UNIVERSITÀ DEGLI STUDI FIRENZE
DIPARTIMENTO DI FISICA E ASTRONOMIA

Light on Optics and Optometry

Tomografia Scheimpflug

12 Aprile 2024 – Lorenzo Fini

- le origini del metodo
- l’applicazione alla tomografia del segmento anteriore dell’occhio
- confronto tra le varie strumentazioni disponibili

Theodor Scheimpflug (1865-1911)

brevetto del 1904: **Improved Method and Apparatus for the Systematic Alteration or Distortion of Plane Pictures and Images by Means of Lenses and Mirrors for Photography and for other purposes**

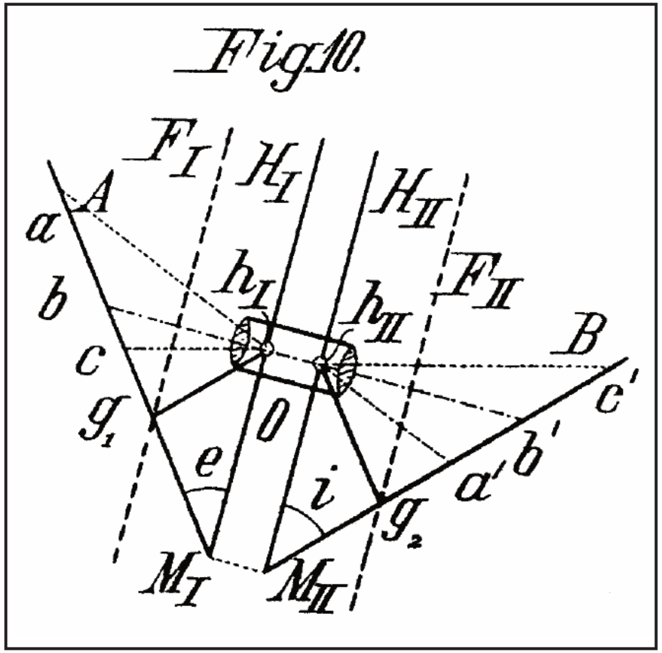


Fig. 10.
F I
H I
H II
F II
A
a
b
c
g1
h I
h II
B
c'
b'
a'
g2
e
0
i
M I
M II

disegno originale dal brevetto del 1904
(H. M. Merklinger, Scheimpflug's patent. Photo Techniques, Nov/Dec 1996)

Jules Carpentier (1851-1921)

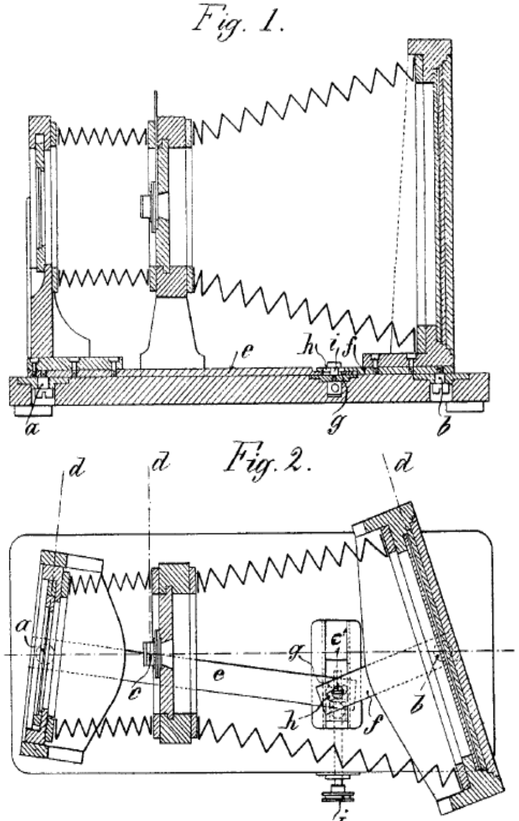
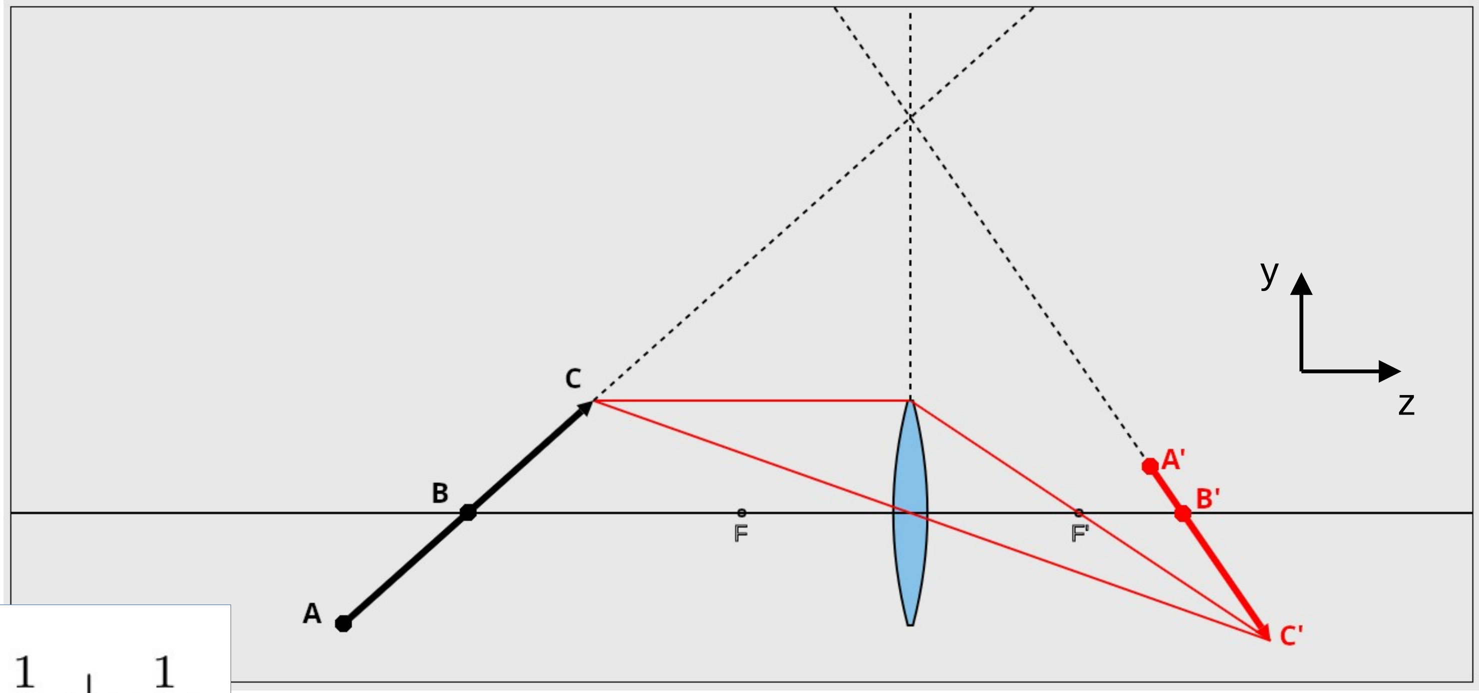


Fig. 1.
e
h
i
f
a
g
b
Fig. 2.
d
d
d
a
c
e
g
c'
h
f
b
i

illustrazioni dal brevetto Inglese (GB 1139/1901)
(H. M. Merklinger, Scheimpflug's patent. Photo Techniques, Nov/Dec 1996)

Jules Carpentier (1851-1921)

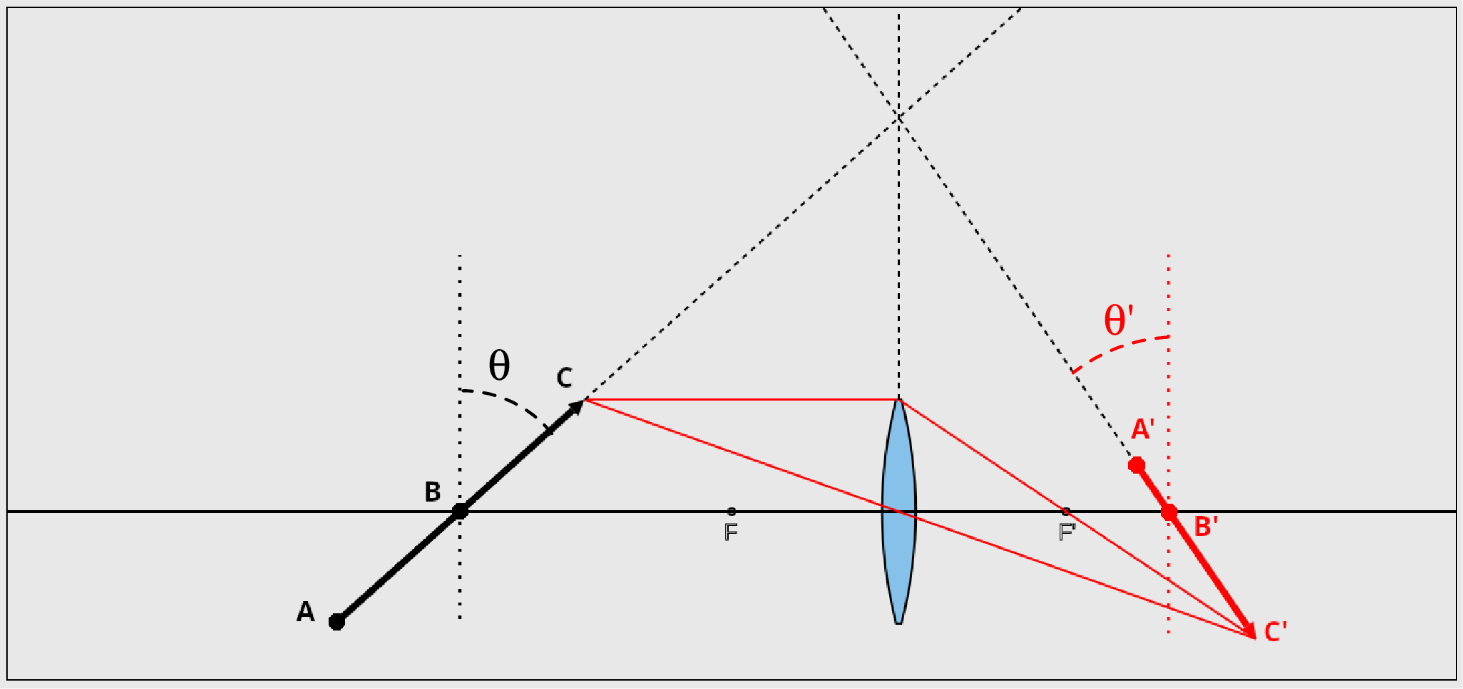
la regola di Scheimpflug


C
B
A
F
F'
A'
B'
C'
y
z

$$\frac{1}{z'} = \frac{1}{z} + \frac{1}{f'}$$

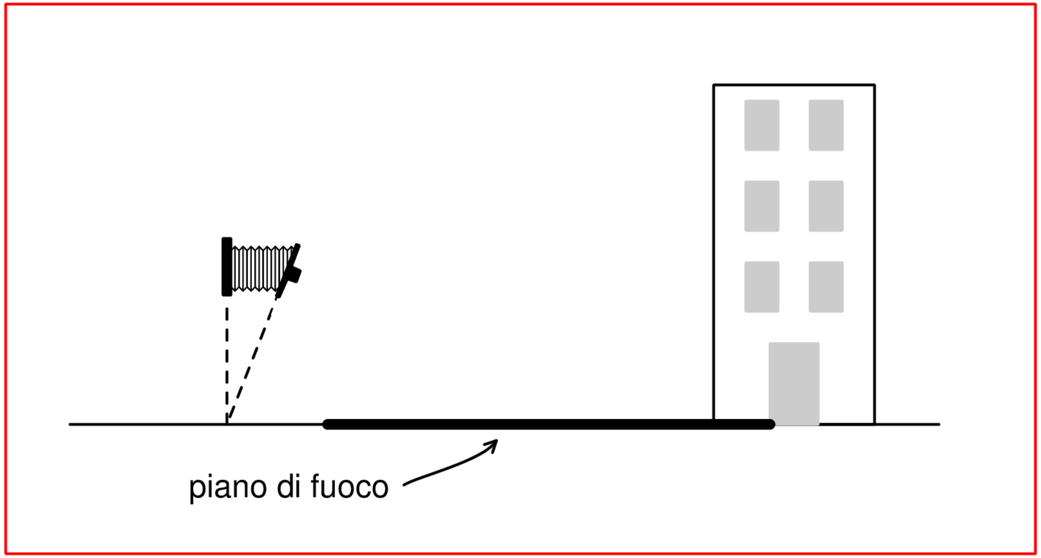
$$y' = \frac{z'}{z} y$$

la regola di Scheimpflug

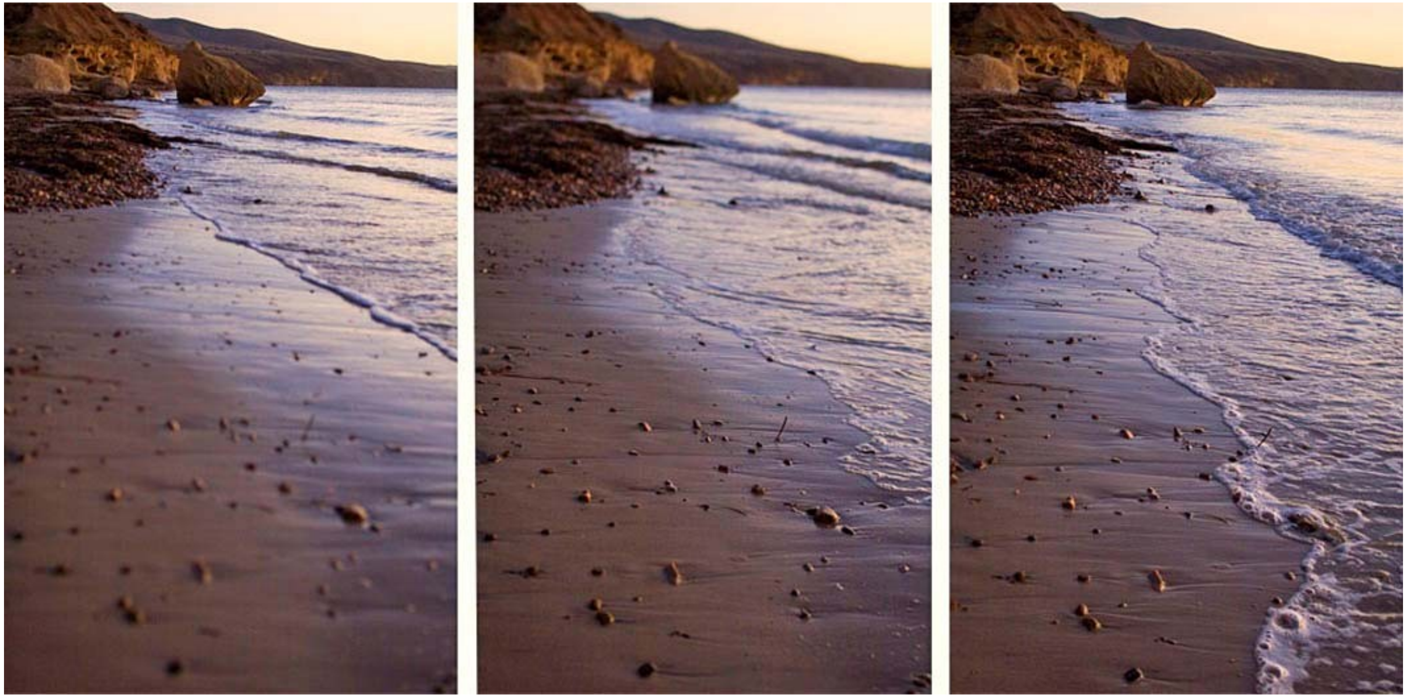

θ
C
B
A
F
F'
θ'
A'
B'
C'

$$\tan\theta' = \frac{z'_B}{z_B}\tan\theta$$

Fotografia Scheimpflug

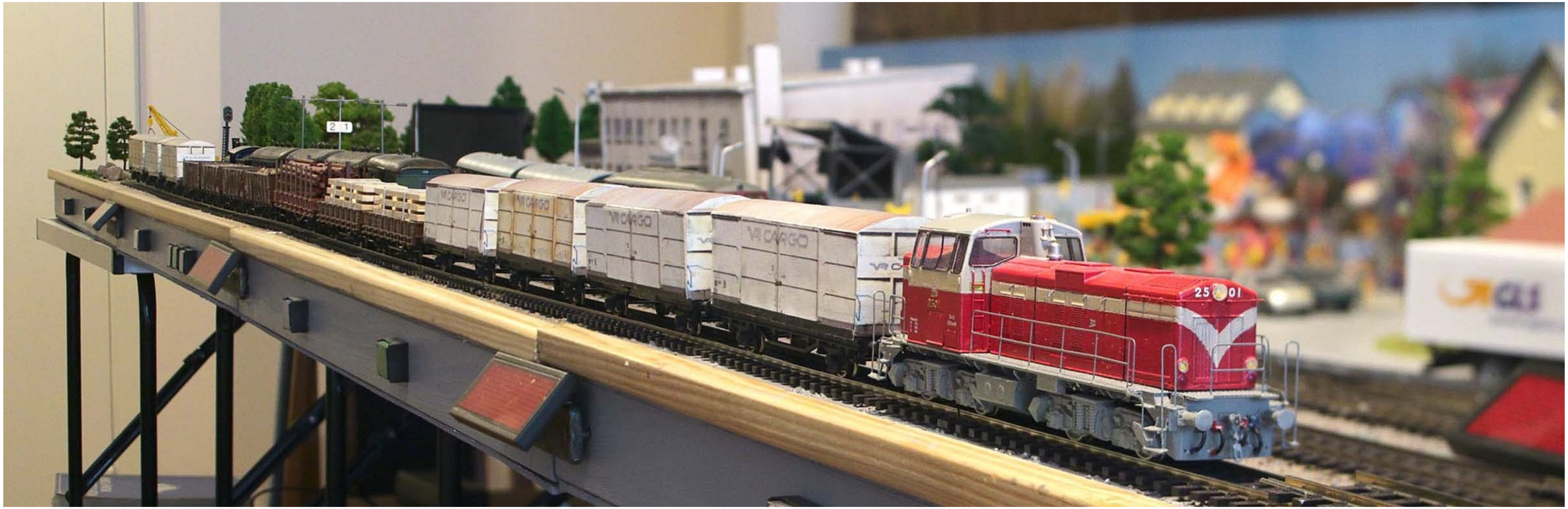

piano di fuoco

Fotografia Scheimpflug



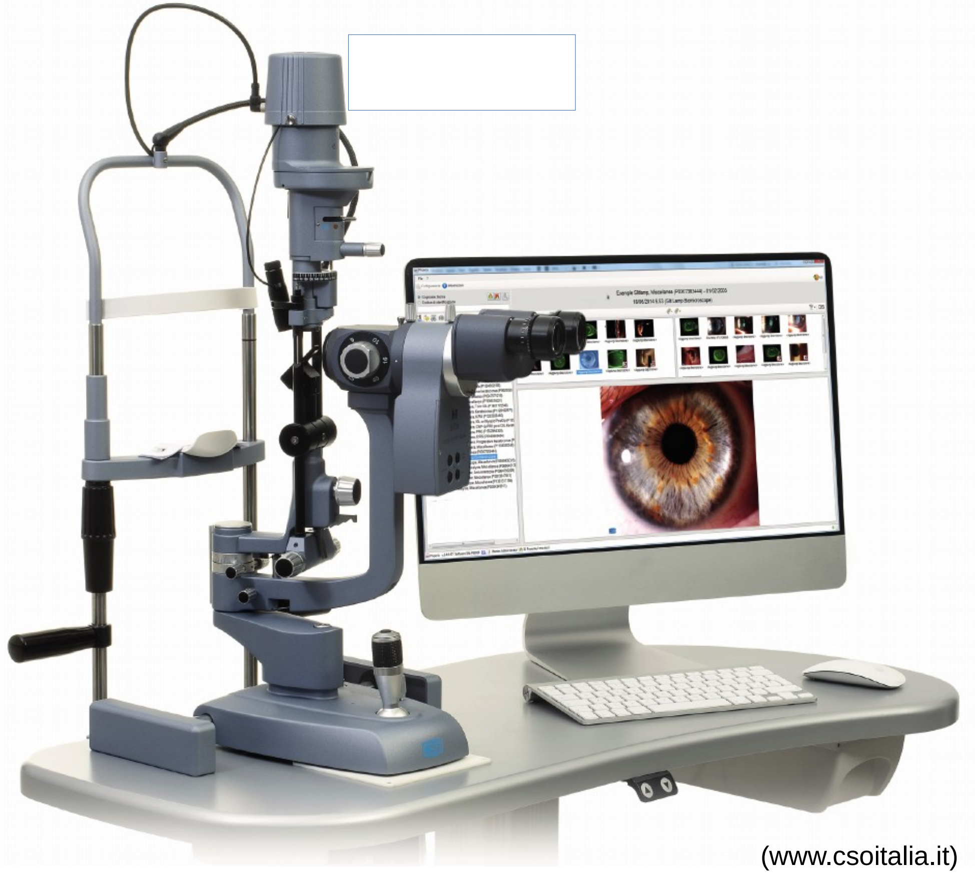
(fonte: wikipedia)

Fotografia Scheimpflug


2 1
VR CARGO
VR CARGO
VR CARGO
25 01
GLS

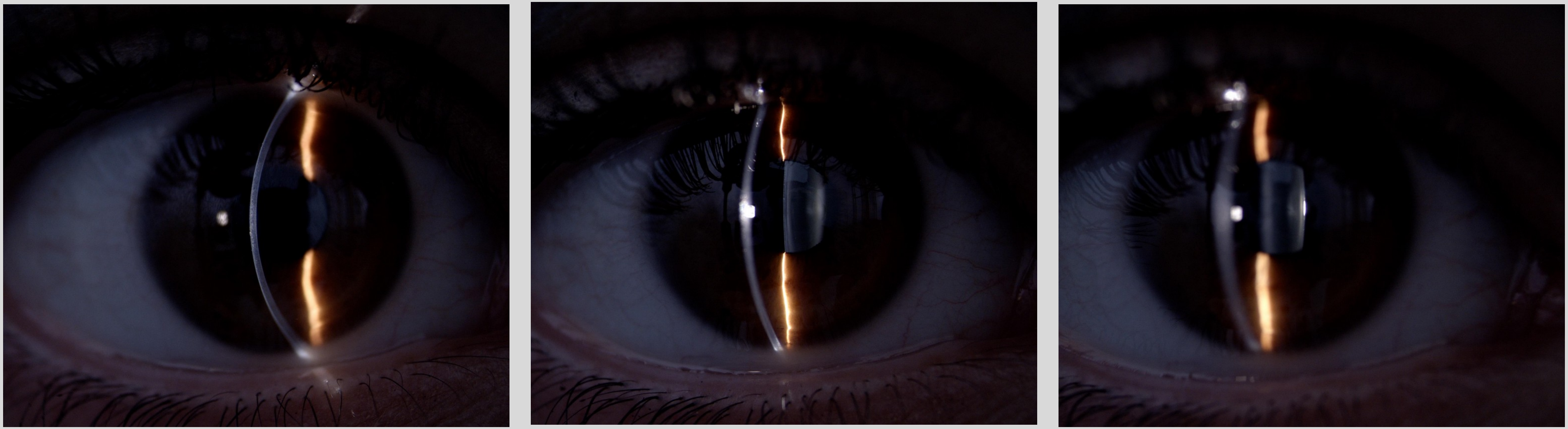
(fonte: wikipedia)

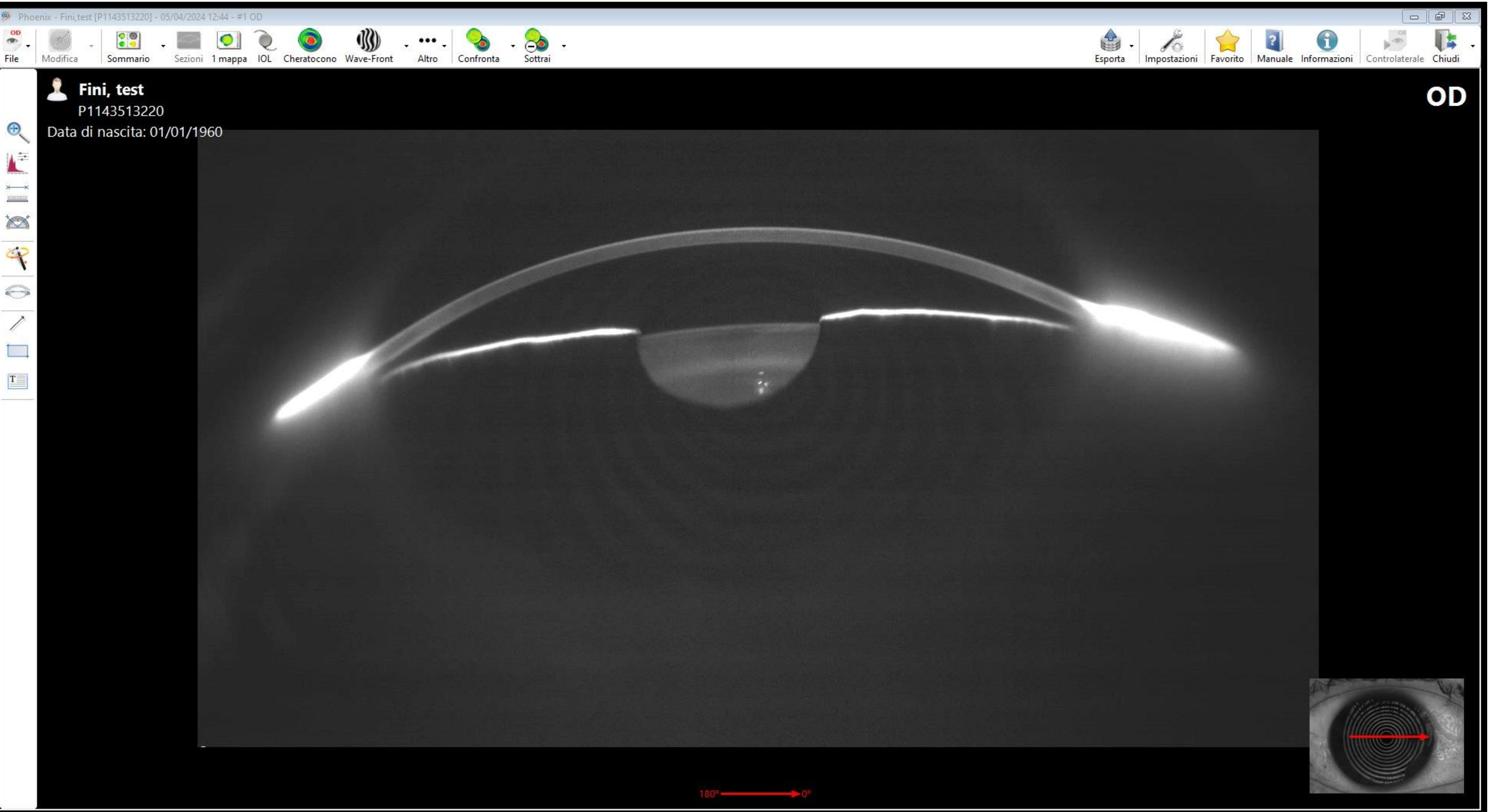
La lampada a fessura



(www.csoitalia.it)

La lampada a fessura





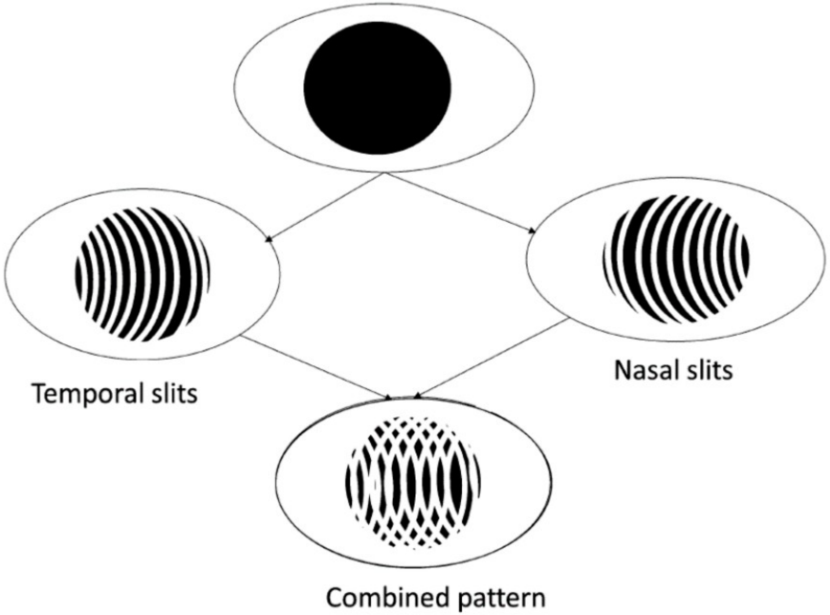
Phoenix - Fini,test [P1143513220] - 05/04/2024 12:44 - #1 OD

Fini, test
P1143513220
Data di nascita: 01/01/1960

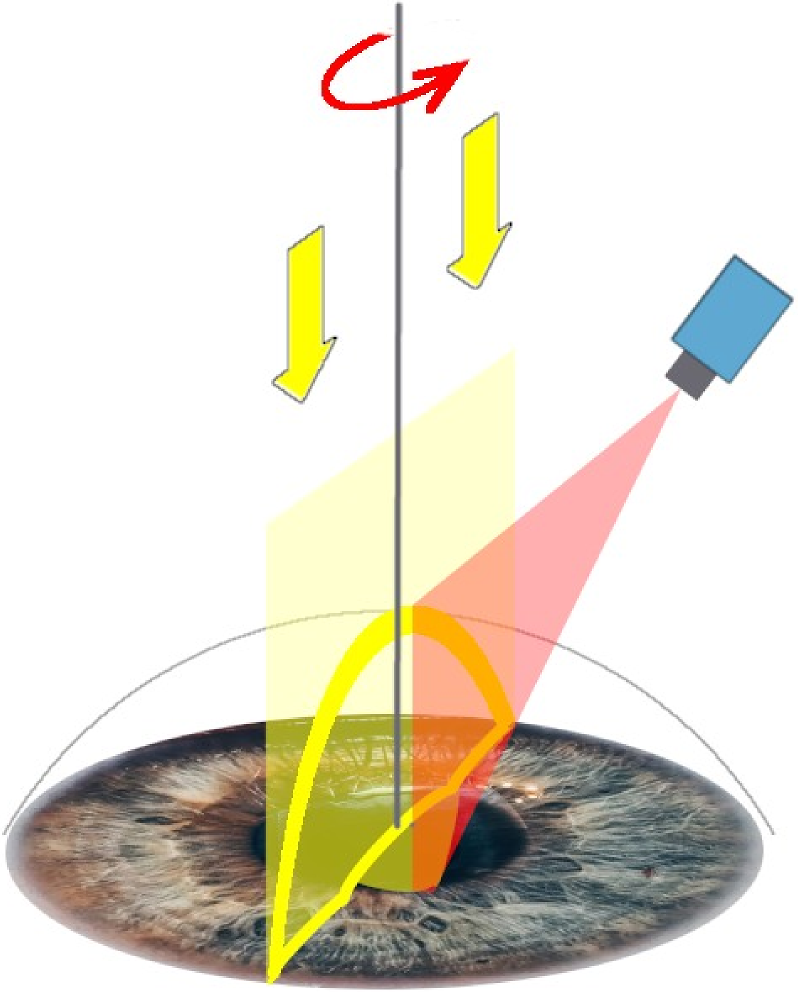
OD

File
Modifica
Sommario
Sezioni
1 mappa
IOL
Cheratocono
Wave-Front
Altro
Confronta
Sottrai
Esporta
Impostazioni
Favorito
Manuale
Informazioni
Controlaterale
Chiudi
180°
0°

Orbscan II


Temporal slits
Nasal slits
Combined pattern

La scansione ruotante



scansione ruotante

La scansione ruotante offre alcuni vantaggi rispetto alla scansione lineare:

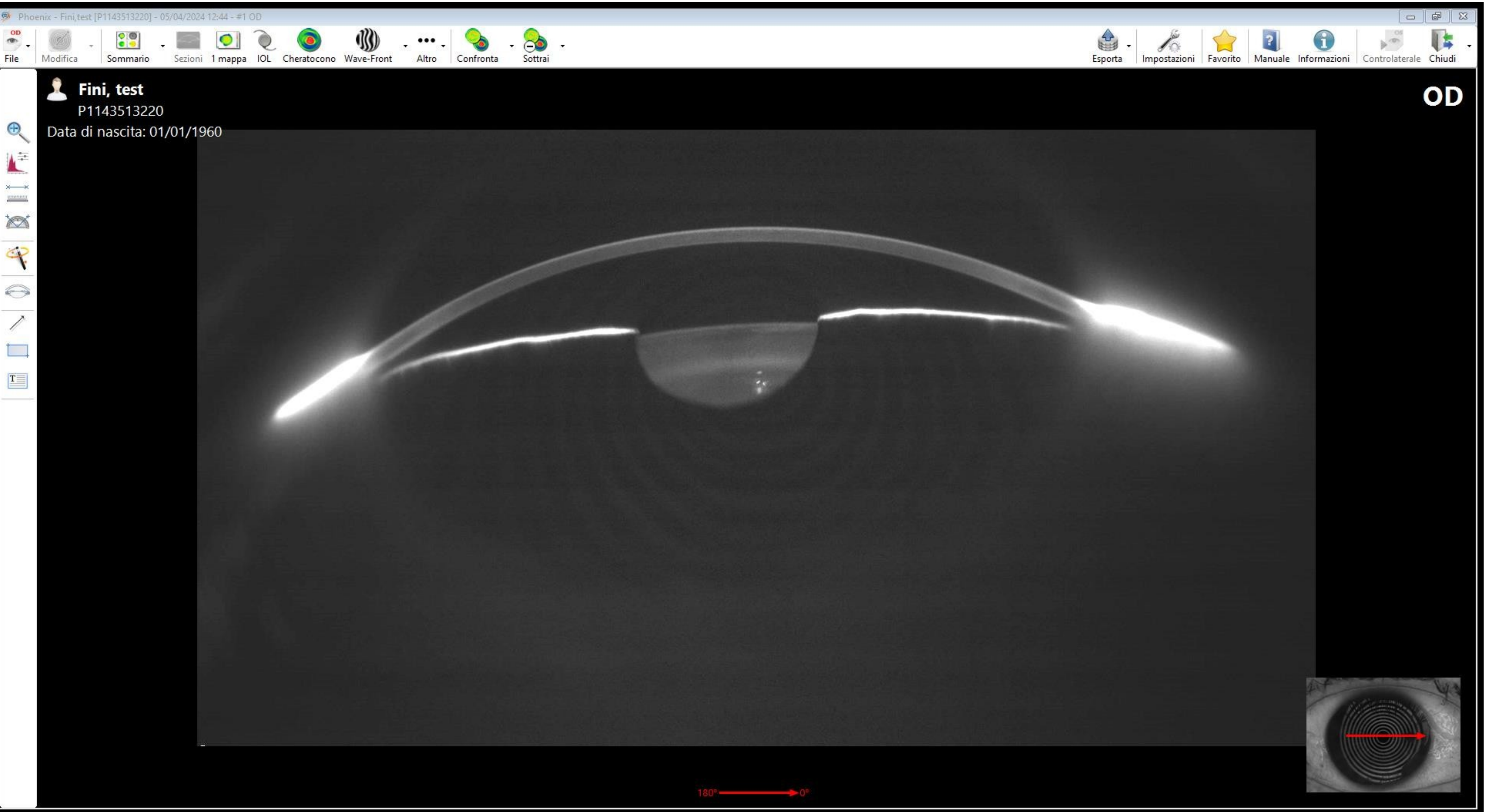
- consente una rappresentazione più accurata della superficie posteriore della cornea
- le immagini acquisite hanno un punto in comune (il centro di rotazione) e questo rende più accurata la ricostruzione del modello tridimensionale del segmento anteriore
- maggiore densità di punti misurati vicino all’asse

Sirius+ di CSO

topografo a disco di Placido e tomografo Scheimpflug

confronto tra alcuni tra gli strumenti più diffusi

modello	produttore	disco di Placido	Scheimpflug	illuminazione	n. immagini	
Orbscan II/IIz	Bausch & Lomb (USA)	✓		flash a luce bianca	40 (20 da destra e 20 da sinistra	scansione parallela
Pentacam	Oculus (DE)		✓	LED 475 nm	da 25 a 100	
Sirius+	CSO (IT)	✓	✓	LED 475 nm	da 20 a 100	
Galilei	Ziemer Ophthalmology Co.(CH)	✓	✓	LED 470 nm	da 15 a 60	doppia telecamera



Phoenix - Fini,test [P1143513220] - 05/04/2024 12:44 - #1 OD

Fini, test
P1143513220
Data di nascita: 01/01/1960

OD

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Controlaterale
Chiudi
180°
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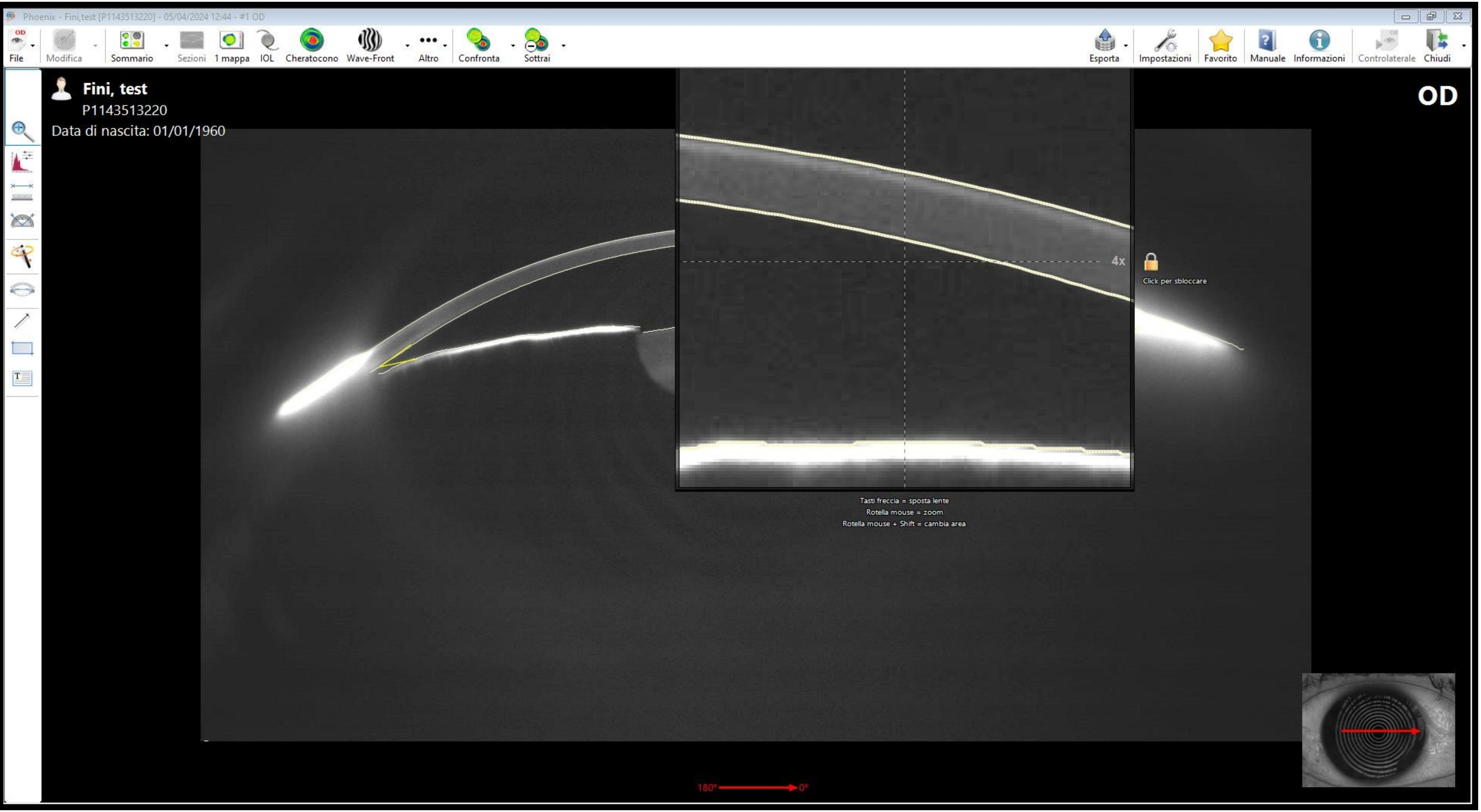

Phoenix - Fini,test [P1143513220] - 05/04/2024 12:44 - #1 OD
OD
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Wave-Front
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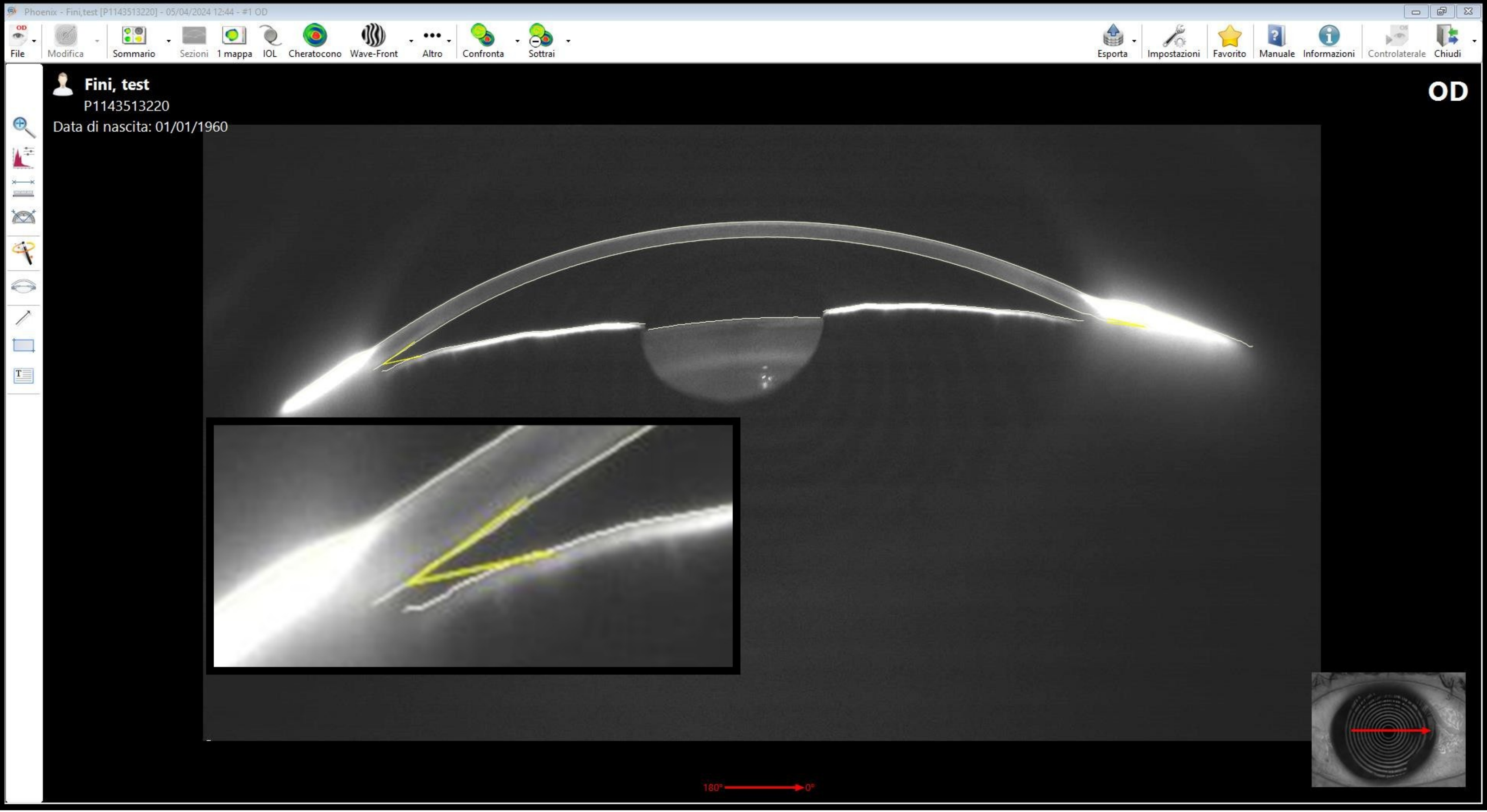
Confronta
Sottrai
Esporta
Impostazioni
Favorito
Manuale
Informazioni
Controlaterale
Chiudi
T
OD
4x
180°
0°

Fini, test
P1143513220
Data di nascita: 01/01/1960

Click per sbloccare

Tasti freccia = sposta lente
Rotella mouse = zoom
Rotella mouse + Shift = cambia area

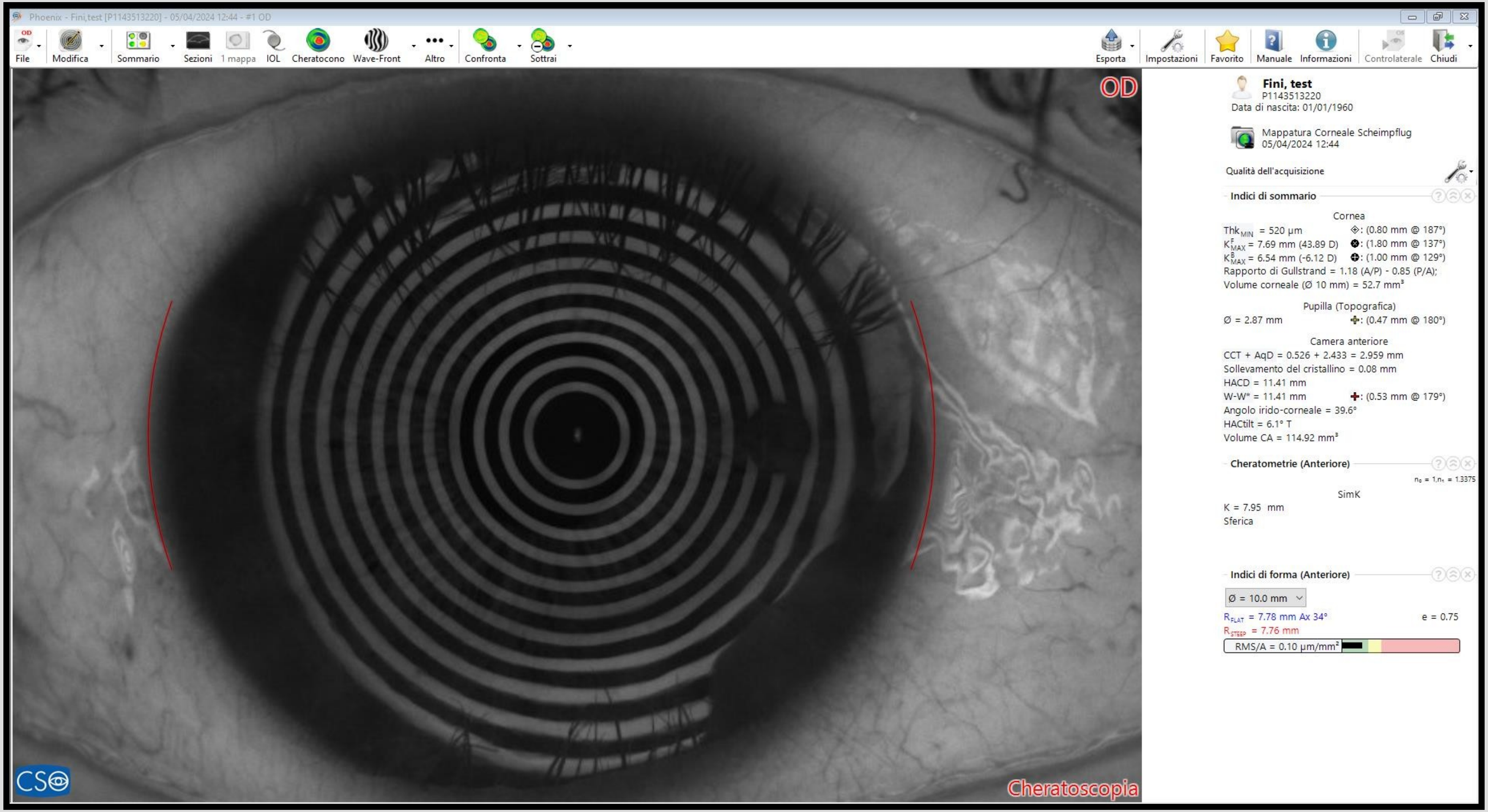

Phoenix - Fini,test [P1143513220] - 05/04/2024 12:44 - #1 OD

Fini, test
P1143513220
Data di nascita: 01/01/1960

OD

File
Modifica
Sommario
Sezioni
1 mappa
IOL
Cheratocono
Wave-Front
Altro
Confronta
Sottrai
Esporta
Impostazioni
Favorito
Manuale
Informazioni
Controlaterale
Chiudi
180°
0°

immagine del disco di Placido


Phoenix - Fini,test [P1143513220] - 05/04/2024 12:44 - #1 OD
File
Modifica
Sommario
Sezioni
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IOL
Cheratocono
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Confronta
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Esporta
Impostazioni
Favorito
Manuale
Informazioni
Controlaterale
Chiudi
OD
CSO
Cheratoscopia

Fini, test
P1143513220
Data di nascita: 01/01/1960

Mappatura Corneale Scheimpflug
05/04/2024 12:44

Qualità dell'acquisizione

Indici di sommario

Cornea

Thk_{MIN} = 520 µm ◈: (0.80 mm @ 187°)
K^F_{MAX} = 7.69 mm (43.89 D) ⊗: (1.80 mm @ 137°)
K^B_{MAX} = 6.54 mm (-6.12 D) ⊕: (1.00 mm @ 129°)
Rapporto di Gullstrand = 1.18 (A/P) - 0.85 (P/A);
Volume corneale (Ø 10 mm) = 52.7 mm³

Pupilla (Topografica)

Ø = 2.87 mm ✛: (0.47 mm @ 180°)

Camera anteriore

CCT + AqD = 0.526 + 2.433 = 2.959 mm
Sollevamento del cristallino = 0.08 mm
HACD = 11.41 mm
W-W* = 11.41 mm ✚: (0.53 mm @ 179°)
Angolo irido-corneale = 39.6°
HACtilt = 6.1° T
Volume CA = 114.92 mm³

Cheratometrie (Anteriore)

$n_0 = 1, n_1 = 1.3375$

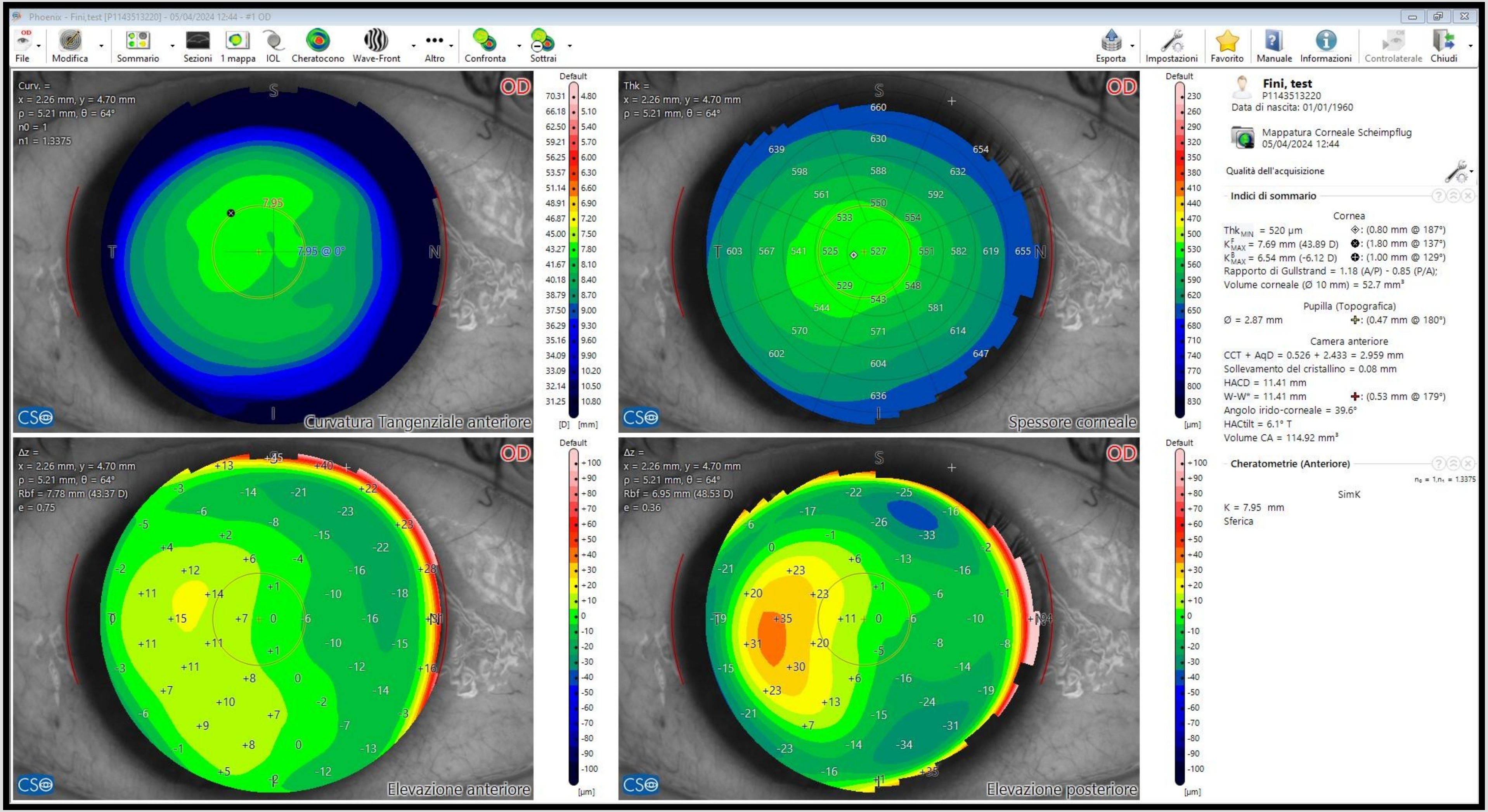
SimK

K = 7.95 mm
Sferica

Indici di forma (Anteriore)

Ø = 10.0 mm

R_{FLAT} = 7.78 mm Ax 34° e = 0.75
R_{STEEP} = 7.76 mm
RMS/A = 0.10 µm/mm²


File
Modifica
Sommario
Sezioni
1 mappa
IOL
Cheratocono
Wave-Front
Altro
Confronta
Sottrai
Esporta
Impostazioni
Favorito
Manuale
Informazioni
Controlaterale
Chiudi
OD
S
T
N
I
7.95
7.95 @ 0°
Default
70.31 4.80
66.18 5.10
62.50 5.40
59.21 5.70
56.25 6.00
53.57 6.30
51.14 6.60
48.91 6.90
46.87 7.20
45.00 7.50
43.27 7.80
41.67 8.10
40.18 8.40
38.79 8.70
37.50 9.00
36.29 9.30
35.16 9.60
34.09 9.90
33.09 10.20
32.14 10.50
31.25 10.80
[D] [mm]
CSO
Curvatura Tangenziale anteriore
660 630 639 654 598 588 632 561 592 550 533 554
603 567 541 525 527 551 582 619 655
529 548 543 544 581 570 571 614 602 647 604 636
230 260 290 320 350 380 410 440 470 500 530 560 590 620 650 680 710 740 770 800 830
[µm]
Spessore corneale
+13 +45 +40 -3 -14 -21 +22 -6 -23 -5 -8 +23 +2 -15 +4 -22 +6 -4 -2 +12 -16 +28
+11 +14 +1 -10 -18 +15 +7 0 -6 -16 +31 +11 +11 -10 -15 -3 +1 +11 -12 +16
+7 +8 0 -14 +10 -2 -6 +7 -3 +9 -7 -1 +8 0 -13 +5 -12 -2
+100 +90 +80 +70 +60 +50 +40 +30 +20 +10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100
[µm]
Elevazione anteriore
-22 -25 -17 -26 -16 -6 -1 -33 0 +6 -13 -2 -21 +23 -16 +20 +23 +1 -6 -1
-19 +35 +11 0 -6 -10 +94 +31 +20 -5 -8 -8 -15 +30 -14 +6 -16 +23 -19 +13
-24 -21 -15 -31 +7 -23 -14 -34 -16 +1 +35
Elevazione posteriore

Phoenix - Fini,test [P1143513220] - 05/04/2024 12:44 - #1 OD

Curv. =
x = 2.26 mm, y = 4.70 mm
ρ = 5.21 mm, θ = 64°
n0 = 1
n1 = 1.3375

Thk =
x = 2.26 mm, y = 4.70 mm
ρ = 5.21 mm, θ = 64°

Δz =
x = 2.26 mm, y = 4.70 mm
ρ = 5.21 mm, θ = 64°
Rbf = 7.78 mm (43.37 D)
e = 0.75

Δz =
x = 2.26 mm, y = 4.70 mm
ρ = 5.21 mm, θ = 64°
Rbf = 6.95 mm (48.53 D)
e = 0.36

Fini, test
P1143513220
Data di nascita: 01/01/1960

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05/04/2024 12:44

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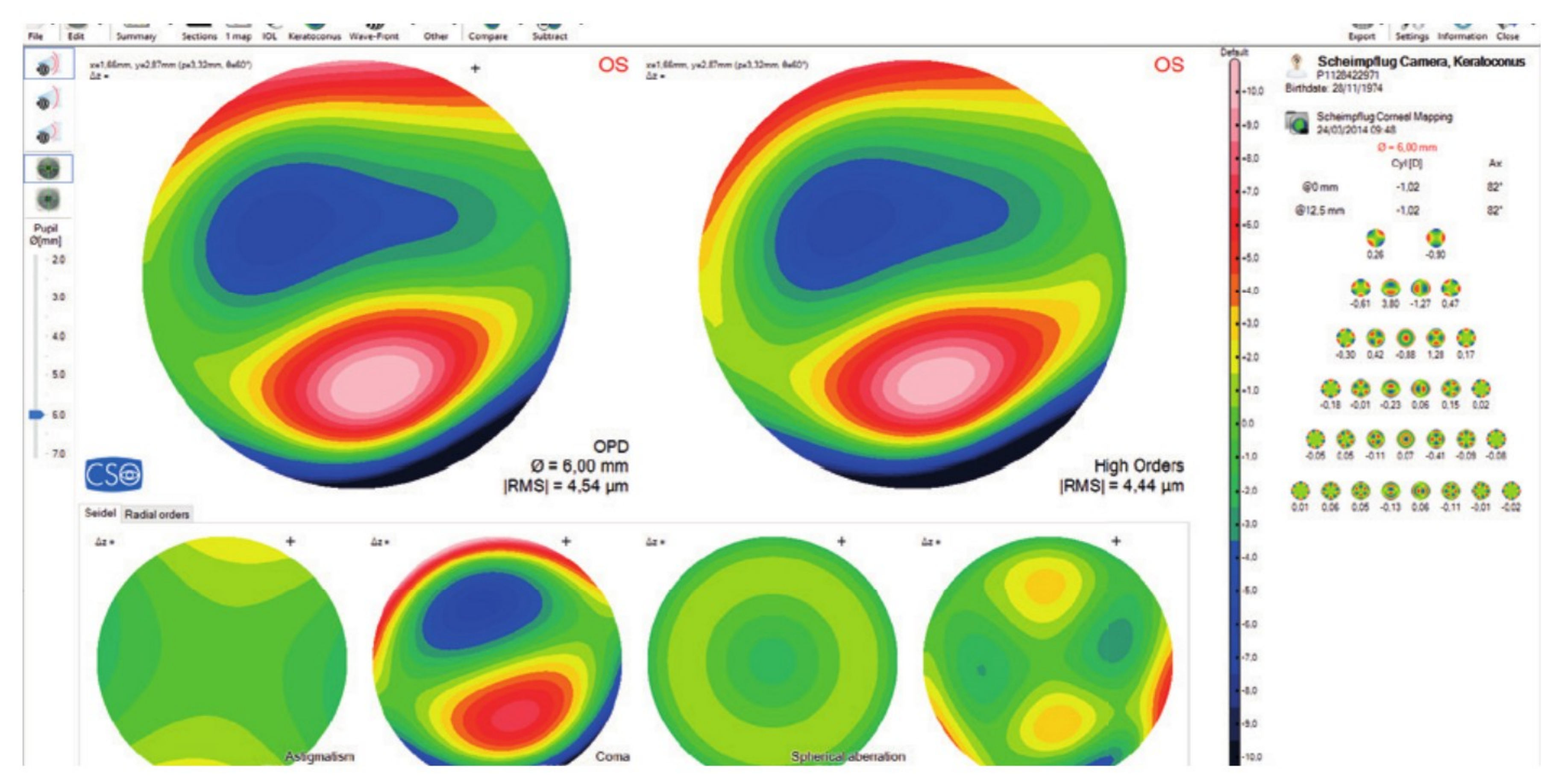
Sferica

analisi aberrometrica


File
Edit
Summary
Sections
1 map
IOL
Keratoconus
Wave-Front
Other
Compare
Subtract
Export
Settings
Information
Close
Pupil Ø[mm]
2.0
3.0
4.0
5.0
6.0
7.0
OS
OS
CSO
Default
+10.0
+9.0
+8.0
+7.0
+6.0
+5.0
+4.0
+3.0
+2.0
+1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
-10.0
Seidel
Radial orders
Astigmatism
Coma
Spherical aberration

x=1,66mm, y=2,87mm (ρ=3,32mm, θ=60°)

OPD
Ø = 6,00 mm
|RMS| = 4,54 µm

High Orders
|RMS| = 4,44 µm

Scheimpflug Camera, Keratoconus
P1128422971
Birthdate: 28/11/1974

Scheimpflug Corneal Mapping
24/03/2014 09:48

Ø = 6,00 mm

	Cyl [D]	Ax
@0 mm	-1,02	82°
@12.5 mm	-1,02	82°

0.26 -0.90

-0.61 3.80 -1.27 0.47

-0.30 0.42 -0.88 1.28 0.17

-0.18 -0.01 -0.23 0.06 0.15 0.02

-0.05 0.05 -0.11 0.07 -0.41 -0.09 -0.08

0.01 0.06 0.05 -0.13 0.06 -0.11 -0.01 -0.02

quali informazioni si possono ottenere (Sirius+)

- mappa altimetrica della superficie anteriore/posteriore della cornea
- mappa di curvatura della superficie anteriore/posteriore
- mappa pachimetrica
- profondità della camera anteriore
- misura degli angoli irido-corneali
- analisi del fronte d’onda corneale e della qualità della visione
- mappa del potere frontale anteriore, potere frontale posteriore e potere equivalente dell’intera cornea.

campi di applicazione (Sirius+)

- Pianificazione della chirurgia per la correzione dei difetti refrattivi
- Screening del glaucoma
- Screening del cheratocono
- overview completa delle aberrazioni corneali. La mappa di OPD/WFE e le simulazioni visive (PSF, MTF, convoluzione di immagine) possono aiutare nella comprensione del disagio visivo del paziente;
- Modulo di calcolo della IOL (opzionale)
- Modulo per applicazione delle lenti a contatto

fonti di errore

- movimenti dell’occhio durante la misura
- distorsione geometrica (effetto della prospettiva)
- distorsione ottica dovuta all’osservazione attraverso la cornea
- anomalie e instabilità del film lacrimale
- stima dei parametri ottici (es. indice di rifrazione)
- saturazione del segnale nelle zone di maggiore backscattering (limbus)
- risoluzione delle immagini peggiore che negli OCT

analisi densitometrica

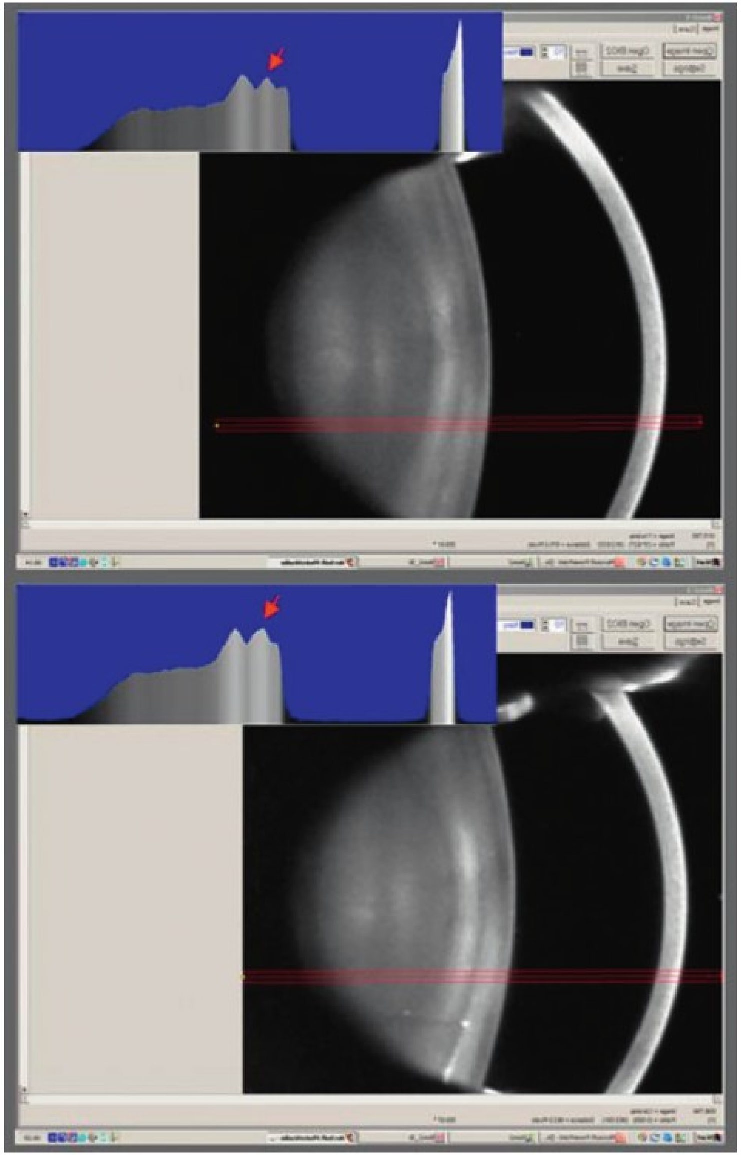


Figure 12. Multilinear densitometry showing the development of a spoke cataract in the lens of a 65-year-old patient.

(da: Clinical and Experimental Ophthalmology 2009; 37: 144–154 doi: 10.1111/j.1442-9071.2009.02018.x)

E’ uno strumento versatile ….

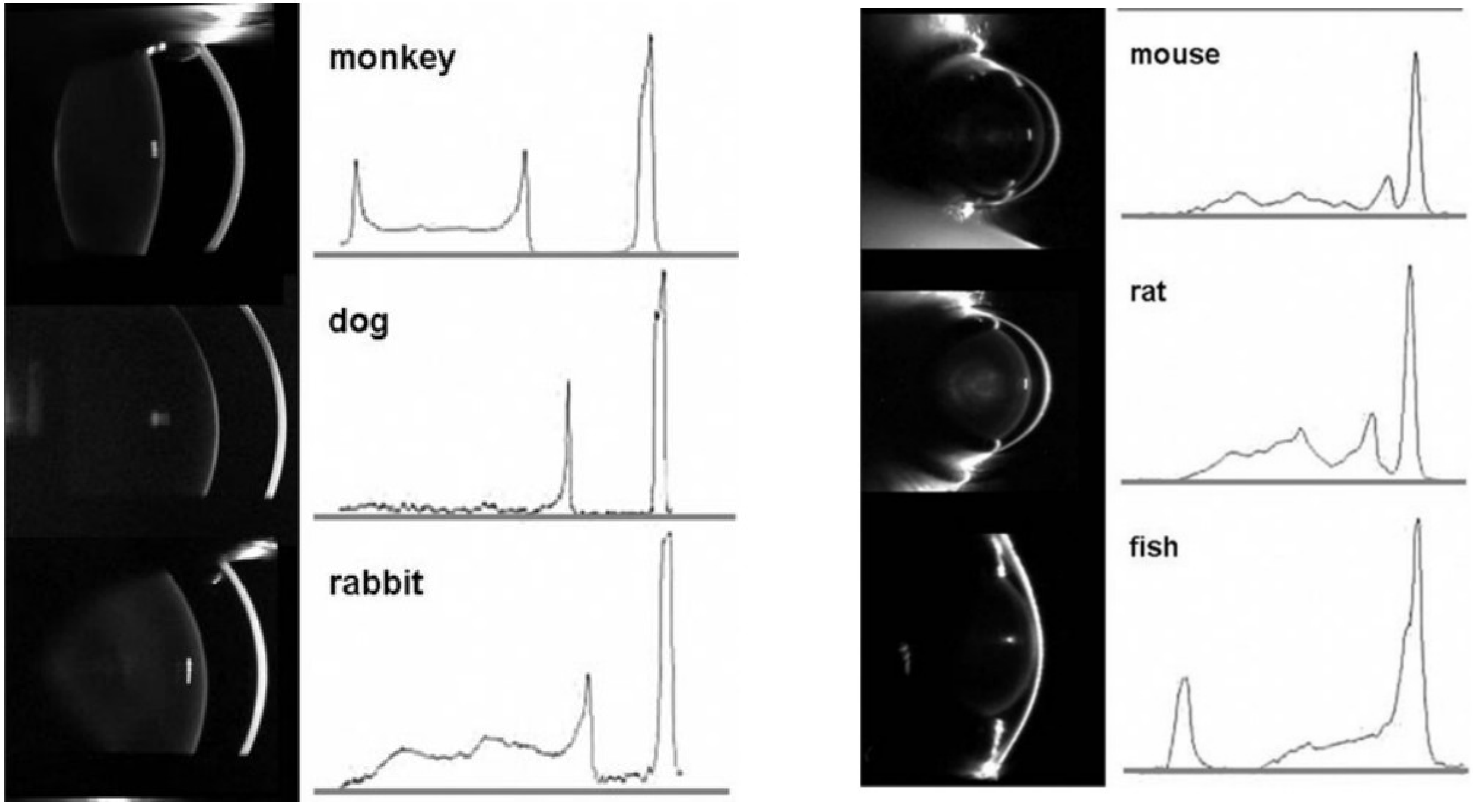

monkey
dog
rabbit
mouse
rat
fish

Figure 10. Scheimpflug images and corresponding densitograms of young experimental animals. Every species has its typical lens light scattering profile.

(Clinical and Experimental Ophthalmology 2009; 37: 144–154 doi: 10.1111/j.1442-9071.2009.02018.x)

altre applicazioni delle immagini Scheimpflug

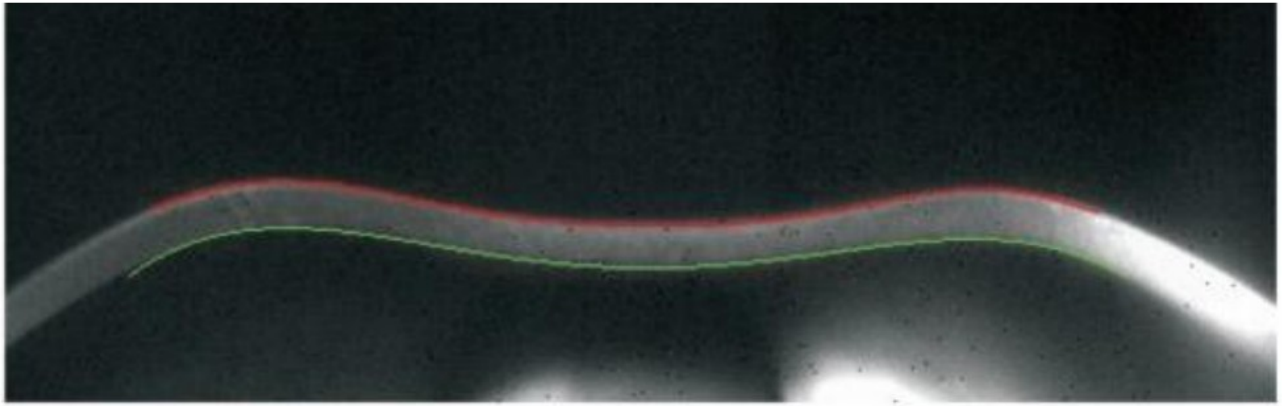
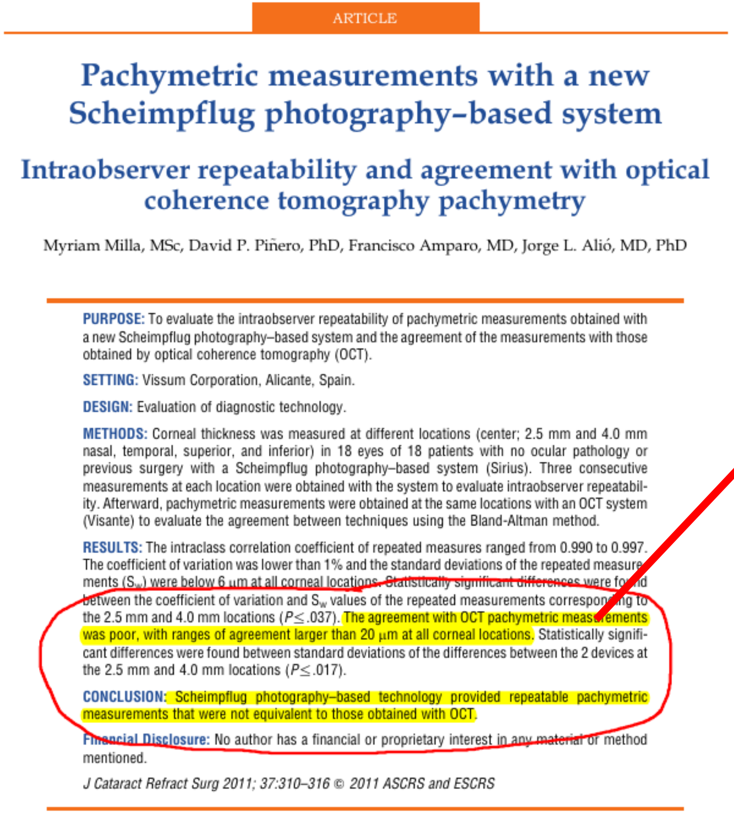


Immagine catturata da un dispositivo Scheimpflug della deformazione della cornea dovuta al getto del soffio d’aria prodotto dal tonometro Corvis ST (Oculus, Germany)

Sirius vs. OCT



ARTICLE

Pachymetric measurements with a new Scheimpflug photography–based system

Intraobserver repeatability and agreement with optical coherence tomography pachymetry

Myriam Milla, MSc, David P. Piñero, PhD, Francisco Amparo, MD, Jorge L. Alió, MD, PhD

PURPOSE: To evaluate the intraobserver repeatability of pachymetric measurements obtained with a new Scheimpflug photography–based system and the agreement of the measurements with those obtained by optical coherence tomography (OCT).

SETTING: Vissum Corporation, Alicante, Spain.

DESIGN: Evaluation of diagnostic technology.

METHODS: Corneal thickness was measured at different locations (center; 2.5 mm and 4.0 mm nasal, temporal, superior, and inferior) in 18 eyes of 18 patients with no ocular pathology or previous surgery with a Scheimpflug photography–based system (Sirius). Three consecutive measurements at each location were obtained with the system to evaluate intraobserver repeatability. Afterward, pachymetric measurements were obtained at the same locations with an OCT system (Visante) to evaluate the agreement between techniques using the Bland-Altman method.

RESULTS: The intraclass correlation coefficient of repeated measures ranged from 0.990 to 0.997. The coefficient of variation was lower than 1% and the standard deviations of the repeated measurements (S_w) were below 6 μm at all corneal locations. Statistically significant differences were found between the coefficient of variation and S_w values of the repeated measurements corresponding to the 2.5 mm and 4.0 mm locations ($P \leq .037$). The agreement with OCT pachymetric measurements was poor, with ranges of agreement larger than 20 μm at all corneal locations. Statistically significant differences were found between standard deviations of the differences between the 2 devices at the 2.5 mm and 4.0 mm locations ($P \leq .017$).

CONCLUSION: Scheimpflug photography–based technology provided repeatable pachymetric measurements that were not equivalent to those obtained with OCT.

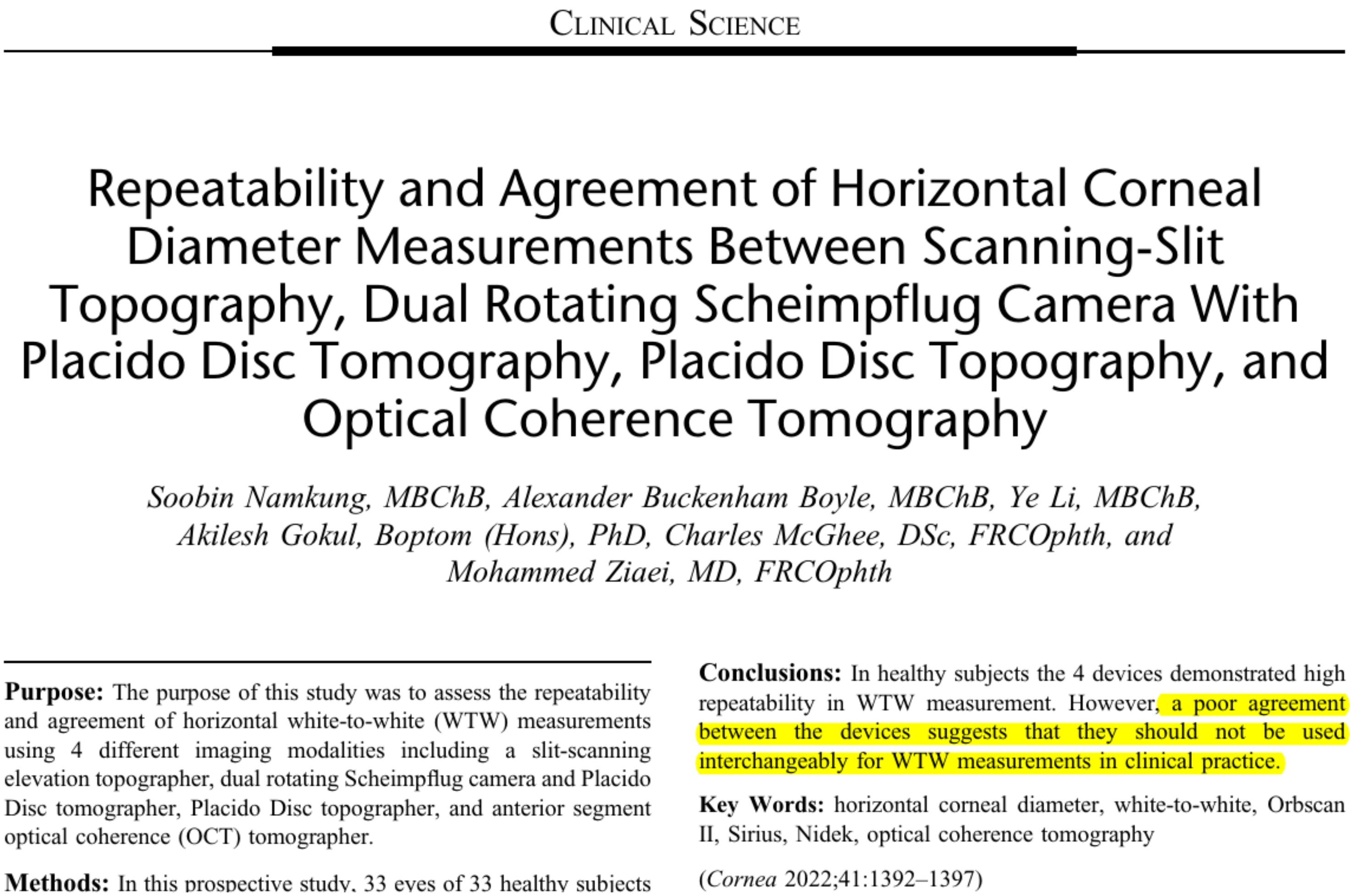
Financial Disclosure: No author has a financial or proprietary interest in any material or method mentioned.

J Cataract Refract Surg 2011; 37:310–316 © 2011 ASCRS and ESCRS

The agreement with OCT pachymetric measurements was poor, with ranges of agreement larger than 20 μm at all corneal locations…

CONCLUSION: Scheimpflug photography–based technology provided repeatable pachymetric measurements that were not equivalent to those obtained with OCT.

Orbscan II vs. Sirius vs. OCT



CLINICAL SCIENCE

Repeatability and Agreement of Horizontal Corneal Diameter Measurements Between Scanning-Slit Topography, Dual Rotating Scheimpflug Camera With Placido Disc Tomography, Placido Disc Topography, and Optical Coherence Tomography

Soobin Namkung, MBChB, Alexander Buckenham Boyle, MBChB, Ye Li, MBChB, Akilesh Gokul, Boptom (Hons), PhD, Charles McGhee, DSc, FRCOphth, and Mohammed Ziaei, MD, FRCOphth

Purpose: The purpose of this study was to assess the repeatability and agreement of horizontal white-to-white (WTW) measurements using 4 different imaging modalities including a slit-scanning elevation topographer, dual rotating Scheimpflug camera and Placido Disc tomographer, Placido Disc topographer, and anterior segment optical coherence (OCT) tomographer.

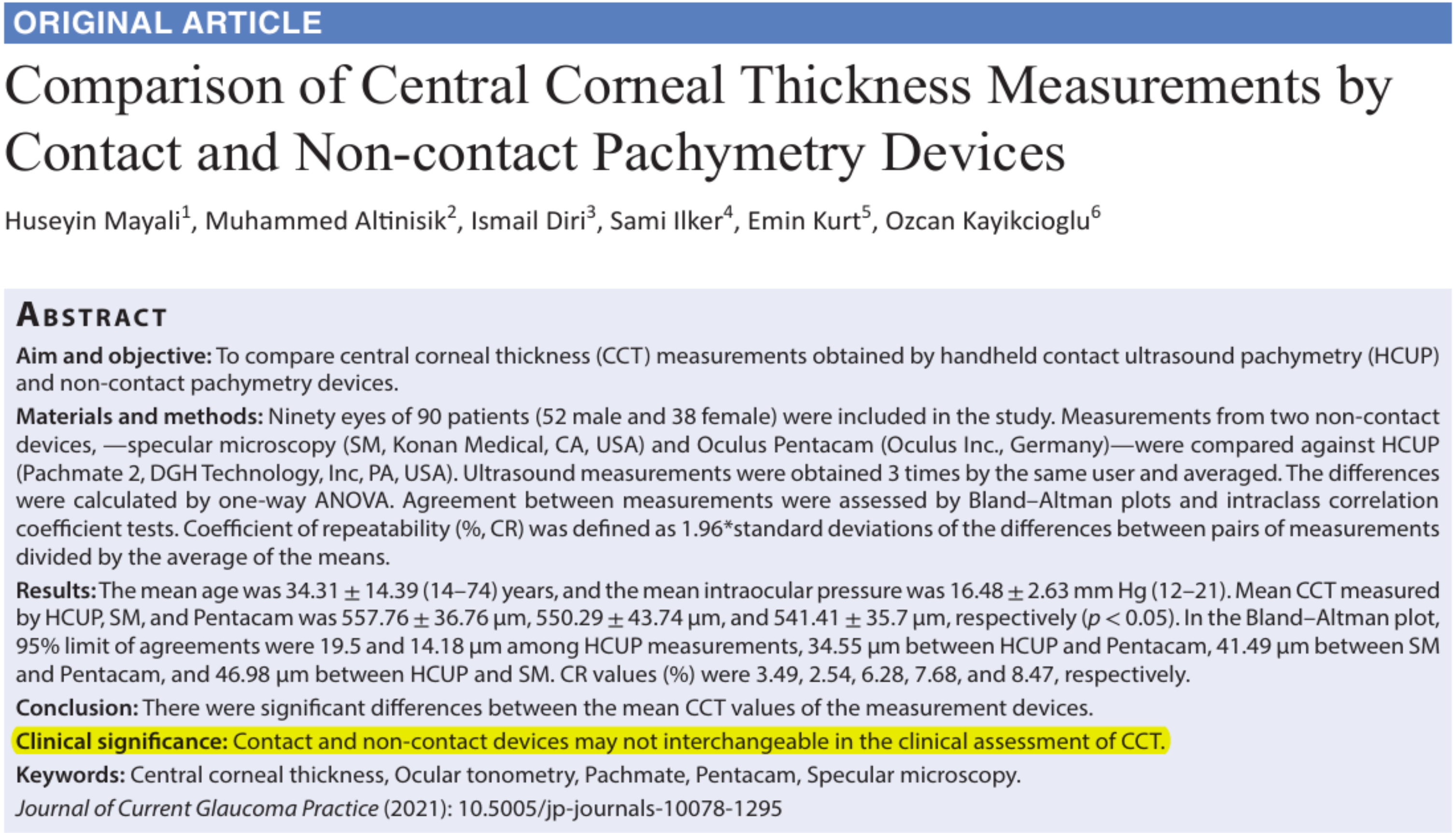
Methods: In this prospective study, 33 eyes of 33 healthy subjects

Conclusions: In healthy subjects the 4 devices demonstrated high repeatability in WTW measurement. However, a poor agreement between the devices suggests that they should not be used interchangeably for WTW measurements in clinical practice.

Key Words: horizontal corneal diameter, white-to-white, Orbscan II, Sirius, Nidek, optical coherence tomography

(*Cornea* 2022;41:1392–1397)

Pentacam vs. pachimetria a ultrasuoni



ORIGINAL ARTICLE

Comparison of Central Corneal Thickness Measurements by Contact and Non-contact Pachymetry Devices

Huseyin Mayali[1], Muhammed Altinisik[2], Ismail Diri[3], Sami Ilker[4], Emin Kurt[5], Ozcan Kayikcioglu[6]

ABSTRACT

Aim and objective: To compare central corneal thickness (CCT) measurements obtained by handheld contact ultrasound pachymetry (HCUP) and non-contact pachymetry devices.

Materials and methods: Ninety eyes of 90 patients (52 male and 38 female) were included in the study. Measurements from two non-contact devices, —specular microscopy (SM, Konan Medical, CA, USA) and Oculus Pentacam (Oculus Inc., Germany)—were compared against HCUP (Pachmate 2, DGH Technology, Inc, PA, USA). Ultrasound measurements were obtained 3 times by the same user and averaged. The differences were calculated by one-way ANOVA. Agreement between measurements were assessed by Bland–Altman plots and intraclass correlation coefficient tests. Coefficient of repeatability (%, CR) was defined as 1.96*standard deviations of the differences between pairs of measurements divided by the average of the means.

Results: The mean age was 34.31 ± 14.39 (14–74) years, and the mean intraocular pressure was 16.48 ± 2.63 mm Hg (12–21). Mean CCT measured by HCUP, SM, and Pentacam was 557.76 ± 36.76 µm, 550.29 ± 43.74 µm, and 541.41 ± 35.7 µm, respectively ($p < 0.05$). In the Bland–Altman plot, 95% limit of agreements were 19.5 and 14.18 µm among HCUP measurements, 34.55 µm between HCUP and Pentacam, 41.49 µm between SM and Pentacam, and 46.98 µm between HCUP and SM. CR values (%) were 3.49, 2.54, 6.28, 7.68, and 8.47, respectively.

Conclusion: There were significant differences between the mean CCT values of the measurement devices.

Clinical significance: Contact and non-contact devices may not interchangeable in the clinical assessment of CCT.

Keywords: Central corneal thickness, Ocular tonometry, Pachmate, Pentacam, Specular microscopy.

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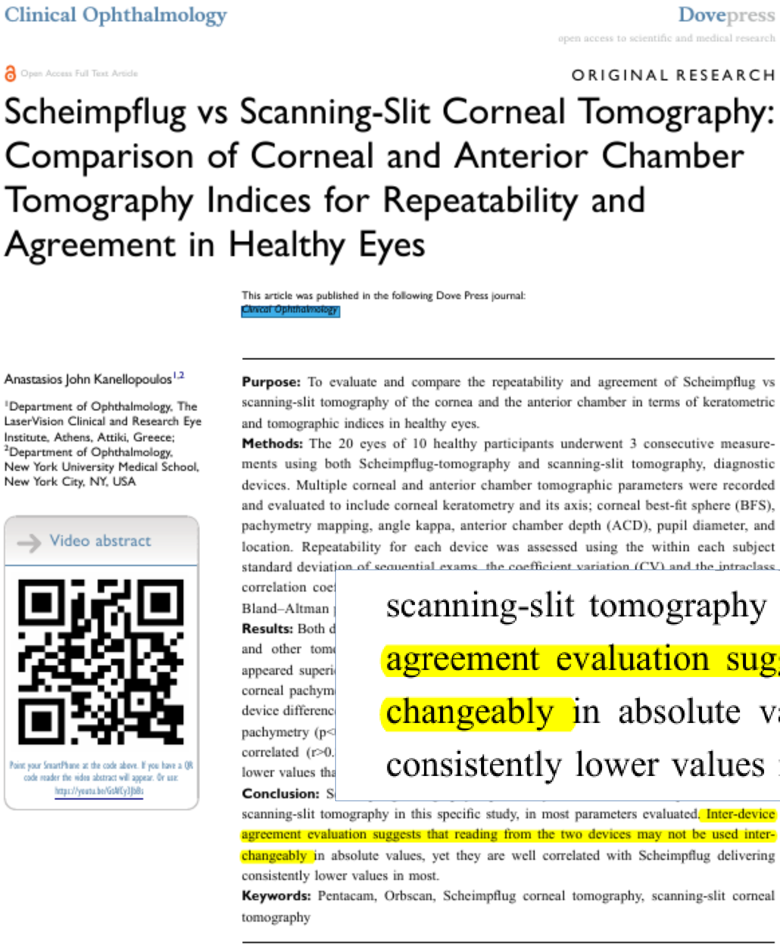
Pentacam HR vs. Orbscan II



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ORIGINAL RESEARCH

Scheimpflug vs Scanning-Slit Corneal Tomography: Comparison of Corneal and Anterior Chamber Tomography Indices for Repeatability and Agreement in Healthy Eyes

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Clinical Ophthalmology

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Video abstract

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Purpose: To evaluate and compare the repeatability and agreement of Scheimpflug vs scanning-slit tomography of the cornea and the anterior chamber in terms of keratometric and tomographic indices in healthy eyes.

Methods: The 20 eyes of 10 healthy participants underwent 3 consecutive measurements using both Scheimpflug-tomography and scanning-slit tomography, diagnostic devices. Multiple corneal and anterior chamber tomographic parameters were recorded and evaluated to include corneal keratometry and its axis; corneal best-fit sphere (BFS), pachymetry mapping, angle kappa, anterior chamber depth (ACD), pupil diameter, and location. Repeatability for each device was assessed using the within each subject standard deviation of sequential exams, the coefficient variation (CV) and the intraclass
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Results: Both d
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Conclusion: S
scanning-slit tomography in this specific study, in most parameters evaluated. Inter-device agreement evaluation suggests that reading from the two devices may not be used interchangeably in absolute values, yet they are well correlated with Scheimpflug delivering consistently lower values in most.

Keywords: Pentacam, Orbscan, Scheimpflug corneal tomography, scanning-slit corneal tomography

scanning-slit tomography in this specific study, in most parameters evaluated. Inter-device agreement evaluation suggests that reading from the two devices may not be used interchangeably in absolute values, yet they are well correlated with Scheimpflug delivering consistently lower values in most.

Tomografia Scheimpflug

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grazie per l’attenzione!