From EYEPLAN to OCTOPUS:

from model based to 3D planning

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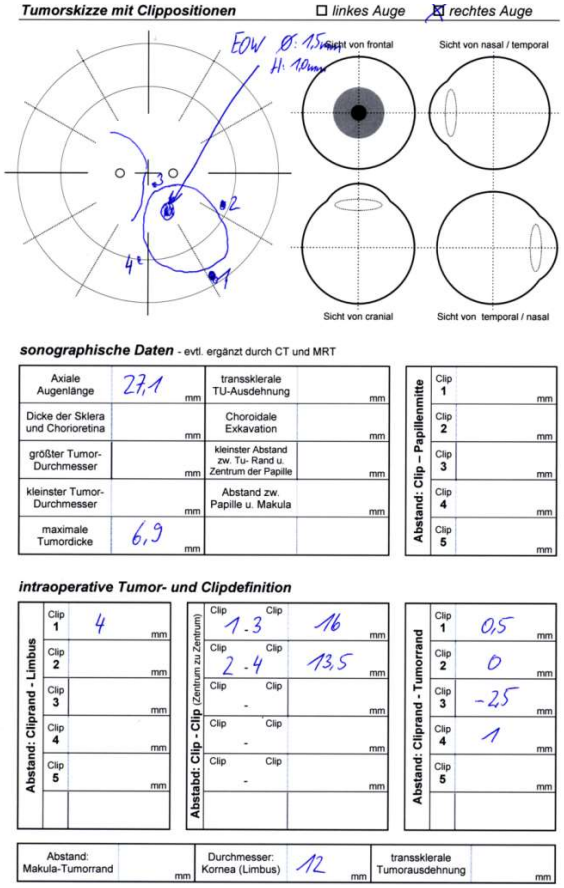
Treatment planning using EYEPLAN

Ophthalmological data



Tumorskizze mit Clippositionen ☐ linkes Auge ☒ rechtes Auge

Sicht von frontal | Sicht von nasal / temporal | Sicht von cranial | Sicht von temporal / nasal

sonographische Daten - evtl. ergänzt durch CT und MRT

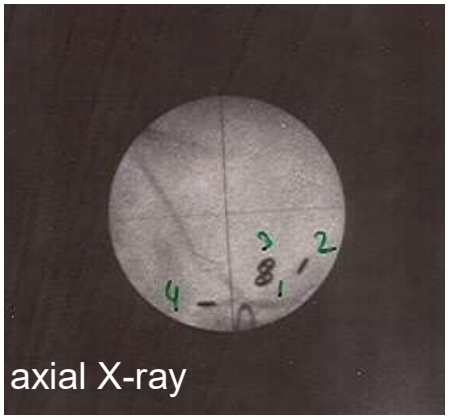
Axiale Augenlänge	27,1 mm	transsklerale TU-Ausdehnung	mm	Abstand: Clip – Papillenmitte Clip 1	mm
Dicke der Sklera und Chorioretina	mm	Choroidale Exkavation	mm	Clip 2	mm
größter Tumor-Durchmesser	mm	kleinster Abstand zw. Tu- Rand u. Zentrum der Papille	mm	Clip 3	mm
kleinster Tumor-Durchmesser	mm	Abstand zw. Papille u. Makula	mm	Clip 4	mm
maximale Tumordicke	6,9 mm			Clip 5	mm

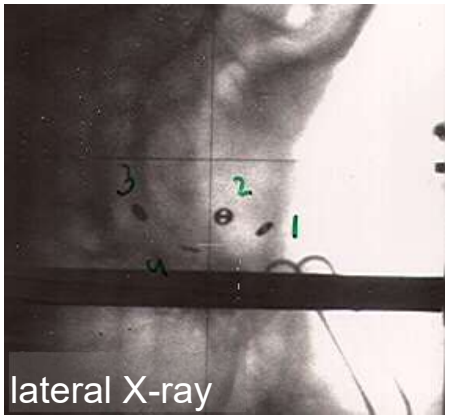
intraoperative Tumor- und Clipdefinition

Abstand: Cliprand - Limbus		Abstand: Clip - Clip (Zentrum zu Zentrum)		Abstand: Cliprand - Tumorrand	
Clip 1	4 mm	Clip 1 – Clip 3	16 mm	Clip 1	0,5 mm
Clip 2	mm	Clip 2 – Clip 4	13,5 mm	Clip 2	0 mm
Clip 3	mm	Clip - Clip	mm	Clip 3	-2,5 mm
Clip 4	mm	Clip - Clip	mm	Clip 4	1 mm
Clip 5	mm	Clip - Clip	mm	Clip 5	mm

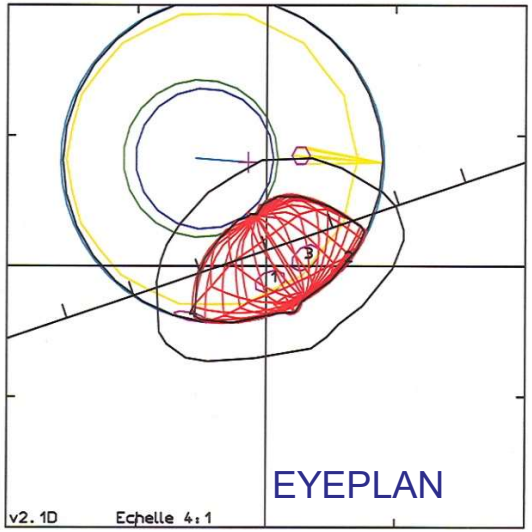
Abstand: Makula-Tumorrand	mm	Durchmesser: Kornea (Limbus)	12 mm	transsklerale Tumorausdehnung mm

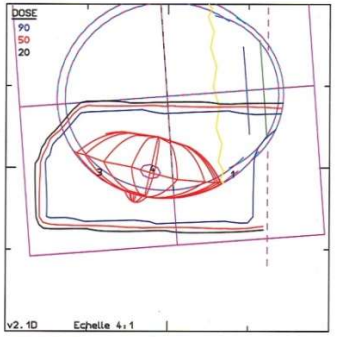
Clip detection

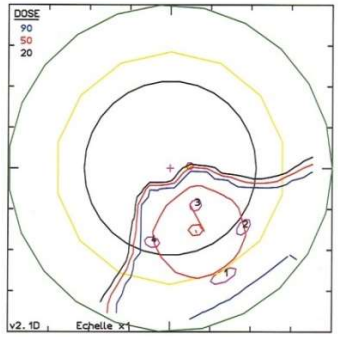




Treatment planning







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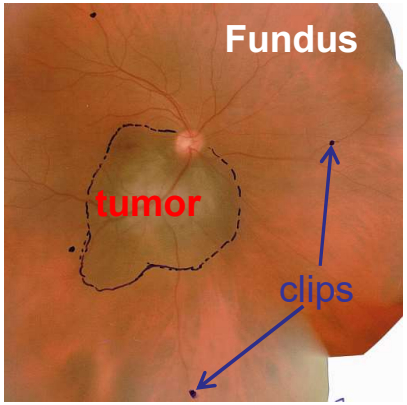
Available ophthalmological and imaging information

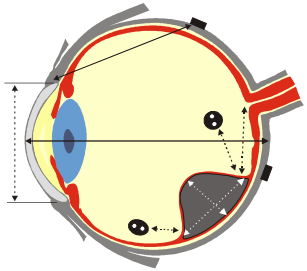
Fundus

- tumor form / location
- distance: tumor - macula / optic disc



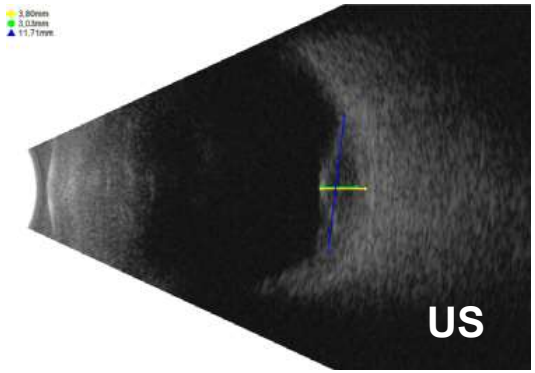
Clip surgery

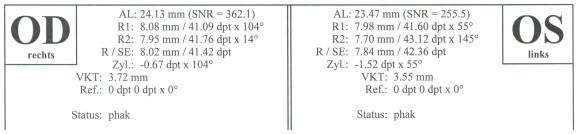
- distances: clip - tumor
- distances: clip - limbus

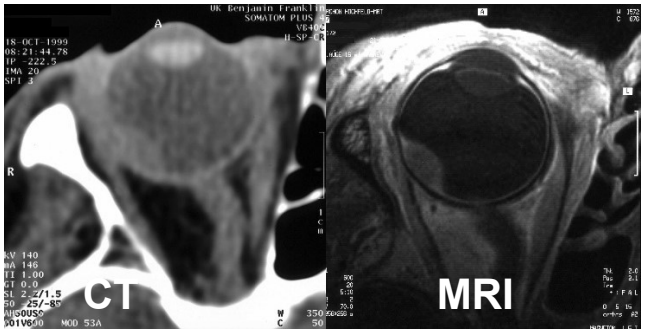


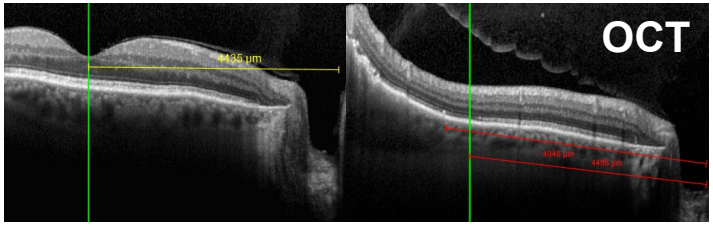
Ultra sound

- tumor size (thickness, length, width)
- distances: optic disc - tumor / clip









Biometry

- eye length
- cornea radii
- anterior chamber depth

High resolution CT / MRI

- geometry of eye and tumor
- clip positions
- material in the eye (normal, gas, Si-oil)

Optical coherence tomography (OCT)

- distance: tumor - macula
- distance: tumor - optic disc
- distance: macula - optic disc

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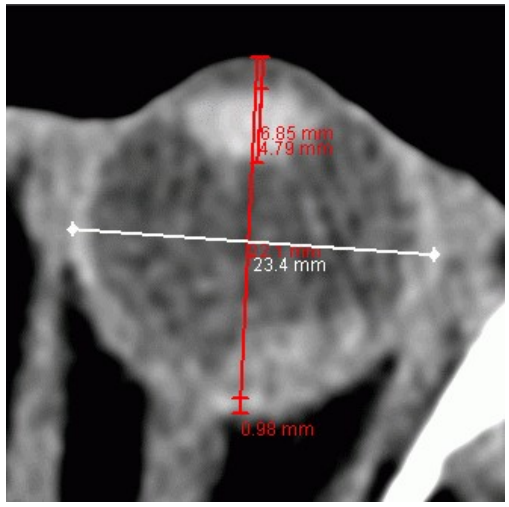
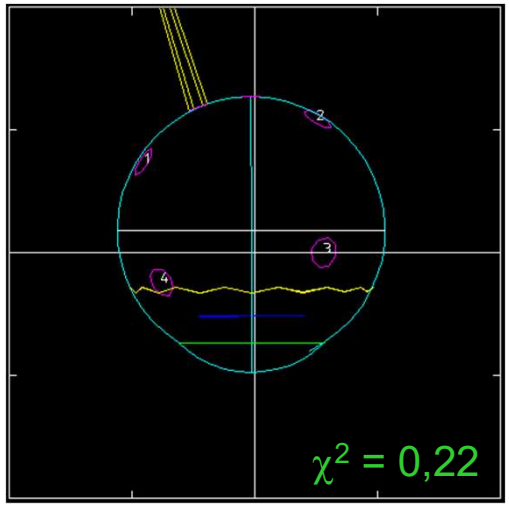
Example: CT in EYEPLAN

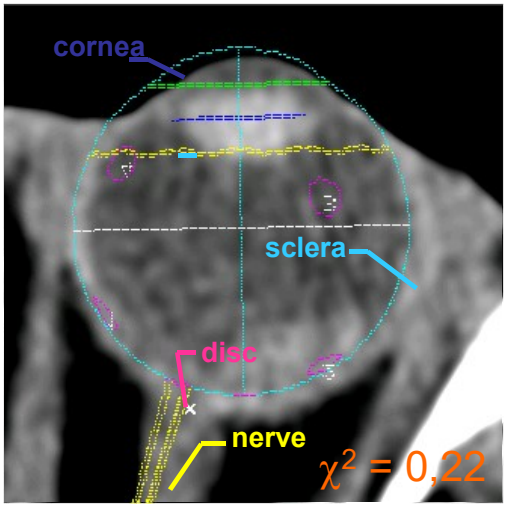


high resolution CT

- eye length & width
- sclera thickness
- lens position & size

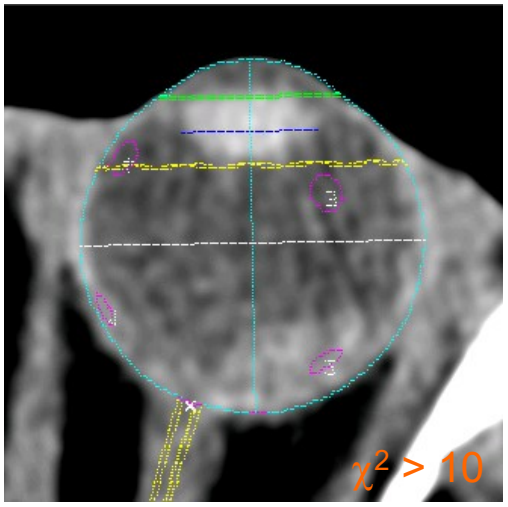


spherical /elliptical eye model fitted to clips



model fitted to CT-clips

→ deviations between model and CT



model manually fitted to CT by rotation and translation, clips stay in position

→ worsening of χ^2

→ time consuming (~3 hrs) and cumbersome

(between1998 to 2006 over 700 patients planned)

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Idea behind OCTOPUS

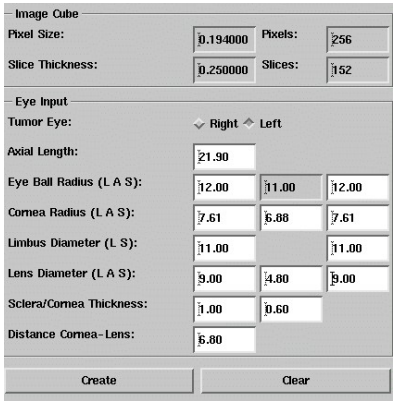
Model based treatment planning like EYEPLAN

Additionally, fusion between EYEPLAN and 3D treatment planning:

- integration of 3D imaging (CT, MRI, …)
- integration of fundus imaging
- fundus based target delineation (like EYEPLAN)
- slice by slice target delineation based on CT, MRI, …

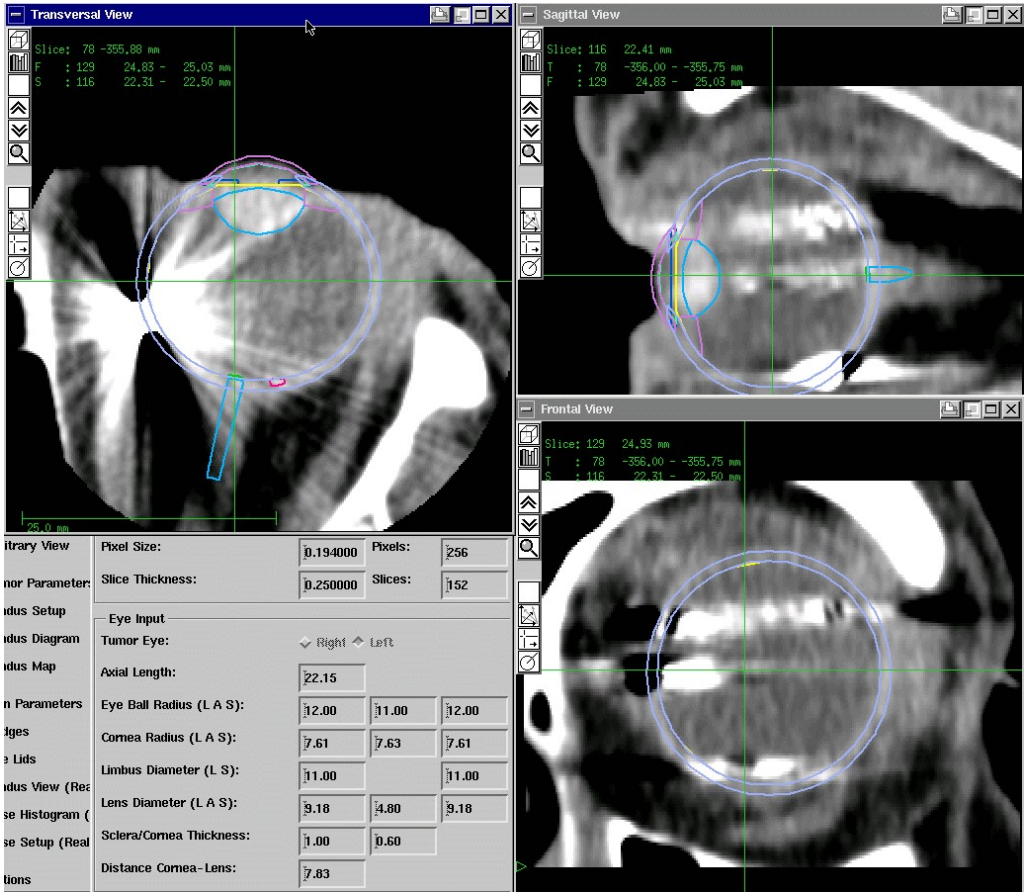
Dose calculation similar to EYEPLAN
(pencil beam planed, but not clinically realised)

OCTOPUS: eye modelling



Eye model set-up

- eye length (biometry)
- eye width (CT)
- cornea radius (biometry)
- limbus diameter (surgery)
- lens thickness/Width (CT)
- lens position (CT/biometry)
- macula position (OCT)



Manual adaption of eye model to the CT

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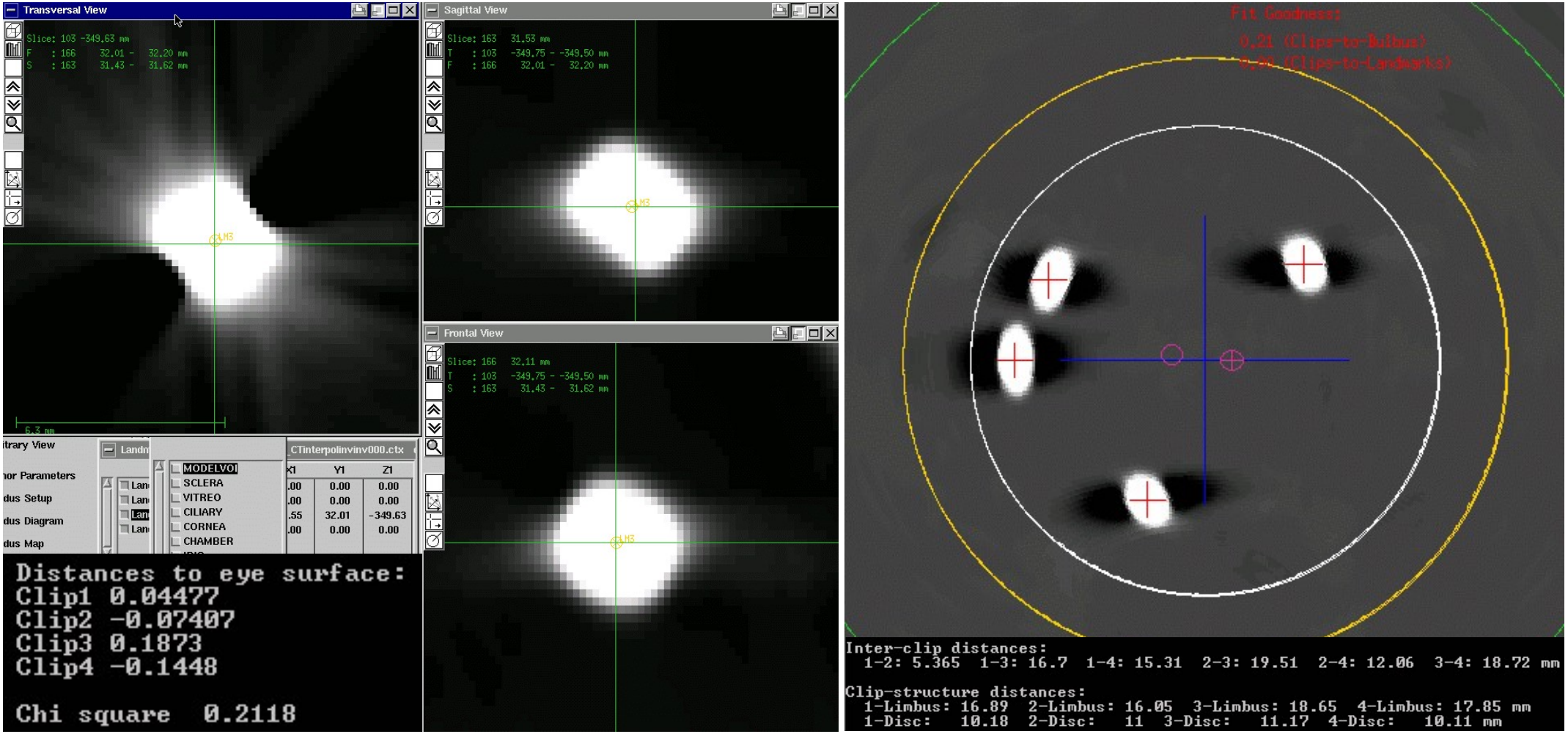
OCTOPUS: clip identification from/by CT



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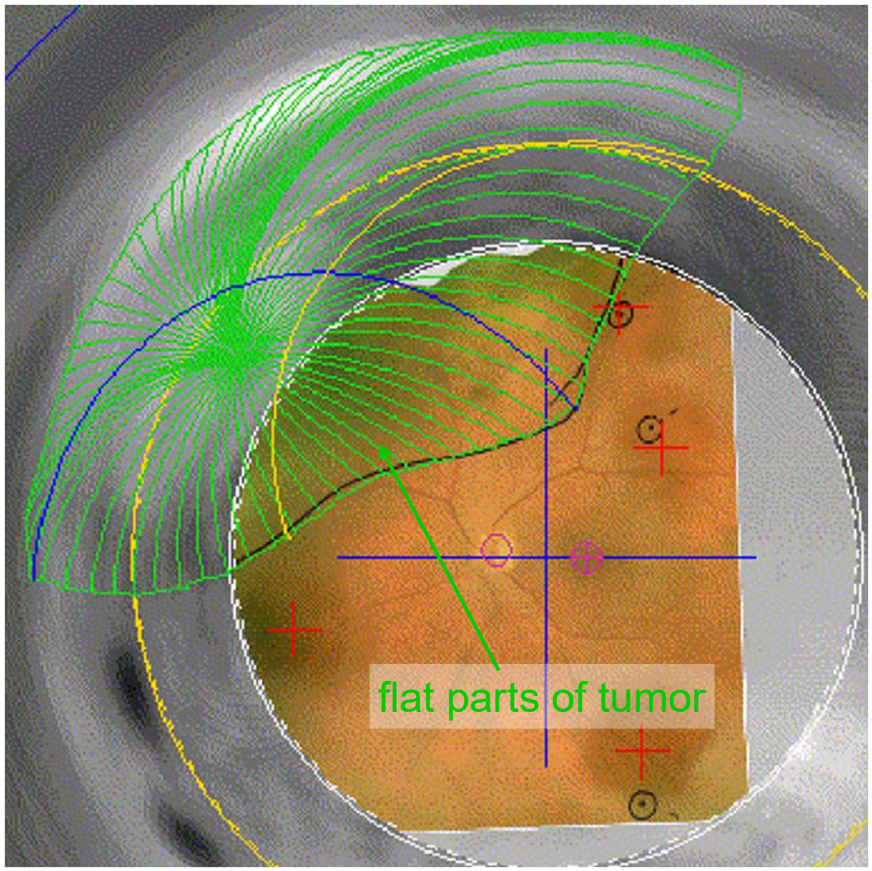
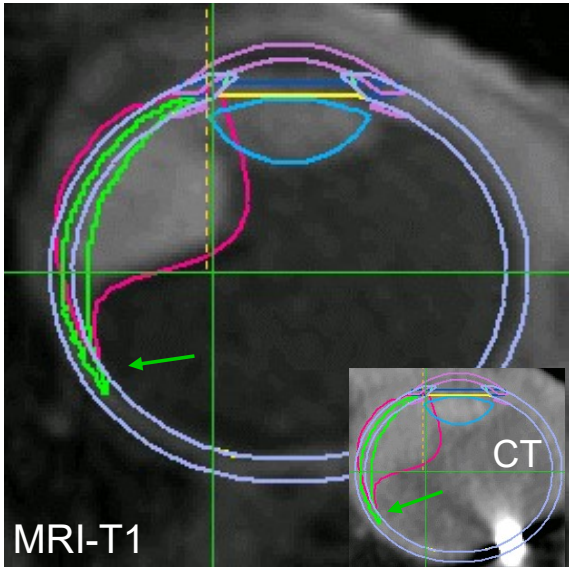
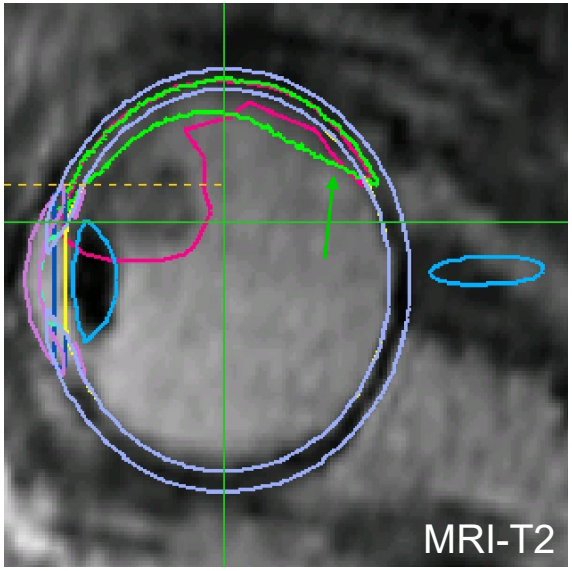
OCTOPUS: CTV delineation



Fundus matched to model considering positions of optic disc, macula and clips





Slice by slice CTV delineation based on 3D data

additional information used (indirect):

- surgery: distance tumor - clip
- US: tumor size (thickness, width), position
- OCT: distance tumor - macula/optic disc

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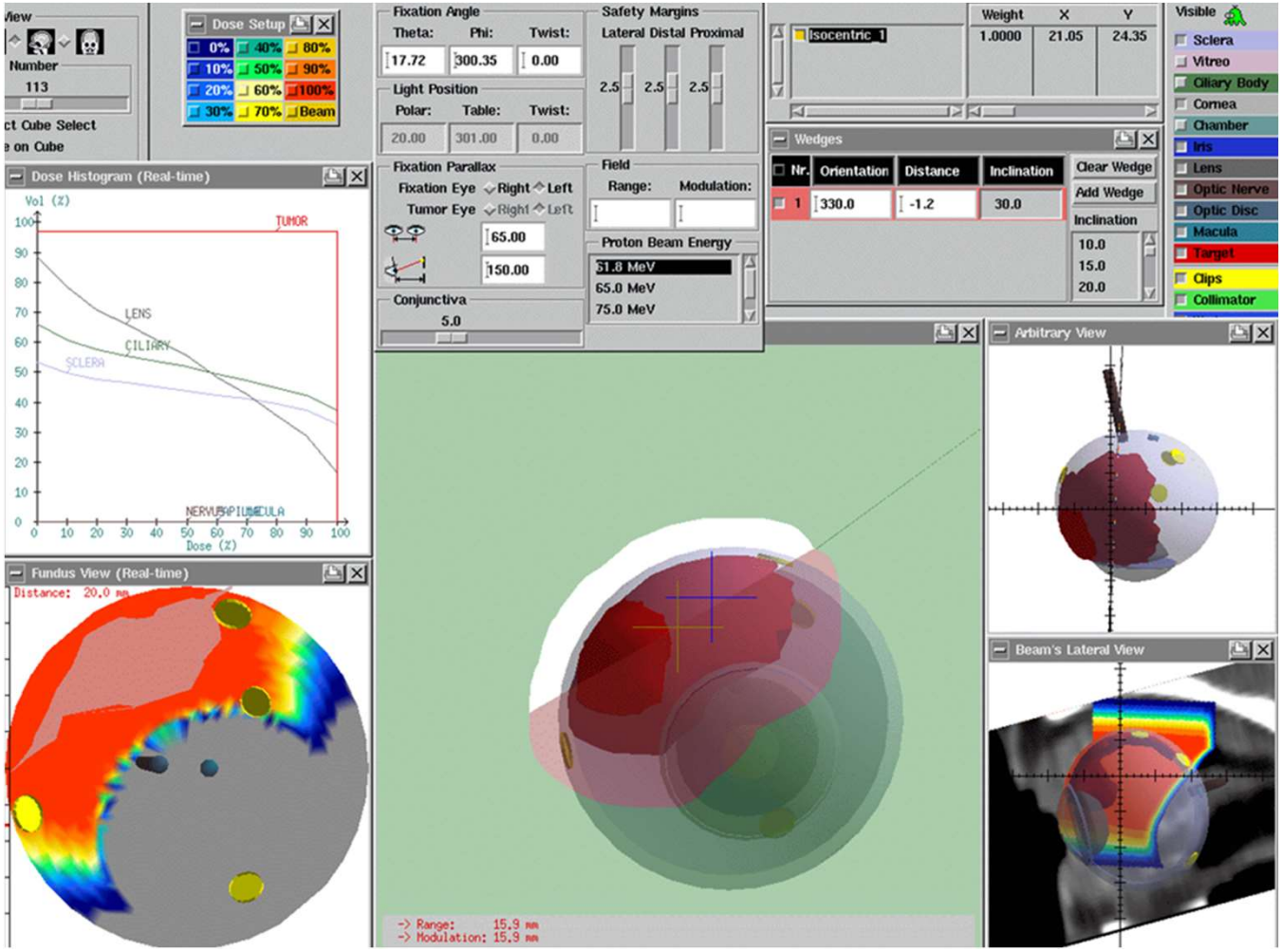
OCTOPUS: treatment plan



work flow:

- setting isocentre (automatic)
- setting margins (manual)
- selecting gaze angle (manual)
- collimator adapted to CTV (automatic)
- selecting wedge (manual): automatic adaption of collimator
- fast dose / DVH calculation

result:

- treatment plan
- collimator milling file
- set-up file / DRR for positioning

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OCTOPUS: experience and results

- Integrated imaging (fundus, CT, MRI) → much faster planning (EYEPLAN + CT)
- More realistic eye models
- “Automatic compensation” of wedge scatter (increased collimator)
- Increased use of 60° wedges and double wedges
- Planning of complicated cases possible: no insight into the eye, silicone oil, cerglage, …
- New workflow: Planning starts, when CT, MRI, fundus images are available (clips from CT)
- Evaluated by parallel planning of 100 patients in EYEPLAN and OCTOPUS in 2005
- Over 3400 patients planed:

  ~ 2300 using CT and fundus (and US, OCT)
  ~ 950 using CT and MRI (and Fundus, US, OCT)
  ~ 150 only model based (photo, US) – iris melanoma

- No change in tumor control observed:

  ~ 95.5% @ 3 years: Höcht et al. 2004 (EYEPLAN)
  ~ 96.4% @ 5 years: Seibel et al. 2015 (EYEPLAN, OCTOPUS)

Conclusion or the 4 questions – part I

Total time to create a plan and adaptability of plans?

- 1 to 2 hrs (with MRI 3 hrs) – plan is ready for testing with patient (simulation)
- simple adaptation during simulation: 2-10 min (patient stays on treatment chair)
- plan finalization (skin plane, twist, eye lids, silicone oil, …): 30-90 min (without plan QA)

Potential areas of improvements; biggest weakness of your system?

- better tools for CTV delineation
- possibility of defining materials in the eye model, e.g. silicone oil
- upgrading simple dose calculation algorithm to pencil beam or Monte Carlo algorithm
  → more realistic dose distributions near clips, for wedges, silicone oil
- HZB nozzle is integral part of OCTOPUS code
- non-commercial program: further developments are limited
- Windows upgrades/changes are difficult

Conclusion or the 4 questions – part II

Pros/cons of using a geometric model-based system vs. image-based approach?

model-based system:

- pro: fast and robust treatment planning (if clips near to tumor)
- con: limited in planning of complex case: silicone oil, highly irregular eyes

image based approach:

- pro: use of redundant information from different imaging modalities
  less dependence on exact clip position (still clips near tumor); more realistic eye models
- con: planning takes much more time

Dealing with structures outside the eye (eyelids, lacrimal glands,...)

- eye lids could be modelled (if necessary): rim drawn, orange peel, 2.5 mm thickness
- lacrimal gland is ignored
- if possible, punctum is kept outside of treatment field using lid retractors
- if scars from clip surgery or extra ocular tissue have effect on range, manual correction is applied

Thank you

Ocular proton therapy is team work:

Ophthalmology CBF:	A.M. Joussen, O. Zeitz, A. Böker, J. Urban, …
Radiotherapy CBF:	J. Gollrad, D. Böhmer, A. Besserer, V. Budach, N. Haberstroh, S. Runge, J. Helmecke, L. Leser, N. Lücke, …
Medical physics:	J. Heufelder, D. Cordini, S. Seidel, R. Stark, A. Weber
Proton therapy HZB:	A. Denker, G. Kourfakas, J. Röhrich, C. Zimmer, S. Ozierenski, J. Bundesmann, T. Damerow, D. Hildebrandt, I. Kailouh, C. Rellier, T. Fanselow, U. Hiller, …