

Effect of dental work on dose distribution: a Monte Carlo study

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Motivation

- mucositis observed in patients
- know that high Z materials \Rightarrow scattered electrons \Rightarrow local dose enhancement
- want to prevent overdose to mucosa

Results

- 21 combinations of materials and geometry
- upshot: 3mm of water-equiv. (0.3 g cm^{-2}) is effective shield
- an air gap (representing a cotton roll) between 2mm and 5mm can partially shield

Mechanism

- overdose caused by localized scatter of secondary e^- ; short range ($\sim 3\text{mm}$)
- metal dental restoration materials
 - high e^- densities
 - high photon mass energy absorp. coeffs.
 - \therefore high secondary e^- emission rates

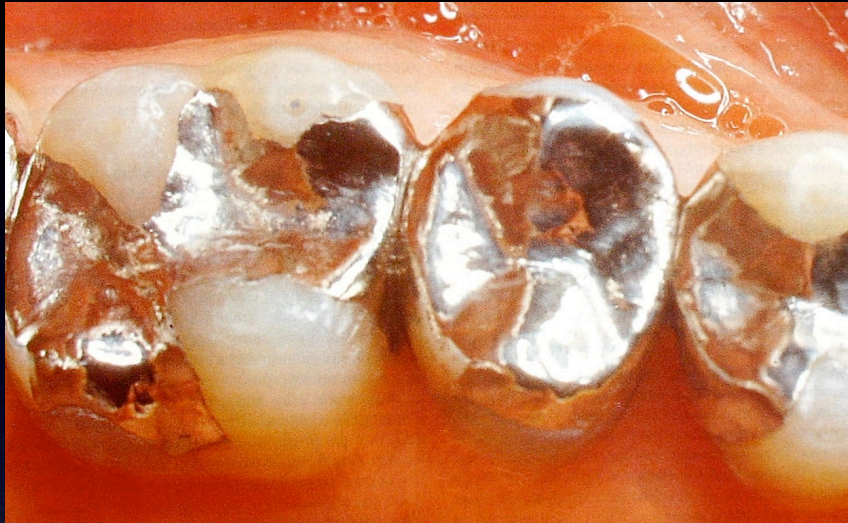
Simulation Configs

BEAMnrc, phantom, DOSXYZnrc

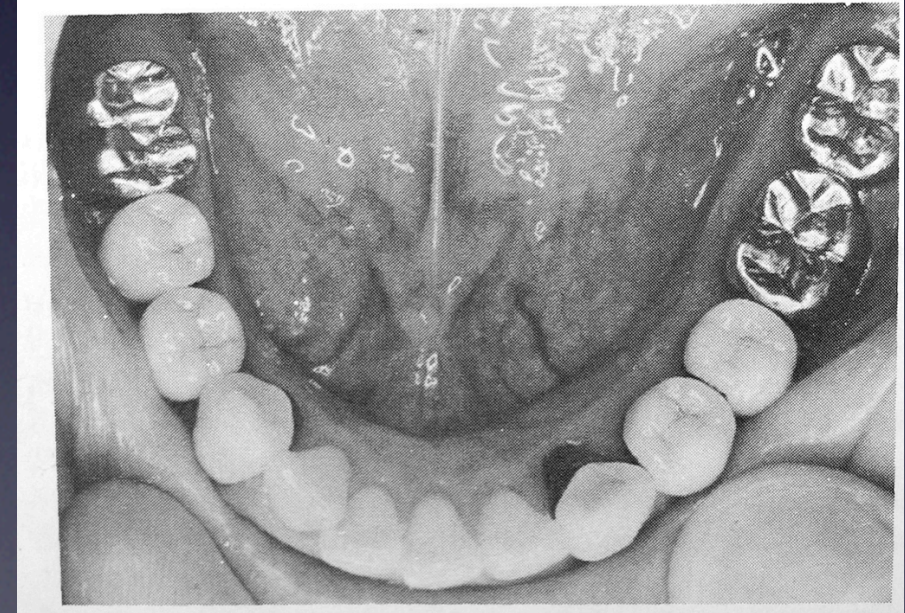
BEAMnrc Config

- 6MV
- incident laterally
- 10cm x 10cm
- isocenter 3 cm below surface

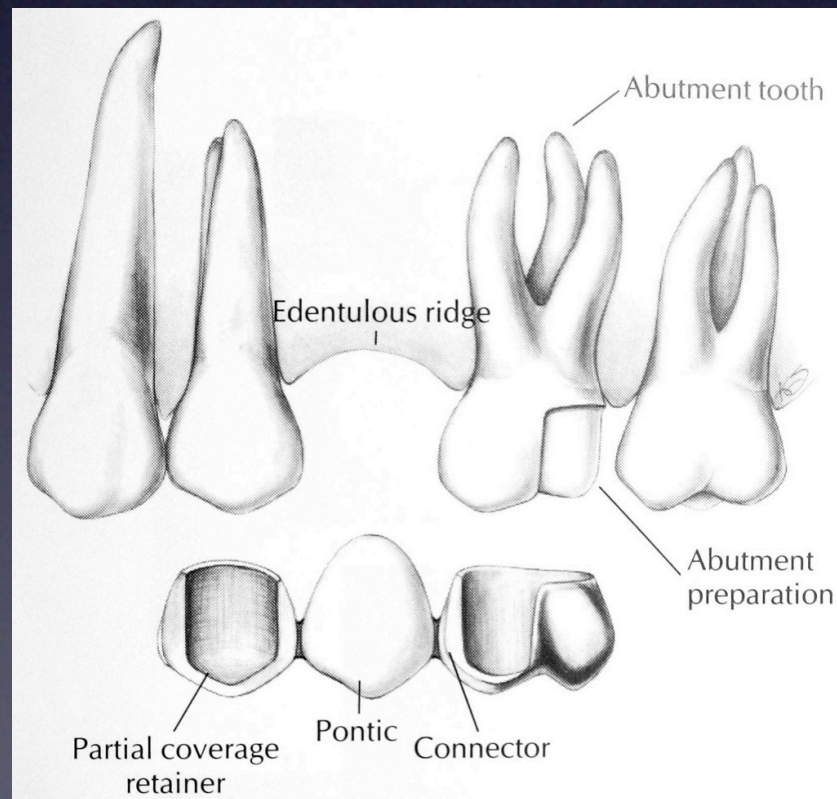
Phantom Configs



Amalgam [Mount et al.]

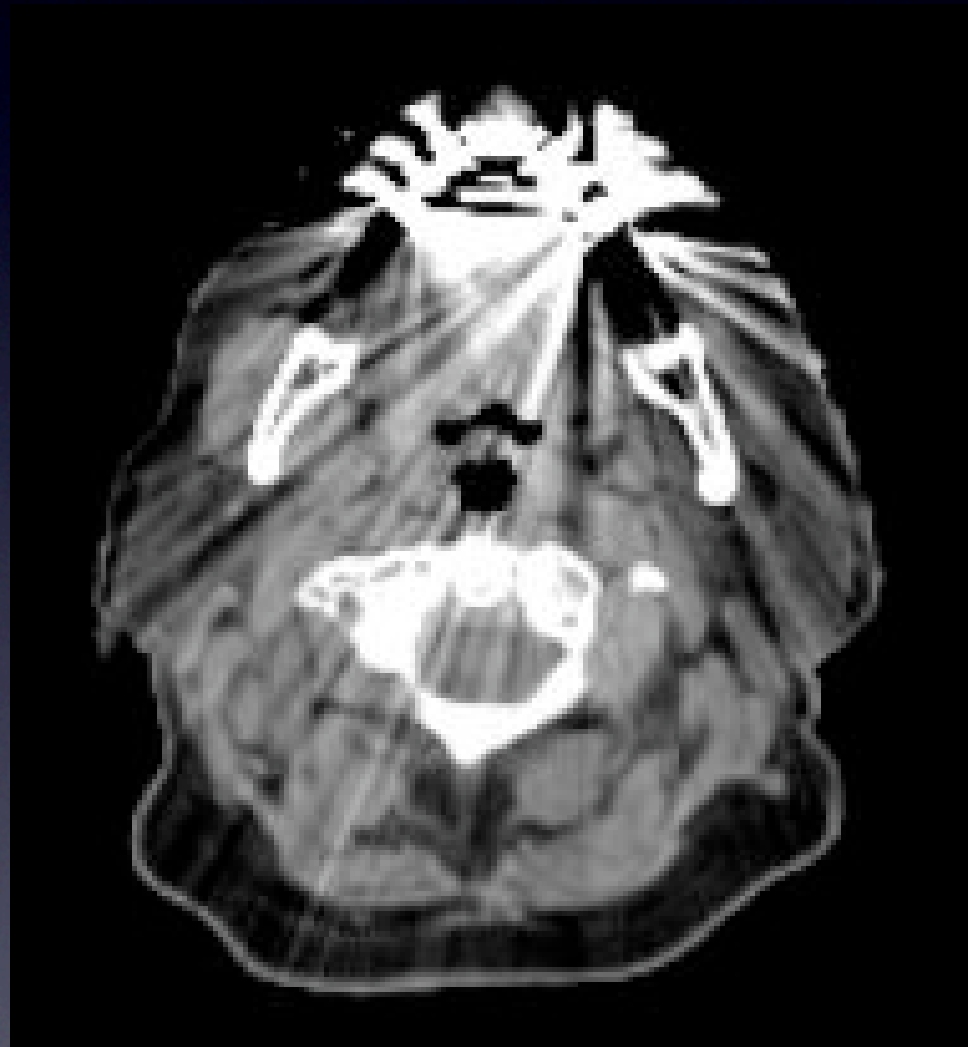


Crown [Rosenstiel et al.]



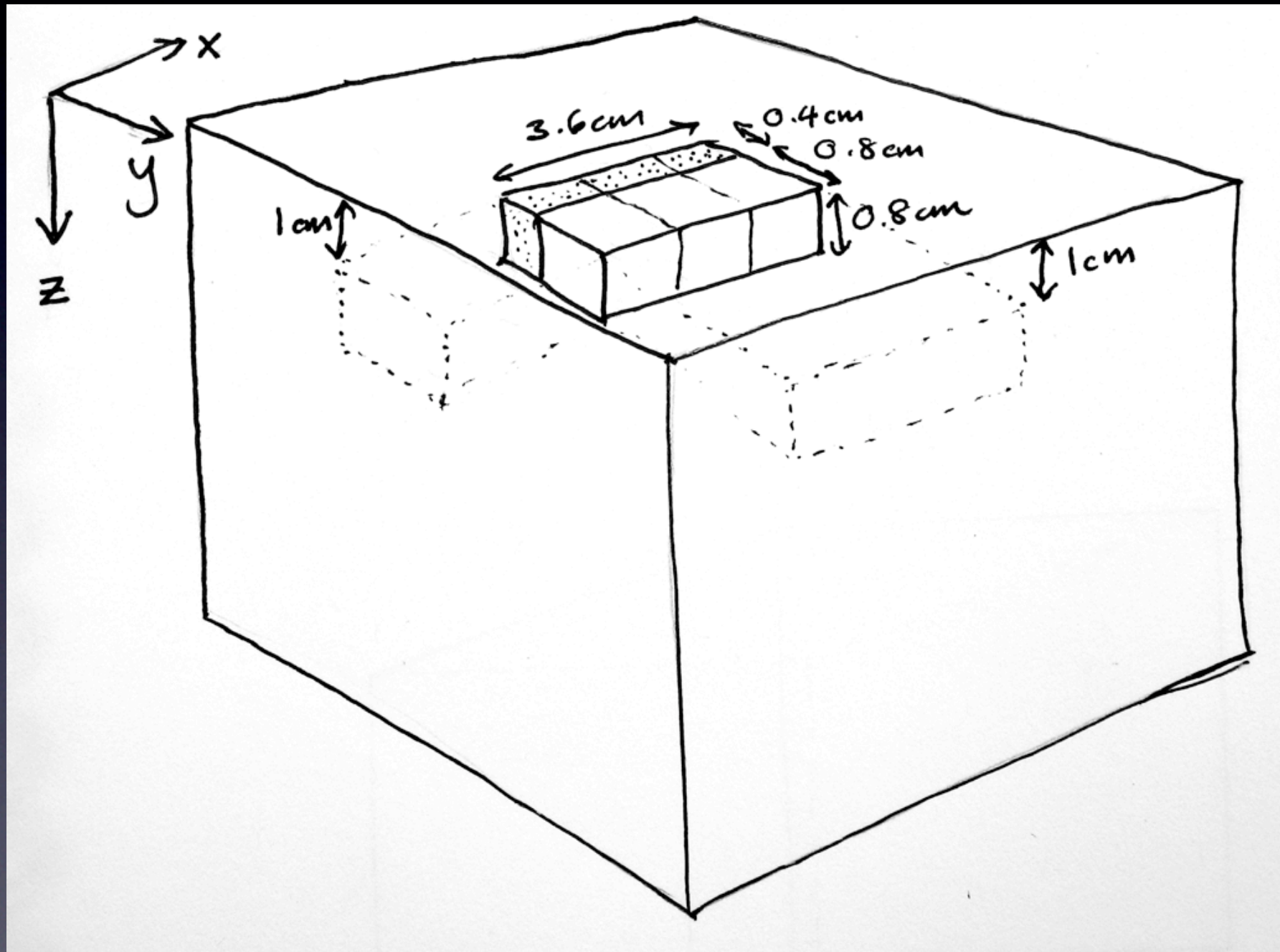
FPD [Rosenstiel et al.]

Phantom Configs, cont.



CT scan showing artifacts from metal dentalwork

Phantom Configs, cont.



Schematic layout of phantoms

Phantom Configs, cont.

- real CT may have artifacts due to metal \Rightarrow unusable as input to MC
- manually create eggsphant “CT” phantoms
 - **ADVANTAGE** almost any configuration and material may be used

Phantom Configs, cont.

- single row of “teeth”
- row of “teeth”, middle tooth replaced by tissue
- amalgam restoration
- amalgam restoration, exposed cheek-side
- fixed partial denture, ceramic veneer over gold alloy
- fixed partial denture, all gold alloy
- gold alloy crown, stainless steel posts

Phantom Configs, cont.

- dental materials; use XCOM x-section data
 - amalgam (8.0 g/cm^3): Ag 69.3%, Sn 17.9%, Cu 11.8%, Zn 1.0%
 - Eclipse gold alloy (13.8 g/cm^3): Au 52.0%, Pd 37.5%, Zn 4.0%, In .3.0%, Sn 3.0%, Re 0.5%
 - Ceramco C3 ceramic (2.6 g/cm^3): $\text{Na}_2\text{K}_1\text{Al}_3\text{Si}_3\text{O}_{12}$
 - stainless steel (8.1 g/cm^3): use STEEL700ICRU; Fe, C, Si, Cr, Ni, Mn

Phantom Configs, cont.

- all the above with 2mm, 5mm air gap at cheek-side
- plots in next section

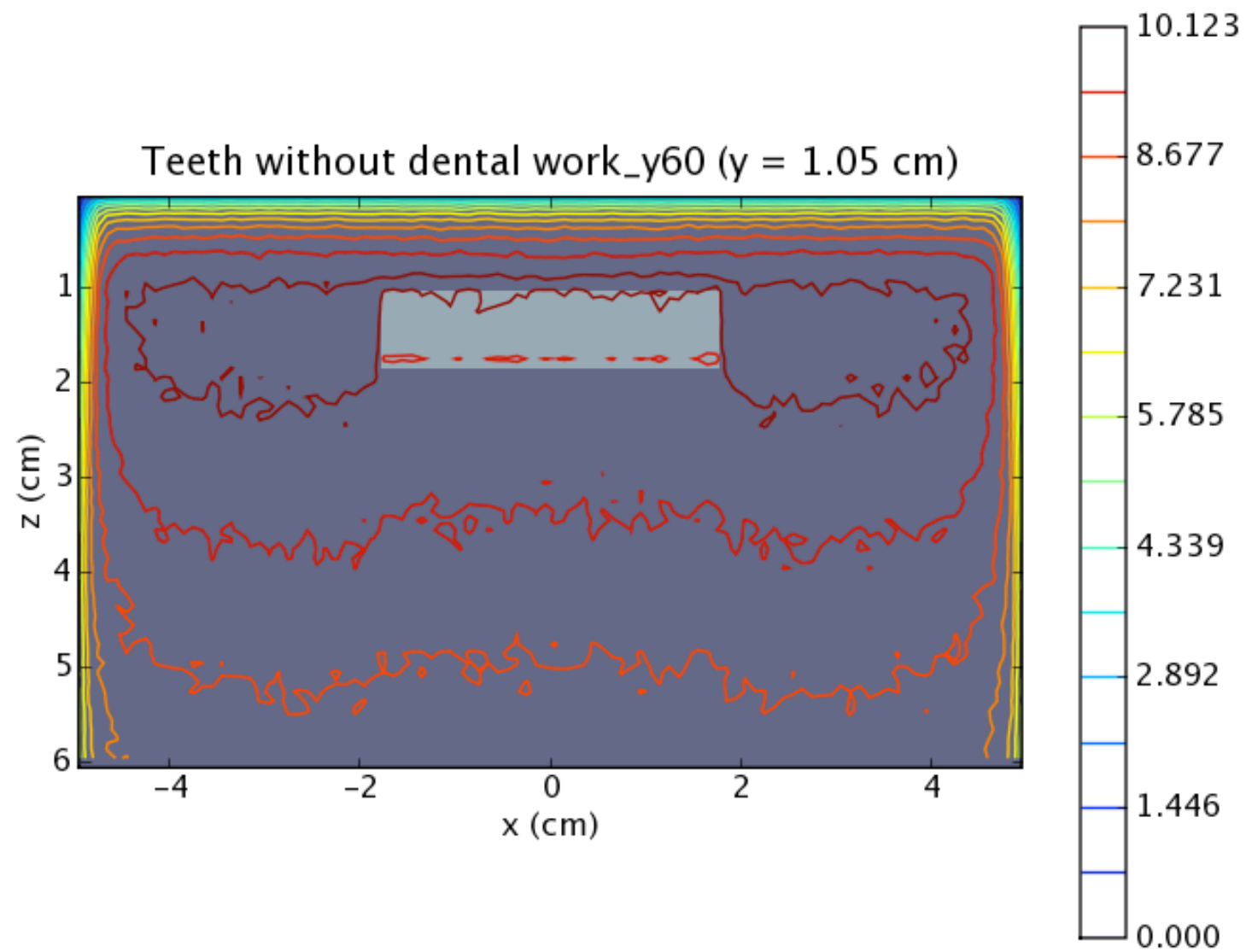
DOSXYZnrc Config

- standard settings (all else default)
 - ecut 0.7, pcut 0.01
 - boundary crossing PRESTA-I
 - e⁻-step PRESTA-II
 - Bremss. split 4x
 - 3×10^9 histories

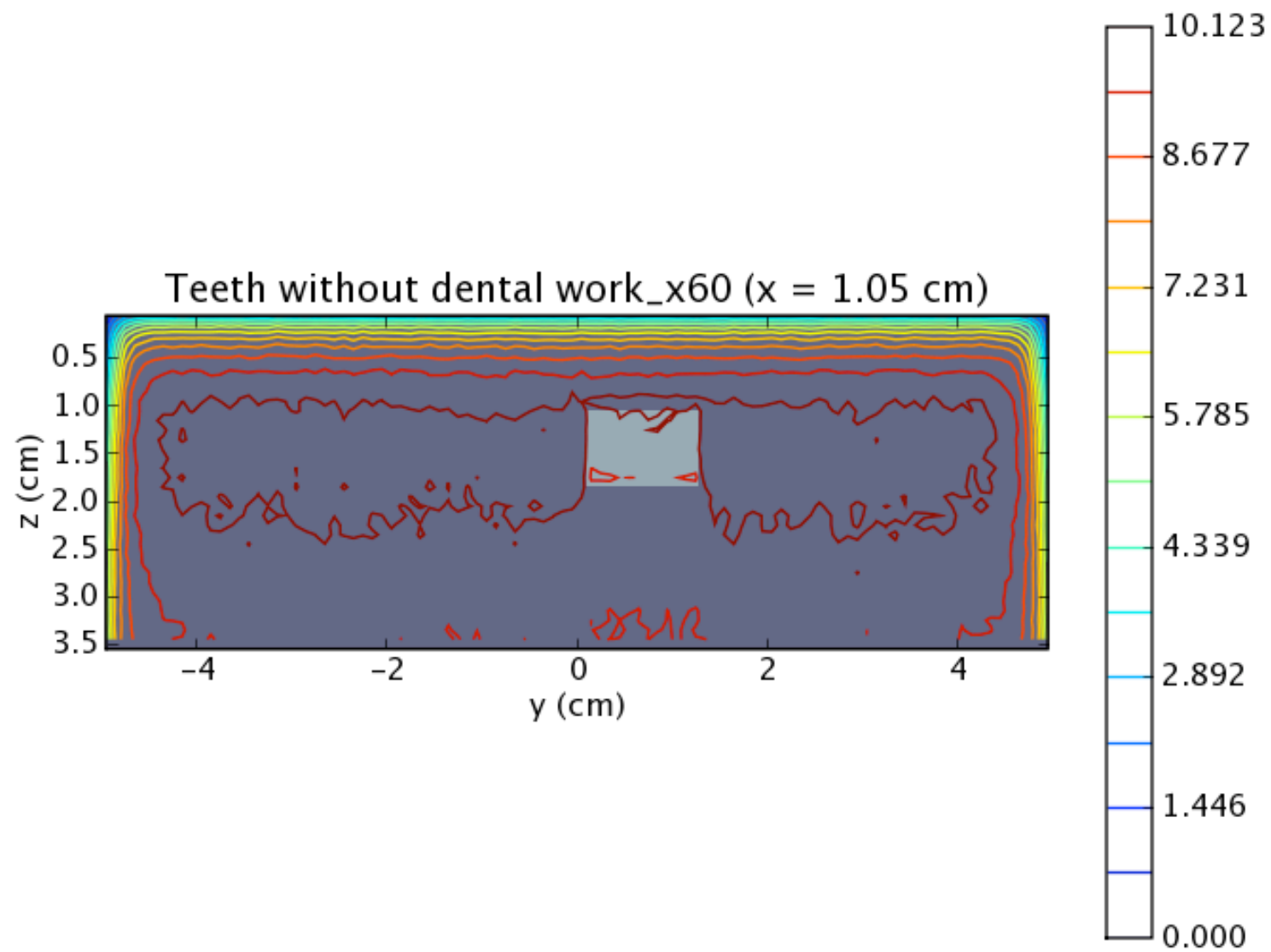
Results

Dose distributions (2D), Dose profiles

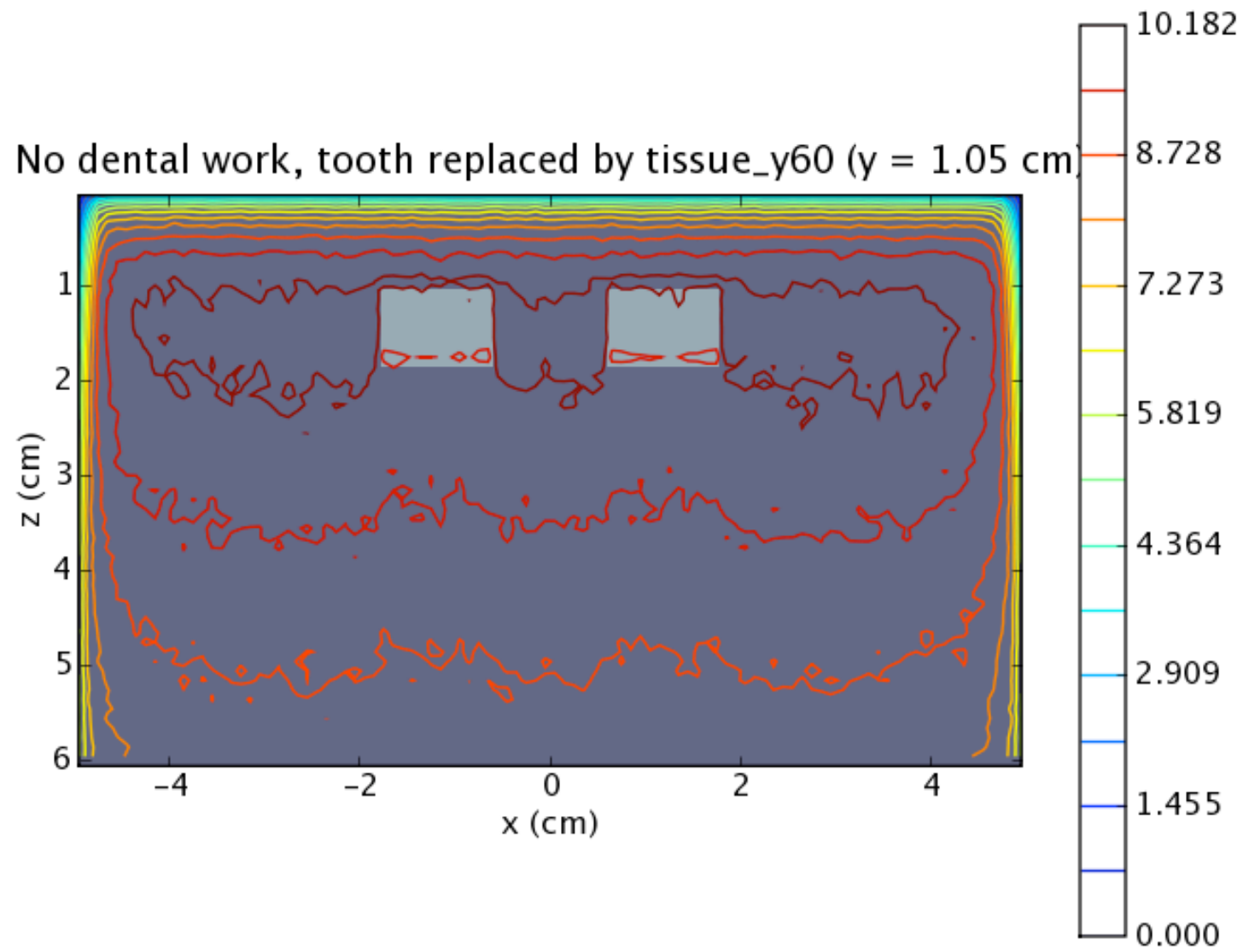
Row teeth



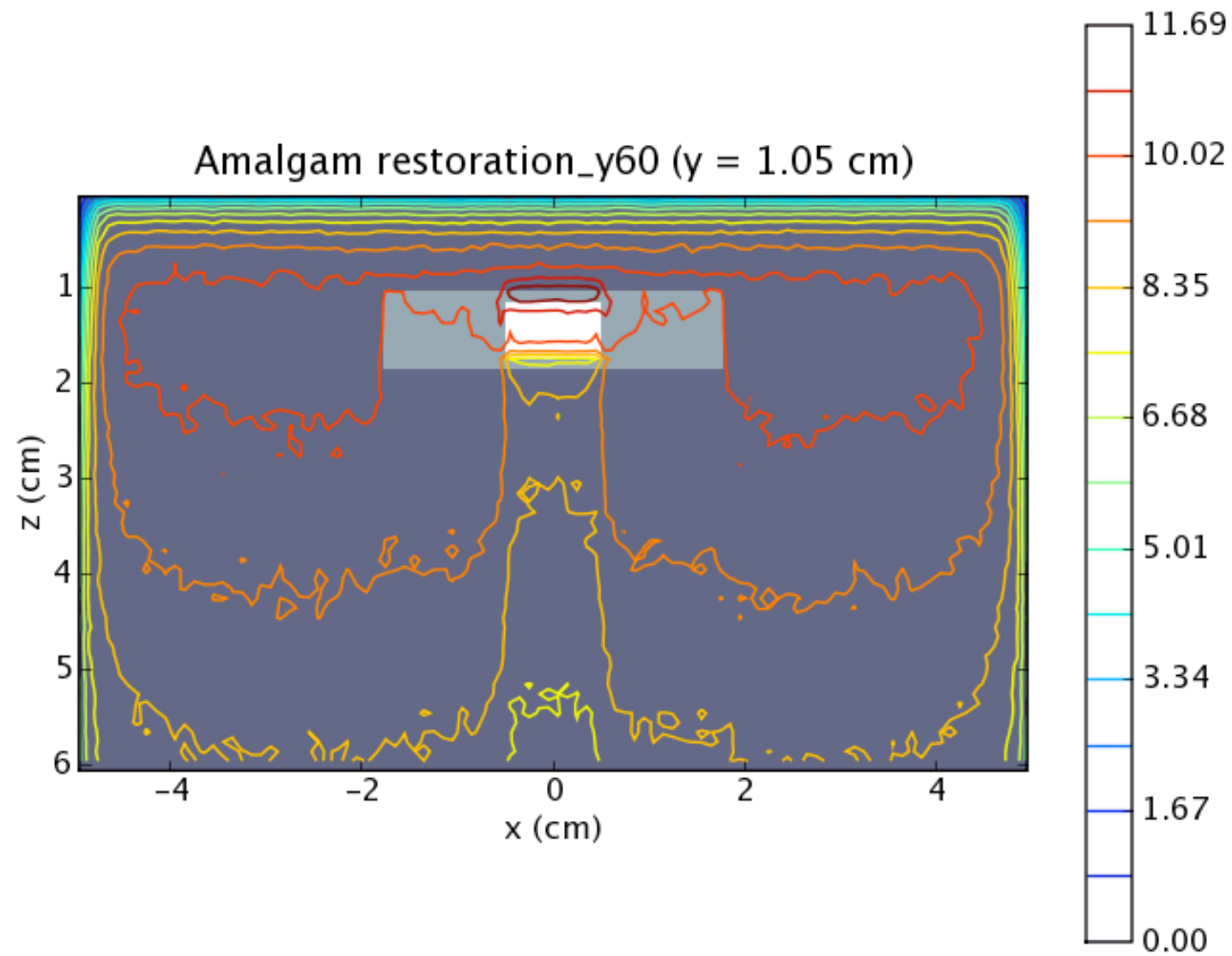
Row teeth, cont.



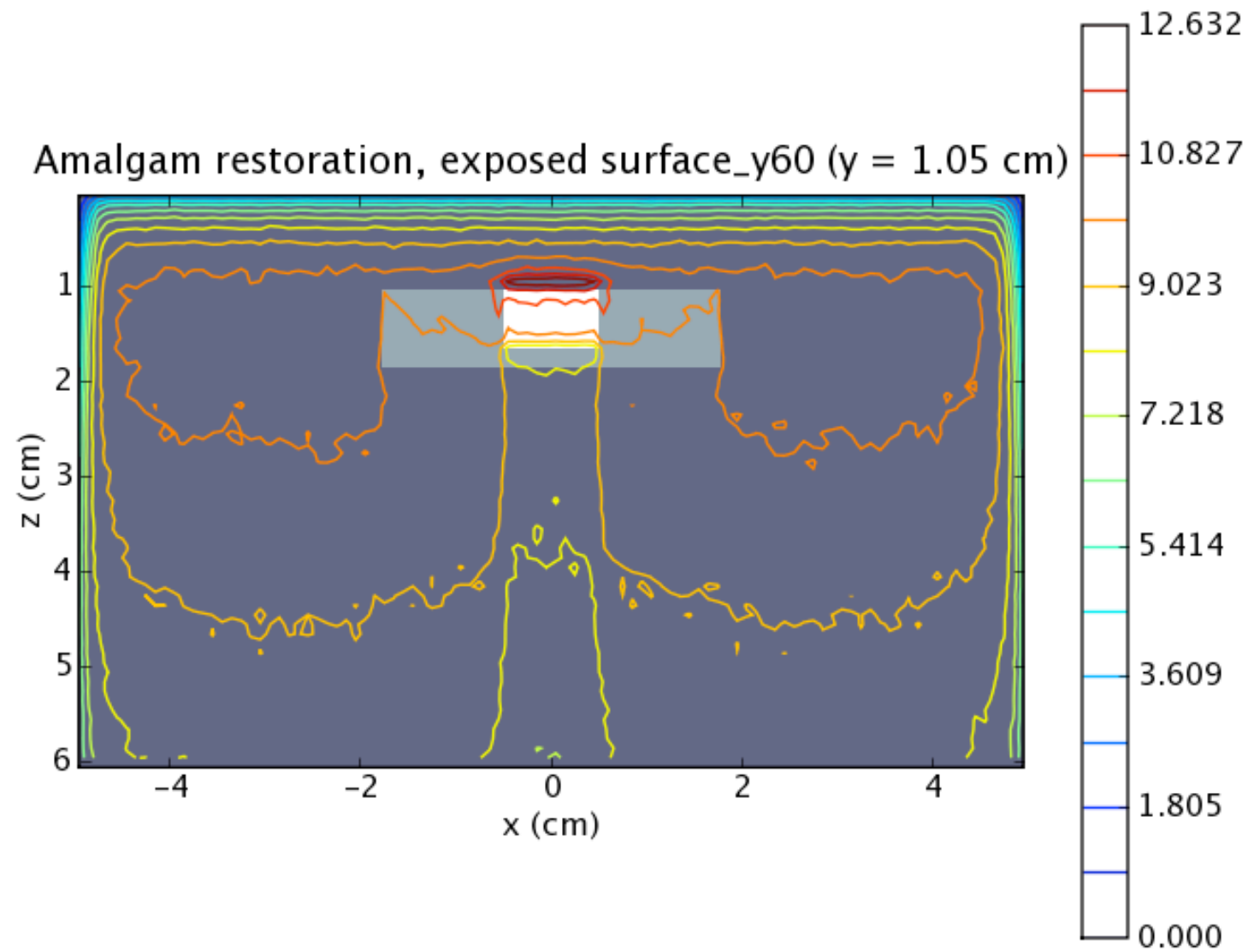
Edentulous



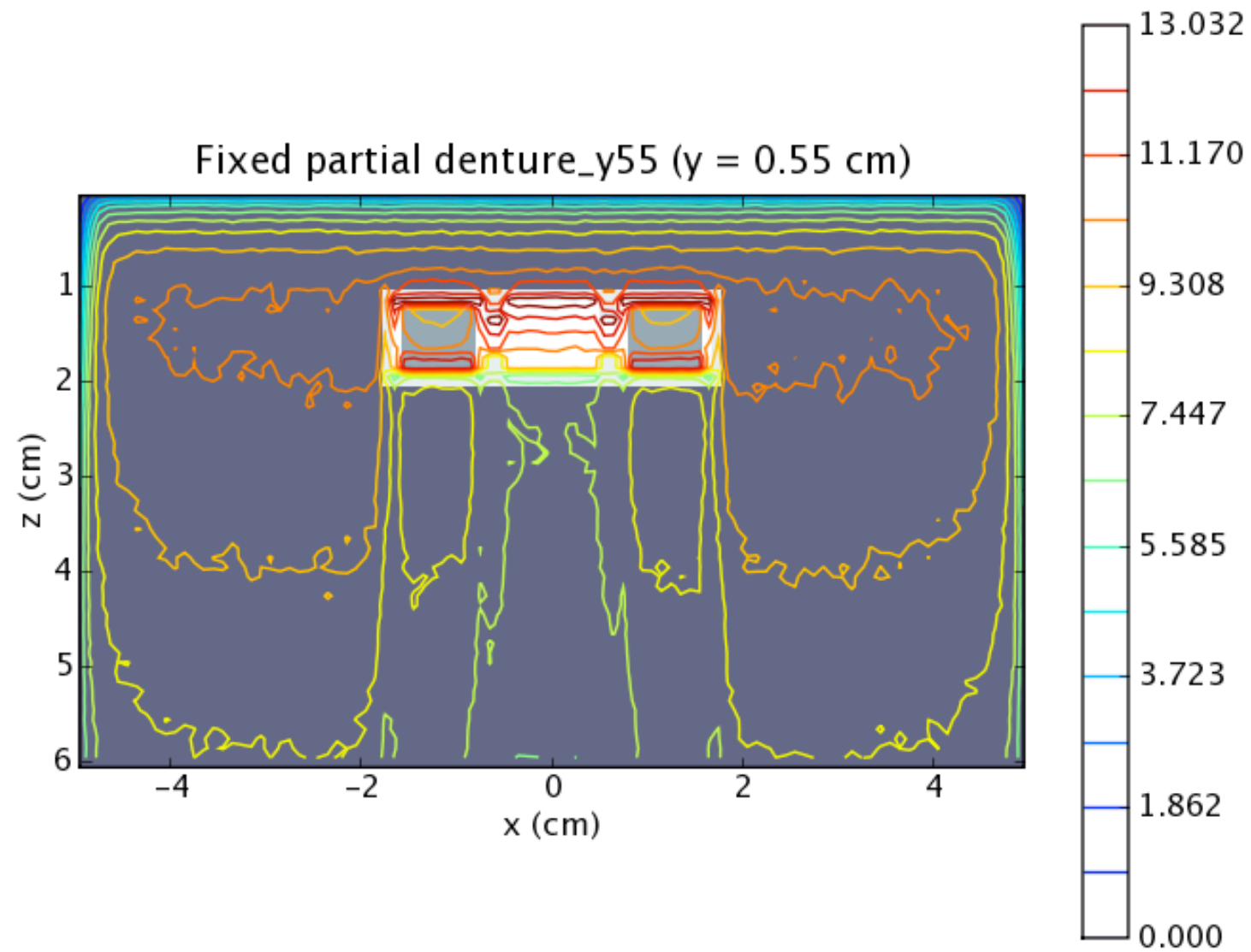
Amalgam restoration



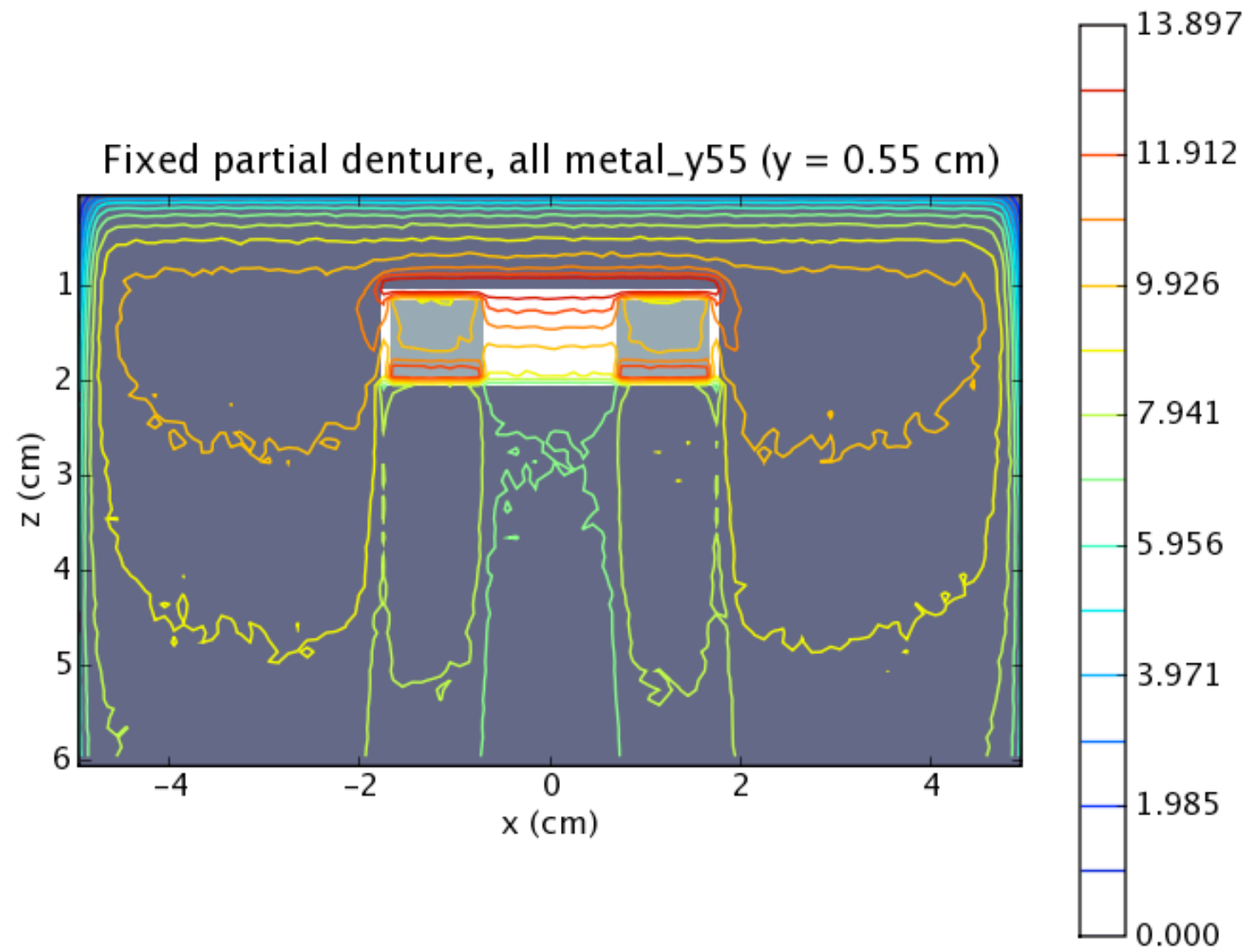
Amalgam, exposed surf.



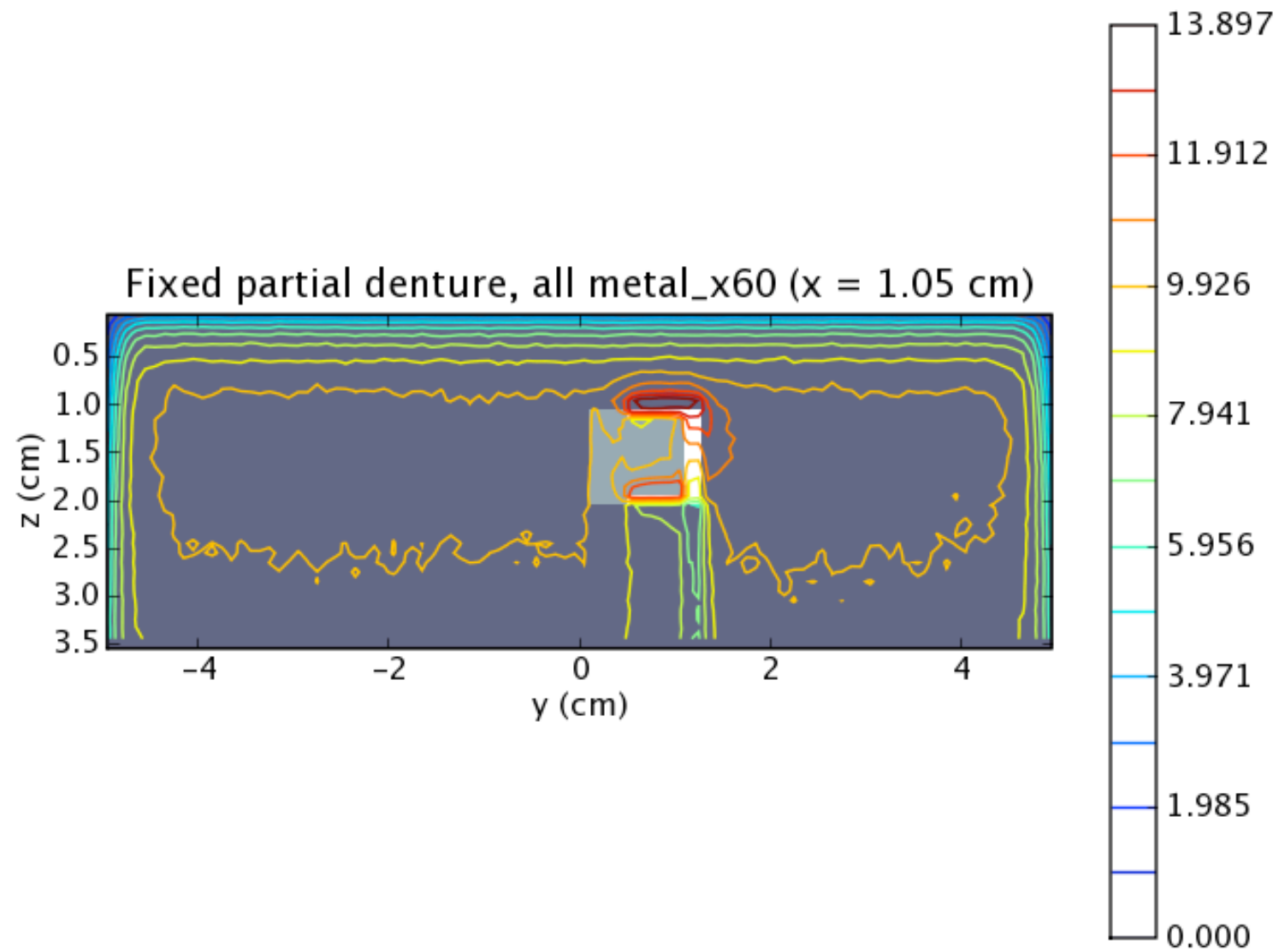
FPD, ceram. ven. pontic



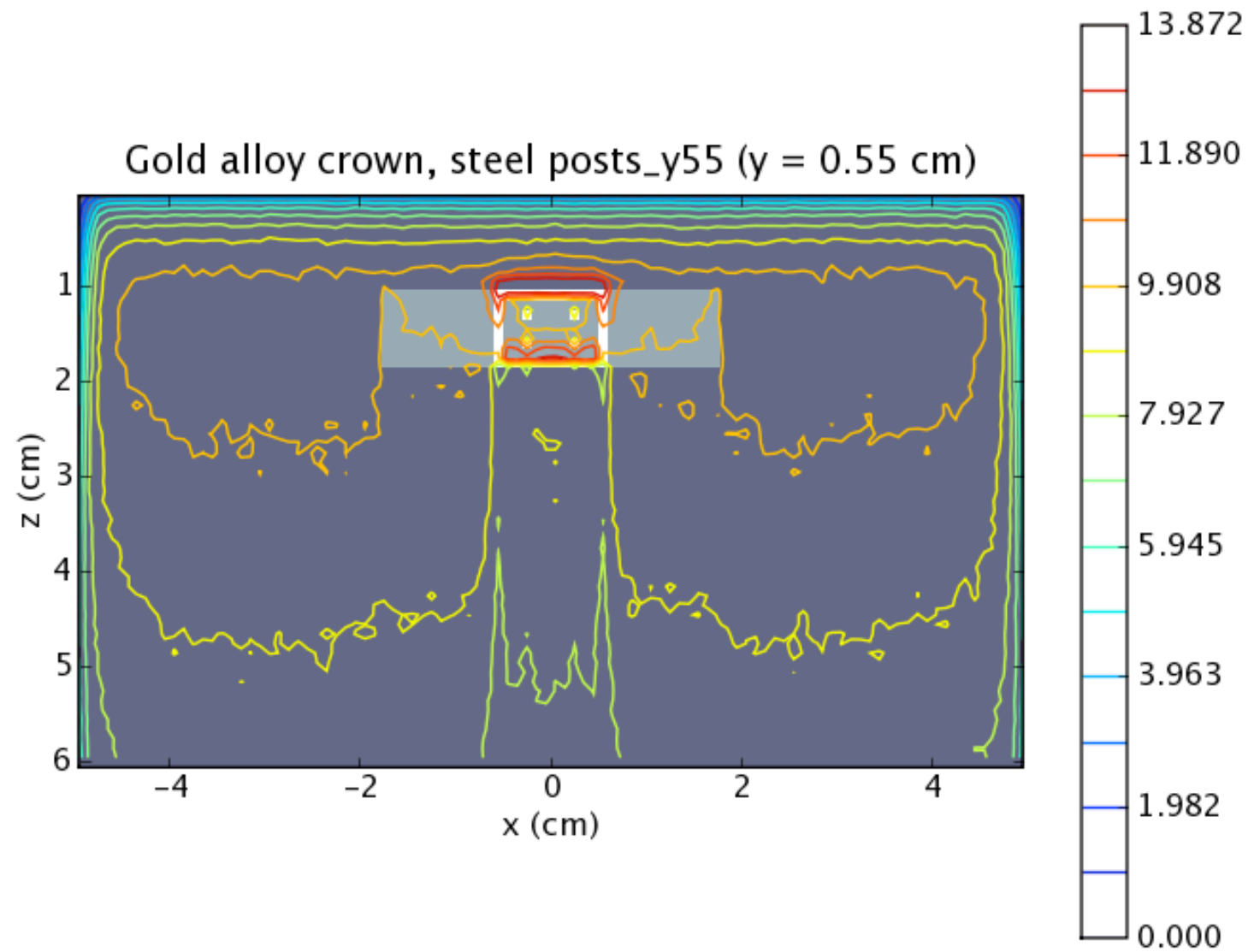
FPD, all metal



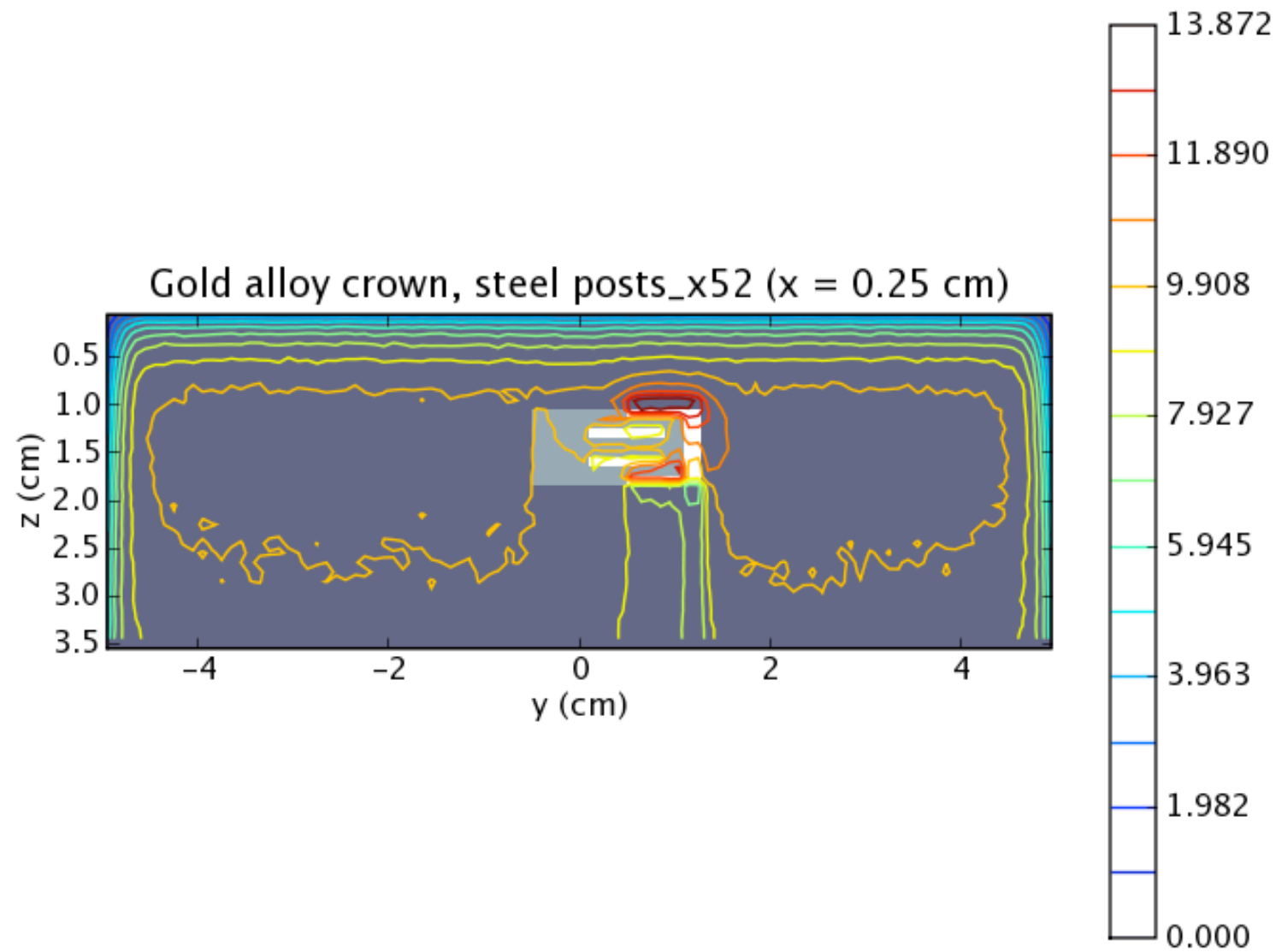
FPD, all metal, cont.



Crown, steel posts



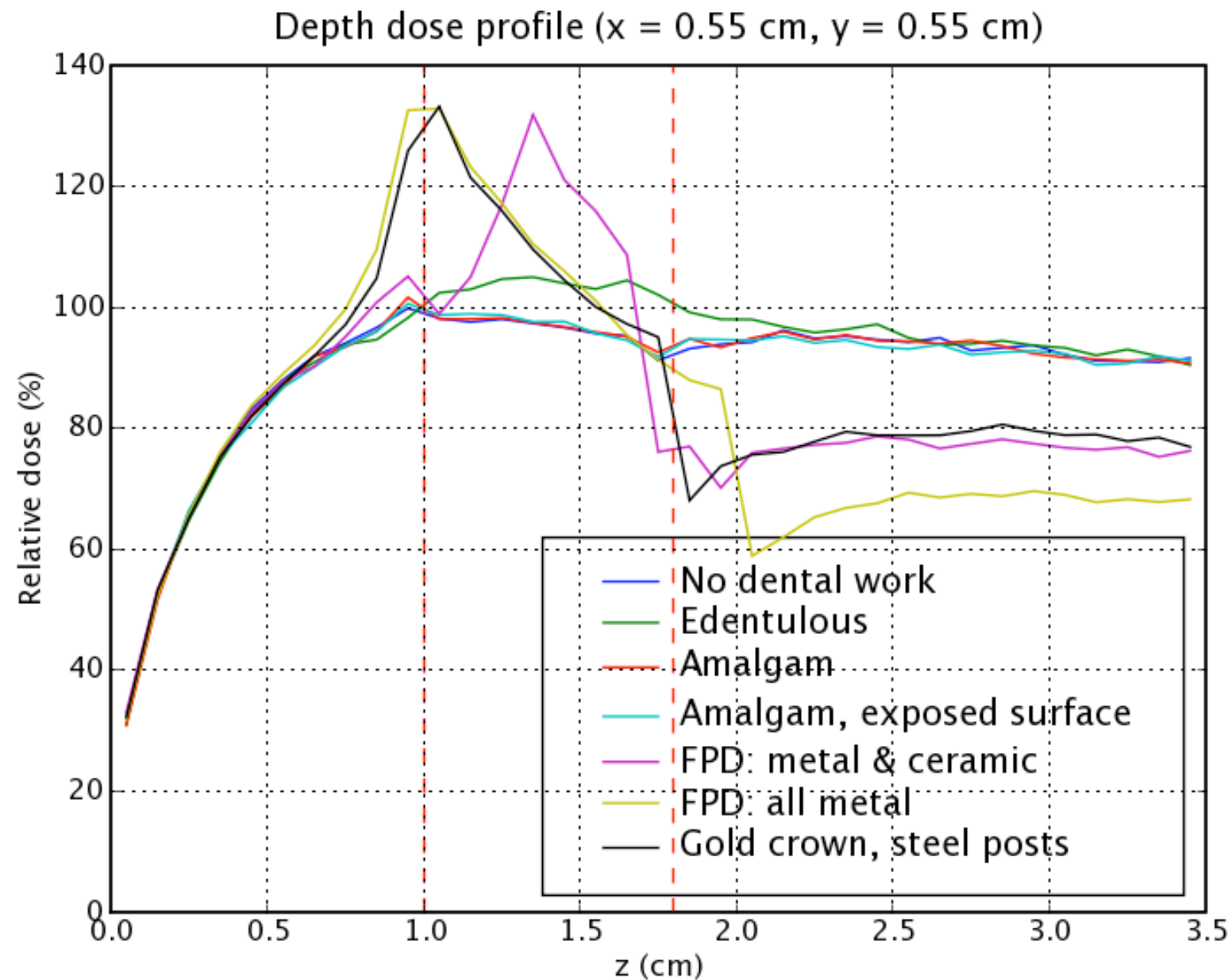
Crown, steel posts



Depth dose curves

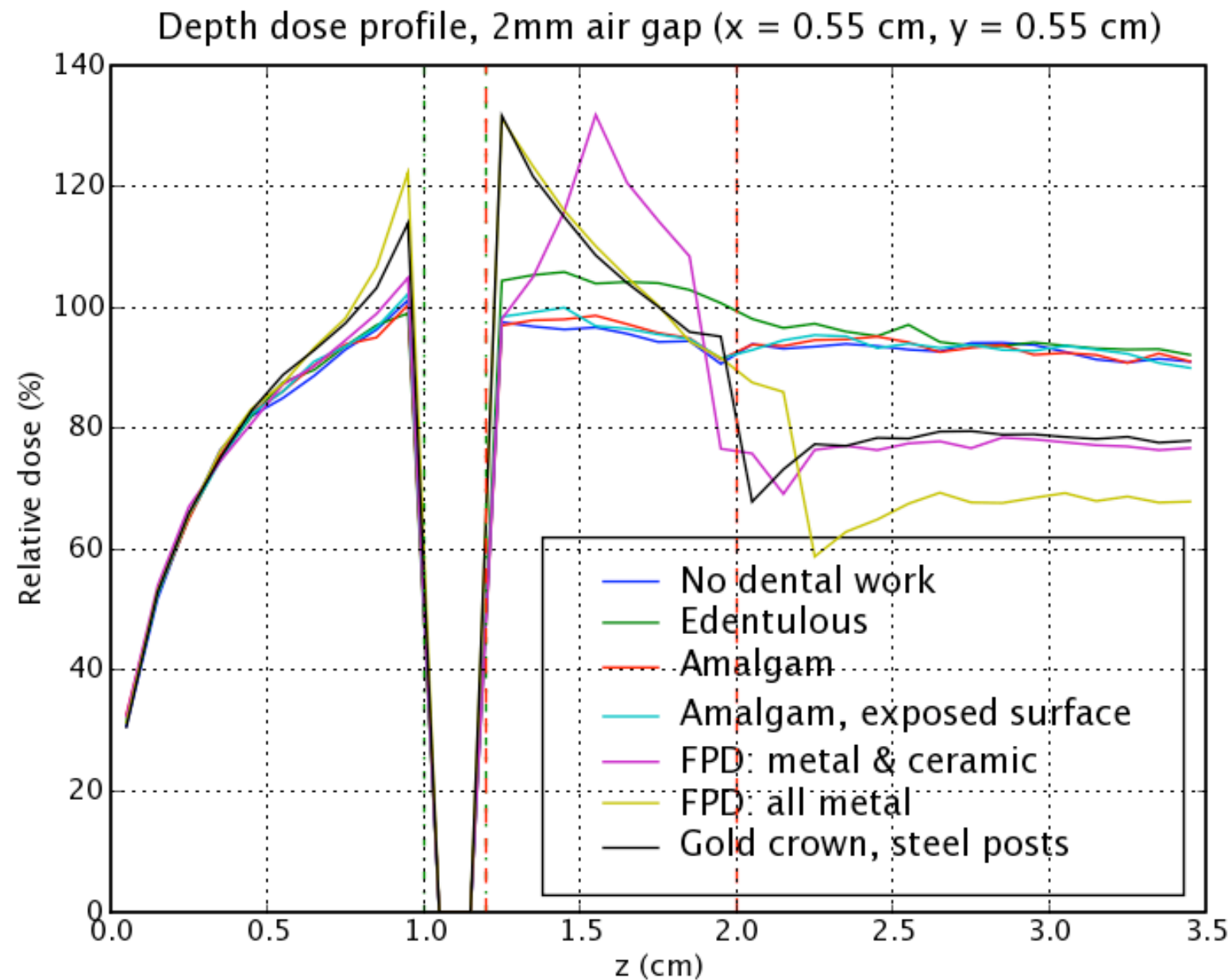
- through body of middle tooth
- normalized to dose @ $z = 1.0\text{cm}$ (inside surface of “cheek”)
- all estimated errors (σ) $< 2\%$

Depth dose curves

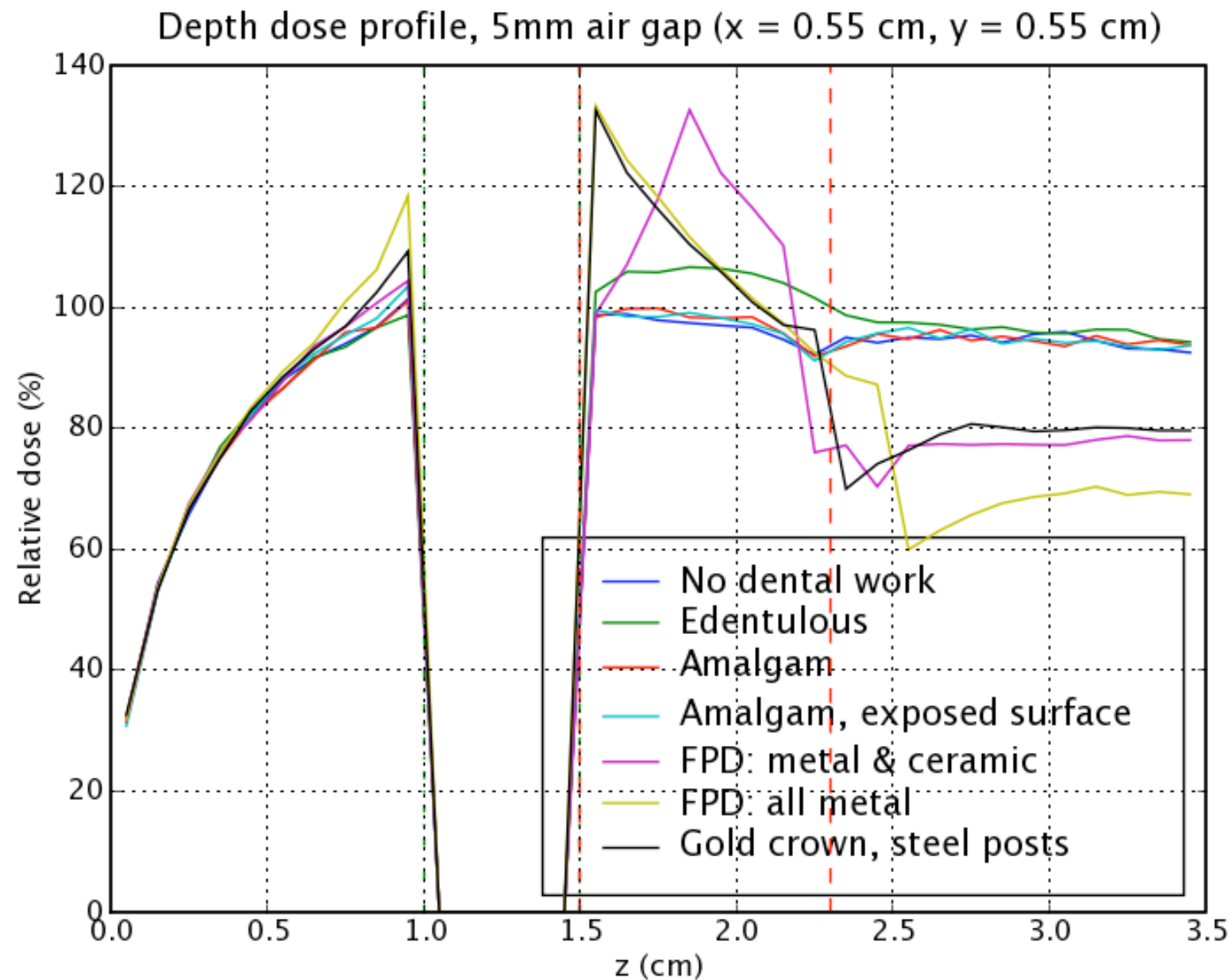


Normalized to dose @ $z = 0.95$ cm

Depth dose (2mm air)



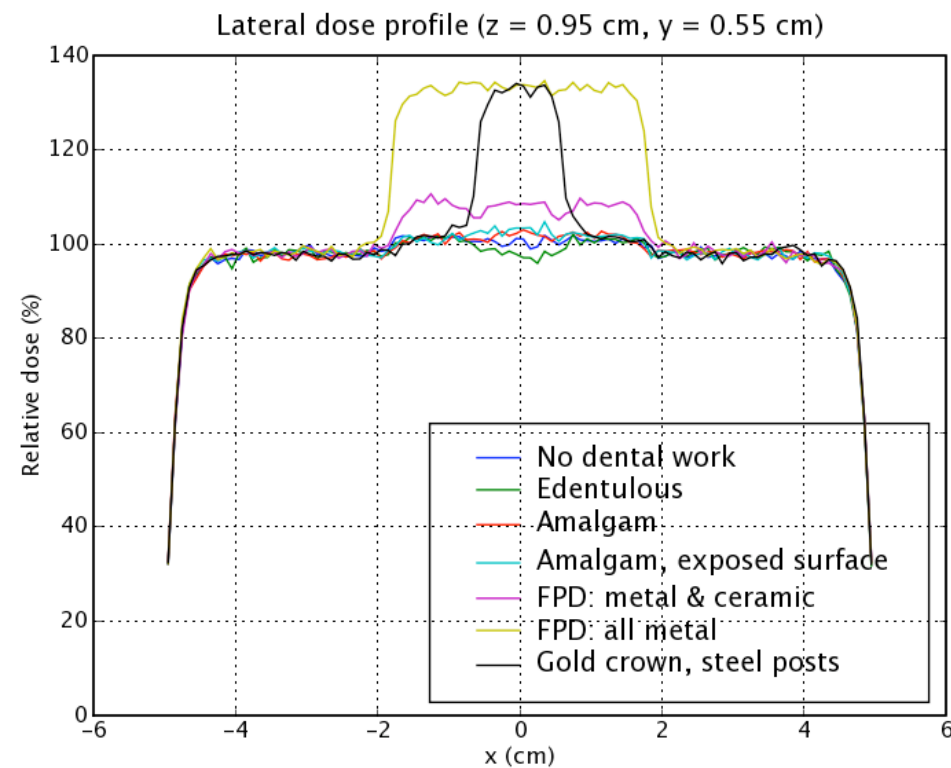
Depth dose (5mm air)



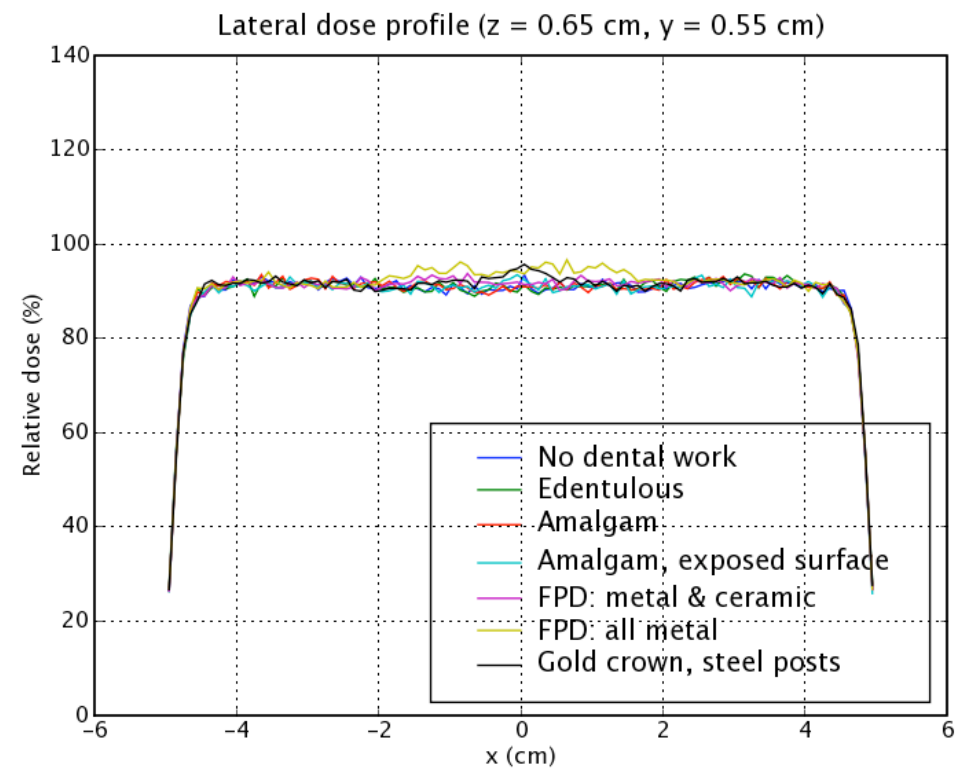
Lateral dose profiles

- 0.5 mm from interface ($z = 0.95$ cm)
- 2.5 mm from interface ($z = 0.75$ cm)
- 3.5 mm from interface ($z = 0.65$ cm)

Lat. profile (no air)

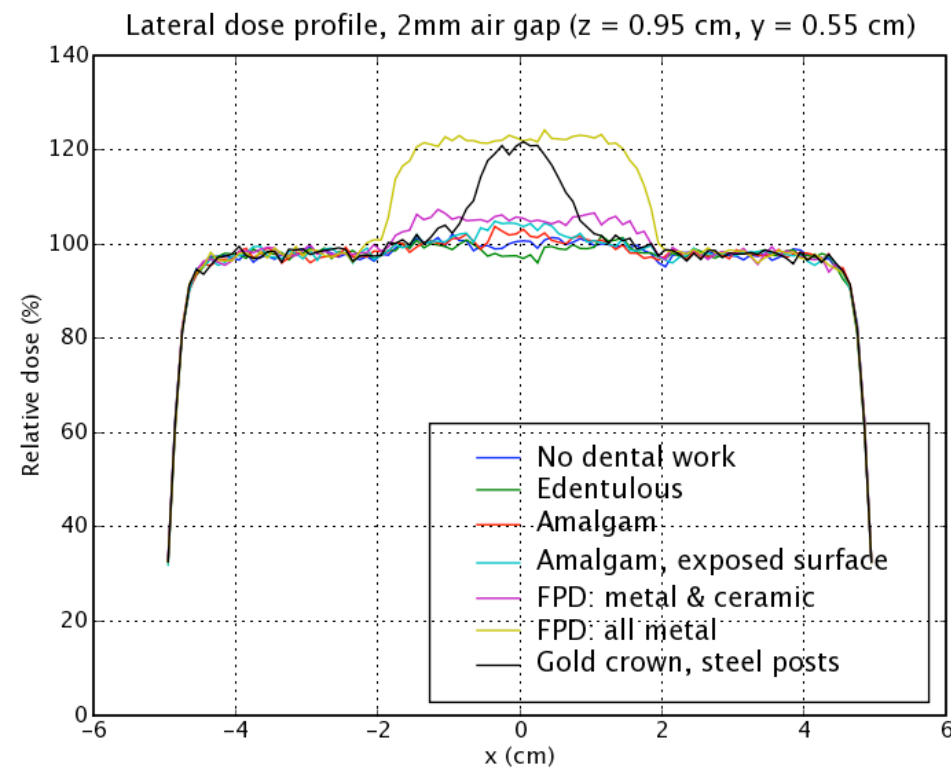


$z = 0.95$ cm

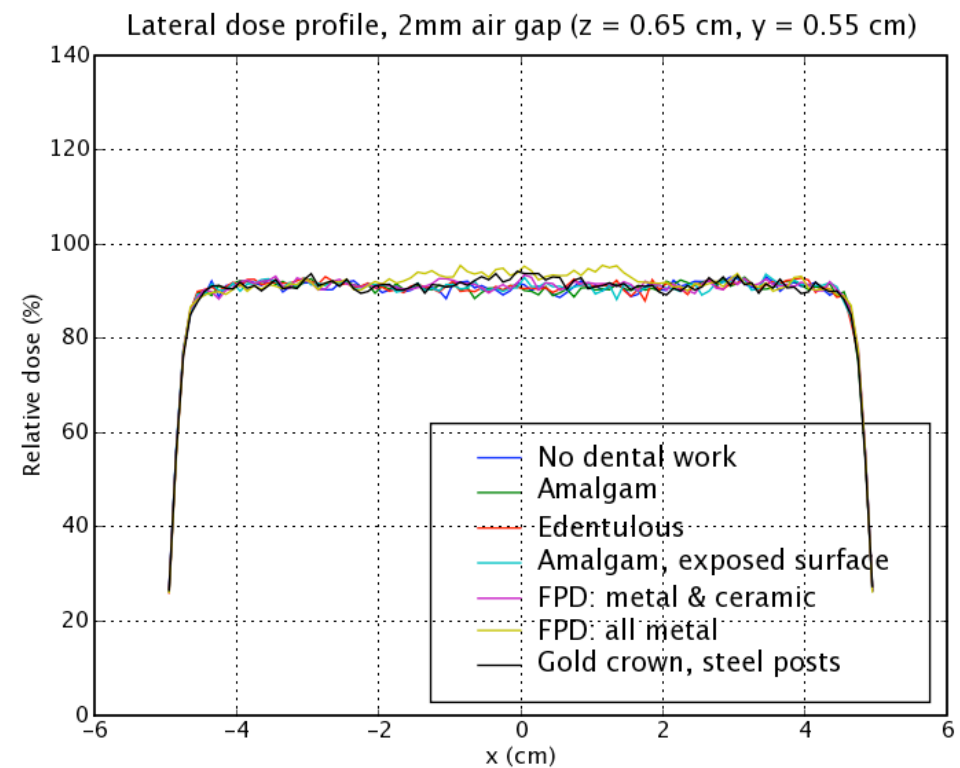


$z = 0.65$ cm

Lat. profile (2mm air)

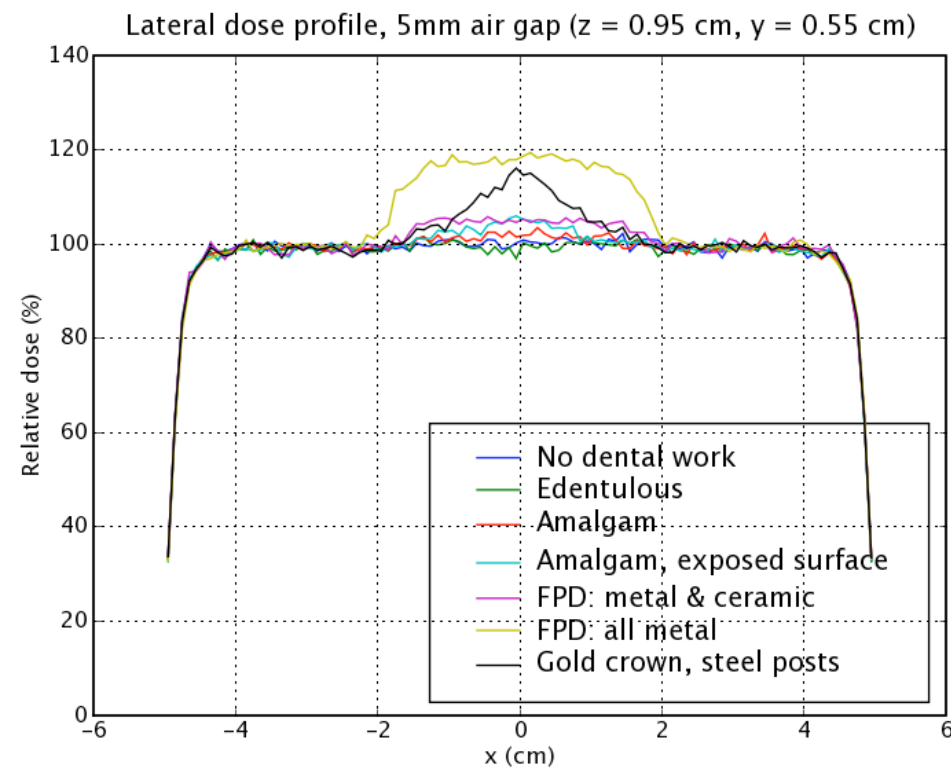


$z = 0.95$ cm

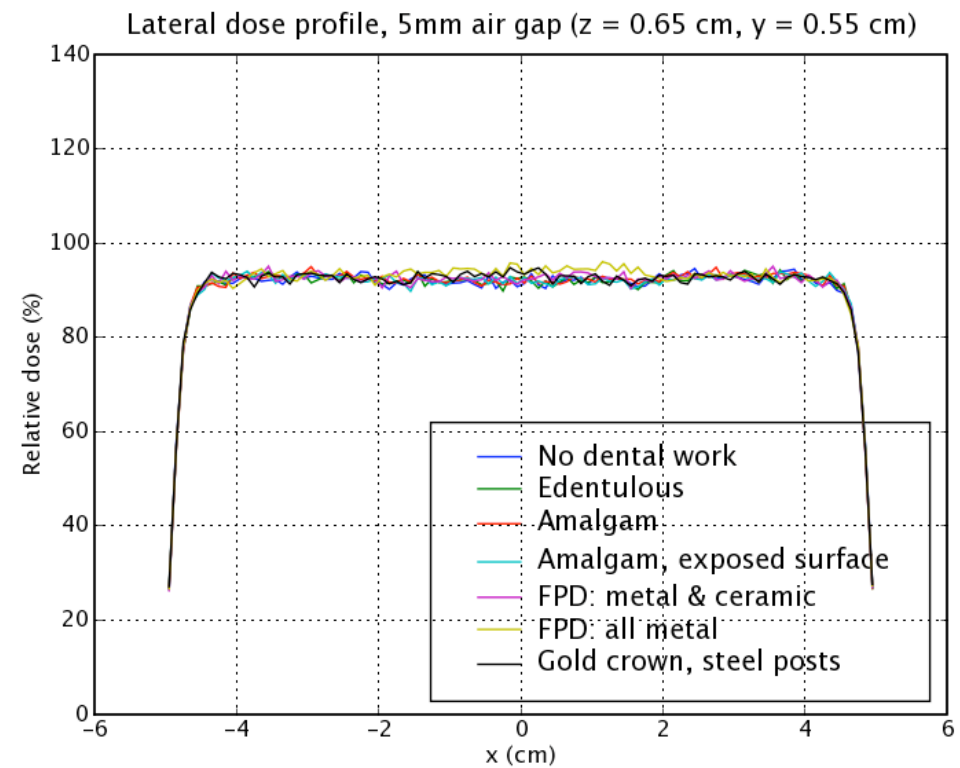


$z = 0.65$ cm

Lat. profile (5mm air)



$z = 0.95$ cm



$z = 0.65$ cm

Backscatter rel. dose (%)

no air gap

	$z = 0.95$	$z = 0.75$	$z = 0.65$
No dental work	100	93	90
Edentulous	97	93	90
Amalgam	102	93	90
Amalgam, exp. surf.	102	95	92
FPD	108	95	91
FPD, all metal	132	100	94
Crown	132	100	94

Backscatter rel. dose (%)

2mm air gap

	$z = 0.95$	$z = 0.75$	$z = 0.65$
No dental work	100	93	90
Edentulous	97	93	90
Amalgam	102	94	90
Amalgam, exp. surf.	104	94	91
FPD	105	95	91
FPD, all metal	122	99	94
Crown	120	98	93

Backscatter rel. dose (%)

5mm air gap

	$z = 0.95$	$z = 0.75$	$z = 0.65$
No dental work	100	94	91
Edentulous	100	94	91
Amalgam	102	95	91
Amalgam, exp. surf.	105	96	91
FPD	104	96	92
FPD, all metal	118	99	94
Crown	114	98	93

Discussion

- Monte Carlo is good way to estimate backscatter dose: flexible, easier than experiment
- exposed gold alloy produces largest backscatter (~30%); amalgam produces much less
- between 2mm and 5mm cotton roll (air gap) may reduce overdose to acceptable level
- 3mm water equivalent gives better shielding
- “shadow” may compensate backscatter for multiple beams
- backscatter also occurs inside capped tooth

References

- M. Farahani et al., PMB **35**(3) pp.369-385
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- S.F. Rosenstiel, M.F. Land, J. Fujimoto, *Contemporary Fixed Prosthodontics 2/e*, Mosby-Year Book, St. Louis, 1995
- G.J. Mount and W.R. Hume, *Preservation and Restoration of Tooth Structure*, Mosby International, London, 1998