Biomedical 2D and 3D Imaging: state of Art and Future Perspectives in Ophthalmology, Dentistry, Prosthesics and Forensic Medicine

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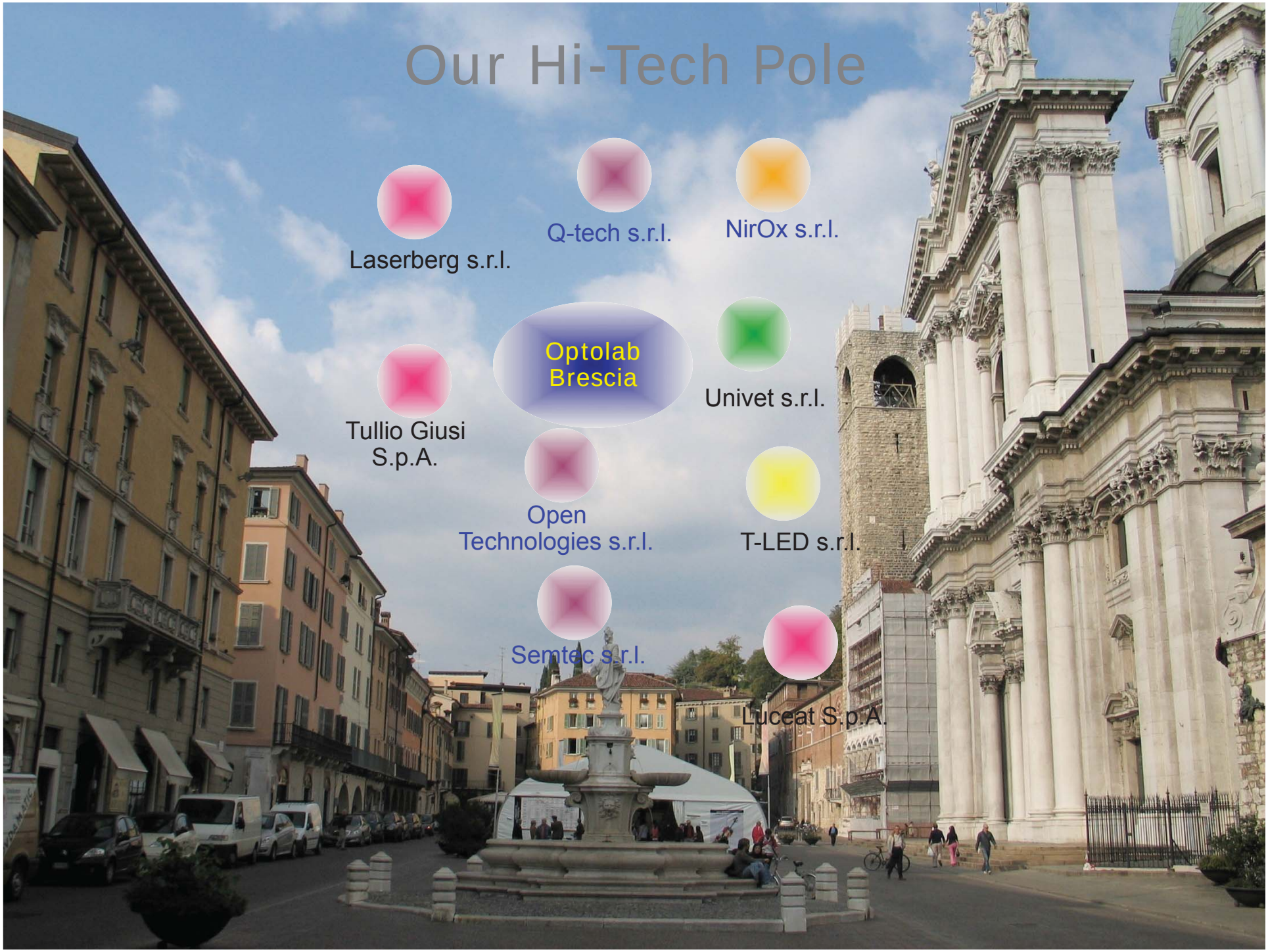
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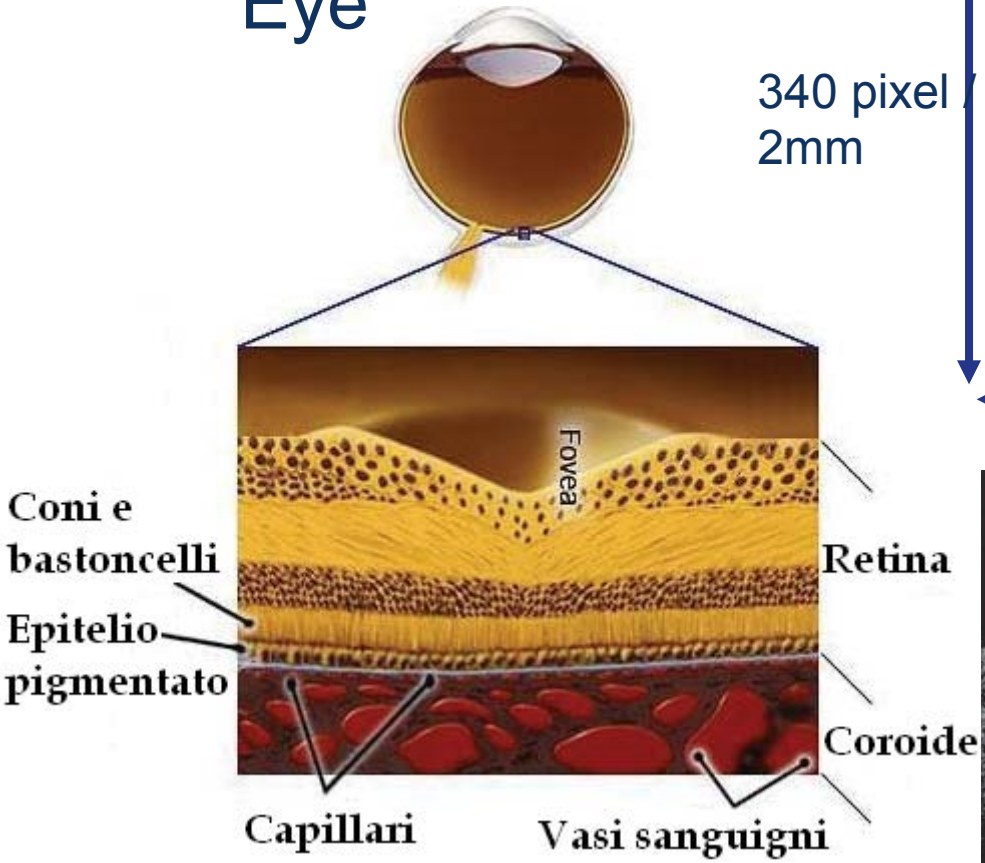
2D and 3D imaging in ophthalmology

Case 1: Improvement of diagnostic ability of OCT scans by means of quantitative image elaboration of OCT scans

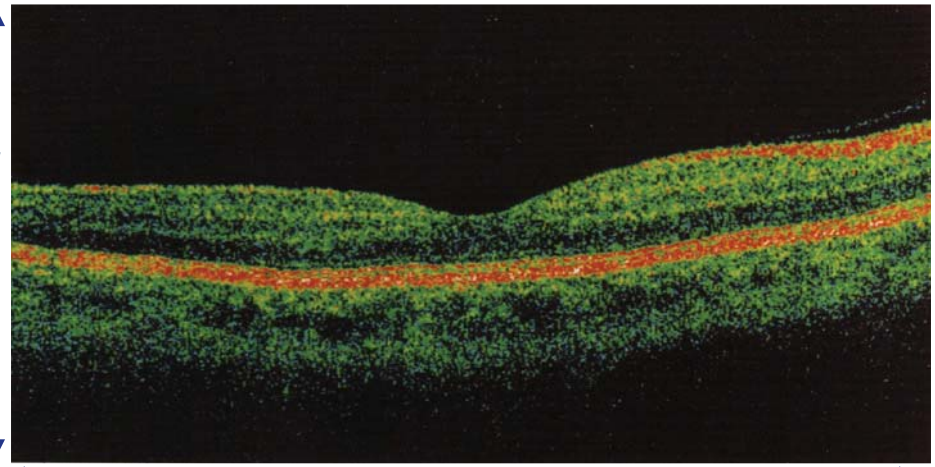
Partnership: Ophthalmic clinic, Varese

Optical Coherence Tomography (OCT): metrology & imaging

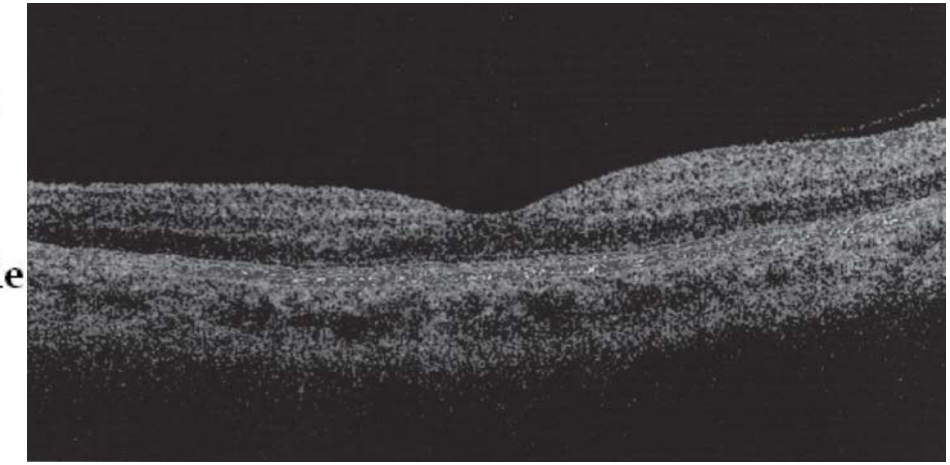
Eye



340 pixel /
2mm

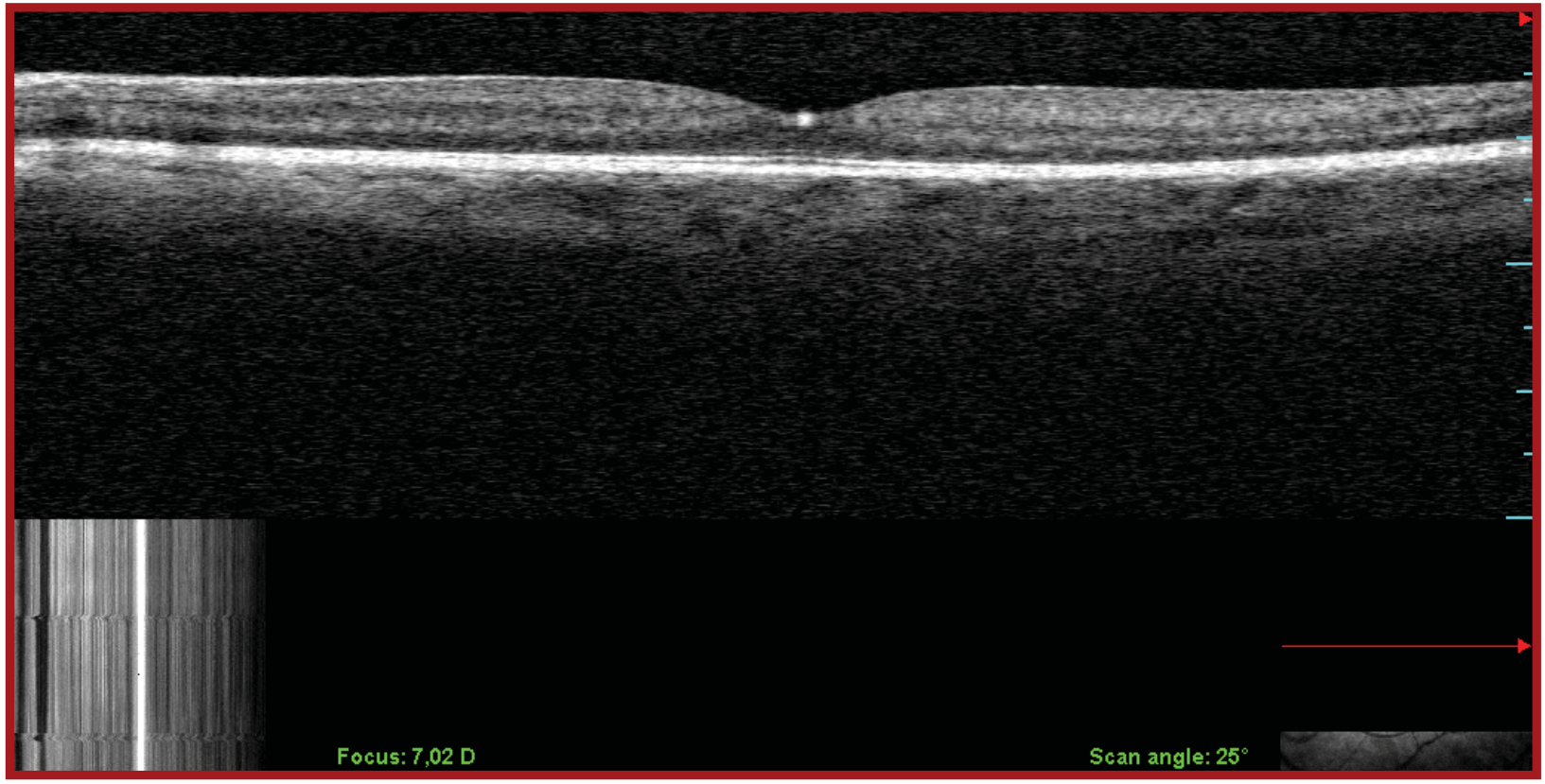


1024 pixel / 8mm



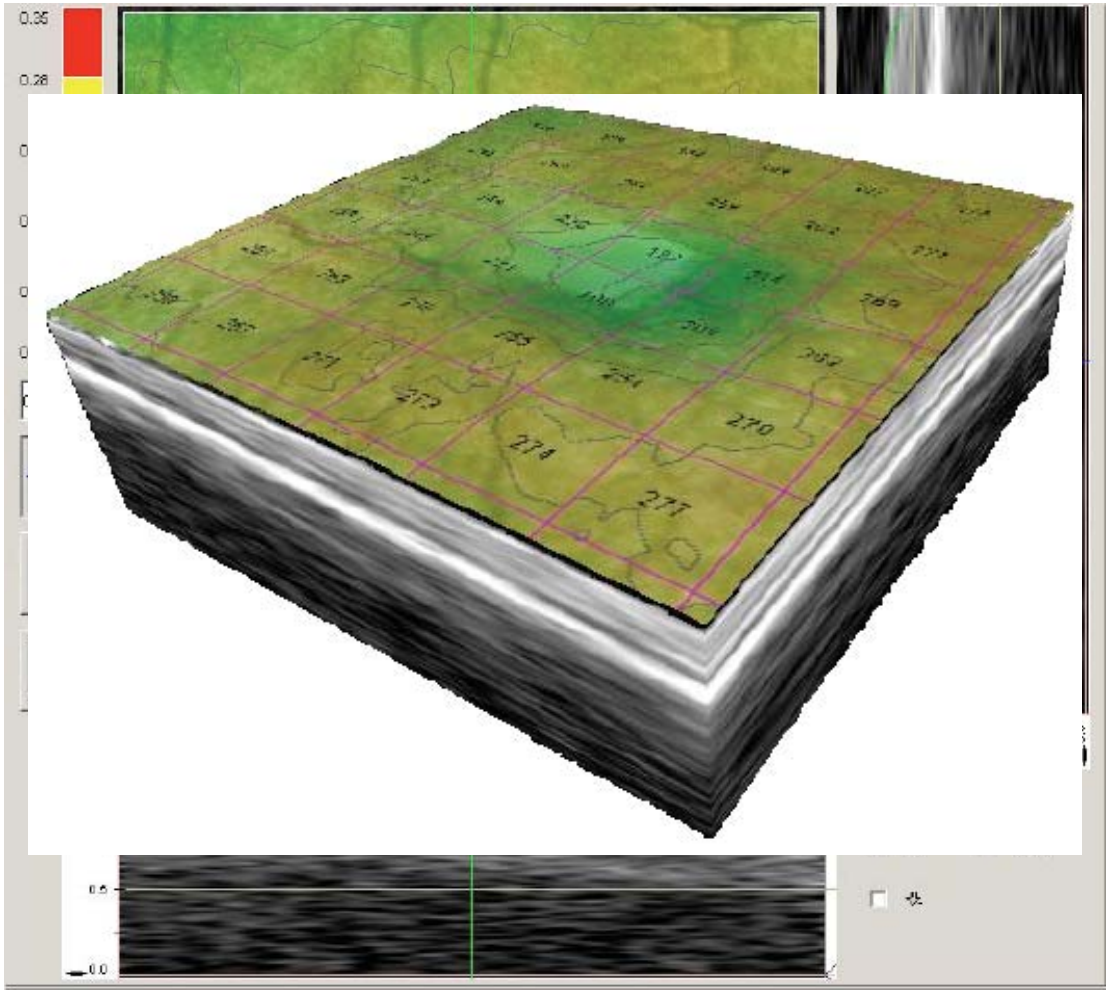
Commercial OCT software

- Tomograph - generated information (qualitative)



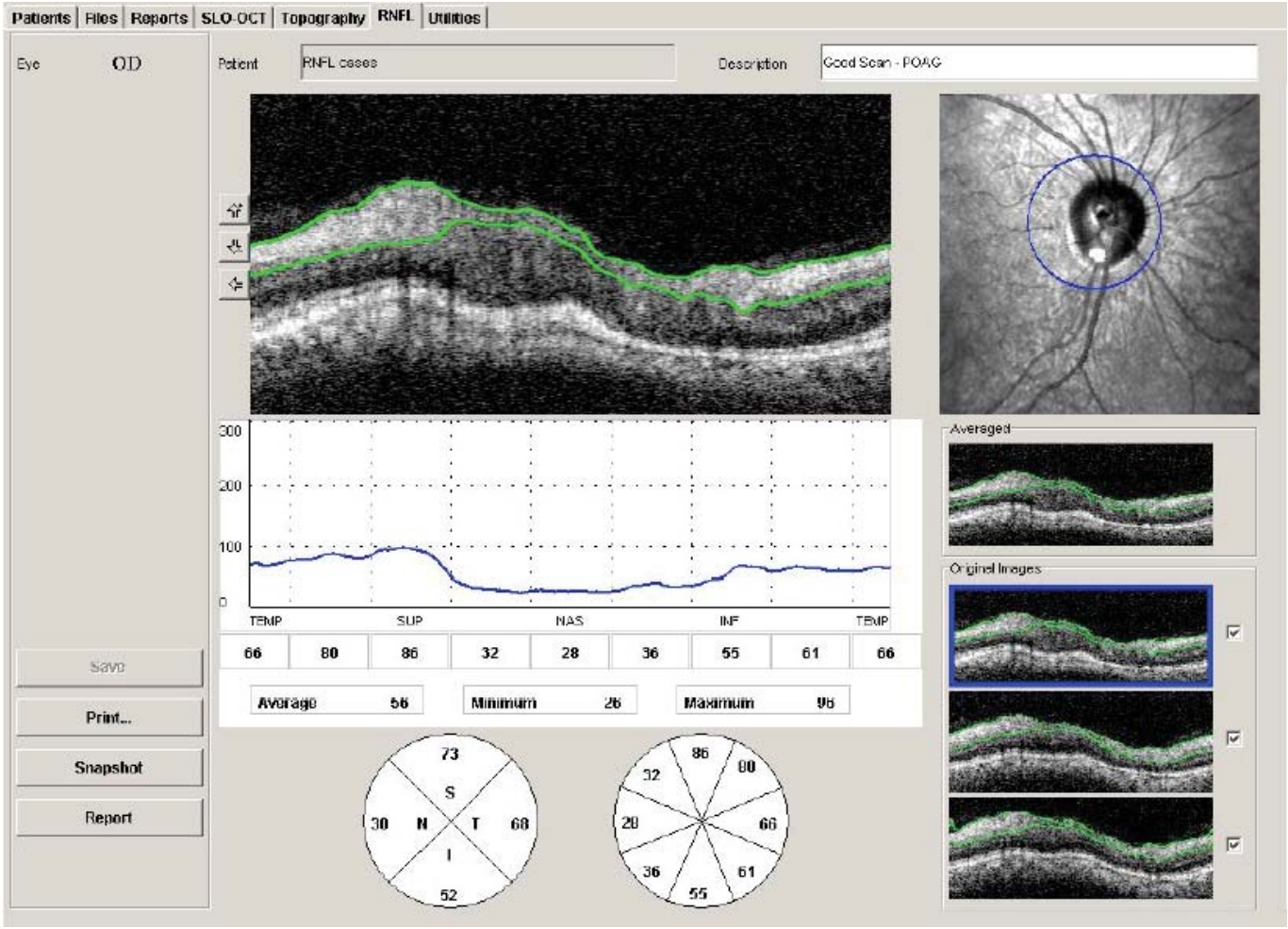
Commercial OCT software

- **3D rendering** (qualitative analysis)



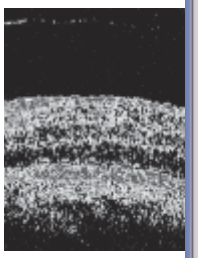
OCT Commercial Software

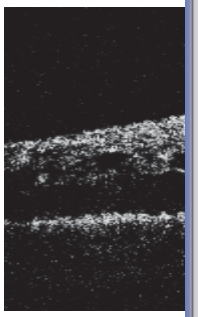
- **Measurement of retinal thickness** (quantitative analysis)

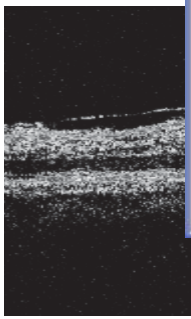


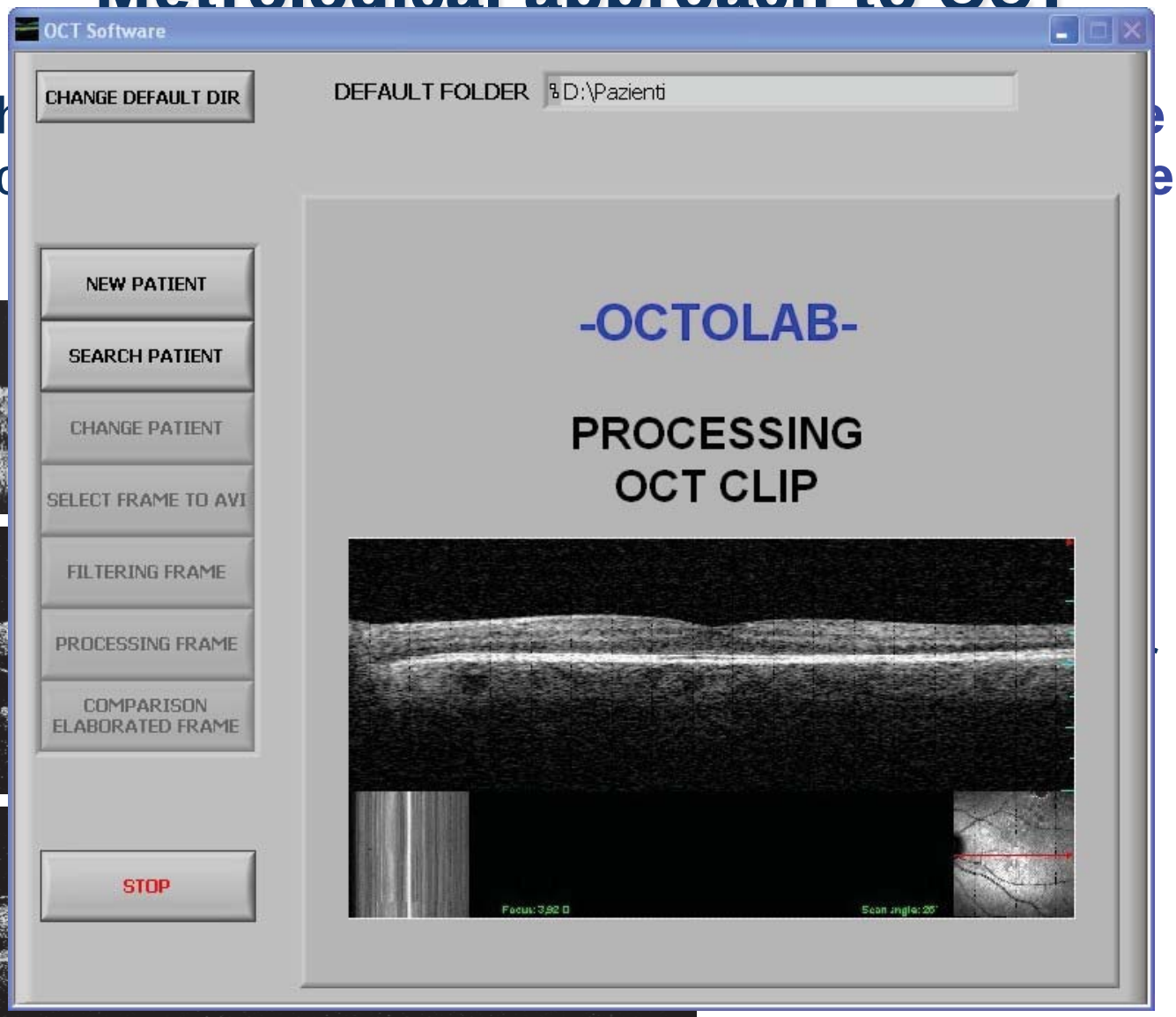
Metrological approach to OCT

- Equip th **analysis** of patho **e** way with OCT



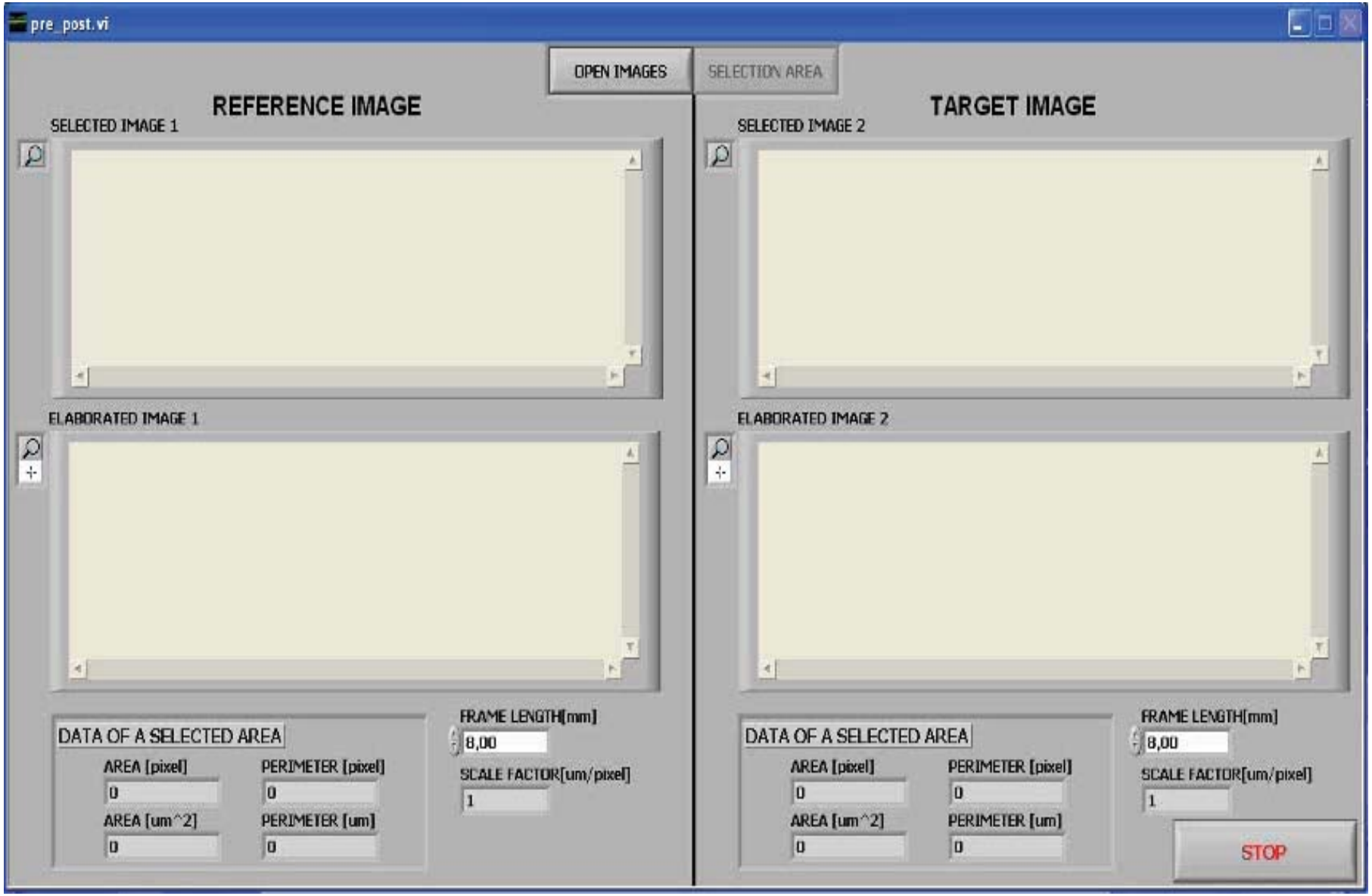






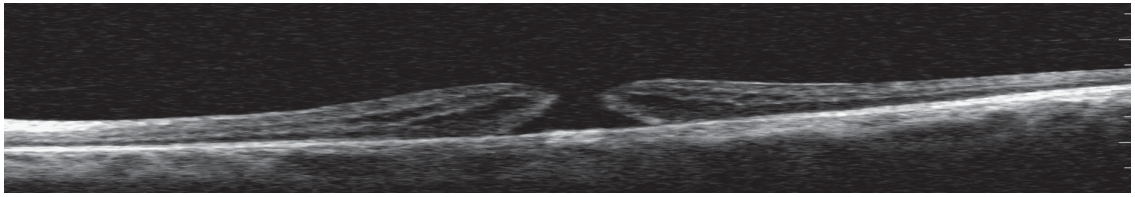
Edema

OCTOLAB: Frame elaboration

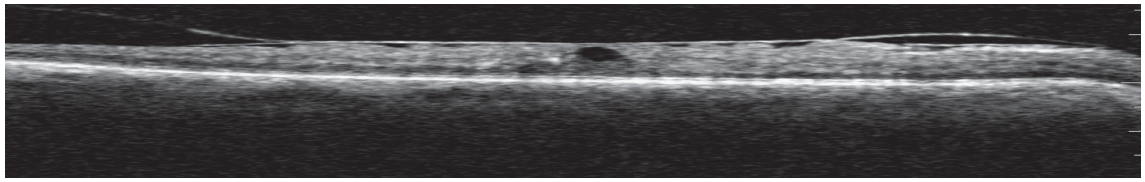


Experimental tests with OCTOLAB

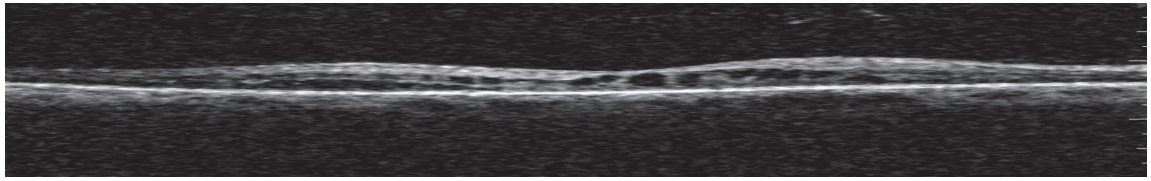
- Evaluation of SW on three groups of patients:
  - 4 patients with macular edema



  - 8 patients with macular pucker

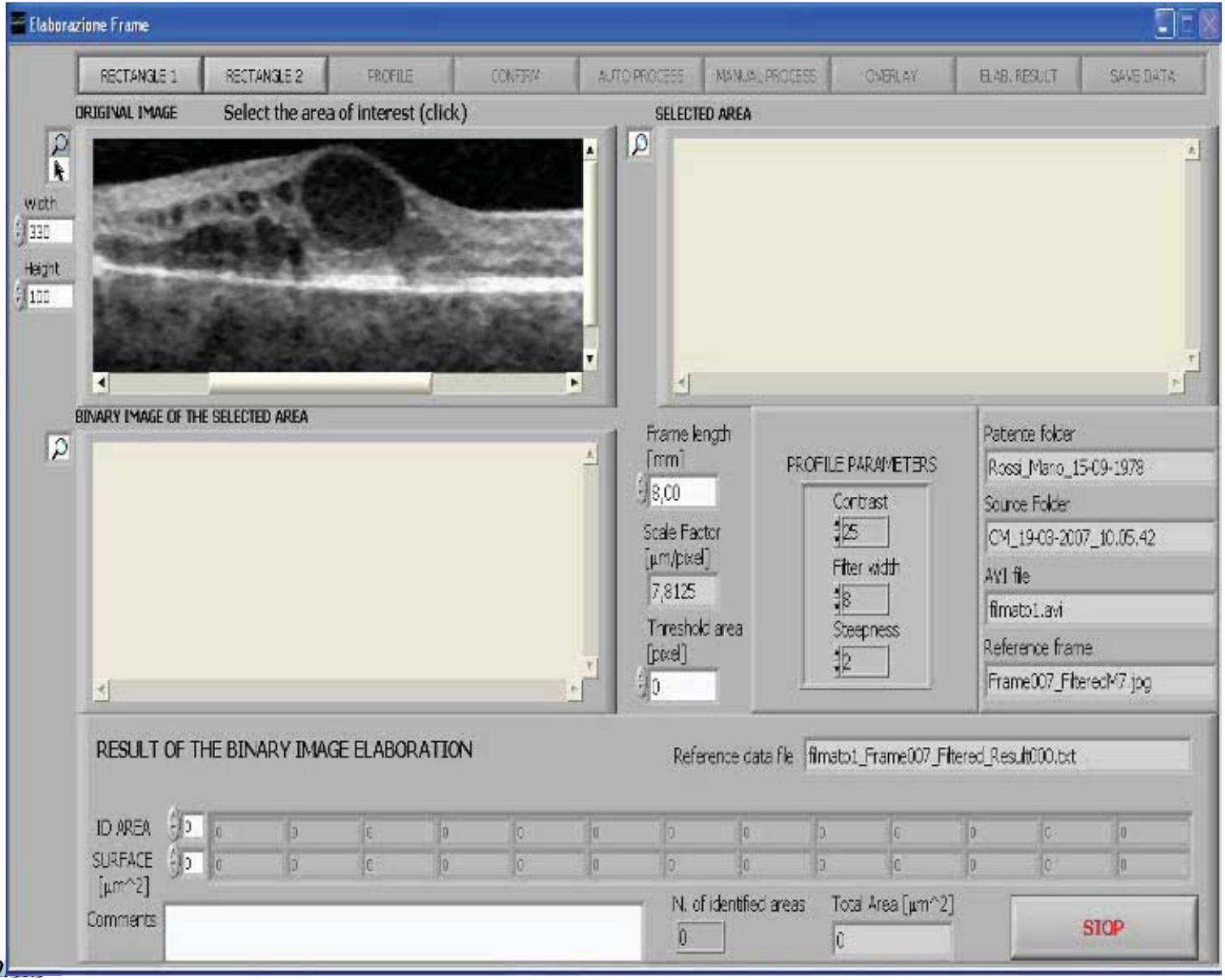


  - 7 patients with diabetic macular edema



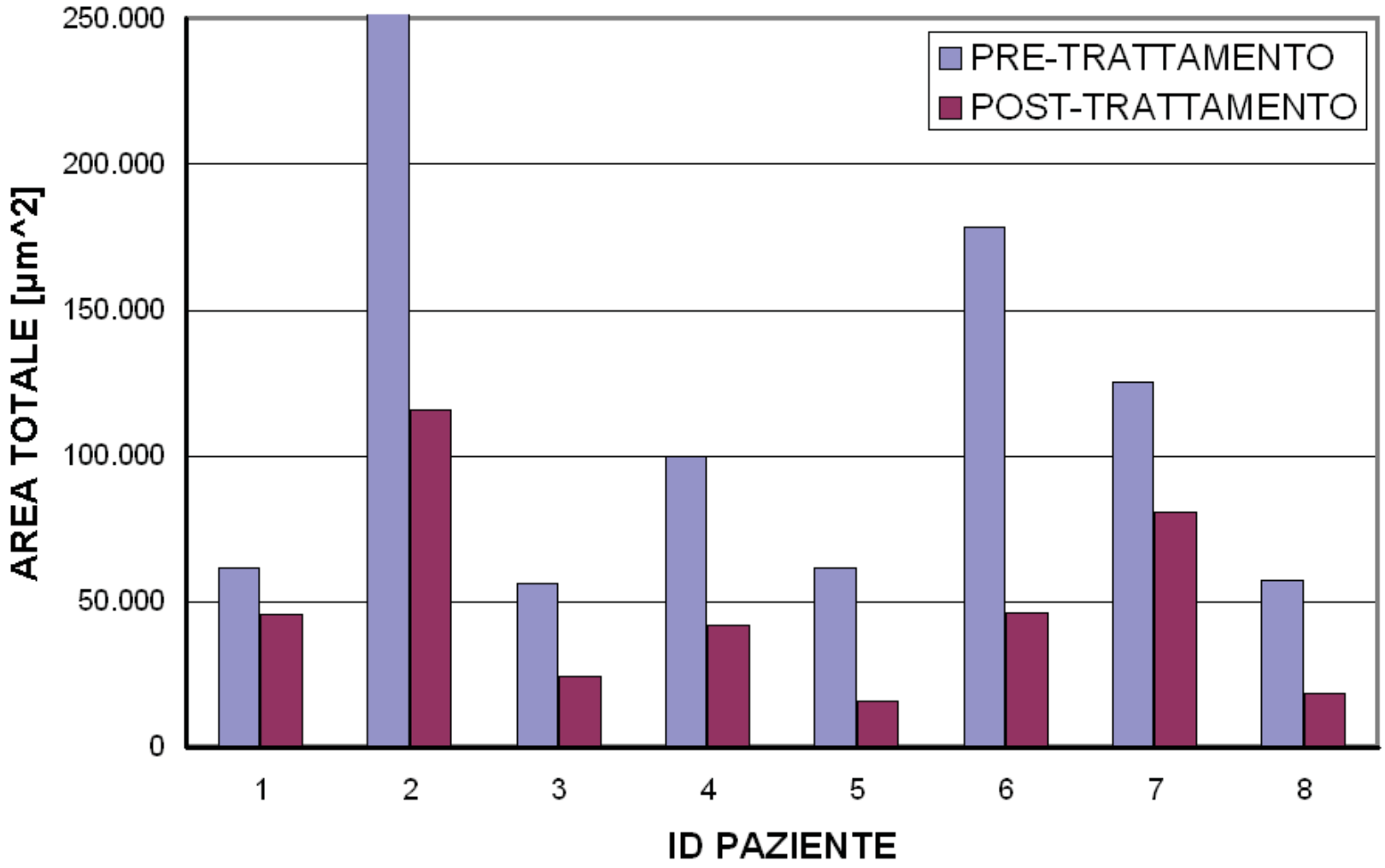
- Patient follow-up

OCTOLAB: Comparison of elaborations



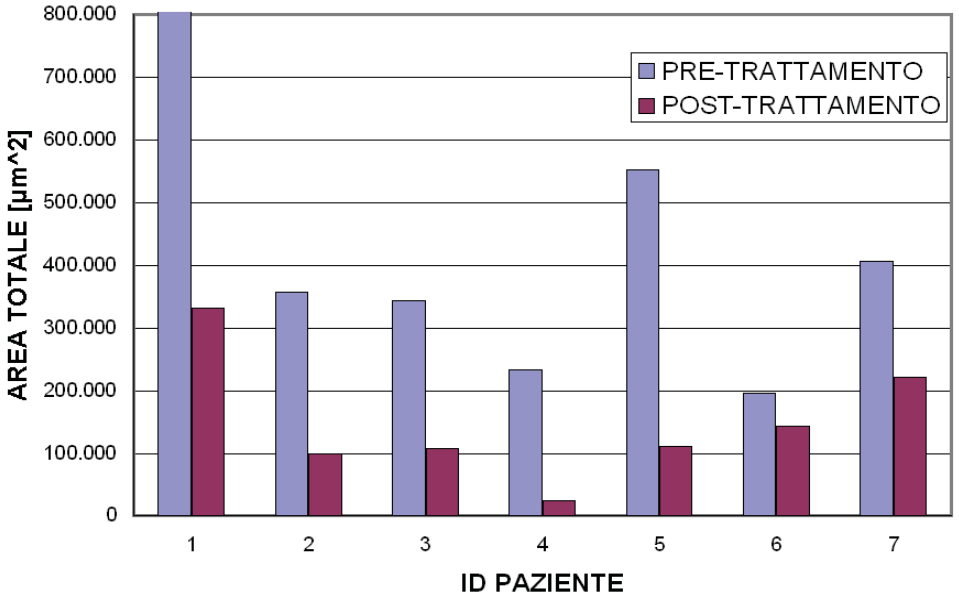
Experimental results

Macular Pucker (Evaluation of total surface of cysts)

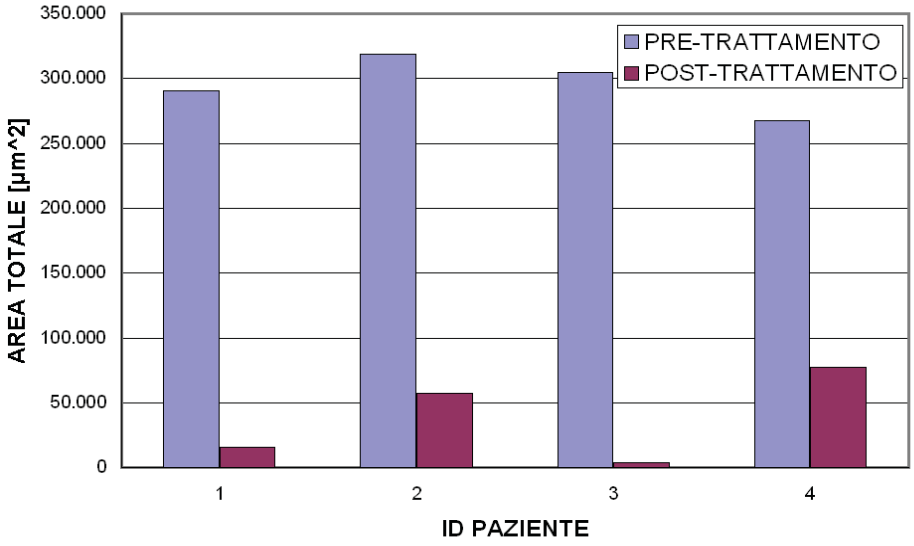


Experimental tests (2)

- Diabetic macular edema
  - Cyst reduction: 27% - 89%



- Macular hole:
  - Cyst reduction: 71% - 99%



Results

- Quantitative image elaboration + image metrology allows the improvement of diagnostic ability of ophthalmic instruments

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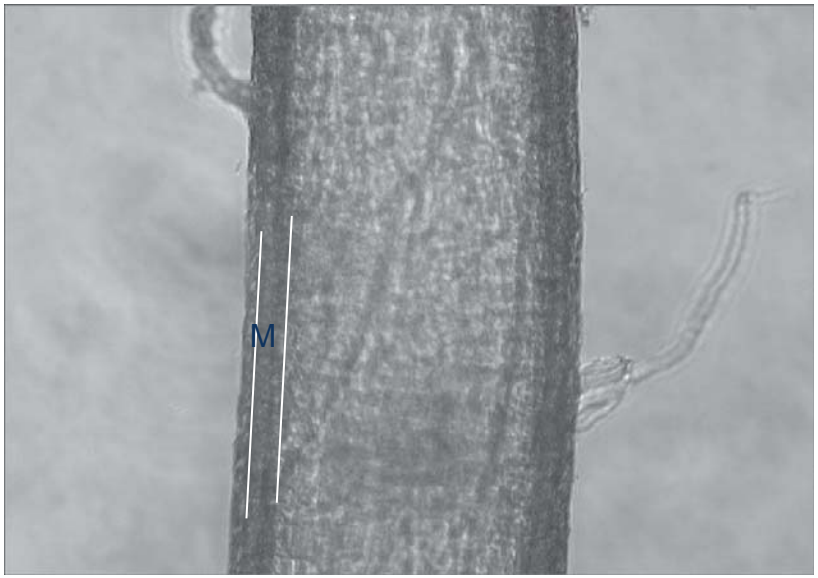
2D and 3D imaging in ophthalmology

Case 2: Retinal arthery evaluation as a predictor of hypertension to predict early structural alterations in hypertensive patients

Partnership: II Medicine & Ophthalmic clinic, Brescia

Structural alterations of cerebral small arteries in patients with essential hypertension

- Media to lumen ratio of cerebral small resistance arteries increases in hypertensive subjects
- the ocular approach: only noninvasive way to assess variation of media to lumen ratio



Cerebral artery of a hypertensive patient (Z.L. 62 years)

Wire micromyograph M/L=0.098 internal diameter 310 µm

Pressure micromyograph M/L=0.083 internal diameter 296 µm

First approach:
Heidelberg Retinal Flowmeter

- Combines fundus camera (To assess outer arthery diameter) to doppler flow imaging to visualize inner diameter
- No longer in production - expensive

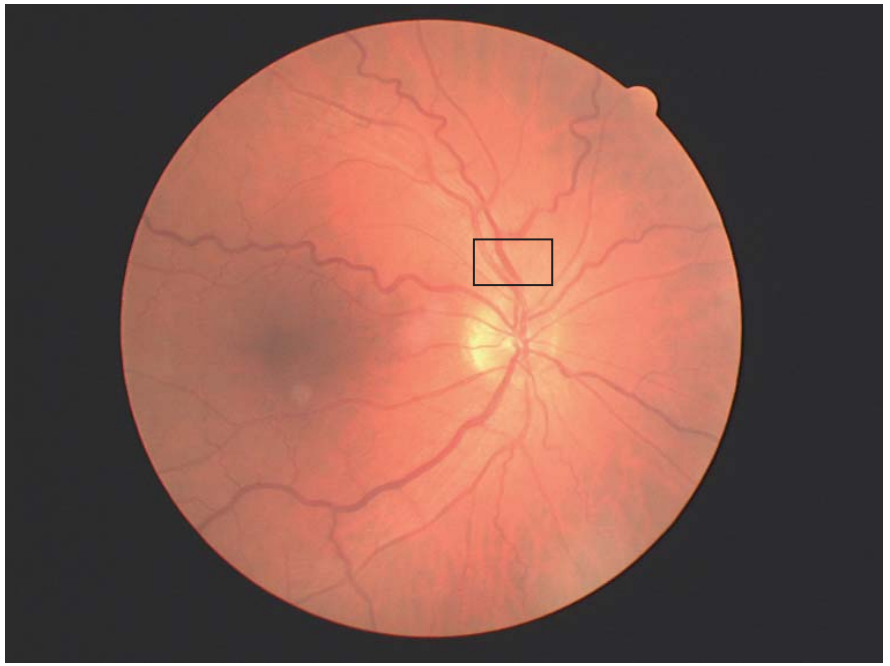
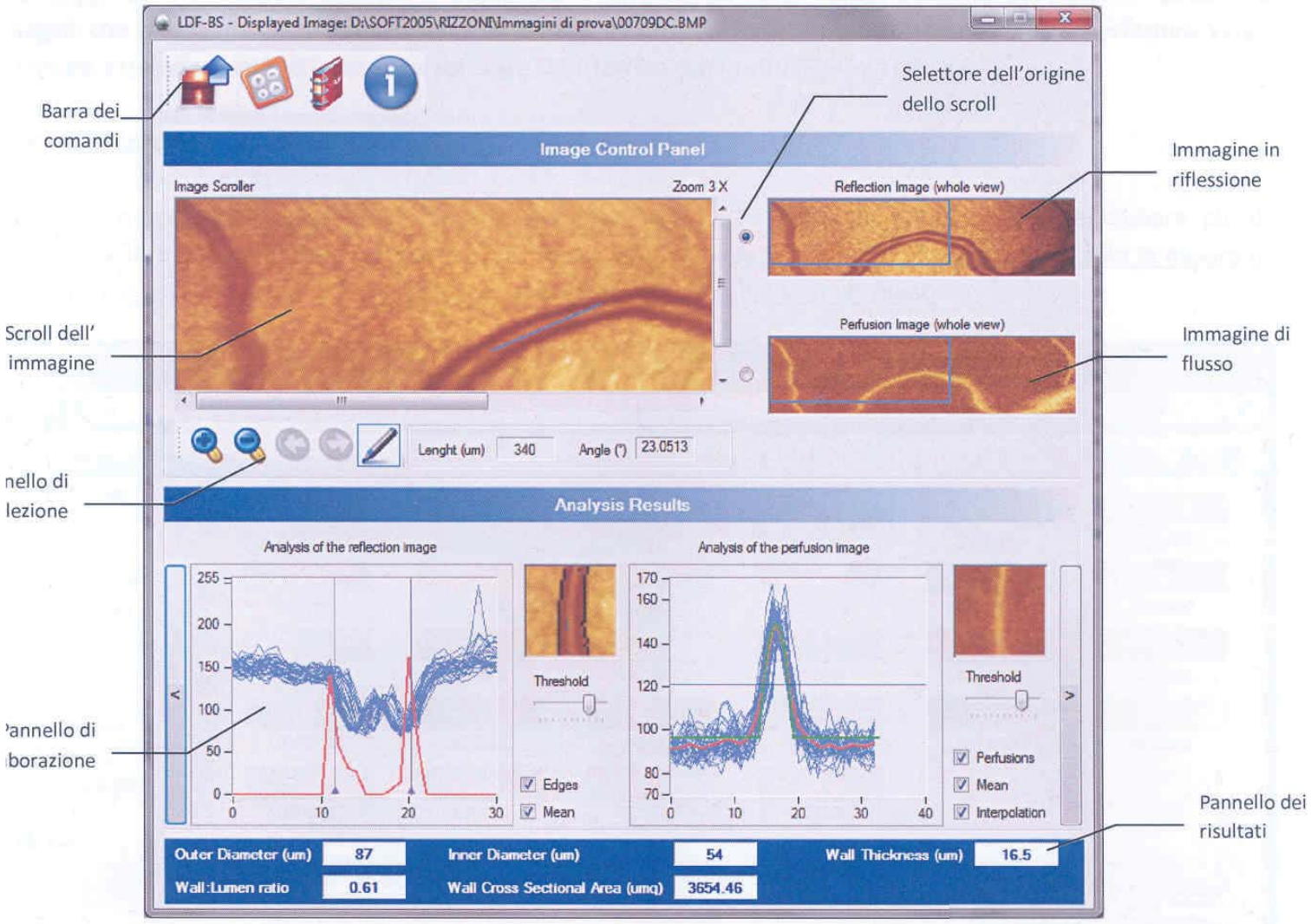
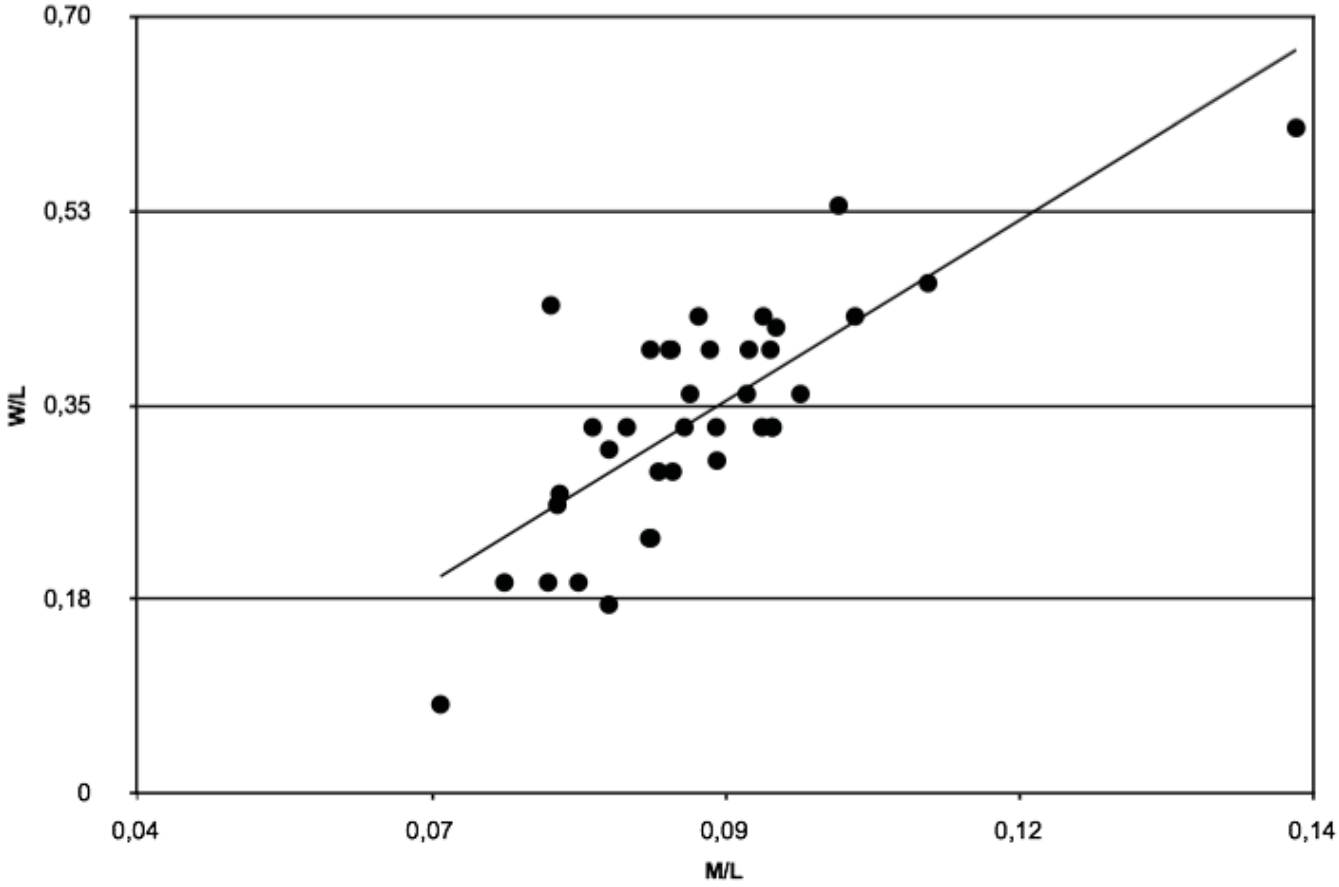


Image elaboration SW tool



Correlation between wall to lumen ratio (W(L) of retinal arteries and media to lumen ratio (M/L) of subcutaneous small arteries

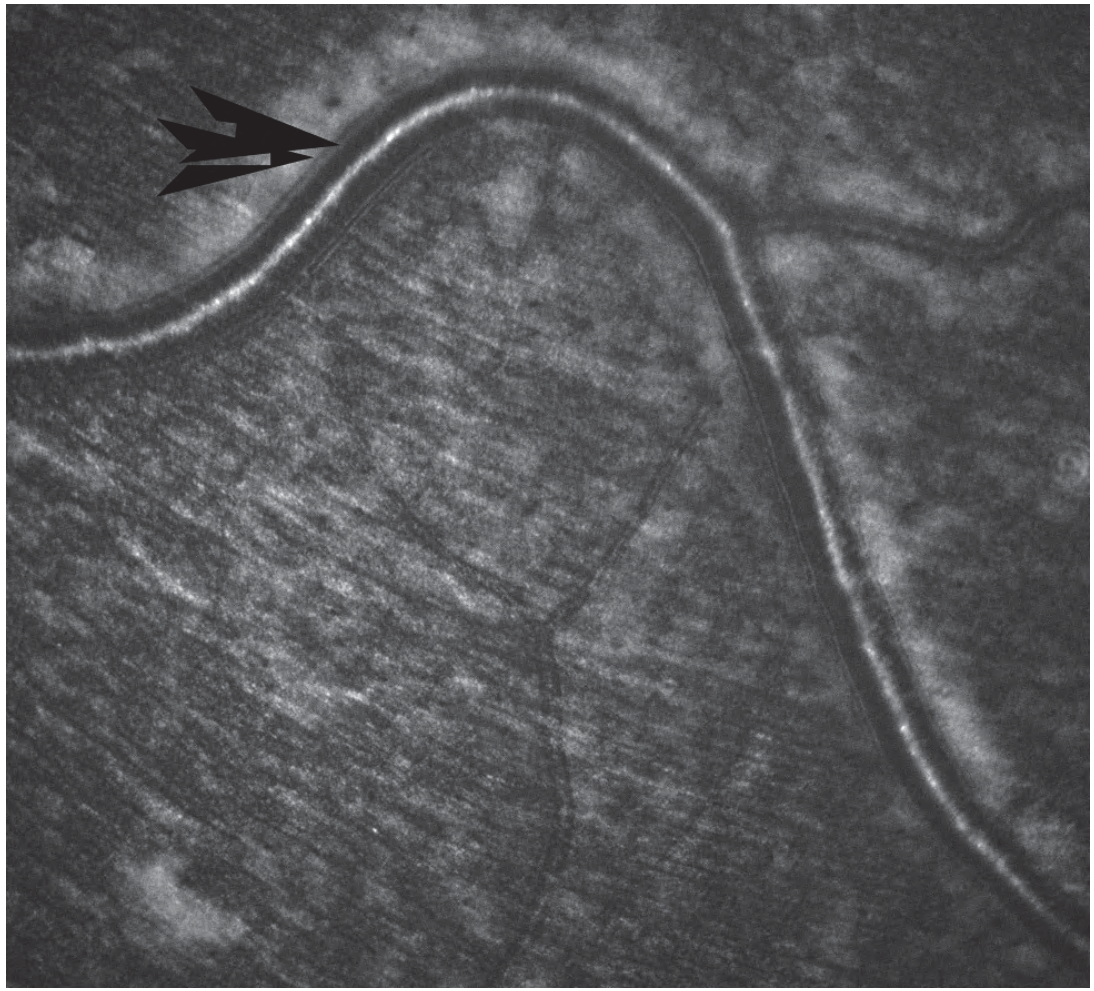


In normotensive subjects: n=14, r=0.54, p<0.05

In hypertensive patients : n=23, r=0.82, p<0.001

New approach:
Adaptive optics fundus cameras!

- Adaptive optics: tool to fit existing fundus cameras for dramatic improvement of image resolution



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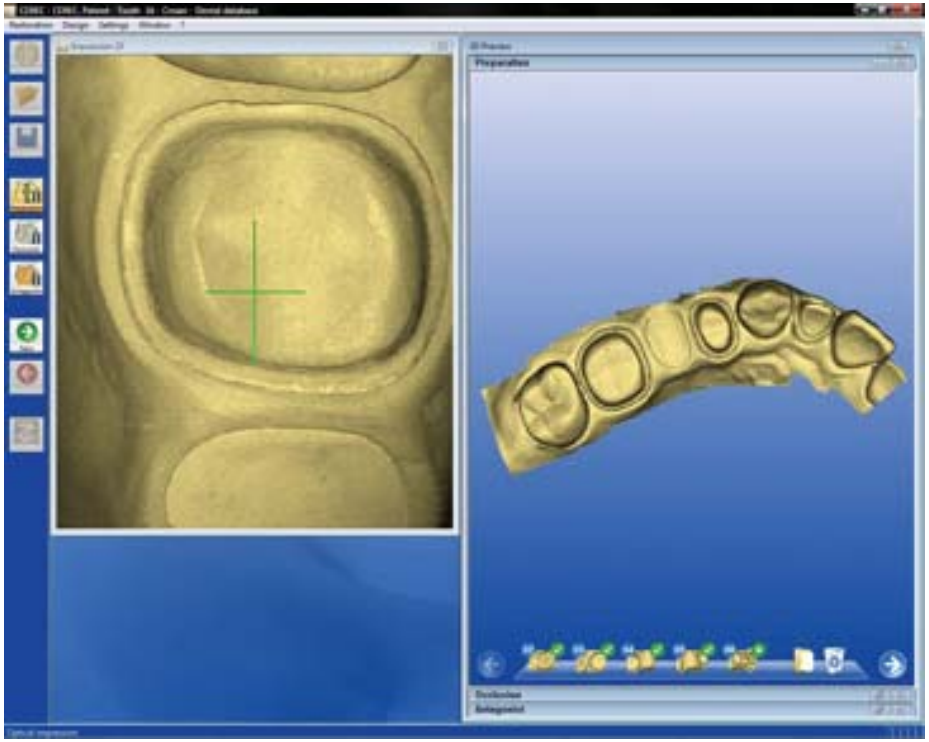
3D imaging in dentistry and orthodontics

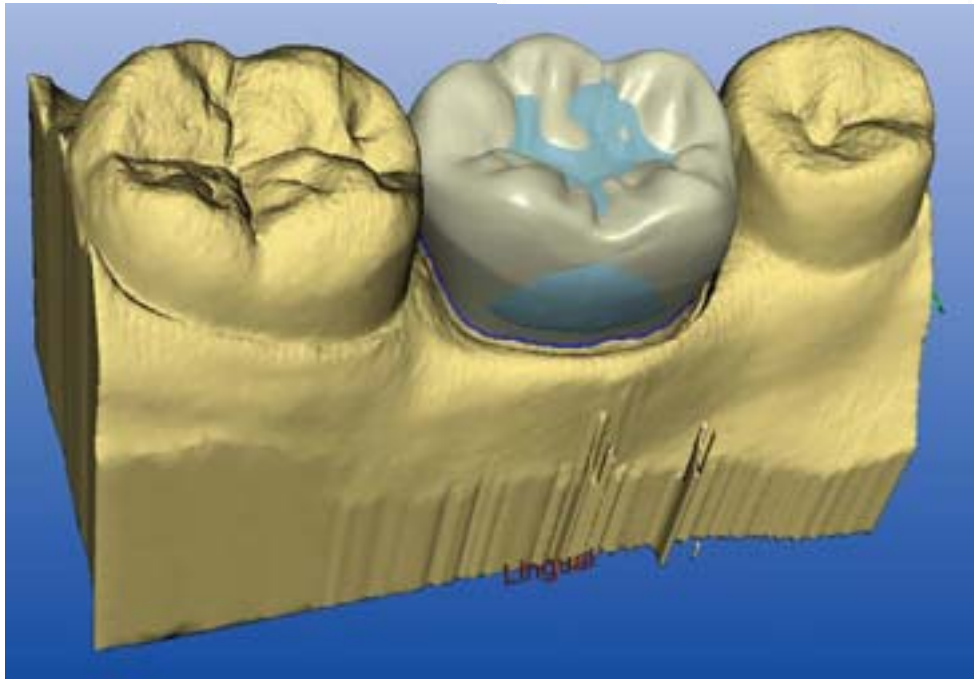
Partnership: Open Technologies

open technologies

Optical 3D Scanner

3D imaging of teeth: a reality





The new 3D optical scanner for teeth plasters

- Structured light projection (2 cameras, 1 projector)
- Accuracy: <5 microns
- Repeatability: <2 microns
- Failure rate: <1%
- Scan resolution: >120,000 triangles (single element), >2,000,000 triangles (entire plaster)

open technologies
Optical 3D Scanner

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3D Imaging in prosthetic technology

Applications to maxillofacial prosthesis reverse engineering

Maxillofacial prosthetics

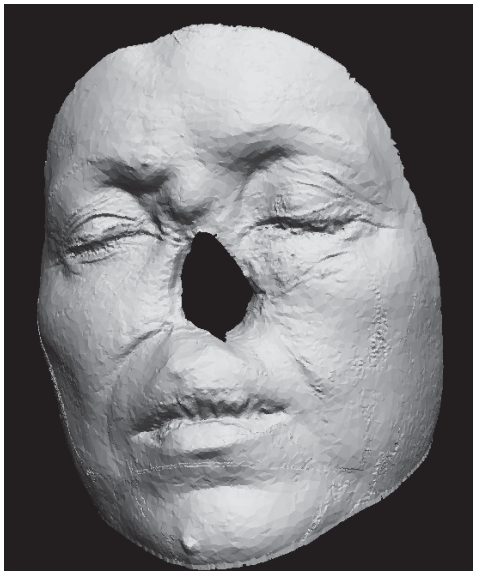
- Post-oncological reconstruction of maxillo-facial defects
  - Nose, orbital region, ear.....
- Real psychological and economic problems deriving from the handicap
- Real functionality problems
- Surgical reconstruction:
  - High invasiveness
  - Very expensive
  - Not always applicable (extension of the defect, soft tissue deformation...)
- **Prosthetic reconstruction**:
  - Reduced invasiveness
  - Reduced maintenance
  - Low cost
  - Simpler implementation

It is performed by…..(traditional method)

- the use of **impression making** procedures
  - to obtain the negative patterns of the site of the deformity
- the **plaster casting** of negative patterns
  - to retrieve the positive defects
- the construction of **wax positive replicas** of the actual prosthesis
- the use of **conventional flasking and investing procedures**
  - to obtain the negative mould
- and the **casting of suitable materials into the negative mould**
  - to obtain the definitive, actual prosthesis

Aim of the work

- Direct fabrication of the prosthesis using 3D acquisition, reverse engineering and rapid prototyping
  - Avoids impression making
  - Shortens try-in on the patient's face
  - Decreases dependence on the anaplasthologist skill
  - High repeteability of the process
  - High flexibility of the process



The proposed method

The proposed method: results

- No patient's stress
- Very fast procedure
- High repeatability (for prosthesis replication)
- High flexibility

Ear reconstruction (symmetry)

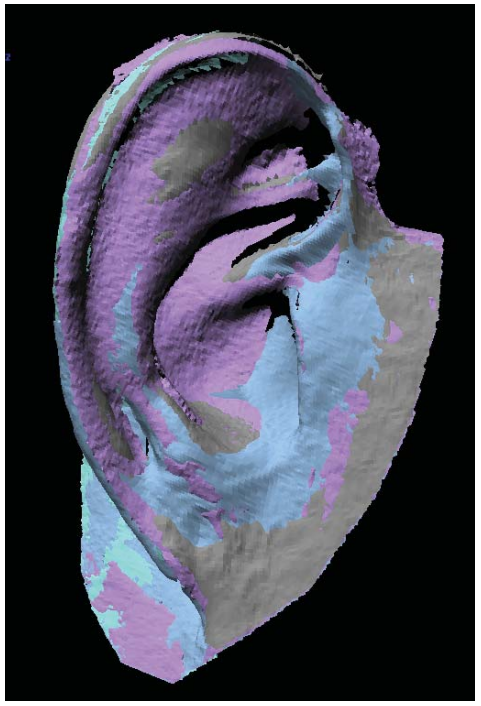
- Acquisition of the safe ear

Patient defect (left ear)

Right, safe ear

- Multiview acquisition, meshing and mirroring of the right ear
  - Vivid 910 in WIDE mode, 4 views

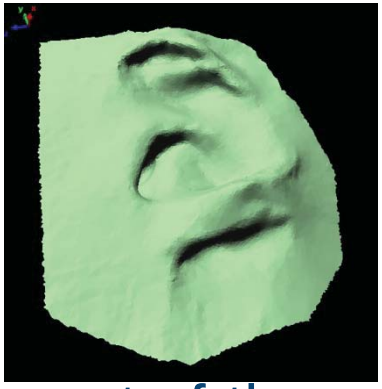
Point cloud



Rendered mesh

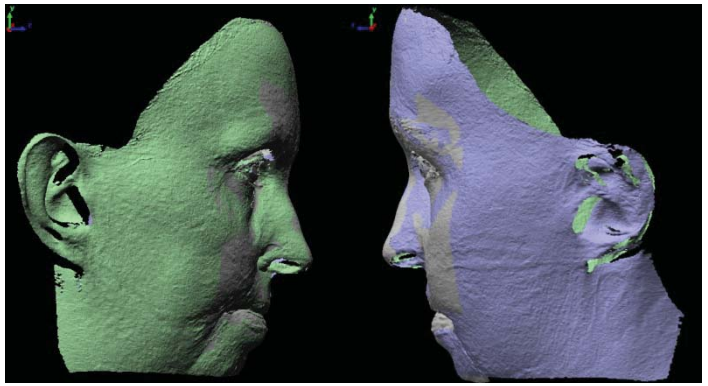
Ear reconstruction

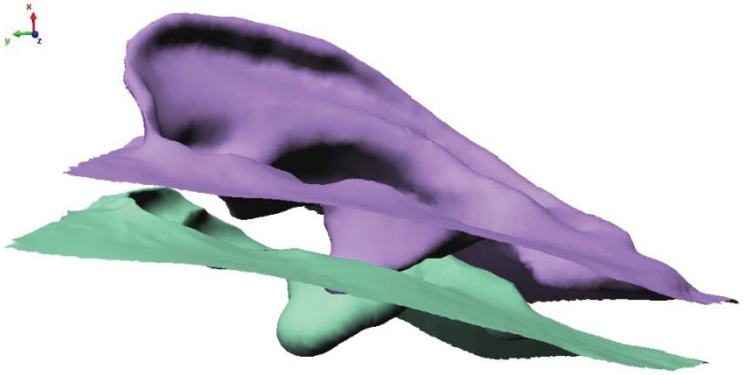
- Modeling of the left ear
  - Vivid 910 in WIDE mode, 2 views



- Alignment of the models

- To precisely align the two models, the whole face is acquired, and used as a skeleton (3 views):





Ear reconstruction

- The copies are prototiped by means of the Connex500™ 3D printing system (www.objet.com), that jets multiple model materials simultaneously.
- Two rubber-like materials are used to produce the prosthetic elements: TangoBlackPlus Shore A85 (auricle zone), TangoBlackPlus Shore A85 (border zone)

Side anchored to the defect

External appearence of the prosthesis

First (and last) try-in

- The prosthetic element fits the tissues and shows perfect matching with the shape underneath.
- Remaining steps:
  - Adding color
  - Fixing the prosthesis
- Cost: 70 Euros
- Time of production: 1 hour

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3D Imaging in forensic science and criminology

Large scale scene documentation, interior documentation, wounds and scratches, metrology of corpses, autoptic room acquisition

Actors of the work

Castellanza M. Picozzi

Criminologists

Labanof: Milan, C. Cattaneo

Legal doctors

Bologna, G. Ceccaroli

Italian Police

Brescia, Laboratory of Optoelectronics

Roma, C. Bui

UACV

Crime scene documentation

- **First step in criminal investigation**
- Very critical. If something is lost or damaged, subsequent steps are compromised.
- **Standard documentation of crime scenes**:
  - on site documentation
    - ✓Videos, photographs, contact measurements (conventional)
    - ✓Range optical scanners (under experimentation)
  - forensic analysis

Aim of the work

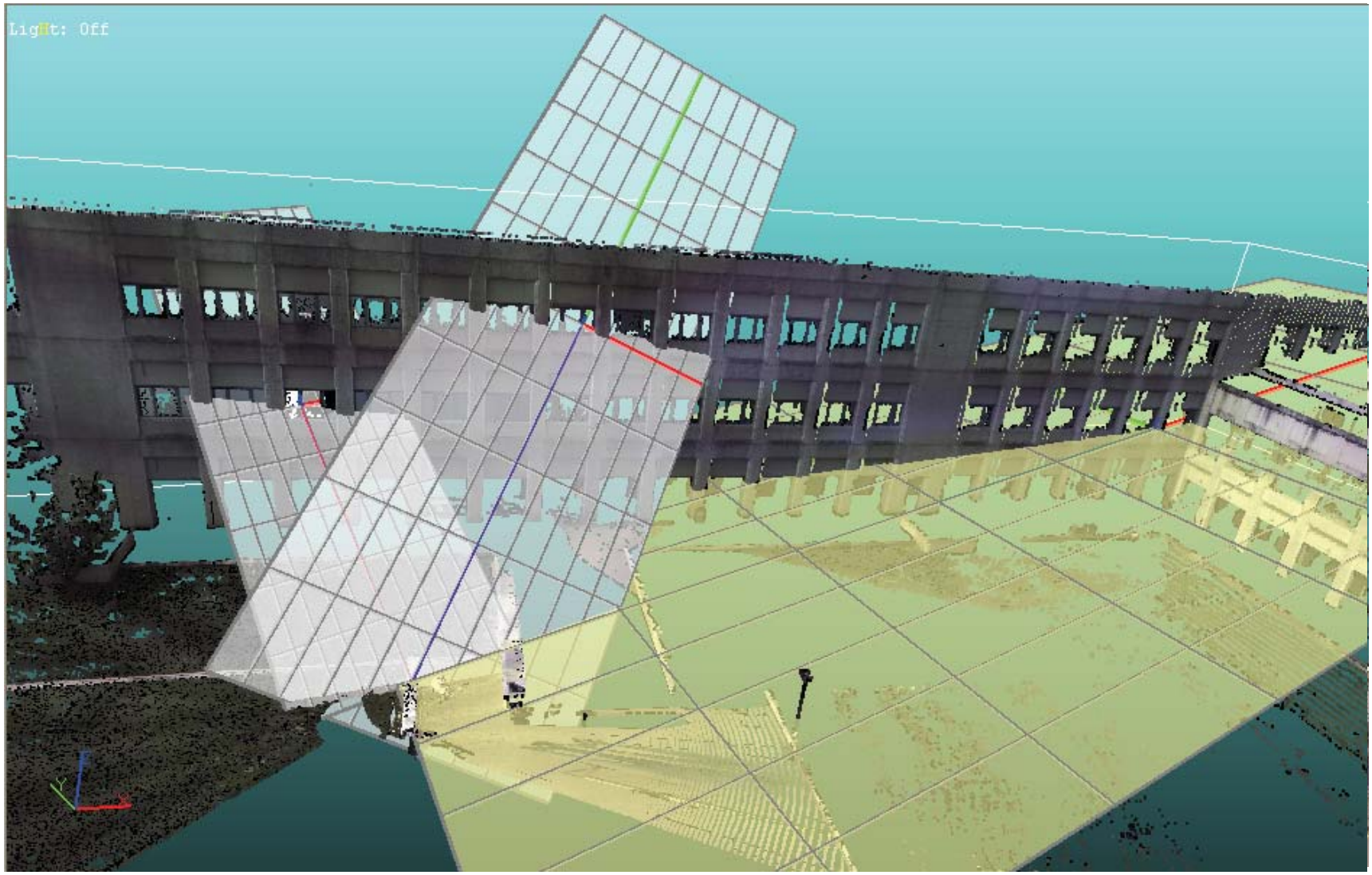
- **To assess the feasibility** of using optical 3D acquisition and reverse engineering for the documentation of crime scenes **before** their removal
- Previous work:
  - » Sansoni, G., Cattaneo, C., Trebeschi, M., Gibelli, D., Porta, D., Picozzi, M., (2009): “Feasibility of contactless 3D optical measurement for the analysis of bone and soft tissues lesions: new technologies and perspectives in forensic sciences”, J Forensic Sci, Vol.54, No.4, pp.540-5.
  - » Sansoni, G., Cattaneo, C., Trebeschi, M., Gibelli, D., Poppa, P., Porta, D., Maldarella, M., Picozzi, M., (2009): “Scene of crime analysis by a 3D optical digitizer: a useful perspective for forensic science”, Am J Forensic Med Pathol, Accepted May 28, 2009.

Acquisition of large scenes

The acquisition step (1)

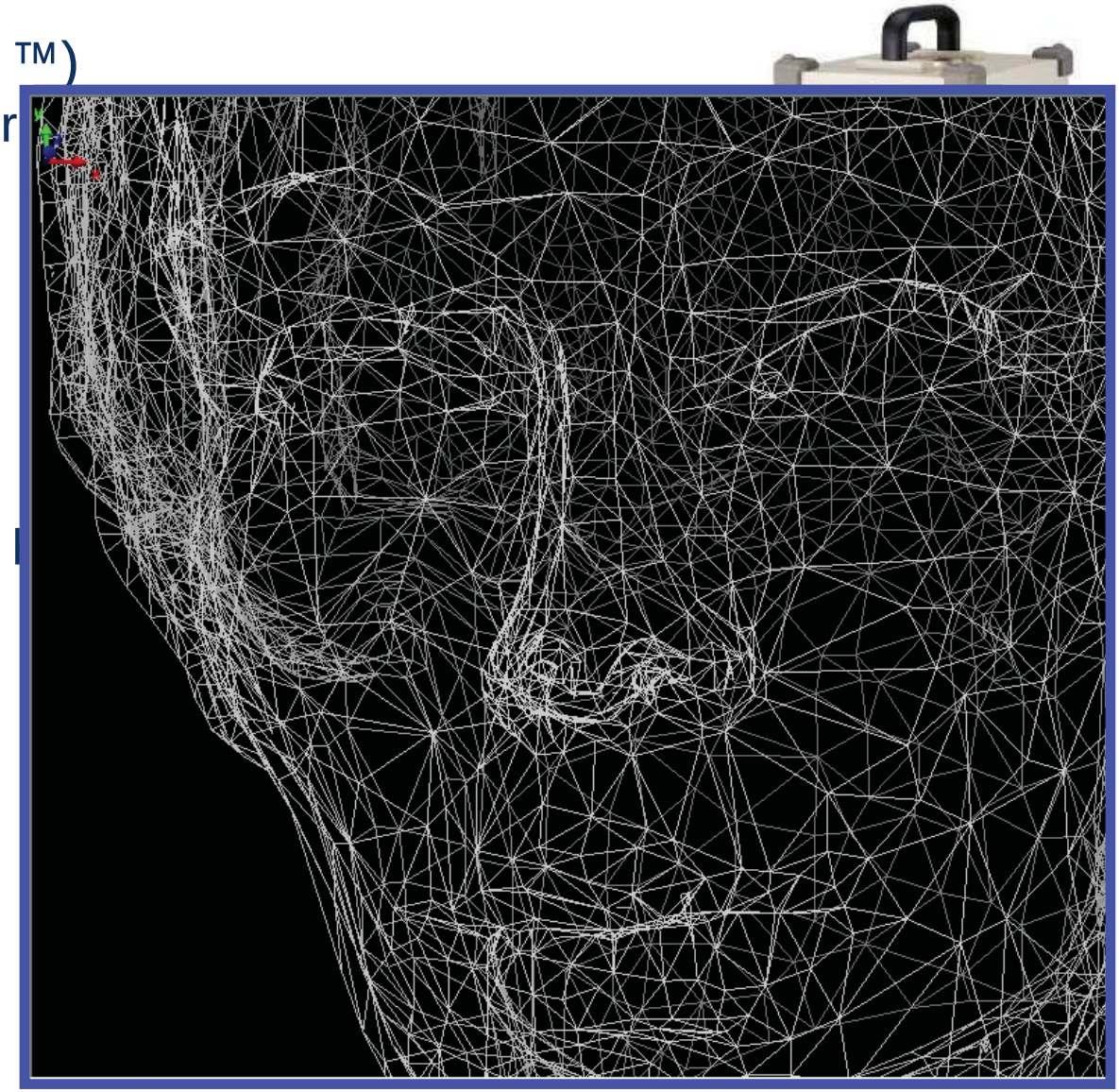
2 mm (resolution)
and 2 m (range)

Reconstruction and ballistics



The optical sensor

- Vivid 910 (Konica Minolta ™)
  - Measurement principle: laser
    - Characteristics
    - The measurement information:
      - Portable
      - Adaptive
      - (x,y,z) point clouds
      - High resolution (up to 100
      - RGB color information

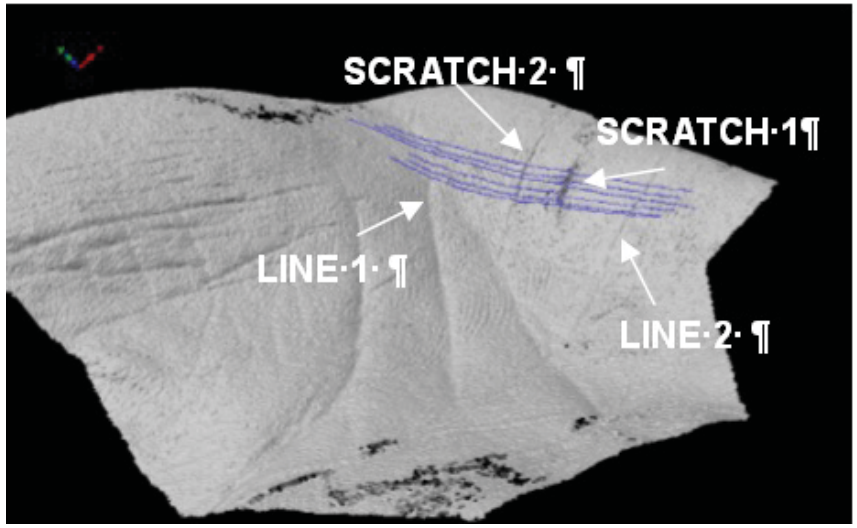


Case of study 1: the scratches

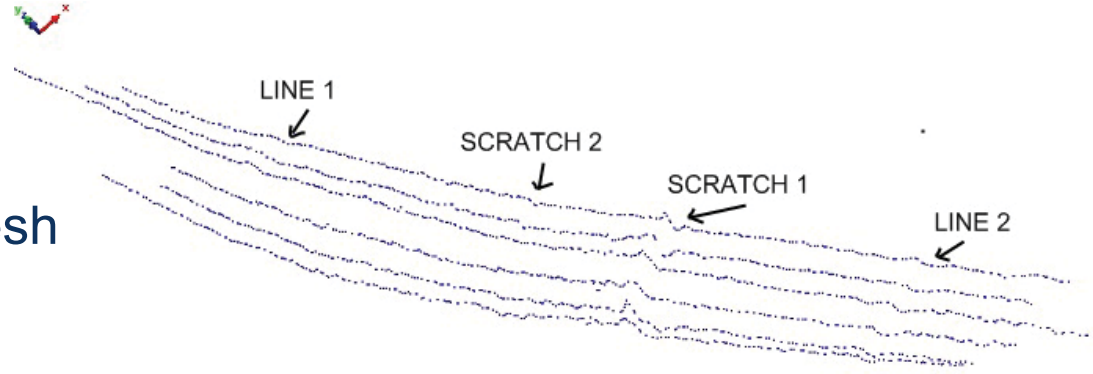
- TELE configuration: is the device sensitive enough to gauge the scratches on the hand?

2D photo

3D mesh



Sections from the 3D mesh

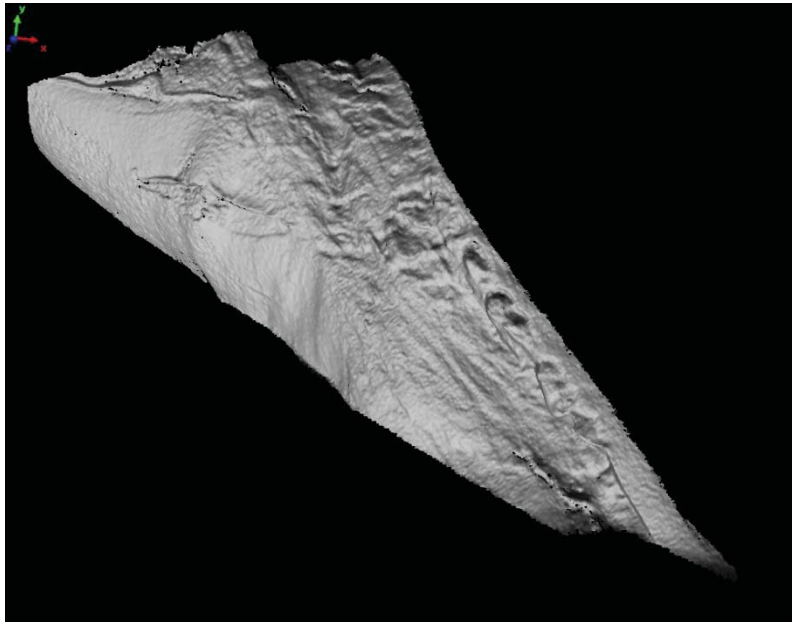


Case of study 1: the thorax region

- WIDE configuration: is the device robust enough to capture both steep slope changes and color variations?

2D photo

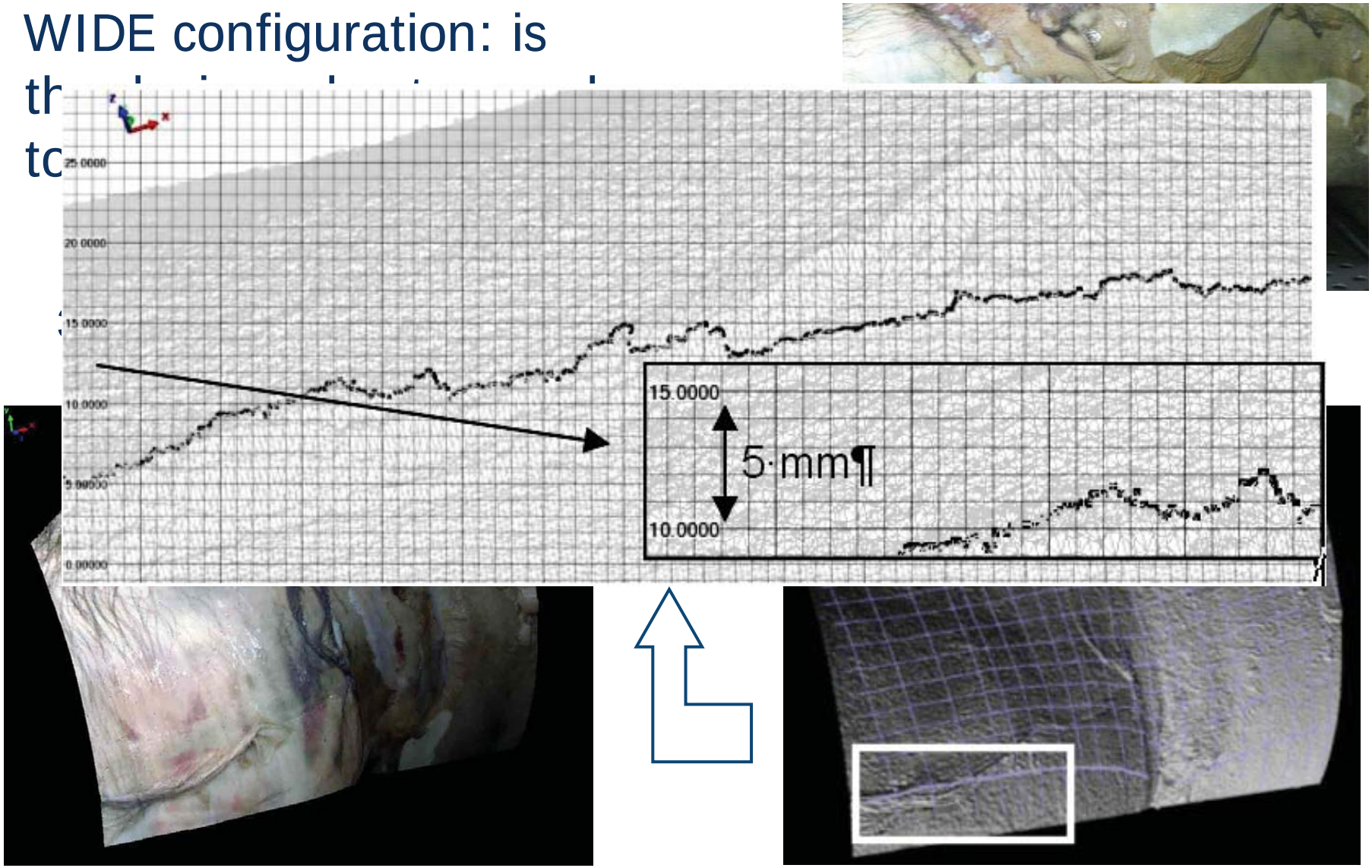
3D mesh (x,y,z)



3D mesh (x,y,z plus color)

Case of study 2: acquisition of a decomposed corpse

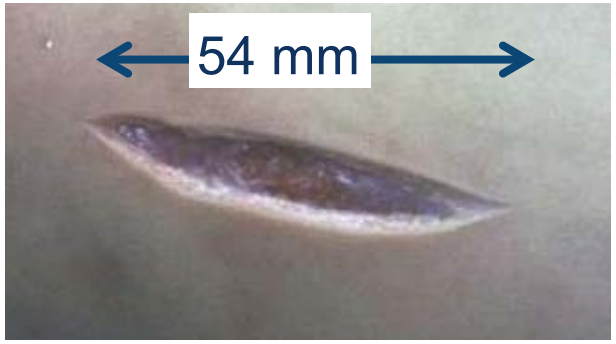
- WIDE configuration: is th
  tc



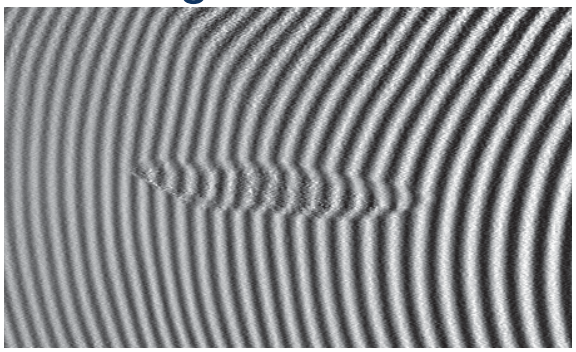
Case of study 3: the wound

- Comparative analysis between laser light and incoherent light (OPL-3D) ⟶ specifications ⟶

The wound

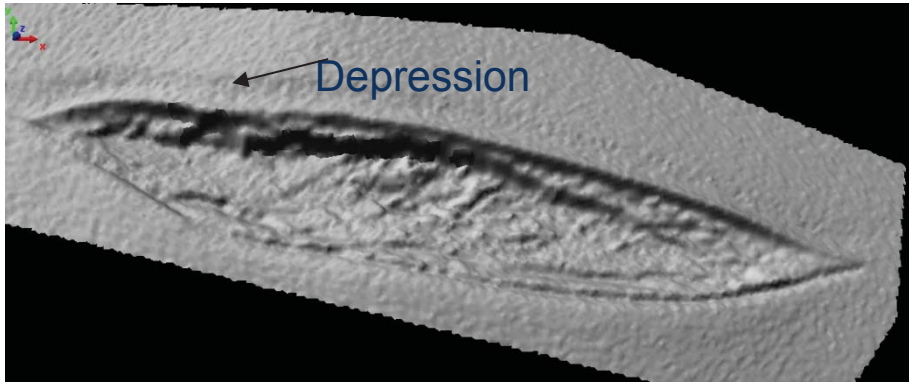


Fringe deformation

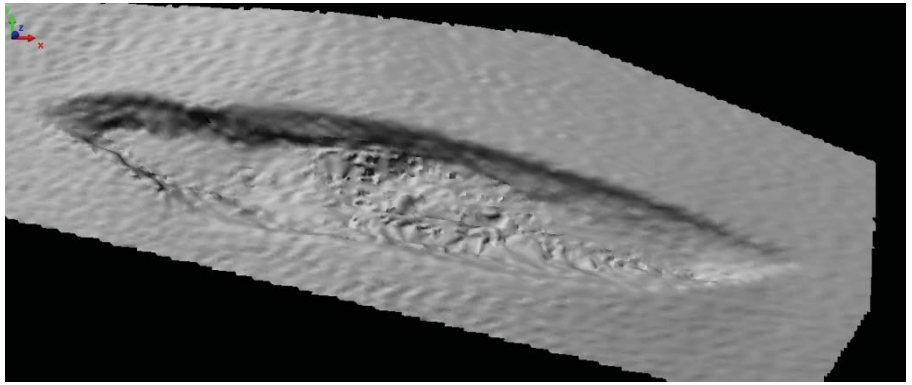


Set up	FOV (mm^2)	Z range (mm)	Rz (mm)
Set-up1	450X350	150	0,3
Set-up2	300x230	100	0,2
Set-up3	**160x123**	**40**	**0,1**

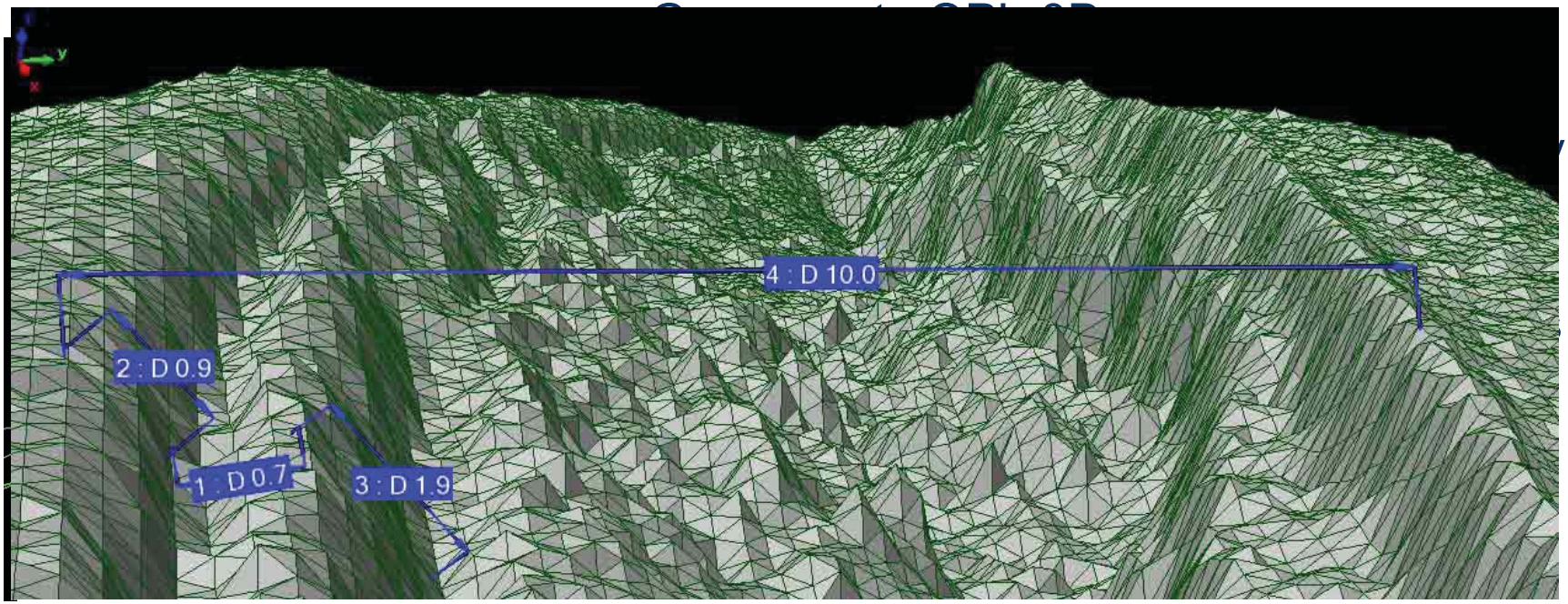
3D mesh from Vivid 910



3D mesh from OPL-3D



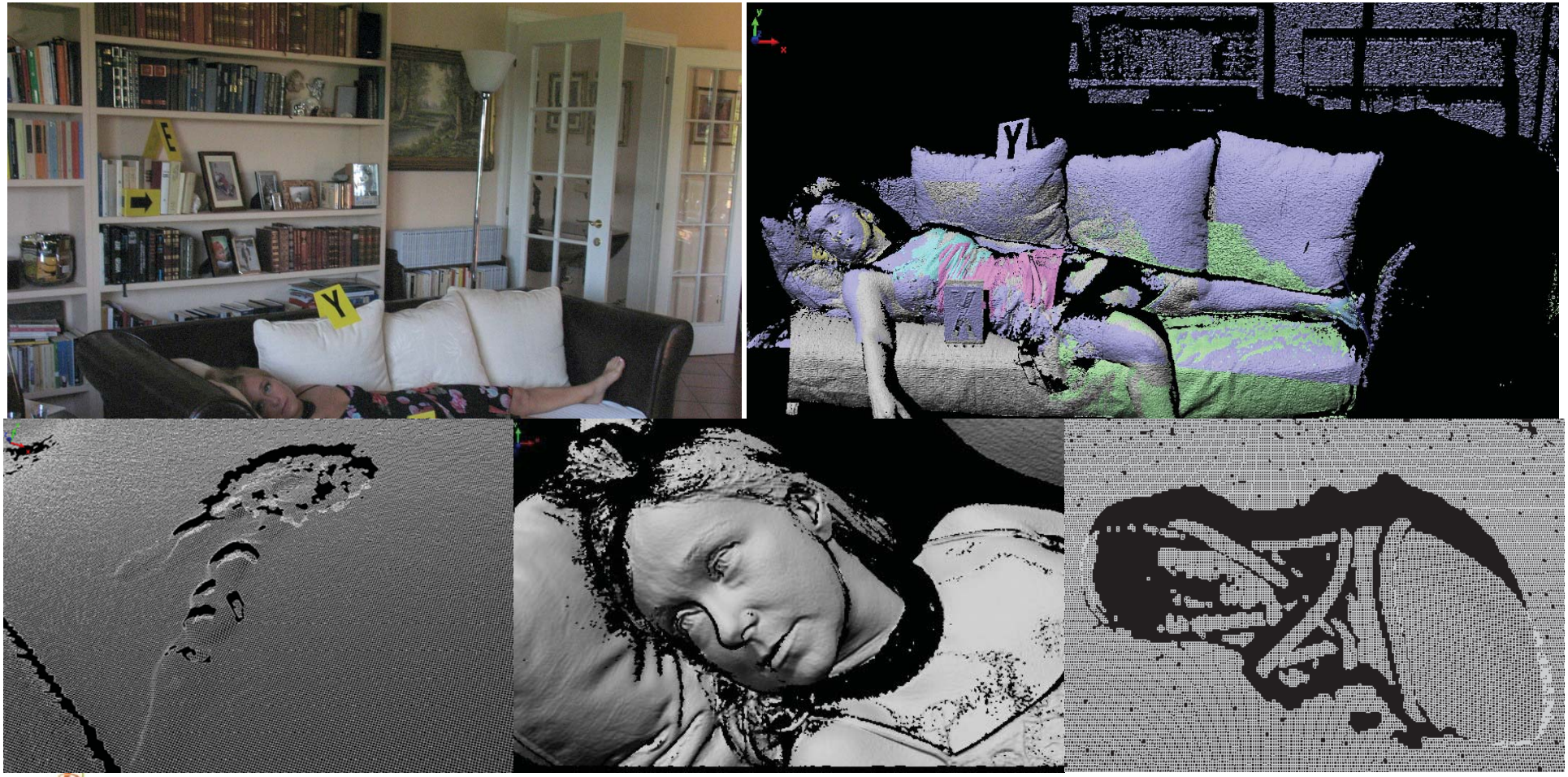
Case of study 3: the wound



Measurements performed on the mesh by using the Minolta device. Forensic specialists were impressed by the adherence of the model to the tissue shapes. The mesh is memorized for subsequent analysis; tissue deterioration is not critical.

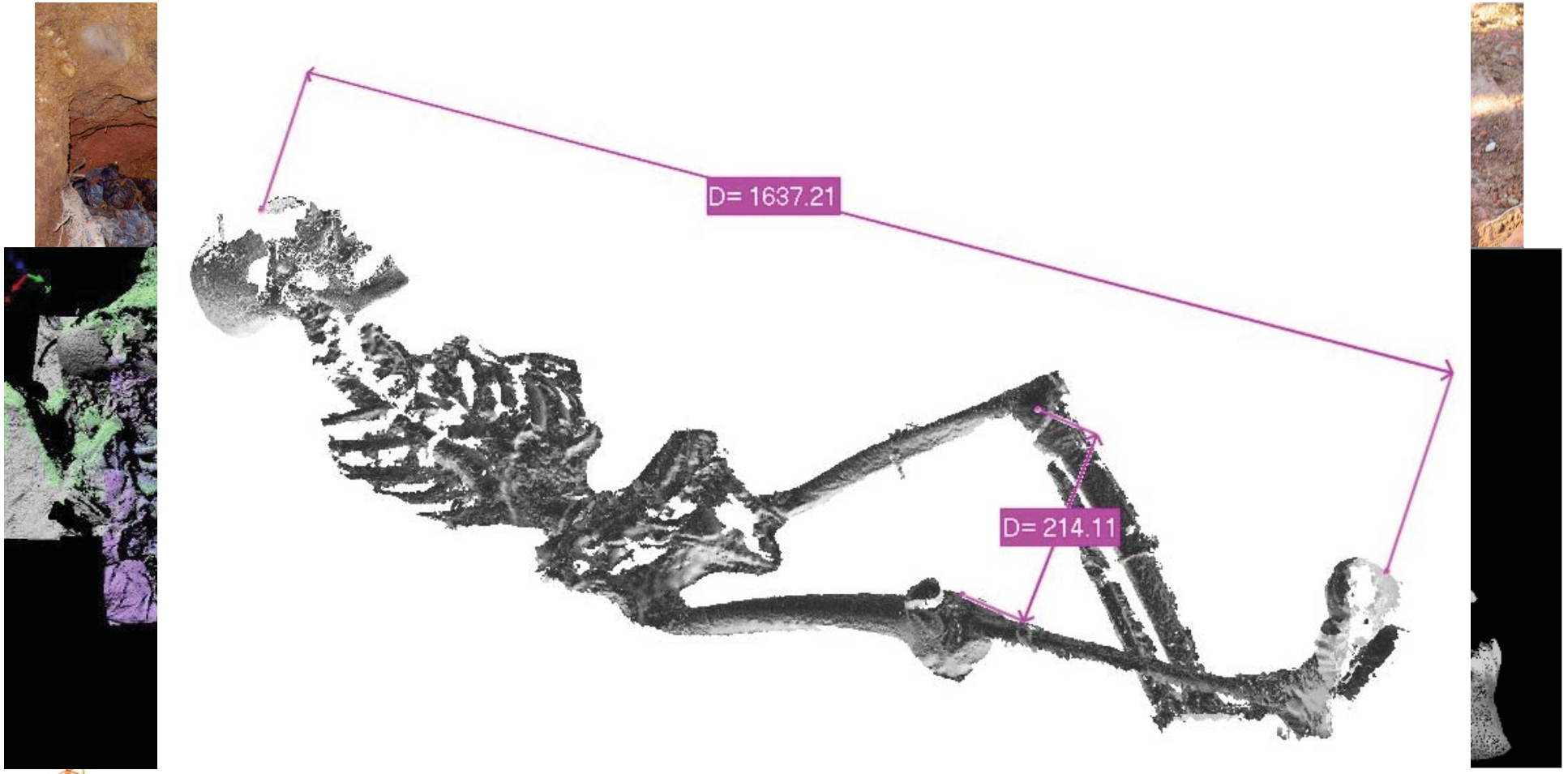
Indoor scene

- Simulated (by the police located in Bologna)
- Realistic



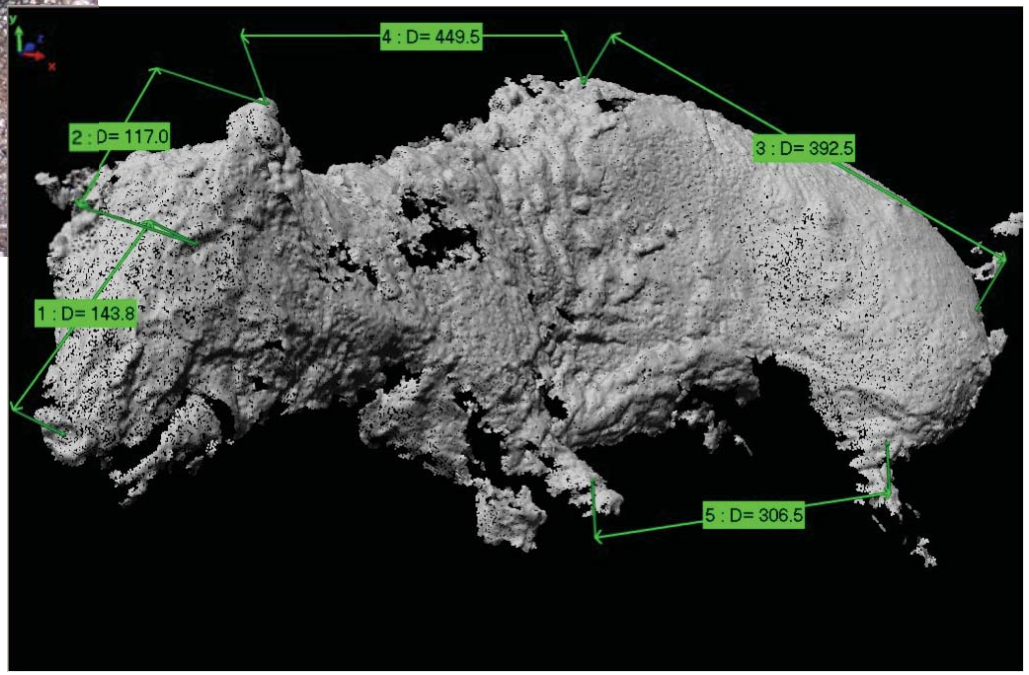
Outdoor scene (real)

- Mafia murder
- Very complex scene, short time, many people



What about carbonization?

- Sucking pigs are the most suitable to study carbonization (they behaves like humans...)

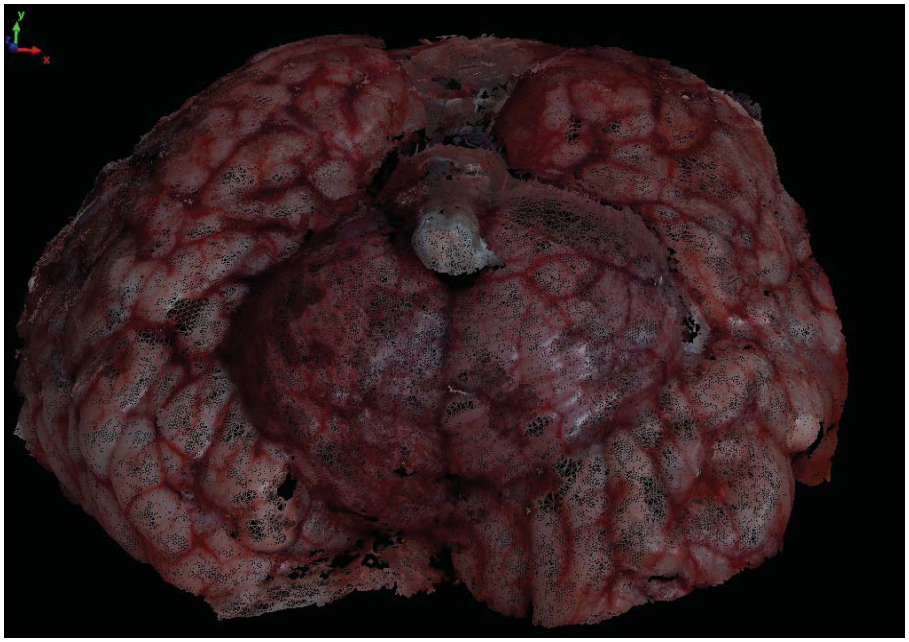


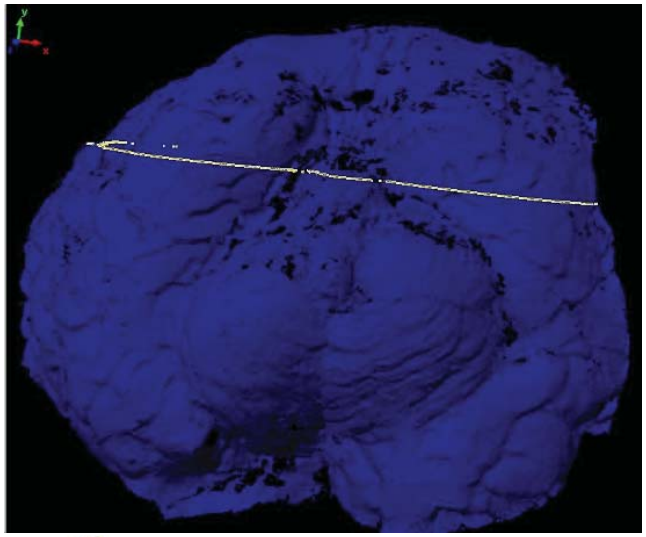
The autoptic room

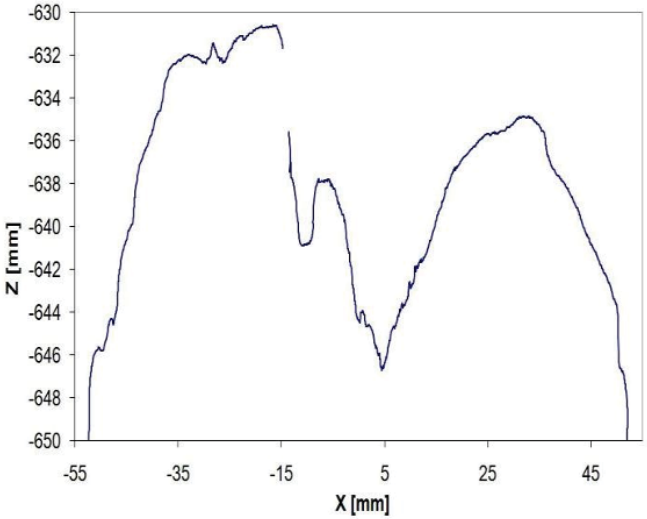
- Feasibility study in view of the in-field use of the process
- Feasibility study to assess the ability to capture reflective parenchymal surfaces
- Sensitivity to the lesions due to the use of cutlass

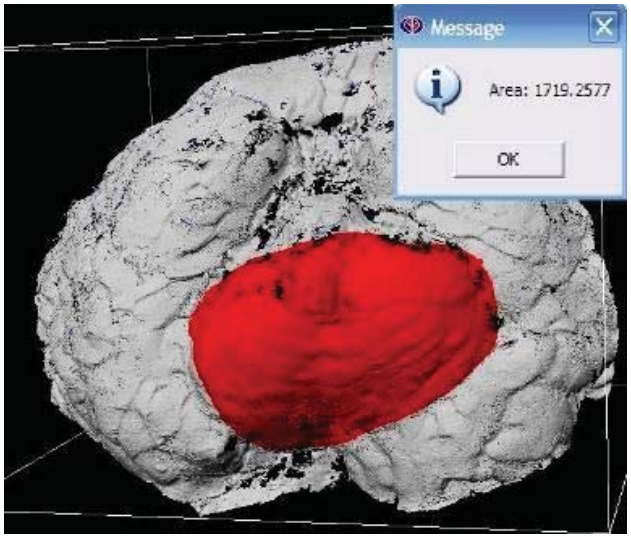
- ➢ Wounds
- ➢ Internal organs
- ➢ Bone tissues

The baby’s brain

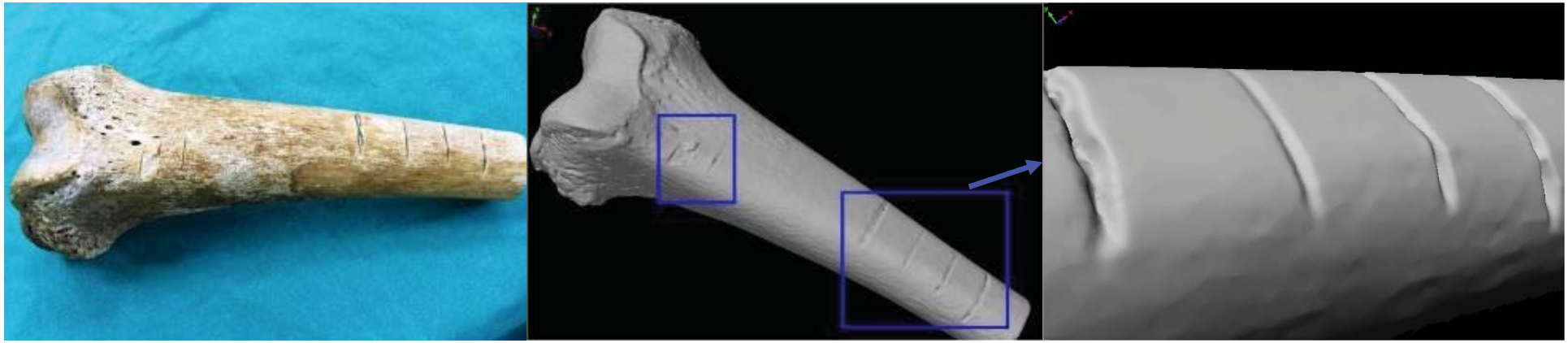


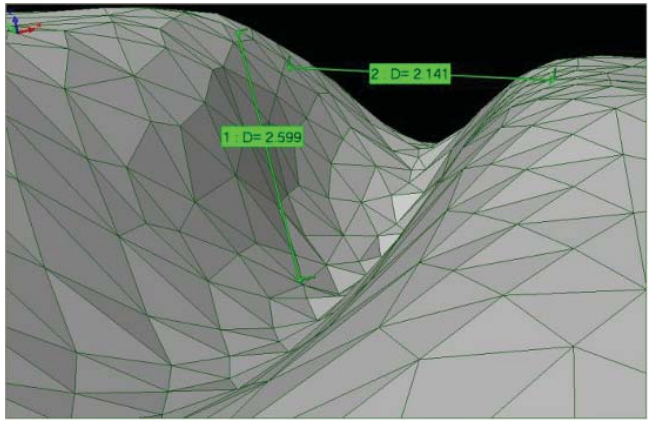


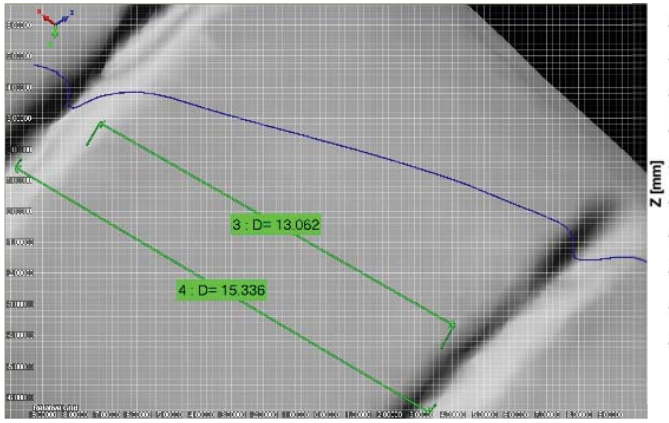


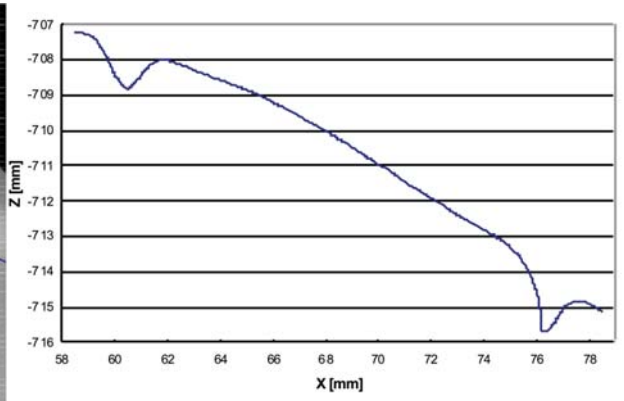


Bone lesions



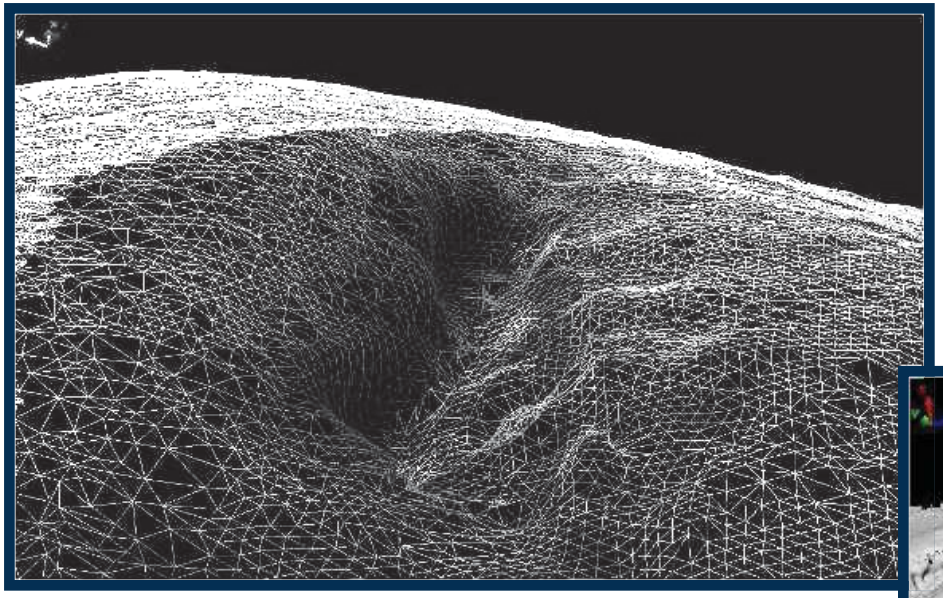


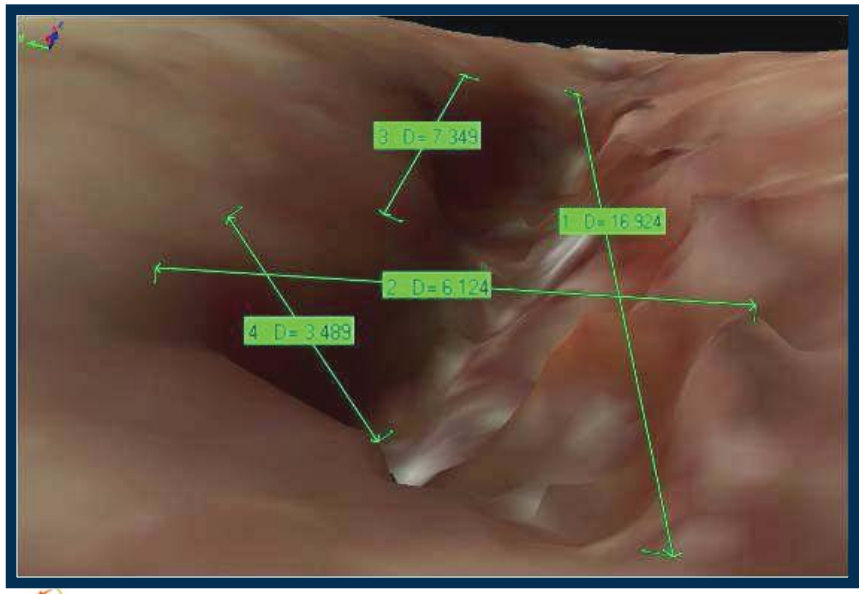


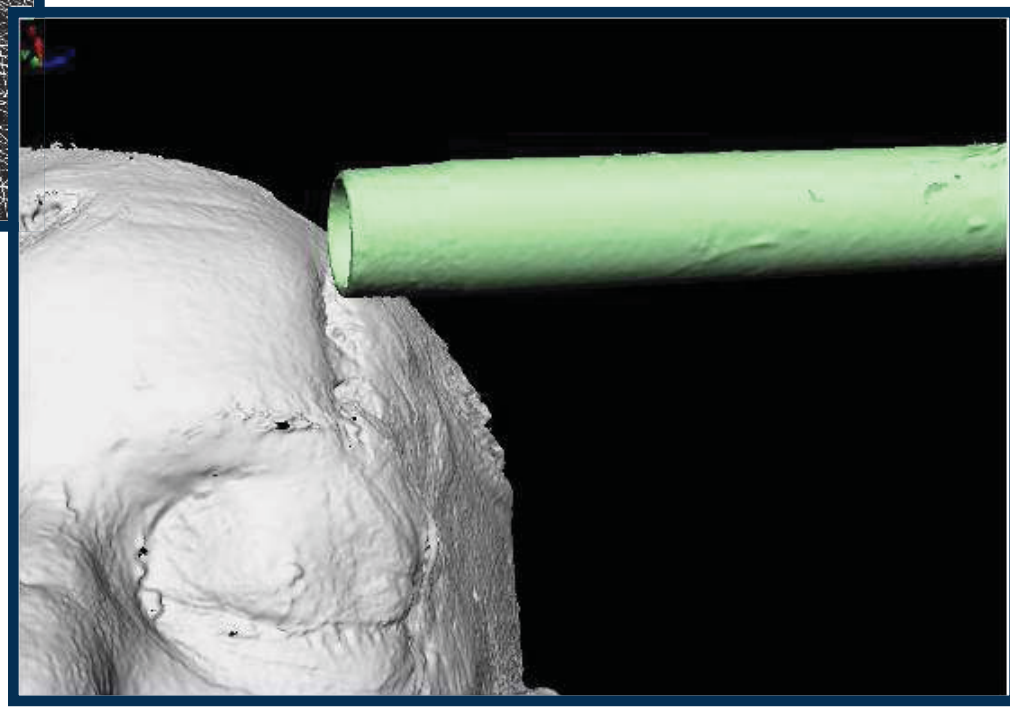


The corpse, the arm, the matching (1)

The corpse, the arm, the matching (2)







Imaging of bone tissues....

... rendering ...

… and rapid prototyping for further study and storage

Conclusions

- 3D optical acquisition is feasible for the documentation of crime scenes, wounds and corpses
- Technology is ready
- Market is ready
- Investigators need it
- The refereability of measurements and systems is crucial
- Precise rules must be specified to avoid the operator manipulation of the models

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The future of imaging and image elaboration: the cloud

How cloud computing will affect the performance of imaging systems and applications

Machine vision systems monitored in the cloud

- Industrial and biomedical imaging systems will be remotely monitored in the cloud
- VPM (Vision program manager) Web Interface


Thank you!