therefore its refractive power. Abnormalities and changes to biomechanics that present due to disease or are introduced due to trauma or surgery, can have profound effects on vision.Corneal diseases such as keratoconus as well as corneal refractive surgery can generate significant changes in the cornea's optical properties. An ongoing challenge is to understand the relationship between the mechanical and structural changes that produce those clinically measured optical modifications in pathological conditions and after refractive surgery and to understand their evolution over time. Better understanding of the biomechanics of the cornea is thus essential to comprehend the consequences of modifications in the geometry of the cornea after excimer laser refractive surgery or non-ablative interventions such as corneal collagen crosslinking (CXL), to improve the diagnosis and management of ectatic corneal disorders such as keratoconus, and to understand the biomechanics of intraocular pressure (IOP).

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Step-wise Approach to Very High Hypermetropia Management : A Clinical Case Report

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ABSTRACT :

We herein report a case involving the refractive correction of a young patient with very high hypermetropia. The treatment plan included an initial clear lens extraction (CLE) surgery with hydrophobic acrylic PCIOL to achieve the maximum possible correction, followed by photorefractive keratectomy (PRK) two months later to address the residual refractive error. This case underscores the significance of a customized, patient-specific approach, ultimately to bring about a satisfactory visual outcome.

KEY WORDS :

High hypermetropia/hyperopia, clear lens extraction (CLE), photorefractive keratectomy (PRK).

INTRODUCTION :

High Hypermetropia typically means refraction of +5.00 D and above. It is associated with many clinical challenges regarding visual acuity, binocular vision and refractive correction.

Hypermetropia management has always been a daunting task for refractive surgeons, especially very high hypermetropia present in young patients. Surgical correction of a highly hyperopic eye is always an uphill task. While there is a plethora of surgical options available for myopia, hyperopic treatment still lags behind myopia as far as the evolution of surgical measures is concerned. Current treatment options include photorefractive keratectomy (PRK), laser in situ keratomileusis (LASIK), phakic intraocular lens (IOL), and clear lens extraction (CLE). Cornea based refractive procedures in these eyes are associated with challenges such as refractive unpredictability, induction of higher-order aberrations, regression, and overall poor long-term stability. [1,2,3]

Hyperopic eyes exhibit anatomical variations, characterized by narrow angles, shallow anterior chambers, and short white-to-white or sulcus diameters which complicate CLE procedure in this set of eyes. But otherwise, is proven to be safe, effective, predictable, and confers long-term stability, unlike the laser vision correction (LVC) procedures. [4]

Additionally, the use of phakic intraocular lenses (pIOL) is not a viable option in this case, owing to the small white-to-white diameter not being suitable for pIOL implantation, moreover, such high-plus power lenses are unavailable.

CASE REPORT :

This case report highlights the refractive management of a 22yearold college-going patient, who presented to our tertiary eye care institute with bilateral high hypermetropia and amblyopia, seeking treatment for his/her high refractive error along with the associated asthenopia symptoms.

Detailed preoperative evaluation was done. Slit lamp examination was normal, gonioscopy revealed open angles with normal intraocular pressure (IOP) and indirect ophthalmoscopy examination showed a normal retina. A full cycloplegic refraction and then post post-mydriatic test were done. Manifest refraction was +12 DS/ + 0.5 DC for both eyes separately, with a corrected distance visual acuity (CDVA) of 6/12 and a near vision of N6 in both eyes. The preoperative central corneal thickness (CCT) were 517?ìm and 503?ìm , and axial length (AL) were 17.3 mm and 17.22 mm in the right and left eye respectively. Internal anterior chamber depth (ACD) was 3.83 mm in both eyes.

Given the high refractive power, a clear lens extraction was planned for both eyes (one by one). The IOL power targeting emmetropia as measured by the Barrett TK Universal II formula in IOL master 700 was +49.34 D and +49 D in the right and left eye, respectively. The availability of such highpower IOLs presents a challenge because they require custom manufacturing and are made from hydrophilic materials. Additionally, obtaining these lenses often involves a long procurement timw.So, both eyes were implanted with monofocal AcrySof single piece IOL of +40.0 D which comprises of a hydrophobic, acrylic material with squared edge optical design. This is the highest plus power available in hydrophobic acrylic material in our country. Under correction is expected after this and the residual refractive error (RRE) could be corrected by LVC later on. A primary posterior continuous curvilinear capsulorhexis (PCCC) was performed and a posterior chamber intraocular lens (PCIOL) was

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implanted in the bag for both eyes. There were no intraoperative complications.

The immediate and early postoperative periods were uneventful. Hence, after ensuring refractive stability, a second procedure was scheduled to correct the RRE. Consequently, two months after CLE, a hyperopic surface ablation was planned sequentially for both eyes. At this point, the uncorrected distance visual acuity (UDVA) was 6/18 for both eyes. Manifest refraction was +3.5 DS /+1.0 DC@80 degree and +4.5 DS in the right and left eye respectively, with a uniocular CDVA of 6/12 in both eyes. Both eyes underwent Streamlight (PRK) using the Alcon WaveLight® Refractive Technology Suite platform, one after the other.

BCL was removed subsequently after completion of epithelisation. 10 months post-PRK, the patient now enjoys a highly satisfactory unaided distance vision of 6/12 uniocularly in both eyes, along with mild grade 1 peripheral anterior stromal haze as confirmed by slit lamp examination, along with a near glass prescription of 2.50 DS in both eye.

effusion or expulsive choroidal hemorrhage. Despite uneventful surgery, these patients are prone to develop pupillary block, angle-closure glaucoma, or aqueous misdirection postoperatively. We did not encounter any such complication in this patient.

Clear lens extraction (CLE) with monofocal IOL implantation offers a relatively easy, safe, and predictable option to treat high hypermetropic patients, without any undue risk of regression as seen with LVCs. The choice of IOL formulae remains debatable, but Haigis, Hoffer Q, and Holladay II are advocated for such small eyes, showing good outcomes in many studies. [5, 6, 7]

Owing to the thick and bulky nature of such high-plus-power IOLs, several IOL-related surgical considerations must be taken into account. The IOL should be loaded into the cartridge under microscopic guidance to ensure precision. Additionally, the main clear corneal incision needs to be extended before IOL insertion to facilitate smooth delivery and prevent complications like Descemet membrane detachment.

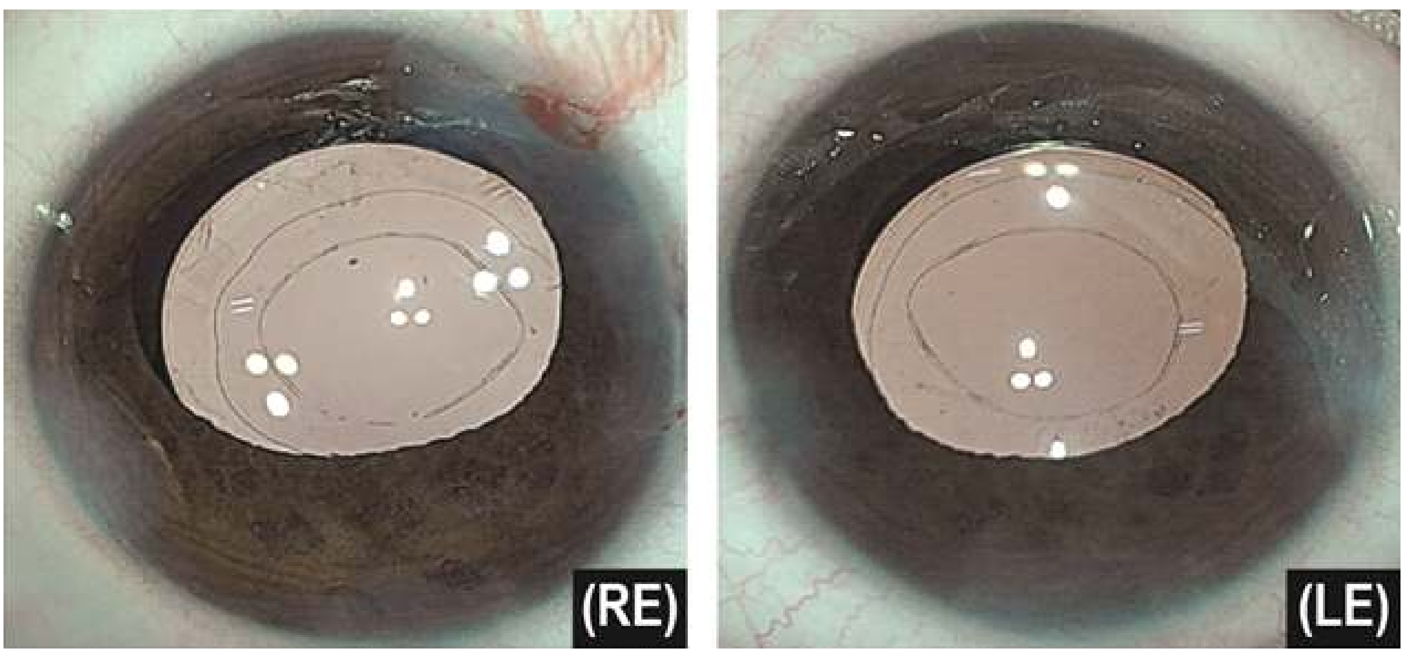

Figure 1 - CLE surgery images showing the right and left eye, with a PCCC and PCIOL in the bag.

DISCUSSION :

We devised a two-step treatment plan for this young patient with very high hyperopia, combining both lens-based and cornea-based approaches in a sequential manner. Due to the limitation of the availability of high power plus lens, we aimed to achieve the maximum possible correction with the IOL and scheduled a second session of surface ablation later.

In CLE, there is increased intraoperative susceptibility of raised positive vitreous pressure and a high risk of developing uveal

Injecting such thick lenses often encounters resistance, so it is essential to ensure smooth delivery with controlled, slow injection pressure. A primary posterior continuous curvilinear capsulorhexis (PCCC) was performed, as posterior capsular opacification (PCO) is almost inevitable in this age group. Moreover, the thickness of these lenses complicates YAG laser capsulotomy and increases the risk of IOL pitting.

Although this patient achieved a satisfactory visual outcome at the last follow-up visit (10 months post-PRK and more than 1-year post clear lens extraction procedure), a still longer follow-up is necessary to monitor a potential regression or other complications related to the surgery.

CONCLUSION :

While there is always an ongoing debate regarding the optimal treatment options for managing high hypermetropia, a tailored, step-by-step approach can be employed to achieve successful outcomes in individual cases. It is also essential to counsel the patient about the guarded visual prognosis, given the potential for refractive surprises and a high likelihood of regression over time.

DECLARATION OF PATIENT CONSENT :

The authors certify that due consent has been taken from the patient for the use of his/her eye clinical details and image for publishing, without any revelation of his/her name or initials.

FINANCIAL SUPPORT :

Nil

CONFLICT OF INTEREST :

Nil

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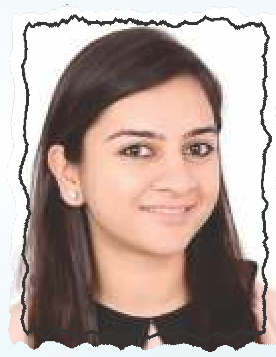
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