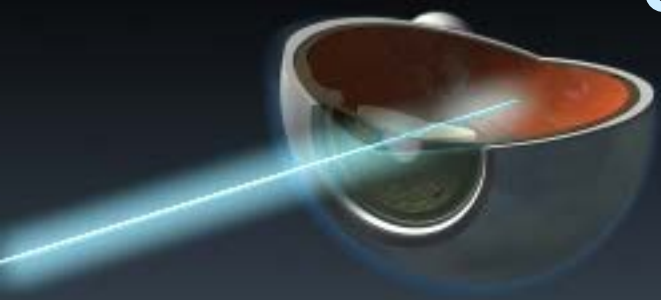


Using the Pentacam for Biometry after Keratorefractive Surgery: the BESSt Formula



Julian D Stevens, Consultant Moorfields Eye Hospital, London
 Edmondo Borasio, Consultant Moorfields Eye Hospital, Dubai
 Guy T Smith, Honorary Consultant Moorfields Eye Hospital, London

2013 Financial Statement

Julian Stevens is consultant
 Optimedica Inc.
 Oculentis GmbH / Topcon Ltd.
 Abbott Medical Optics Inc.
 Revision Optics Inc.

Edmondo Borasio is a shareholder in
 EB Eye Ltd

Moorfields Eye Hospital



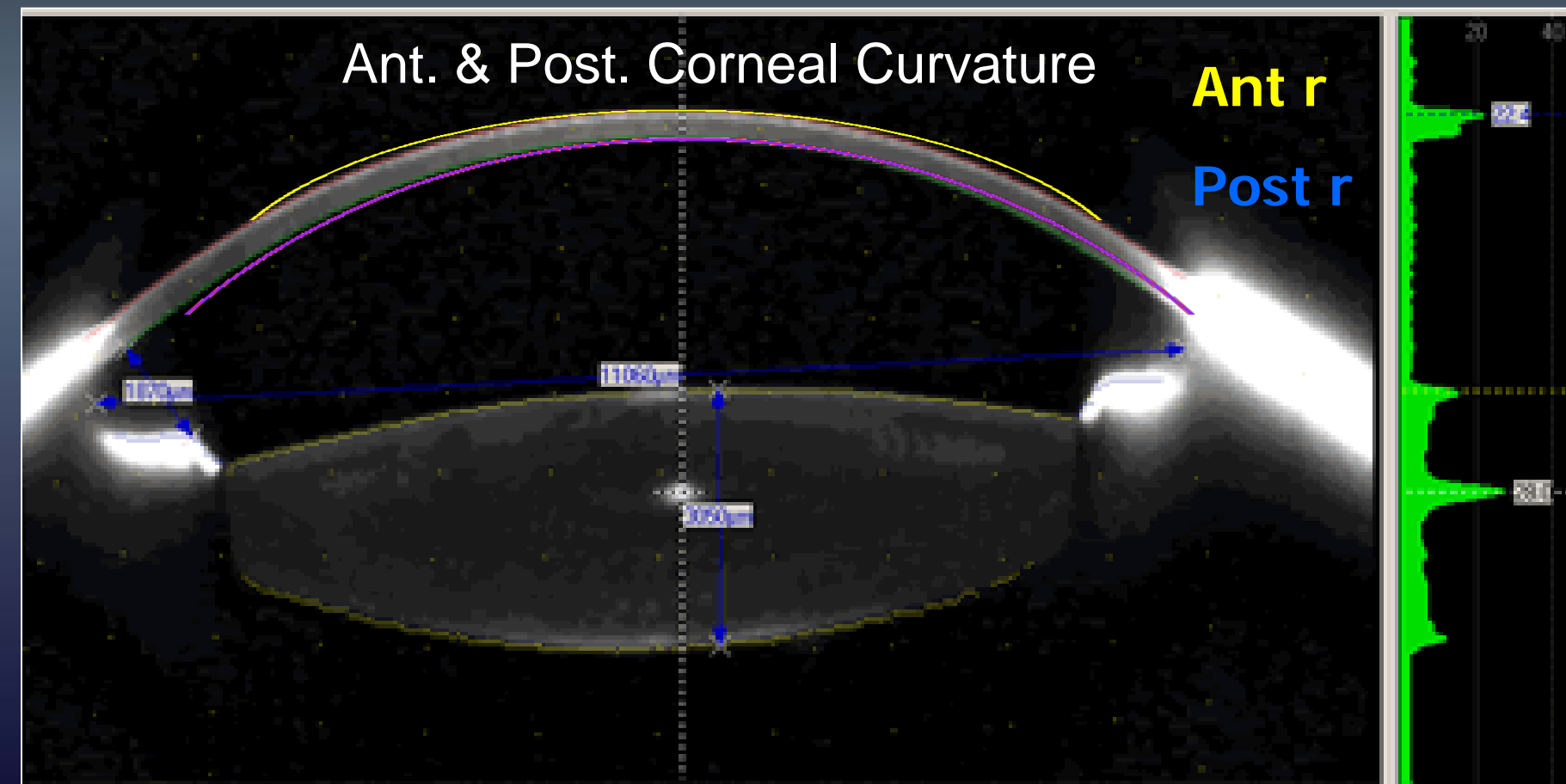
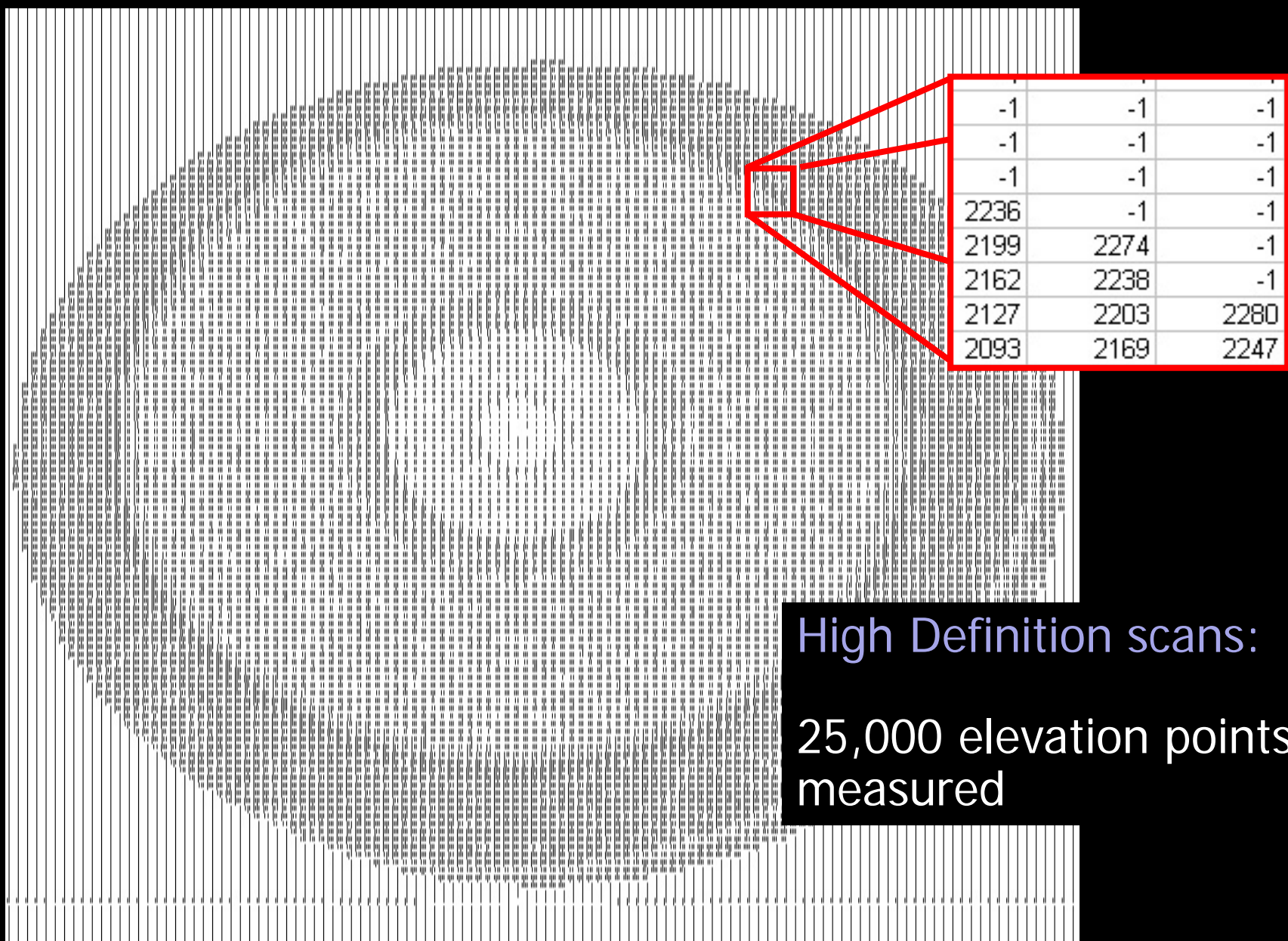
2013 ASCRS,

Julian D Stevens, MRCP,FRCS,FRCOphth.
 Consultant Ophthalmic Surgeon,
 Moorfields Eye Hospital,
 London



The Pentacam

The Pentacam



Right eye

1/25	Segment: 47° - 227°
2/25	Segment: 55° - 235°
3/25	Segment: 62° - 242°
4/25	Segment: 69° - 249°
5/25	Segment: 76° - 256°

Contrast Normal

Adjust Image

Last Name:

First Name:

ID:

Date of Birth: Eye: Right

Exam Date: Time:

Rh: 49.7 D Astig: +0.4 D

Rv: 49.2 D Ecc: 1.32

Axis: 102.9° QS: OK

Pachy: x[mm] y[mm]

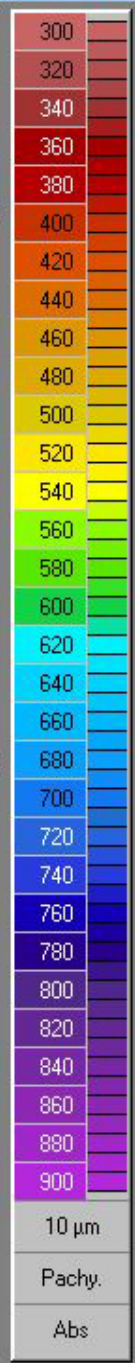
Pupil Center: + 481 μm -0.29 -0.04

Thinnest Locat.: o 456 μm -1.88 +1.07

Chamber Volume: 150 mm³ Angle: 31.5°

A. C. Depth (Endo.): 2.67 mm Pupil Dia: 3.08 mm

Enter IOP IOP(corr): Lens Th.:



Last Name:

First Name:

ID:

Date of Birth:

Exam Date:

Exam Info:

Cornea Front

Rm: 8.97 mm Rm: 37.6 D

Rh: 9.09 mm Rh: 37.1 D

Rv: 8.85 mm Rv: 38.1 D

QS: OK Axis: 173.5° Astig: -1.0 D

Ecc: -1.16 Rper: 7.87 mm Rmin: 7.47 mm

Cornea Back

Rm: 5.89 mm Rm: -6.8 D

Rh: 6.08 mm Rh: -6.6 D

Rv: 5.69 mm Rv: -7.0 D

QS: OK Axis: 170.3° Astig: +0.4 D

Ecc: 0.36 Rper: 6.32 mm Rmin: 5.63 mm

Pachy: x[mm] y[mm]

Pupil Center: + 349 μm +0.07 -0.05

Pachy Apex: • 349 μm 0.00 0.00

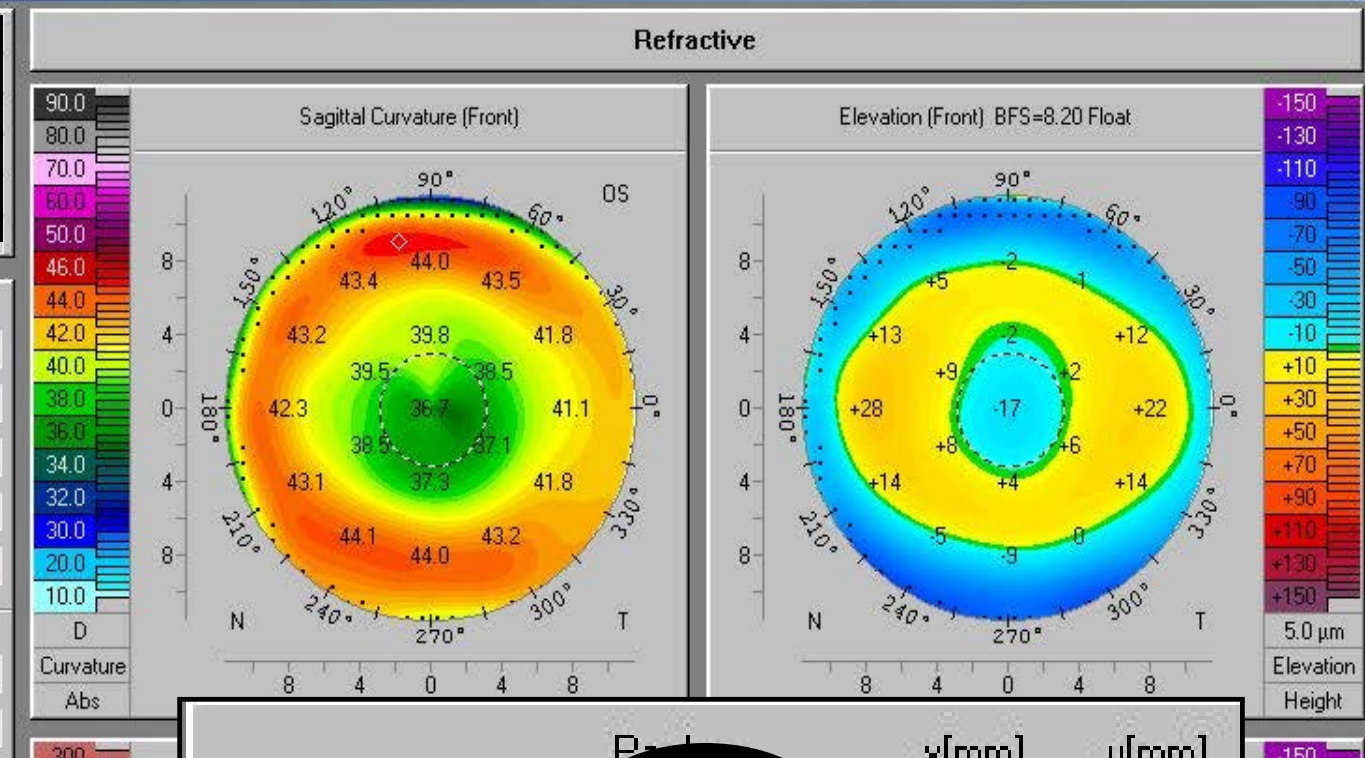
Thinnest Locat.: o 349 μm +0.19 0.00

Cornea Volume: 56.7 mm³ KPD: +2.5 D

Chamber Volume: 145 mm³ Angle: 34.7°

A. C. Depth (Endo.): 2.72 mm Pupil Dia: 3.03 mm

Enter IOP IOP(corr): Lens Th.:



Show Fill

Cornea Front

Cornea Back

Iris

Lens Front

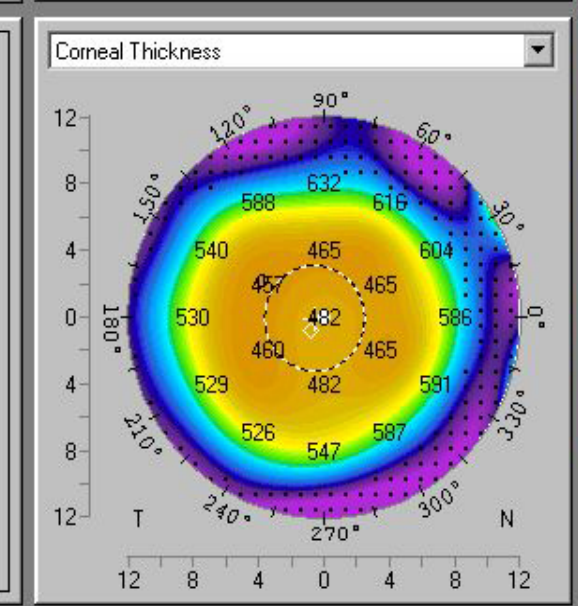
Lens Back

Scale

Cutout Width: 100°

Cutout Pos: 280°

Normalize Animate



Pupil Center: + 349 μm +0.07 -0.05

Pachy Apex: • 349 μm 0.00 0.00

Thinnest Locat.: o 349 μm +0.19 0.00

Last Name:

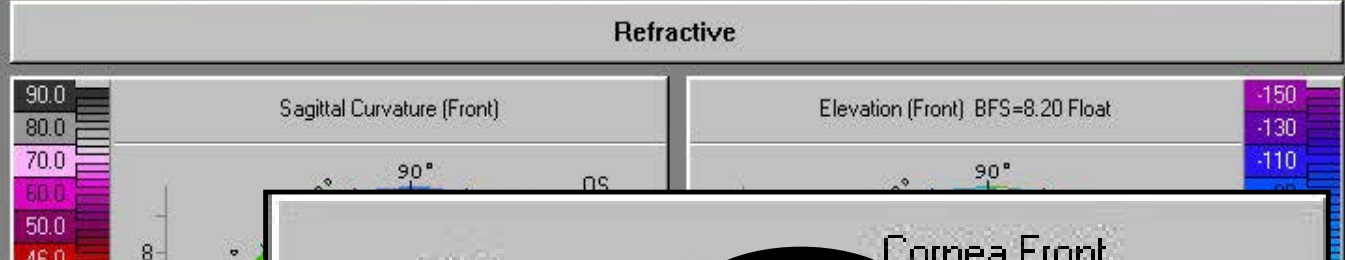
First Name:

ID:

Date of Birth:

Exam Date:

Exam Info:



Cornea Front

Rm: 8.97 mm Rm: 37.6 D

Rh: 9.09 mm Rh: 37.1 D

Rv: 8.85 mm Rv: 38.1 D

QS: OK Axis: 173.5° Astig: -1.0 D

Ecc: -1.16 Rper: 7.87 mm Rmin: 7.47 mm

Cornea Back

Rm: 5.89 mm Rm: -6.8 D

Rh: 6.08 mm Rh: -6.6 D

Rv: 5.69 mm Rv: -7.0 D

QS: OK Axis: 170.3° Astig: +0.4 D

Ecc: 0.36 Rper: 6.32 mm Rmin: 5.63 mm

Pachy: x[mm] y[mm]

Pupil Center: + 349 μm +0.07 -0.05

Pachy Apex: • 349 μm 0.00 0.00

Thinnest Locat.: o 349 μm +0.19 0.00

Cornea Volume: 56.7 mm³ KPD: +2.5 D

Chamber Volume: 145 mm³ Angle: 34.7°

A. C. Depth (Endo.): 2.72 mm Pupil Dia: 3.03 mm

Enter IOP IOP(corr): Lens Th.:

Cornea Front

Rm: 8.97 mm Rm: 37.6 D

Rh: 9.09 mm Rh: 37.1 D

Rv: 8.85 mm Rv: 38.1 D

QS: OK Axis: 173.5° Astig: -1.0 D

Ecc: -1.16 Rper: 7.87 mm Rmin: 7.47 mm

Cornea Back

Rm: 5.89 mm Rm: -6.8 D

Rh: 6.08 mm Rh: -6.6 D

Rv: 5.69 mm Rv: -7.0 D

QS: OK Axis: 170.3° Astig: +0.4 D

Ecc: 0.36 Rper: 6.32 mm Rmin: 5.63 mm

Pachy: x[mm] y[mm]

Pupil Center: + 349 μm +0.07 -0.05

Pachy Apex: • 349 μm 0.00 0.00

Thinnest Locat.: o 349 μm +0.19 0.00

Cornea Volume: 56.7 mm³ KPD: +2.5 D

Chamber Volume: 145 mm³ Angle: 34.7°

A. C. Depth (Endo.): 2.72 mm Pupil Dia: 3.03 mm

Enter IOP IOP(corr): Lens Th.:

Last Name:

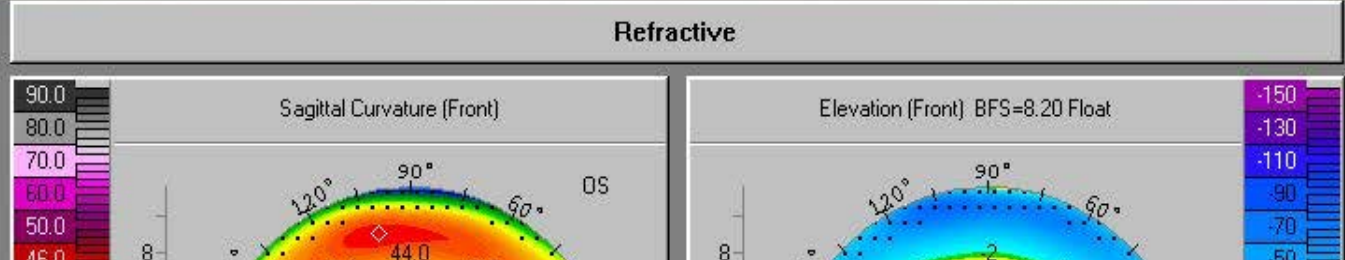
First Name:

ID:

Date of Birth:

Exam Date:

Exam Info:



Cornea Front

Rm: 8.97 mm Rm: 37.6 D

Rh: 9.09 mm Rh: 37.1 D

Rv: 8.85 mm Rv: 38.1 D

QS: OK Axis: 173.5° Astig: -1.0 D

Ecc: -1.16 Rper: 7.87 mm Rmin: 7.47 mm

Cornea Back

Rm: 5.89 mm Rm: -6.8 D

Rh: 6.08 mm Rh: -6.6 D

Rv: 5.69 mm Rv: -7.0 D

QS: OK Axis: 170.3° Astig: +0.4 D

Ecc: 0.36 Rper: 6.32 mm Rmin: 5.63 mm

Pachy: x[mm] y[mm]

Pupil Center: + 349 μm +0.07 -0.05

Pachy Apex: • 349 μm 0.00 0.00

Thinnest Locat.: o 349 μm +0.19 0.00

Cornea Volume: 56.7 mm³ KPD: +2.5 D

Chamber Volume: 145 mm³ Angle: 34.7°

A. C. Depth (Endo.): 2.72 mm Pupil Dia: 3.03 mm

Enter IOP IOP(corr): Lens Th.:

Cornea Back

Rm: 5.89 mm Rm: -6.8 D

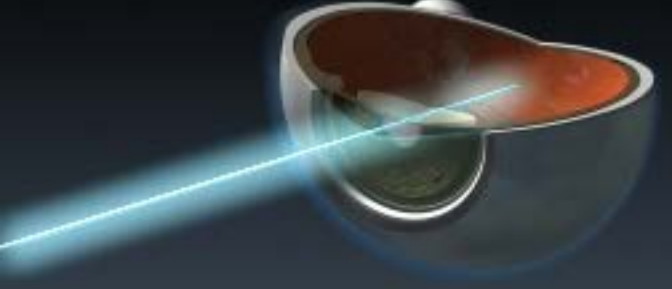
Rh: 6.08 mm Rh: -6.6 D

Rv: 5.69 mm Rv: -7.0 D

QS: OK Axis: 170.3° Astig: +0.4 D

Ecc: 0.36 Rper: 6.32 mm Rmin: 5.63 mm

[Range: -10.00 to +4.50 D]



Study Design

1) Development of the BESSt Formula

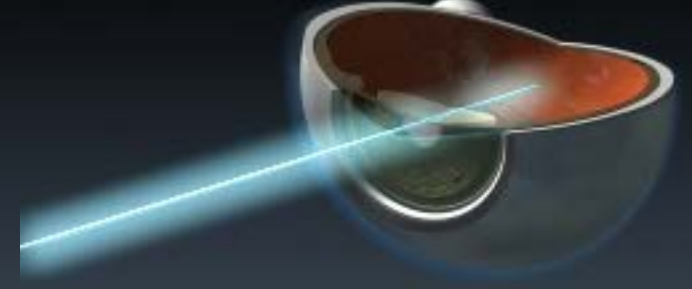
Developed on the outcomes of 170 eyes (WF LASIK-EK)

Myopia (123) Hyperopia (47)

Regression analysis

Variables of GOF (n; K) adjusted to achieve closest fit with the History Method-derived Ks → BESSt Formula.

The Gaussian Optics Formula (GOF)



$$F_{tot} = F_{ant} + F_{post} - (d/n) * (F_{ant} * F_{post})$$

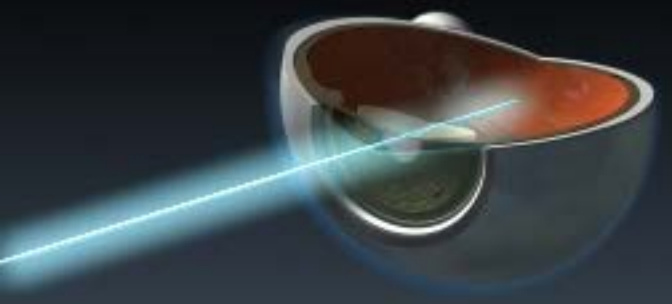
$$F_{tot} = (1/r_1 * (n_1 - n_0)) + (1/r_2 * (n_2 - n_1)) - (d/n_1) * (1/r_1 * (n_1 - n_0)) * (1/r_2 * (n_2 - n_1))$$

*Michaels DD
Visual Optics and Refraction: A Clinical Approach
3rd ed. St Louis: CV Mosby, 1985;25-45*

- r₁ = Radius of curvature Ant. Cornea (m)
- r₂ = Radius of curvature Pos. Cornea (m)
- d = Corneal Thickness (m)
- n₀ = Refr Index Air (1.000)
- n₁ = Refr Index Ant Surf. Cornea (1.376)
- n₂ = Refr Index Aqueous Humor (1.336)

n cornea = ideally should be measured

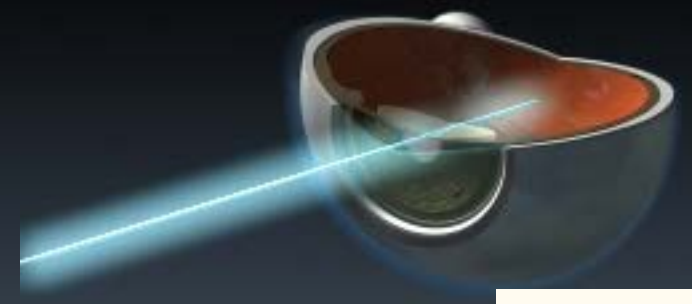
Methods



Data regarding:

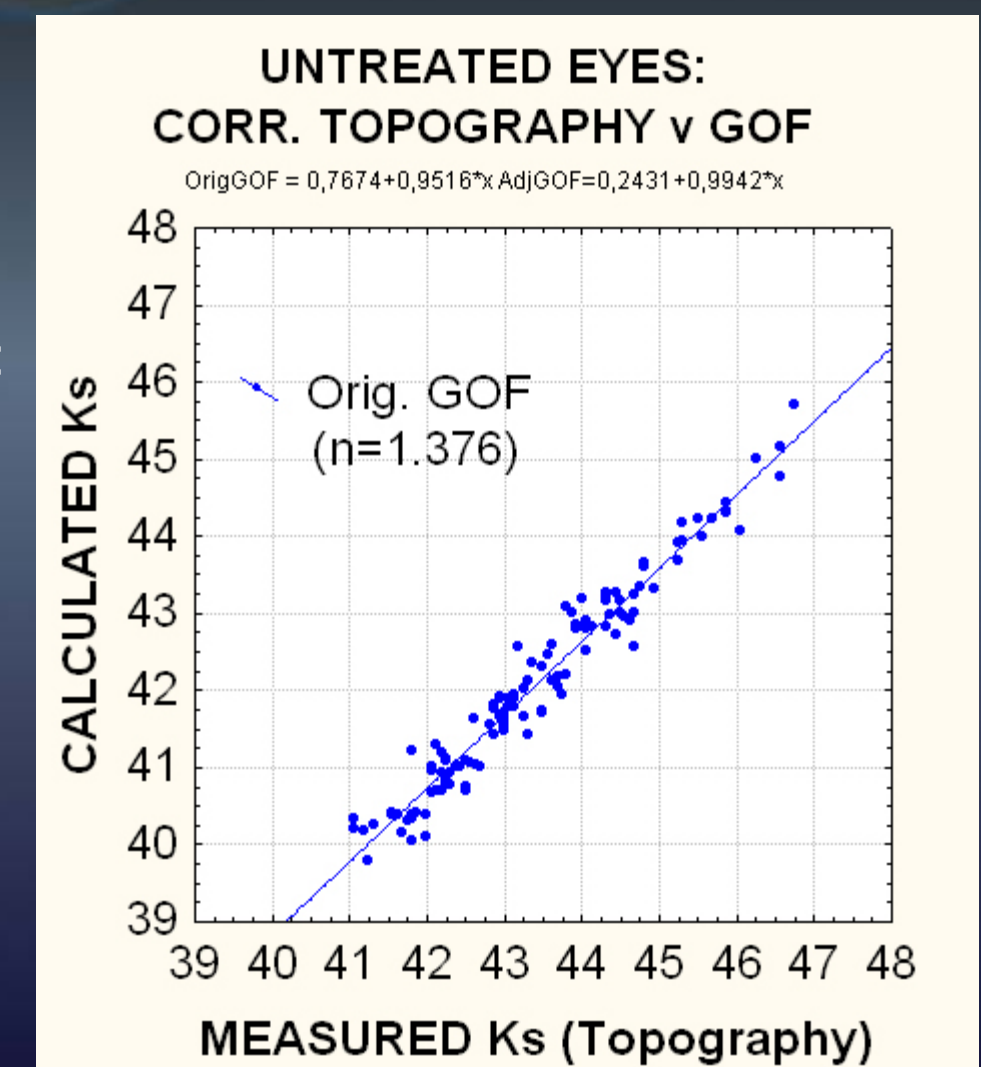
- Axial length (IOL Master, Zeiss™)
- Anterior and Posterior corneal curvature and
- Corneal thickness (Pentacam Scheimpflug Imaging, Oculus™)
- Corneal Topography (KR 8100PA, Topcon)

Correlation GOF- v Topography-derived Ks in untreated corneas



Corr. with Topography:

r = **0.97**
r² = **0.95**
p < **0.05**



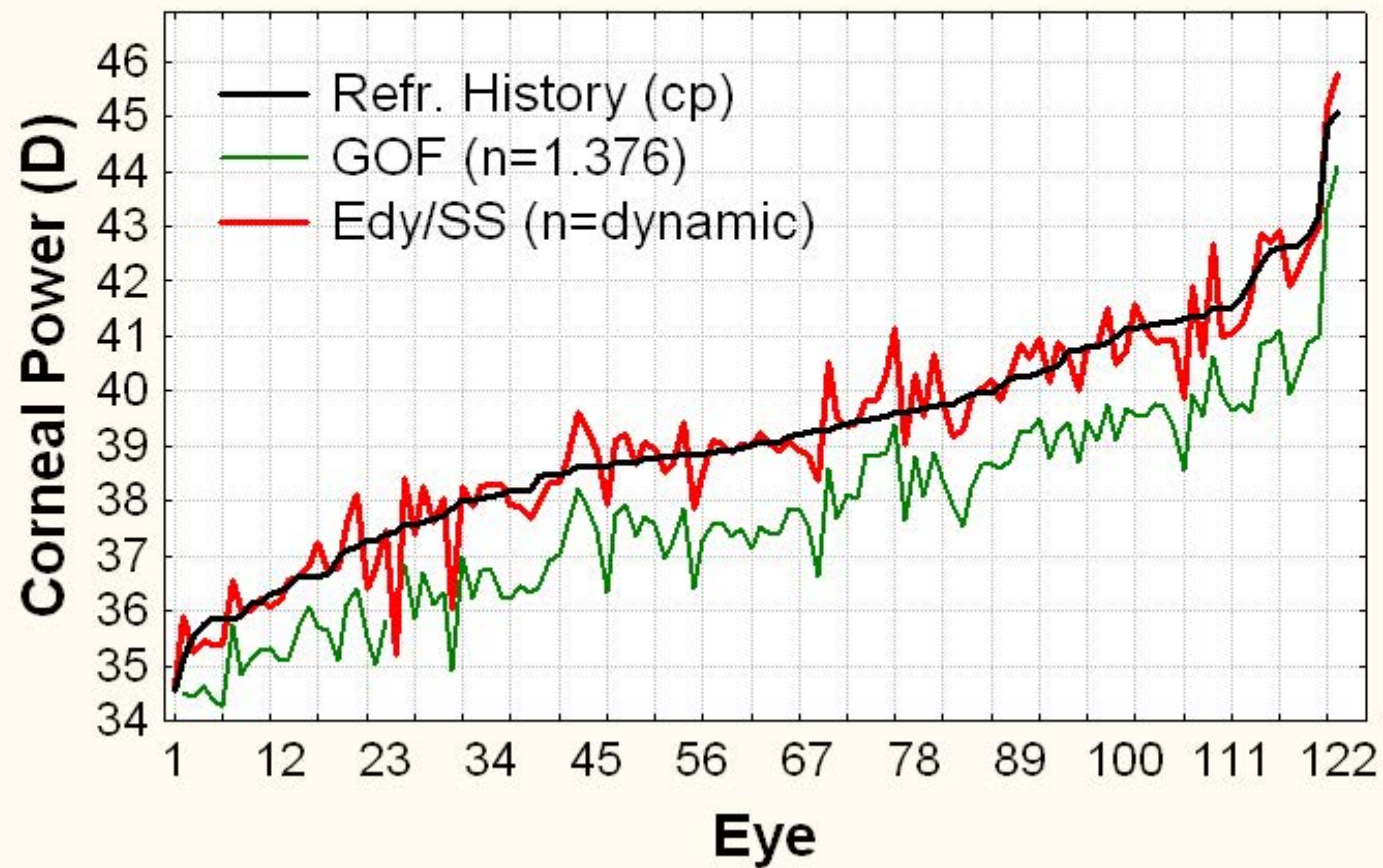
Mean Deviation from Topography:

-1.3
±0.29 SD

Corneas After Myopic Refractive Surgery

Dioptries of Myopia treated & changes in Refractive Index

CALCULATION OF CORNEAL POWER AFTER MYOPIC WF LASIK & LASEK



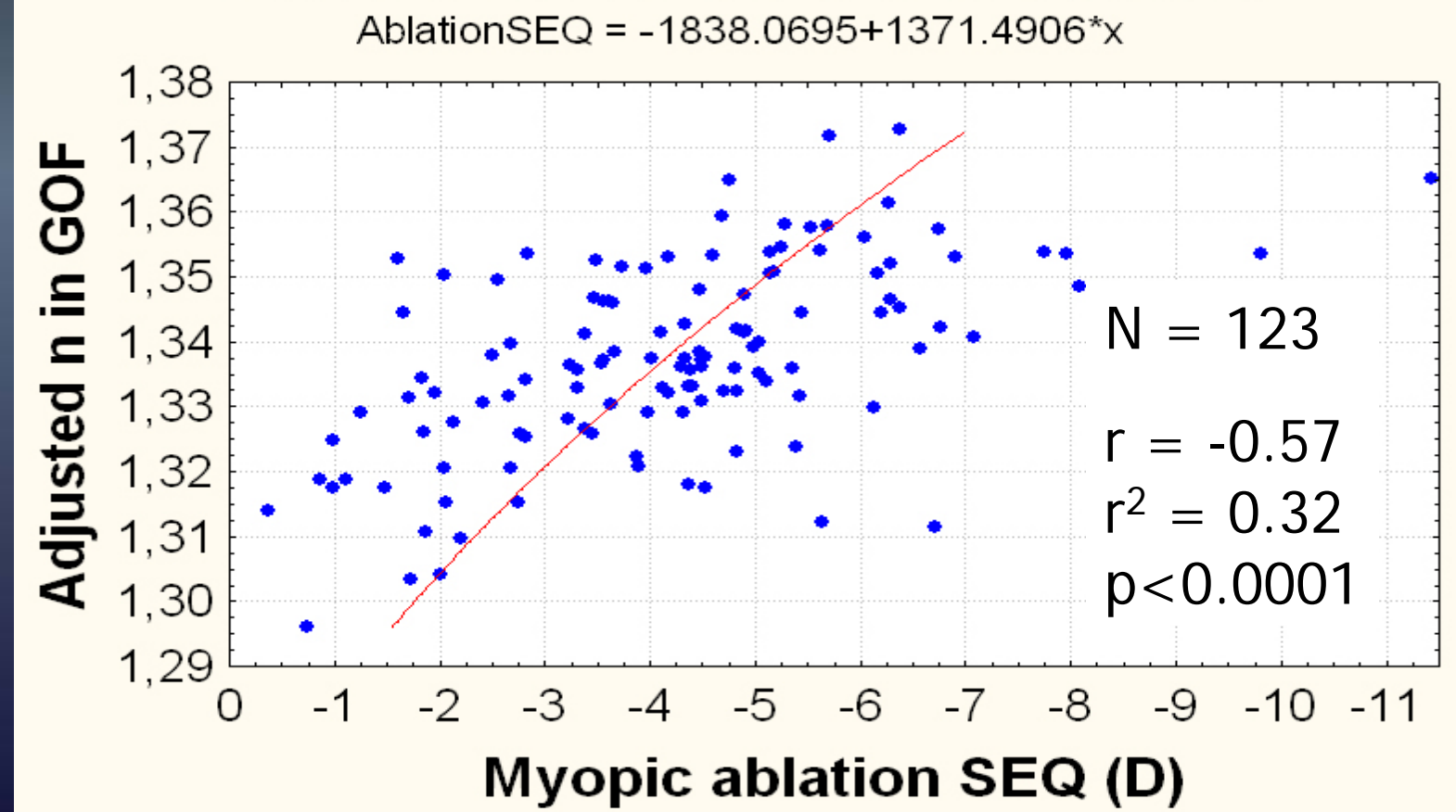
BESSt
v
Refr. Hist:

Correlation:
 $r = 0,96$
 $r^2 = 0.93$
 $p < 0.05$

Mean Deviation:
 -0.01 ± 0.55 SD

Abs. Deviation:
 -0.41 ± 0.36 SD

CORNEAL REFRACTIVE INDEX (n) v DIOPTRIES OF MYOPIC ABLATION



Direct correlation between Myopia treated & apparent increase in corneal refractive index

...without further adjustments, the GOF-derived Ks correlate to, but also significantly underestimate corneal power.

GOF measures the full corneal power (anterior & negative posterior surface), rather than the power of the sole anterior surface, as standard keratometers do.

JCRS, December 2006

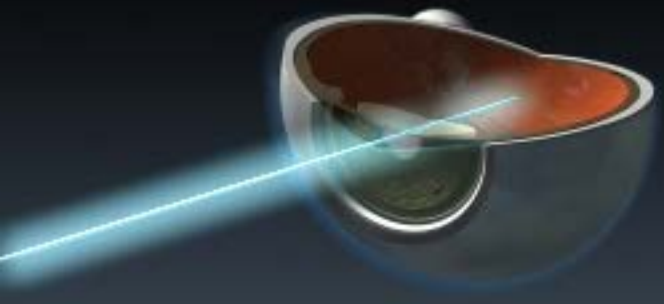
J CATARACT REFRACT SURG - VOL 32, DECEMBER 2006

ARTICLES

Estimation of true corneal power after keratorefractive surgery in eyes requiring cataract surgery: BESSt formula

Edmondo Borasio, MedC BQ Ophth, FEBO,
Julian Stevens, MRCP, FRCS, FRCOphth, Guy T. Smith, FRCOphth

Study Design



Prospective application of the BESSt Formula

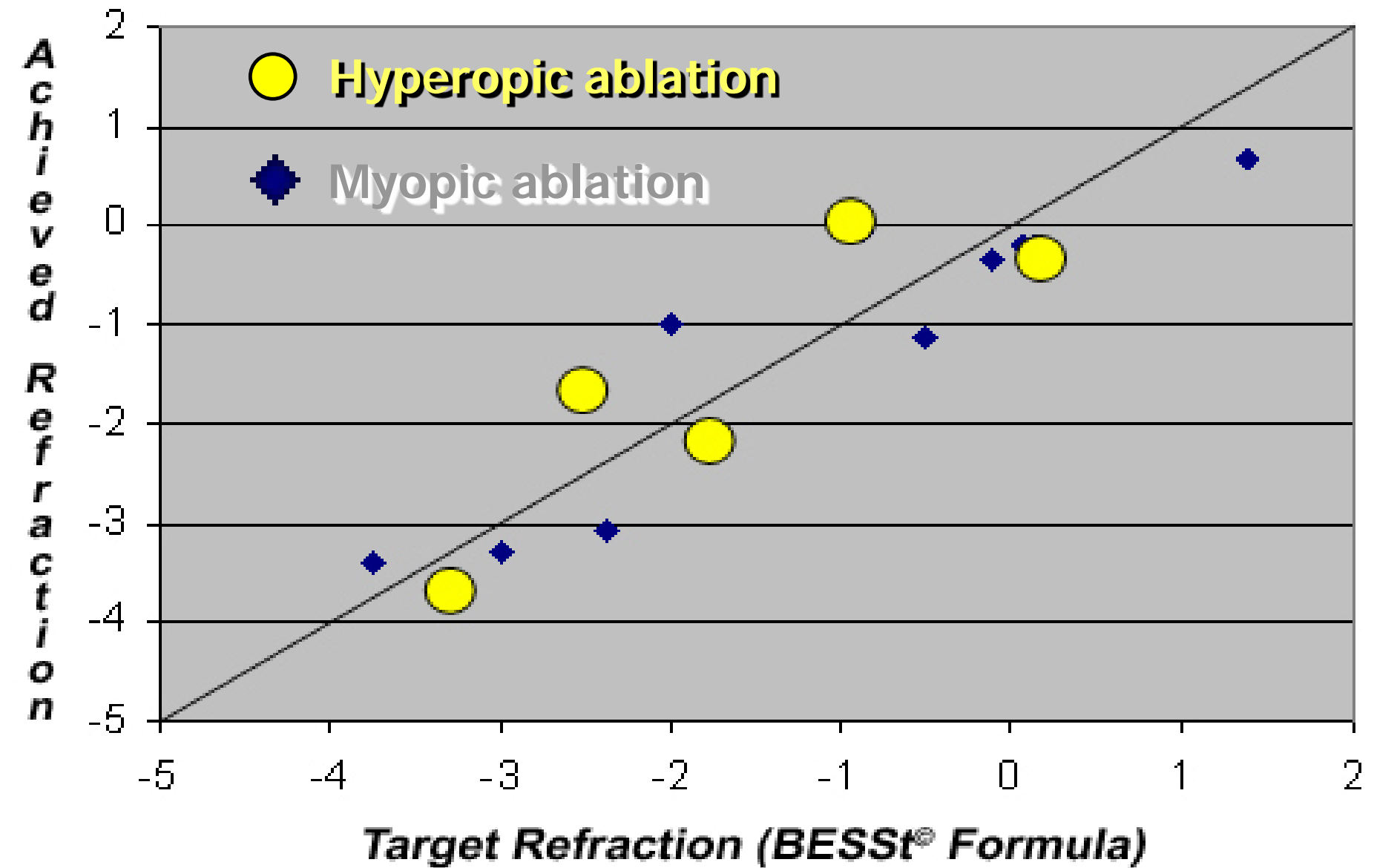
25 eyes post-Refractive surgery undergoing Phako+IOL

Myopia: $-5.5 \text{ D} \pm 2.1 \text{ SD}$. [Range -2.9 to -8.6]

Hyperopia: $+5.3 \text{ D} \pm 3.6 \text{ SD}$. [Range +1.7 to +8.5]

[Range: -8.6 to +8.5 D]

Achieved v Target Refraction (BESSt® Formula) after Phacoemulsification following Refractive Surgery

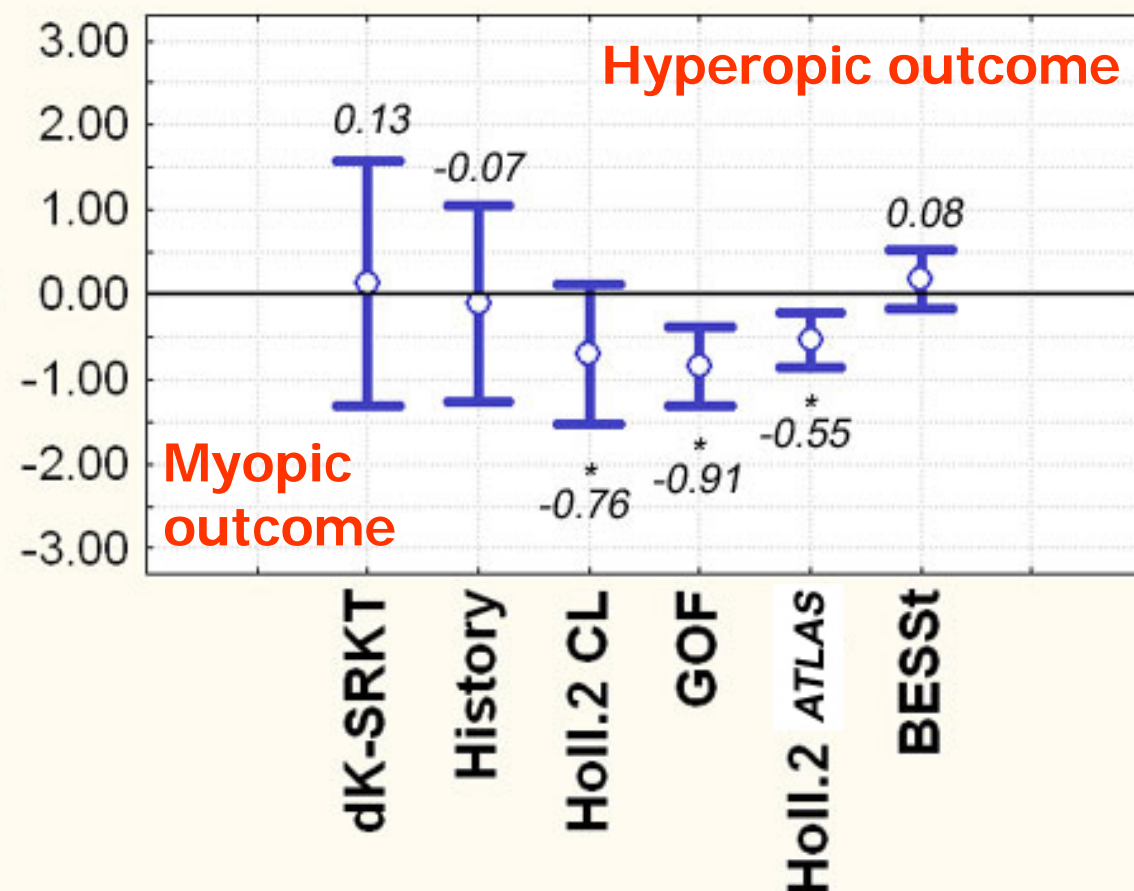


Outcomes Phako post Refr. Sx

Outcomes Phako post Refr. Sx

MEAN DEVIATION FROM TARGET REFRACTION

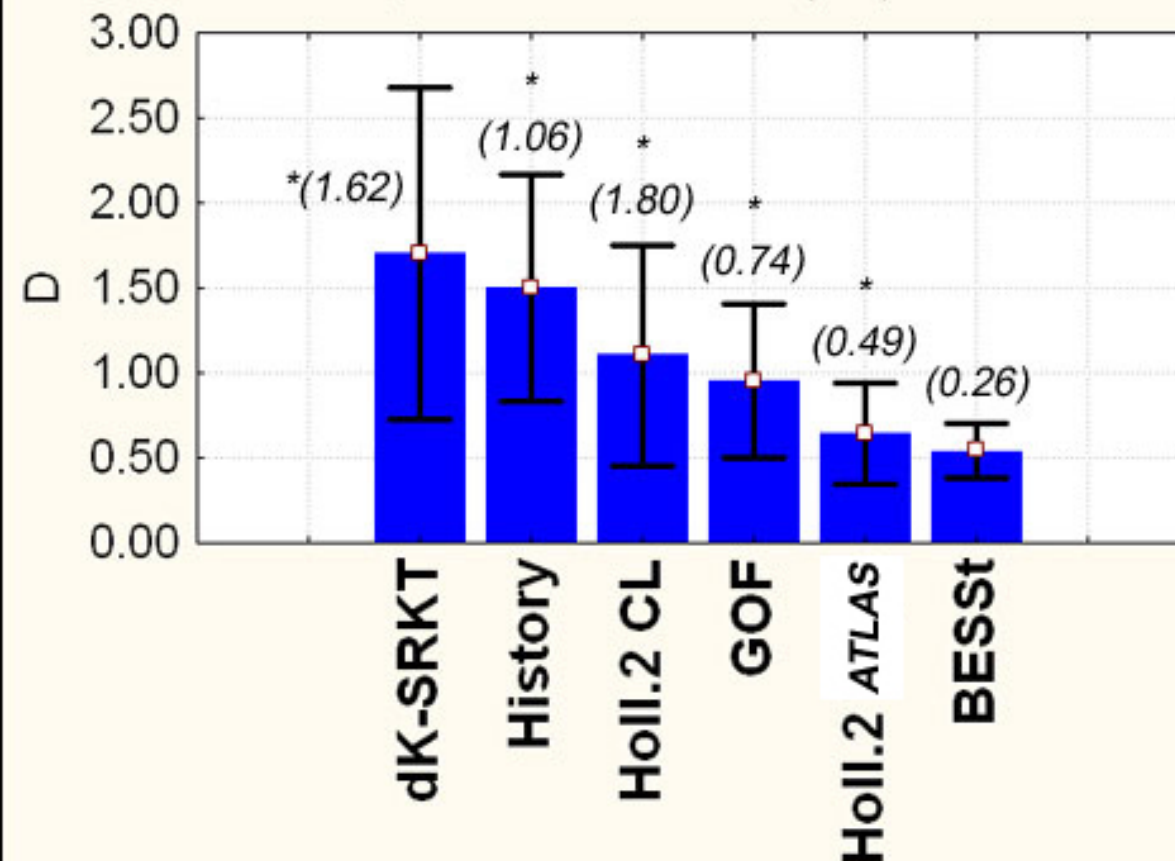
Mean; Whisker: Mean ± 0.95 Confidence Interv. (C.I.)



Reported values represent mean deviations

ABS. DEVIATION FROM TARGET REFRACTION

Abs. Mean; Whisker: Abs. Mean ± 0.95 Confidence Interv. (C.I.)



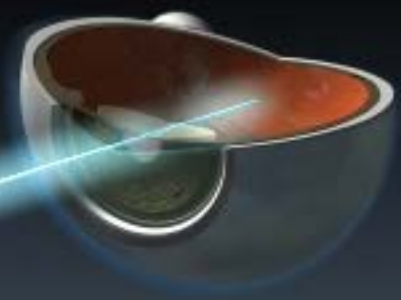
(SD in brackets)

* BESSt significantly more accurate (p<0.05)

○ Mean
 ┆ ±0.95 C.I.

■ Abs. Mean
 ┆ ±0.95 C.I.

Study



Mean Difference from Target

Original group
(N = 13)

2nd data set
(N = 25)

-0.08 ± 0.62 SD

0.31 ± 0.72 SD

0.03 ± 0.42 SD

0.45 ± 0.67 SD

-0.11 ± 0.78 SD

0.10 ± 0.72 SD

Myopic
Hyper

2007 BESSt formula (N = 25)



Difference From Intended					
≤0.50 D					
≤0.75 D					
≤1.00 D					
>1.50 D					

2007 BESSt formula (N = 25)



Difference From Intended	BESSt				Holladay2 Atlas
≤0.50 D	60 %				52 %
≤0.75 D	76 %				60 %
≤1.00 D	84 %				68 %
>1.50 D	0 %				8 %

2007 BESSt formula (N = 25)



Difference From Intended	BESSt	BESSt-M (Myopia) N=14			Holladay2 Atlas
≤0.50 D	60 %	64 %			52 %
≤0.75 D	76 %	79 %			60 %
≤1.00 D	84 %	86 %			68 %
>1.50 D	0 %	0 %			8 %

2007 BESSt formula (N = 25)



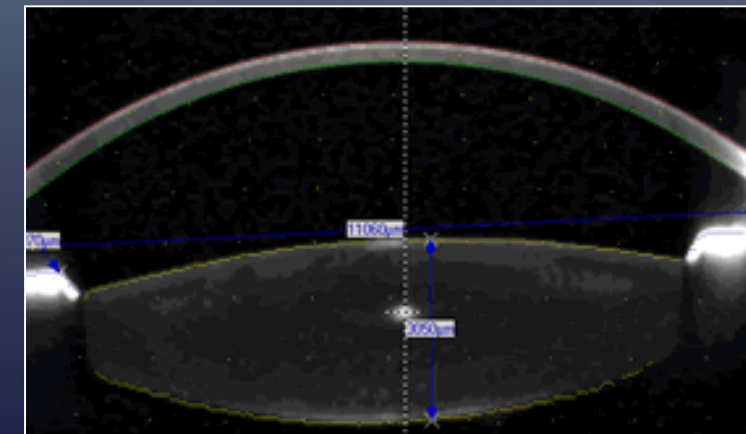
Difference From Intended	BESSt	BESSt-M (Myopia) N=14	BESSt-H (Hyperop) N=11	Holladay2 Atlas
≤0.50 D	60 %	64 %	55 %	52 %
≤0.75 D	76 %	79 %	73 %	60 %
≤1.00 D	84 %	86 %	82 %	68 %
>1.50 D	0 %	0 %	0 %	8 %

www.besstformula.com

The BESSt® Formula



- Is a modified version of the Gaussian Optics Formula (GOF) for Paraxial Imagery
- The **GOF** is an optical formula which allows to estimate corneal power from:
 - Corneal Radius (ant & post)
 - Corneal Thickness



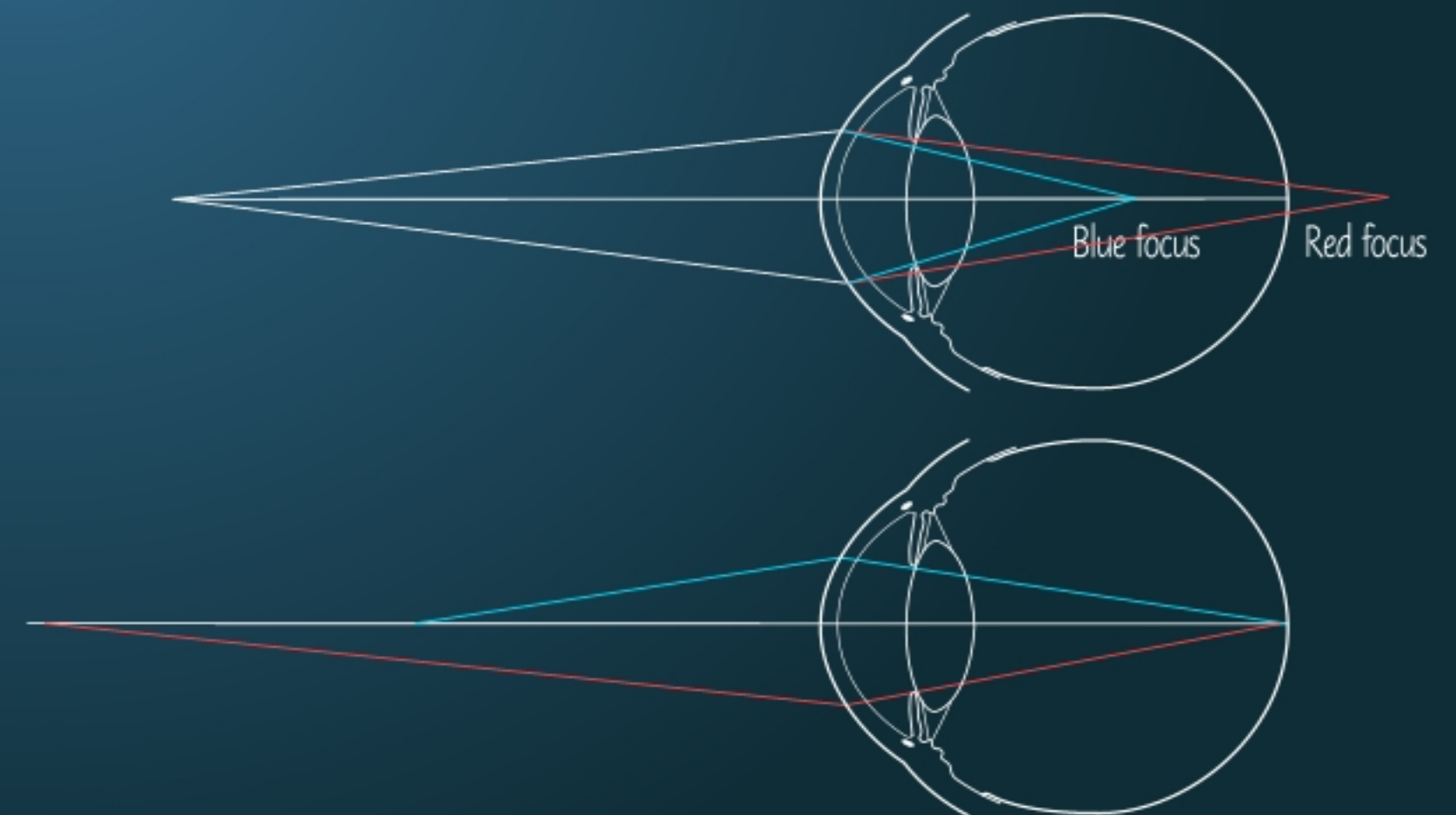
The Pentacam (Oculus™)

The BESSt® Formula Limitations

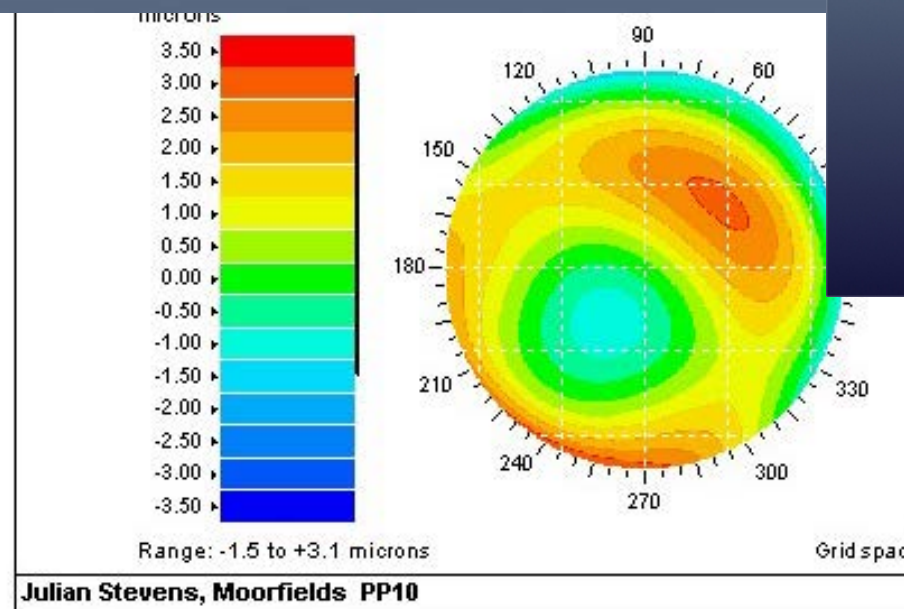
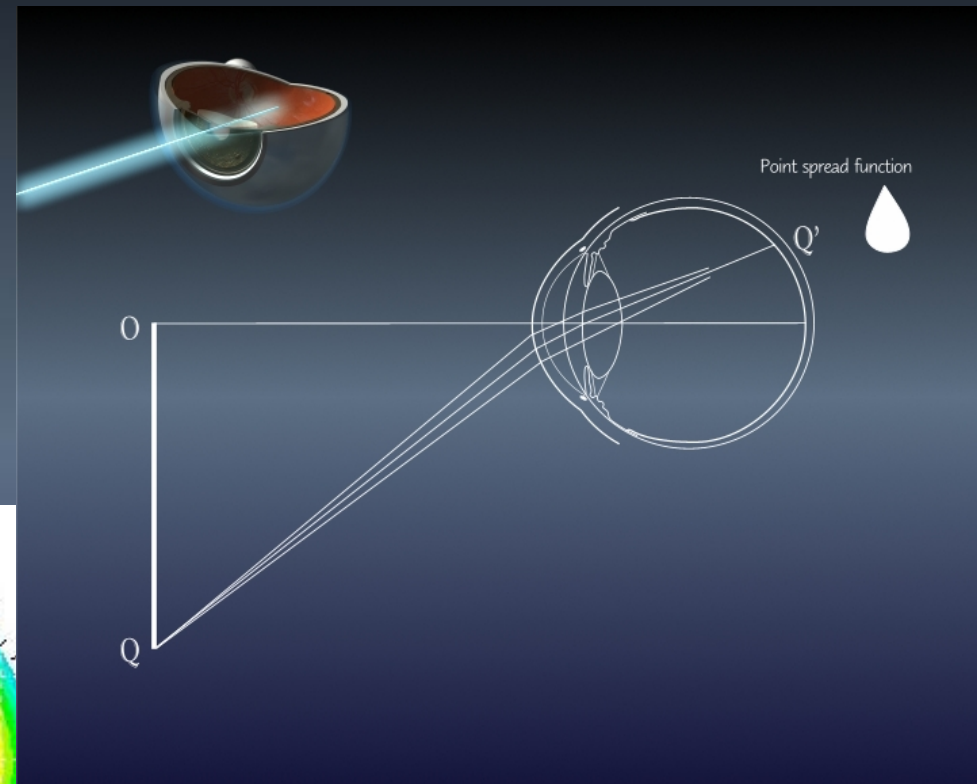
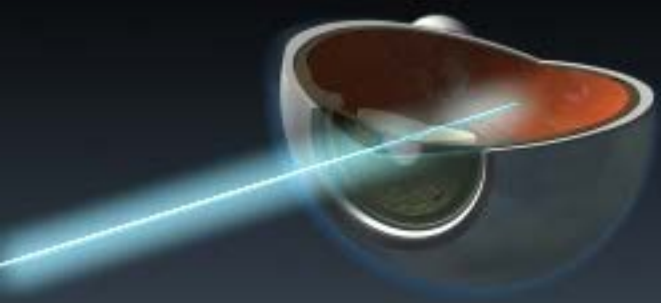


- Variation between Pentacam units
- The biometry formula the corneal effective power is entered into (SRK-T, Haigis, Hoffer-Q, Holladay II)
- Multifocality of ablations, especially hyperopia

The BESSt® Formula Limitations



The BESSt[®] Formula Limitations



BESSt v1.8 Formula



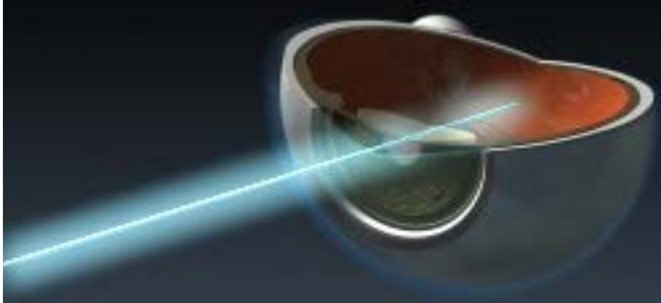
Is a modified version of the **Gaussian Optics Formula (GOF)** and **Vergence formula**.

It estimates Corneal and IOL power from:

- Ant & Post r (Corneal Radii after Ref Sx)
- Corneal Thickness (after Ref Sx)
- AL (After Ref Sx)

No need for pre-refractive surgery data

BESSt v1.8 Formula



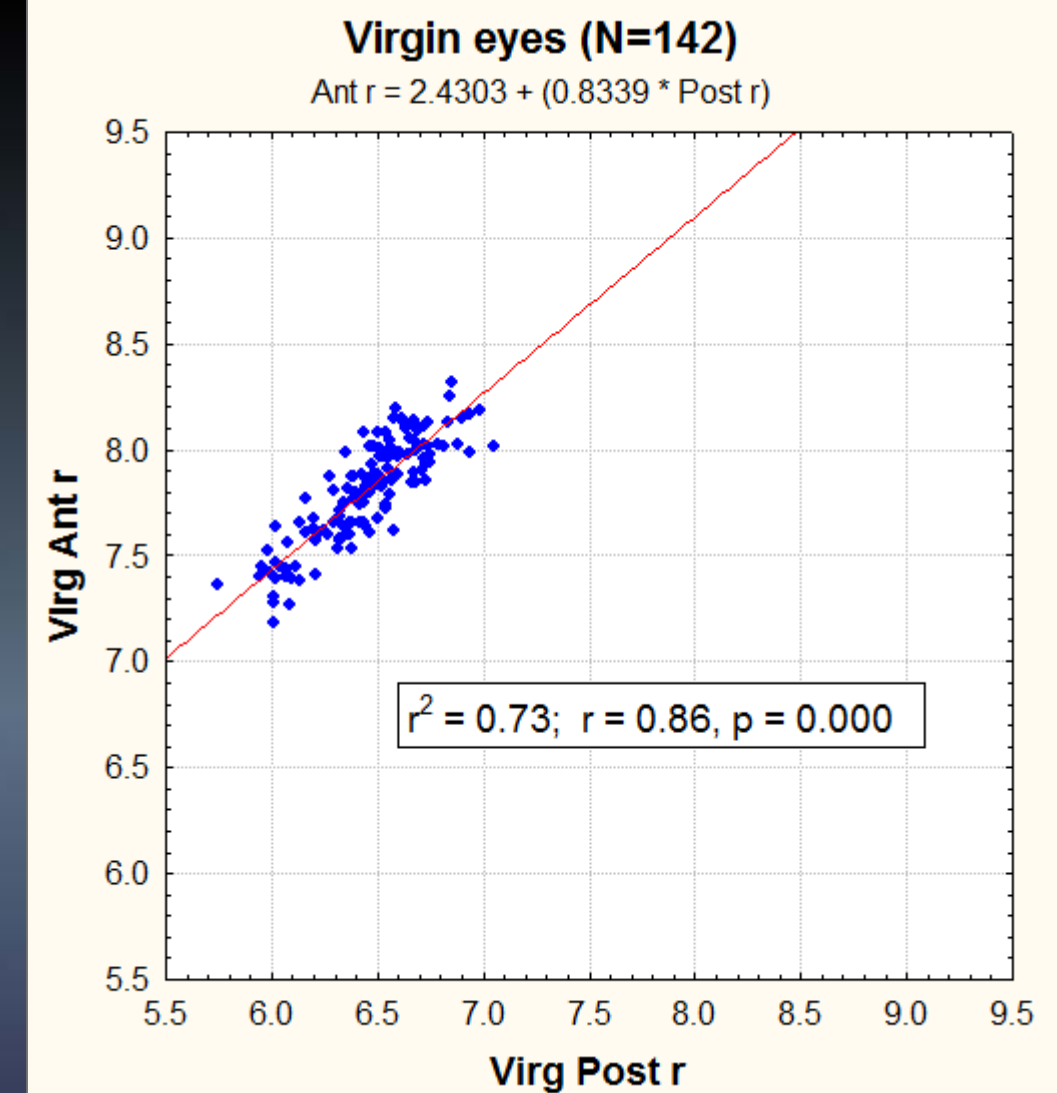
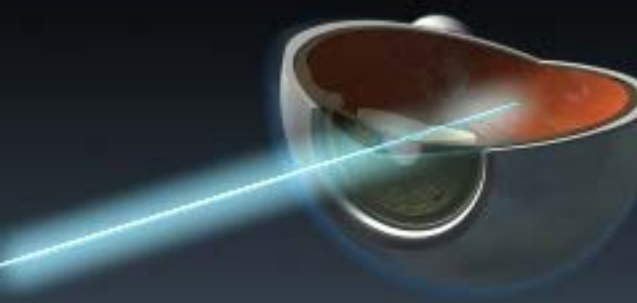
3rd Generation formulae:

SRK/T, HofferQ, Holladay 1

They underestimate the Effective Lens Position due to the centrally flattened cornea from the Myopic ablation.

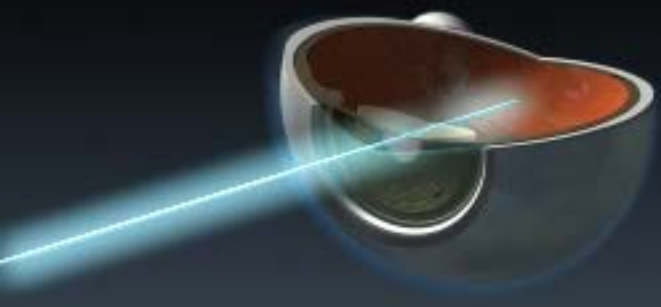
They require double-K adjustment after laser refractive surgery:

- **Double-K** (*pre-op K for Effective Lens Position; post-op K for IOL power*)



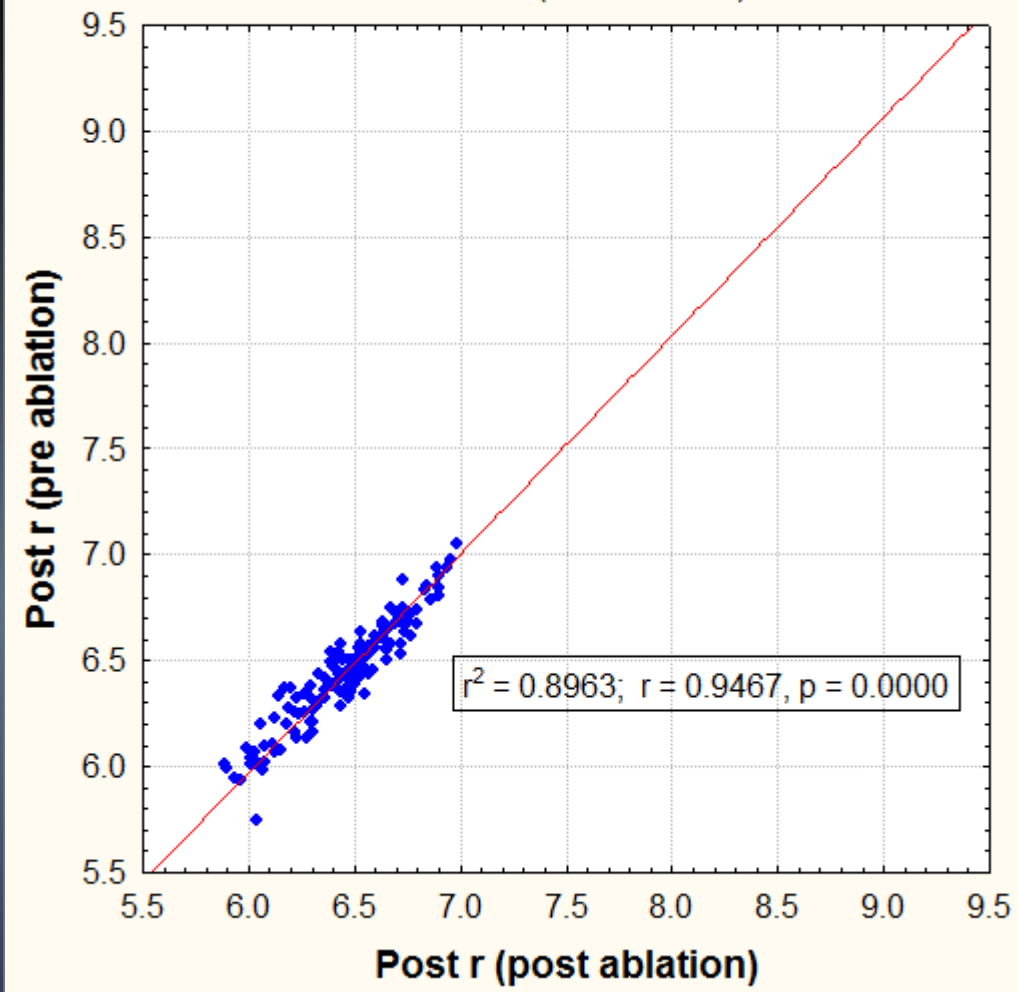
In Virgin eyes

Ant r can be predicted WELL (86%) From Post r

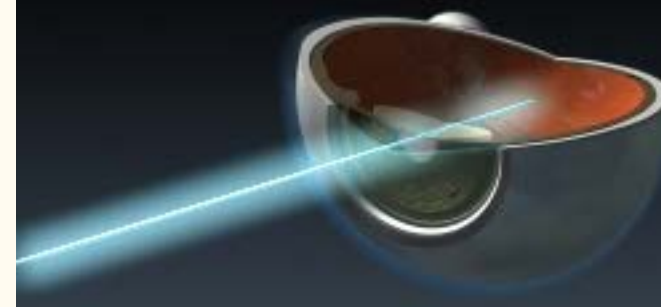


Change in Post r before & after surgery (N=143)

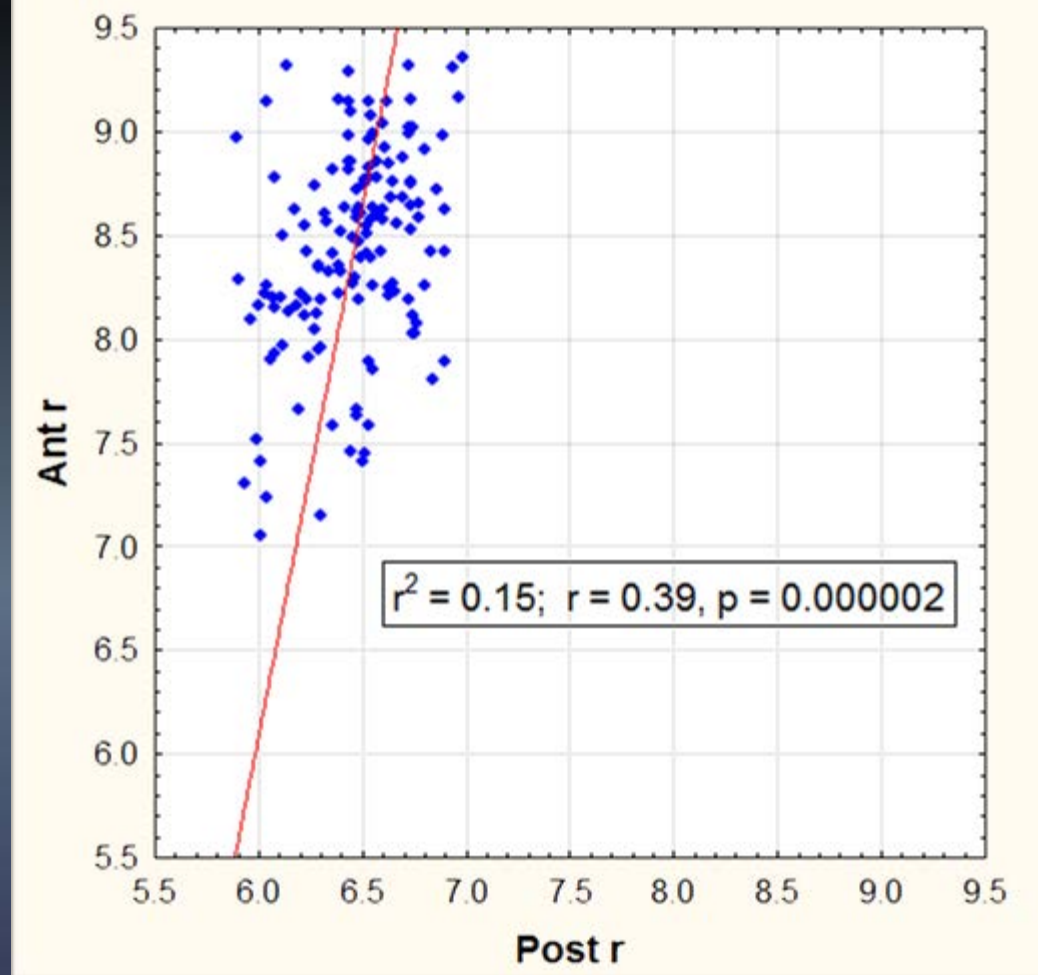
$$\text{Post r} = 0.2052 + (0.9701 * \text{Ant r})$$



Post r does NOT change after laser refractive surgery

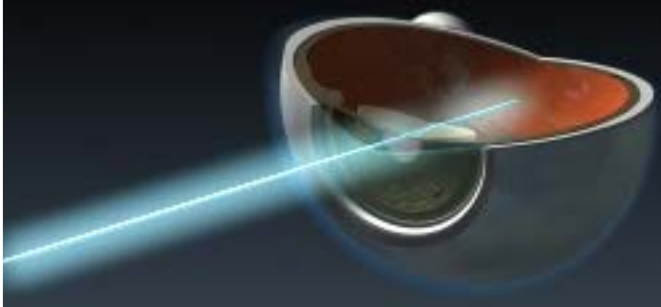


Post Myopic & Hyperopic Sx (N=142)



After laser refractive surgery Ant r becomes POORLY PREDICTABLE (39%) From Post r measurements

Conclusions BESSt Formula



Limitation of the reproducibility of the Pentacam

Limitation of prediction of final lens position in variable anterior chamber depth eyes: double K issue

76 % eyes within 0.75 D of intended

It does NOT require pre-Refr. Surg. information