# Understanding the standard algorithm for corneal refractive surgery using laser ablation of PMMA surfaces


Carlos Dorronsoro[1], Daniel Cano[1], Sergio Barbero[1], Jesús Merayo[2], Lourdes Llorente[1] & Susana Marcos[1]

[1]Instituto de Optica, CSIC, Madrid, Spain e-mail: danielcanoreolgm@hotmail.com

[2]Instituto de Oftalmobiología Aplicada, Universidad de Valladolid, Valladolid, Spain



ARVO's 2003 Annual Meeting

May 4 – May 9. Fort Lauderdale, Florida

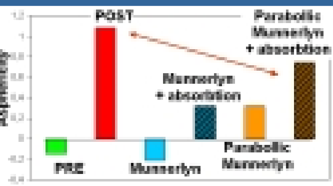

## ❶ Background & Purpose

### Goal: PMMA model

1. To understand standard algorithms for corneal refractive surgery
2. To validate different measurement techniques for ablated PMMA surfaces
3. To study changes in asphericity (spherical aber.) and test predictions

### Background

1. Clinical results: Corneal refractive surgery for myopia (PRK and LASIK) induces positive spherical aberration
2. The Munnerlyn algorithm should not induce spherical aberration. A parabolic approximation of this algorithm produces a slight increase in asphericity




3. Radial changes in laser efficiency (due to the curved corneal shape) produce additional increase in asphericity
4. A PMMA model can test the contributions of the algorithm and reflection to increased asphericity as opposed to biomechanical effects / epithelial healing

## ❷ Methods

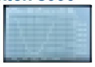
**Standard** LASIK **Ablation of** flat and spherical **(7.5, 8 and 8.6 mm radius)** PMMA surfaces

- **Spherical correction: -3 thru -12 D** Optical zone: 6 mm
- **Flying spot laser** (B&L, Chiron Technolas 217) Conventional software
- **Post-ablation profilometry** Three different methods

### Contact Profilometry

On flat surfaces: Dektek 3000

On spheres: Talysurf



### Confocal imaging profiler

SENSOFAR PLμ

Scanning microscope

### Videokeratoscopy

Atlas Humphrey, Zeiss

Control of all spherical surfaces prior to ablation

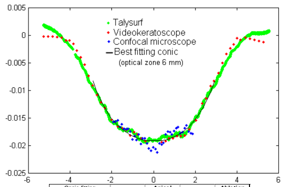
Post-ablation measurements of ablated spheres after slight polishing

### Data Proccessing

Custom software to obtain: 1. Ablation profiles on flat / spherical surfaces. 2. Post ablation curvature and asphericity

### Comparison

- Same results for different methods
- Adecuate fitting of ablation profiles

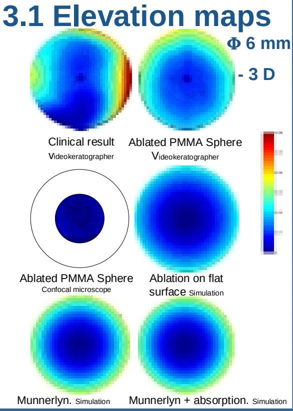



| Conic fitting | Radious PRE | Apical radious POST | Asphericity | Ablation Depth (microns) |
|---|---|---|---|---|
| Talysurf | 8.01 | 8.10 | -0.17 | 19.39 |
| Videokeratographer | 8.01 | 8.11 | -0.19 | 18.71 |
| Confocal | 8.01 | 8.08 | - | - |

Example ablation: Nominal correction: -3 Dp. Optical zone 6 mm. Only one random meridian plotted and fitted

## ❸ Results

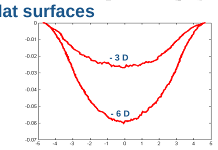
### 3.1 Elevation maps



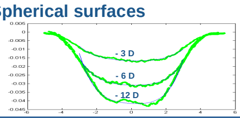

### 3.2 Ablation profiles

Predictions

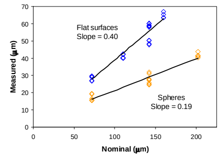

Flat surfaces



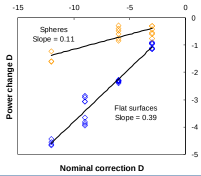

Spherical surfaces




### 3.3 Ablation depth

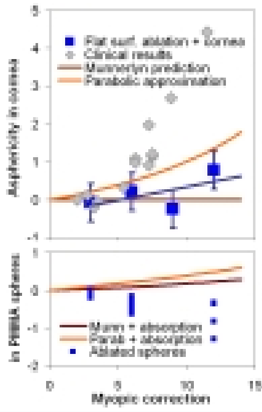



### 3.4 Correction




### 3.5 POST- ablation asphericity (Flat surfaces & spheres)

- Ablations found for **flat surfaces match closely the predictions** from a parabolic approximation of the Munnerlyn algorithm: applied on ideal corneas produced a **slight increase in asphericity**, but much less than for post-operative corneas
- Ablation profiles for **PMMA spheres** should incorporate additionally the effects of radial changes in laser efficiency. However, we found negative asphericity and undercorrection, probably due to central island effects



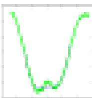

## ❹ Discussion

### 4.1 What have we learnt?

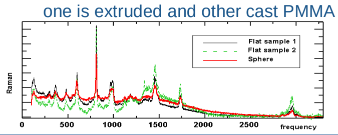
1. We have tested a **model for ablation on PMMA**
2. We have **validated different methods** of measurement for ablated surfaces, in particular, the use of **corneal topography**
3. Results match predictions on flat surfaces but not on spheres. That may be due to the material used (extruded vs cast).

### 4.2 Cause for flat/spherical surfaces disagreement?

1. **We found central island effects in spheres.** Ablation separates from a conic (R,K) causing smaller ablation depth, undercorrection, and negative asphericity
2. **Central islands were not found on flat surfaces** of regular PMMA, but were found on PMMA LASIK calibration plates

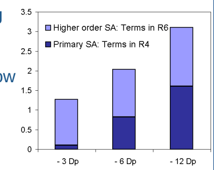


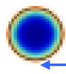
3. **Same conditions**: surgeon, laser, software, transition and optical zones. Careful alignment, focus, air flow and calibration
4. **Redeposition of material and laser shielding** by plume may be different, if there are structural differences across different PMMAs
5. **Raman Spectroscopy** does not detect differences in chemical composition or cristallization state
6. Different **porosity or hardness** may explain the ablation differences,if one is extruded and other cast PMMA



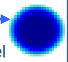

### 4.3 Higher order SA

- **Virtual ray tracing** on ablated surfaces provides accurate information about how ablation algorithm changes spherical aberration.



- **Higher order SA** (terms in $R^6$) **influence total SA as much as primary SA** ($R^4$) in PMMA model



## ❺ Conclusions

1. It is possible to develop PMMA models for the study of refractive surgery
2. Material has to be carefully selected
3. We have explored different techniques to measure profile/topography of ablated spheres finding equivalent results. Videokeratoscopy after polishing is the preferred method
4. Ablation profiles found on PMMA flat surfaces produce asphericity between Munnerlyn and parabolic approximation prediction
5. Ablated PMMA spheres did not reproduce the predicted increase in asphericity due to peripheral changes of laser efficiency
6. Increased post-op corneal asphericity must be the result of ablation effects and biomechanical factors

## ❻ References


1. D.Cano, S.Barbero, S.Marcos. "Computer Simulations of Corneal Shape and Corneal Aberrations after Laser Correction: Do They Match Real Outcomes?" ARVO Abstract #2090, 2003. (Tuesday, May 06, 2003, 11:30 AM -11:45 AM)
2. Marcos S, Barbero B, Llorente L, Merayo-Lloves J. Optical response to LASIK for myopia from total and corneal aberrations. Inv. Oph. Vis. Sci. 2001;42:3349-56.
3. Srinivasan R. Ablation of polymers and biological tissue by ultraviolet lasers. Science. 1986 Oct 31;234(4776):559-65.
4. J.R.Jimenez, R.G.Anera, L.Jimenez del B ,E.Hita. Effect on laser-ablation algorithms of reflection losses and nonnormal incidence on the anterior cornea. Appl. Phys. Lett.. 2002 81 , 1521-1523
5. Fuxbruner A, Hemo I, Lewis A, Zauberman H, Blau D, Polotsky D. Controlled lens formation with unapertured excimer lasers: Use with organic polymers and corneal tissue. Appl Opt 1990;29:5380-5386.
6. John D . Lytle. Polymeric optics. Chapter 34. Handbook of optics. Volume II. Sponsored by the Optical Society of America; Michael Bass, editor in chief. 2nd edition. 1995
7. Anera RG, Jimenez JR, Jimenez del Barco L, Hita E. Changes in corneal asphericity after laser refractive surgery, including reflection losses and nonnormal incidence upon the anterior cornea. Opt Lett. 2003 Mar 15;28(6):417-9.
8. Til Anschutz, Stefan Pieger. Correlation of Laser Profilometry Scans With Clinical Results. Journal of Refractive Surgery Volume 15 March/April (suppl) 1999; 252-256
9. Shimmick JK, Telfair WB, Munnerlyn CR, Bartlett JD, Trokel SL. Corneal ablation profilometry and steep central islands.J Refract Surg. 1997 May-Jun;13(3):235-45.


### Acknowledgements:


- Funded by CAM 08.7/0010./2000 - Comunidad de Madrid - Spain, BFM2002-02638 - Ministerio de Ciencia y Tecnología - Spain, Emory Vision, Atlanta, GA (USA)
- C. Dorronsoro thanks AlconCusí (Spain) and CSIC (Spain). S. Barbero thanks Ministerio de Educación y Cultura. D. Cano thanks Comunidad de Madrid
- Carl Zeiss, S.A. Spain, lent the Mastervue Atlas Corneal Topography System used in this study
- Flat surfaces were measured (contact profilometry) at Departamento de Investigación, CIDA, Madrid, Spain, thanks to Fernando Sánchez Sanz
- Contact profilometry on ablated spheres was made at INDRA, Aranjuez, Spain, thanks to Antonio Baeza
- Confocal microscopy measurements were made at Departamento de Óptica, Universidad Complutense de Madrid, thanks to José Sáez Landete
- Raman spectroscopy measurements were made at Instituto de Estructura de la Materia, CSIC, Spain, thanks to Santiago Sánchez Cortés
- The authors acknowledge Charlie Campbell for helpful suggestions