Use of Monte Carlo to assist in the removal of scatter from diagnostic computed radiographic images

G. Johnston, A. McCann, A. Workman, C. McGivern and K. Cranley

Northern Ireland Regional Medical Physics Agency

gail.johnston@mpa.n-i.nhs.uk

Aim

- To obtain a quantitative measure of fracture healing using computed radiography imaging techniques

Rationale

- Orthopaedic surgery: need for quantitative measure of healing
- Facilitates prompt healing and secondary intervention as required
- Allows removal of external splintage or fixators
- Provides objective measure: useful in clinical trials

Previous Approaches

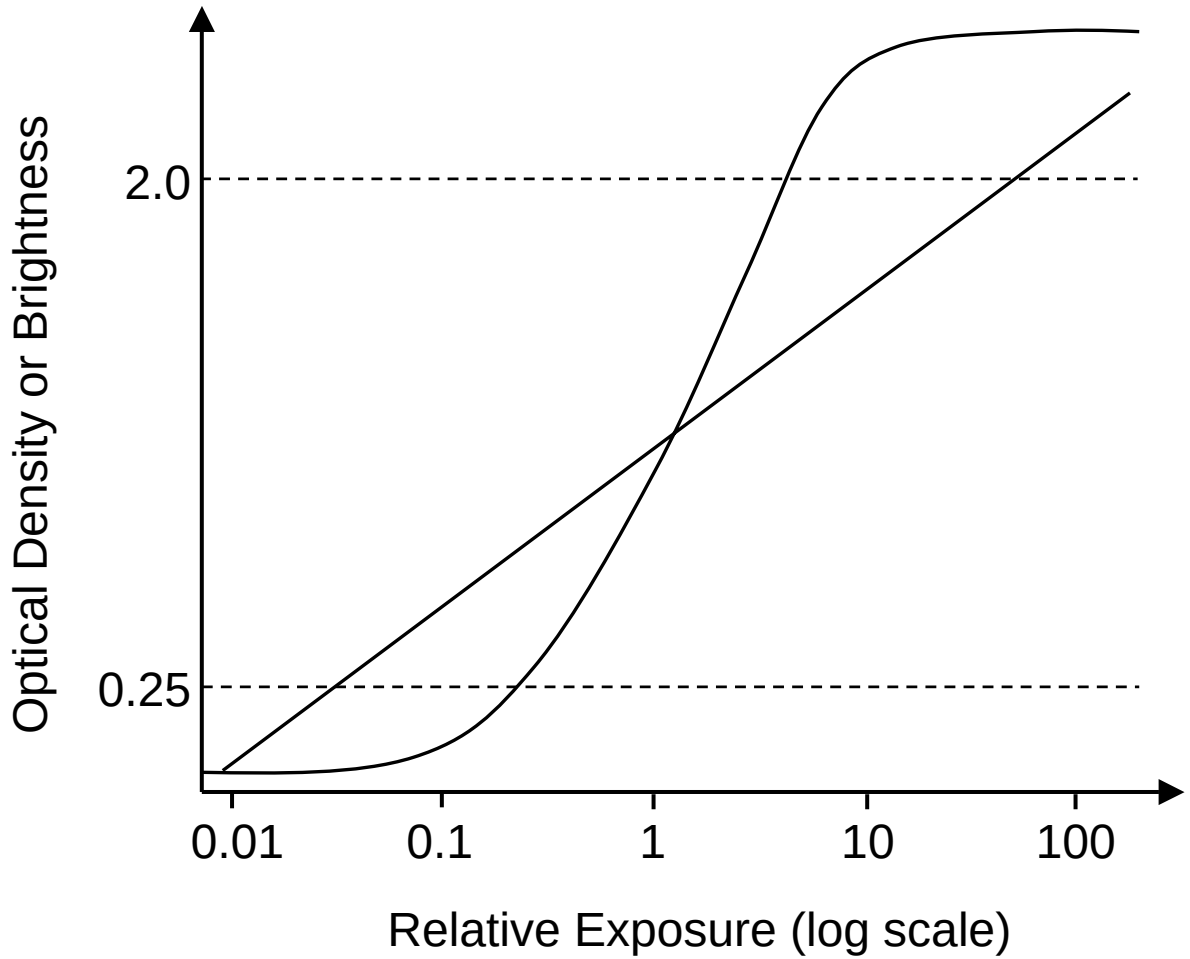
- Subjective assessment by clinician
- Bending stiffness measurements [1]
  - intramedullary nail
- Other imaging techniques e.g. CT, µCT, DEXA
  - not routinely available

[1] D.Marsh, *Clin. Orthop.* 355 Supp: S22-30

CR

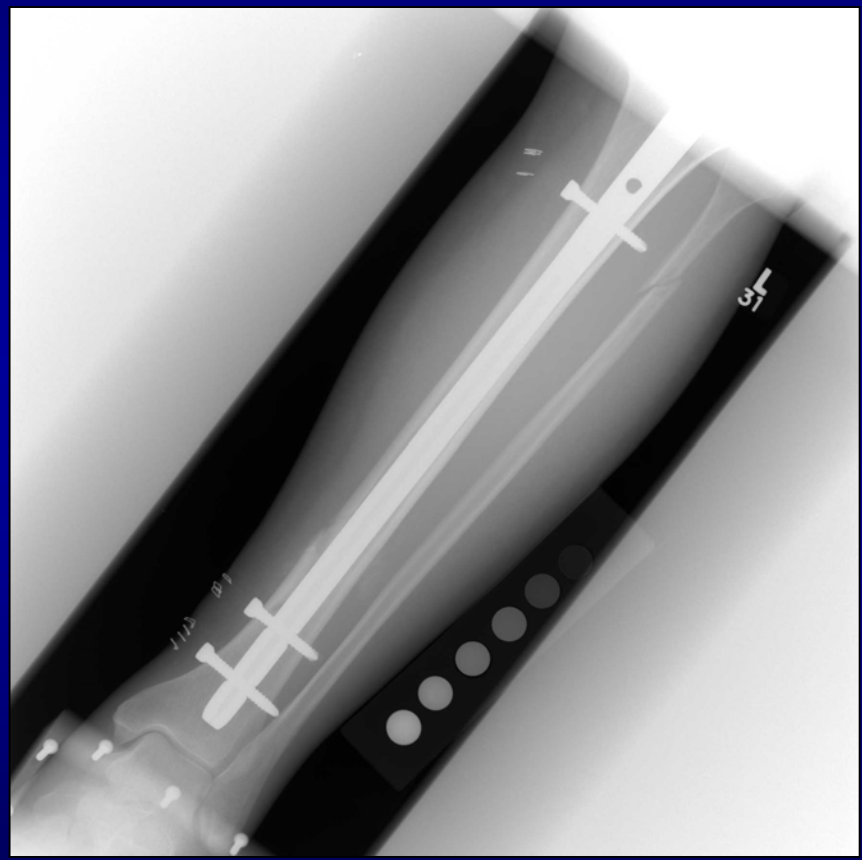
- CR readily available
- Pixel value can be related to bone mineral density
- Wide dynamic range
- Linear response
- Settings can be standardised e.g. kV, mAs

CR vs. Screen-Film



Previous Trials

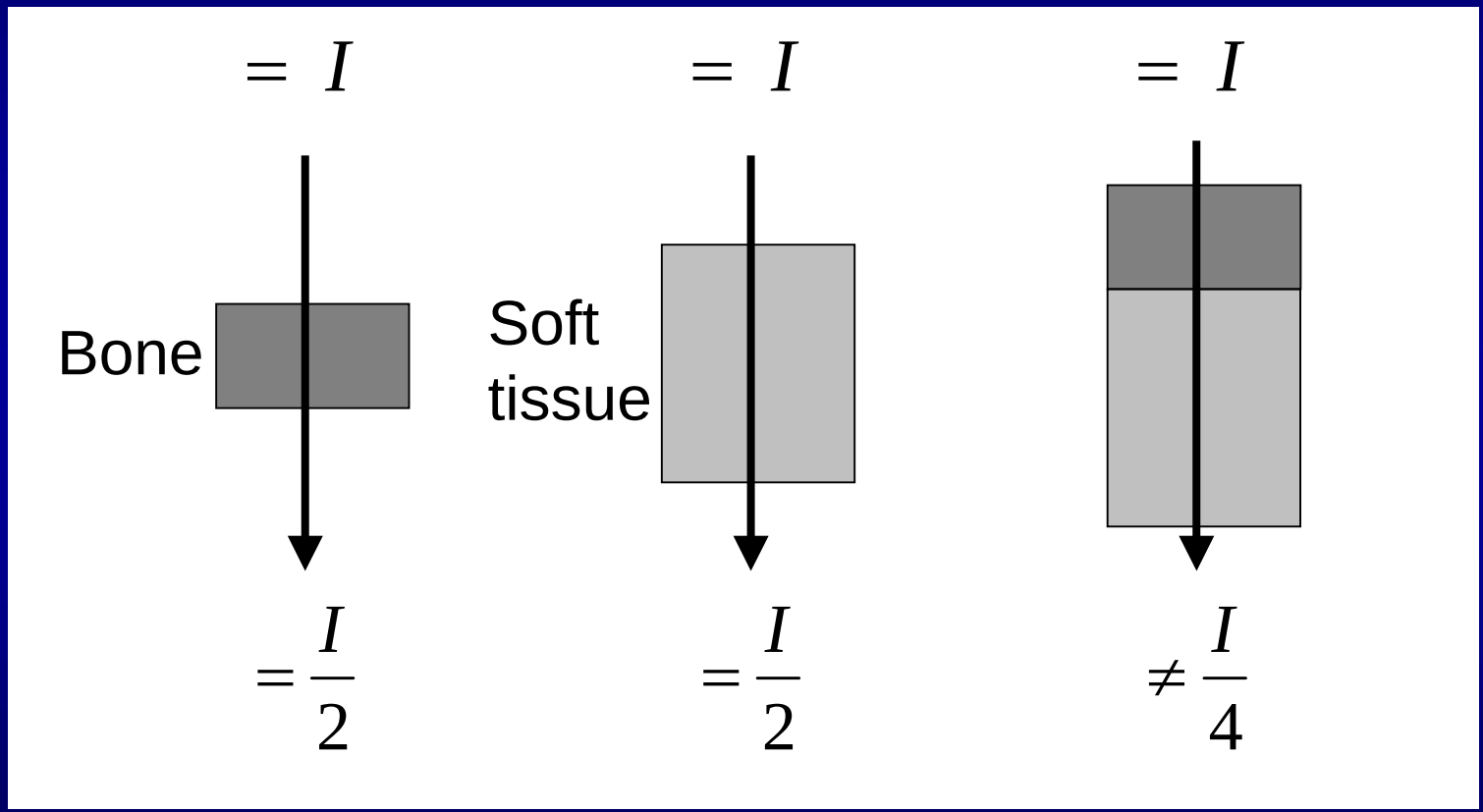
- HAP phantom of known density used to calibrate image
- PV plotted against BMD
- Each pixel in bony region then assigned a BMD value



Problems

- Image capture
- Non-uniformity of beam
- Soft tissue contribution
- Beam hardening
- Scatter contribution

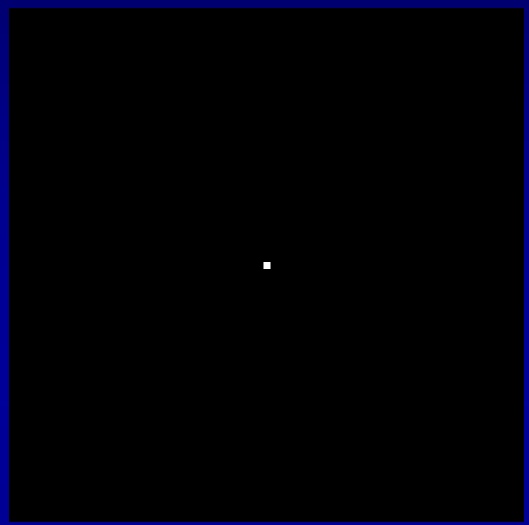
Beam Hardening



Scatter

- 3 possibilities
  - absorption
  - transmission
  - collision and scatter
- Absorption and transmission processes result in recognisable radiographic image
- Scattered photons carry no useful information
- Direct link between image pixel value and attenuation properties of material is lost
- Hence, necessary to remove scatter component

Point Spread Function



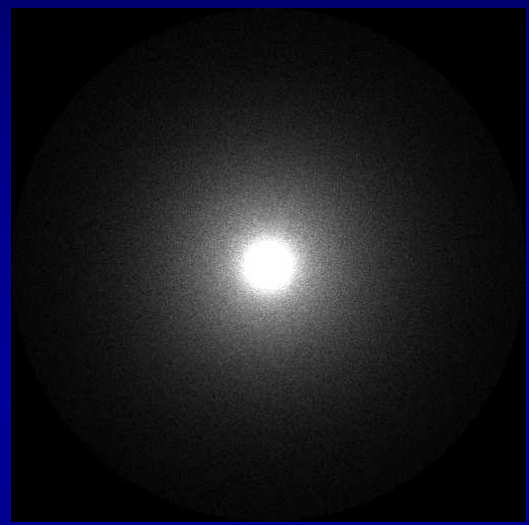
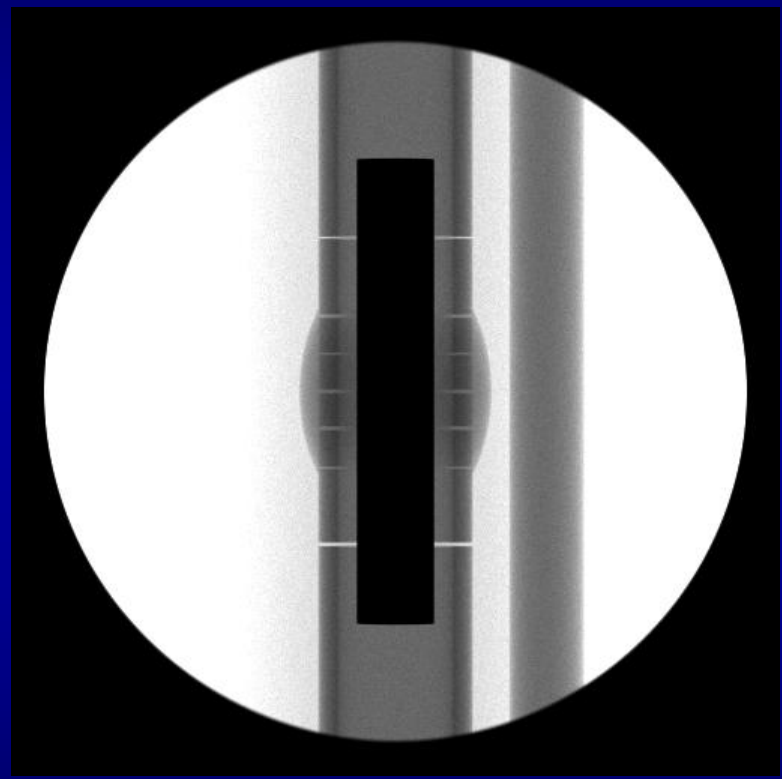


Image = $I_{primary}$ * PSF

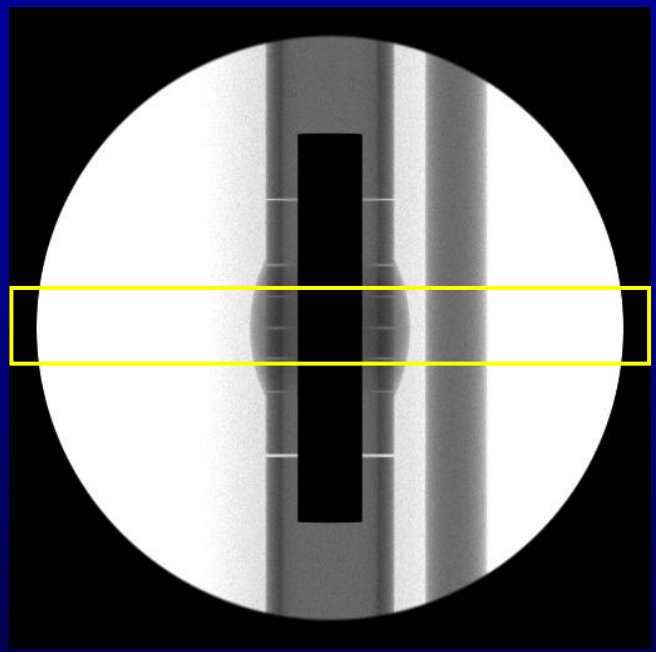
MC Approach

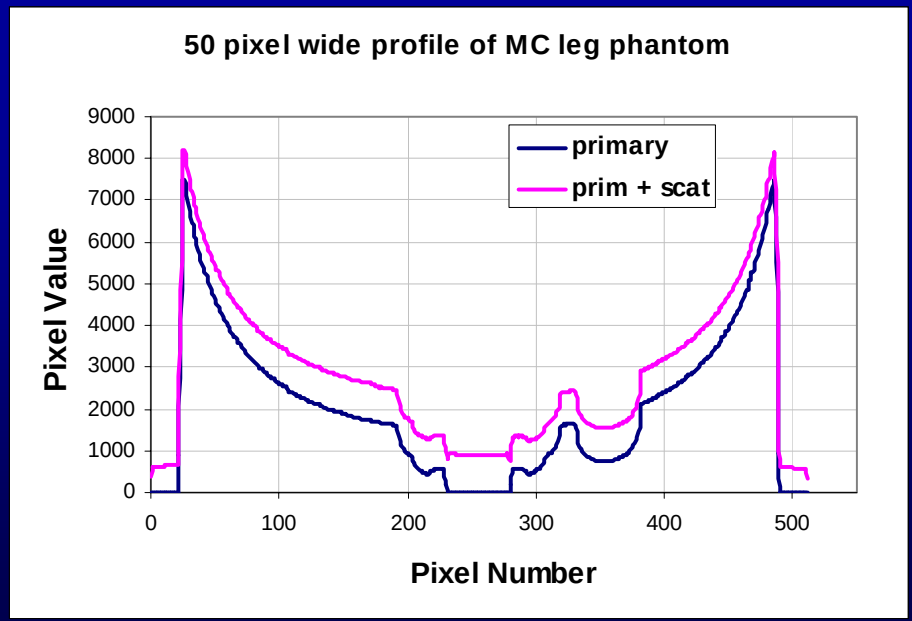
- MC simulates images of tibial phantom
- Steel pin and callus included to mimic clinical situation
- Java program used to extract primary and scatter images



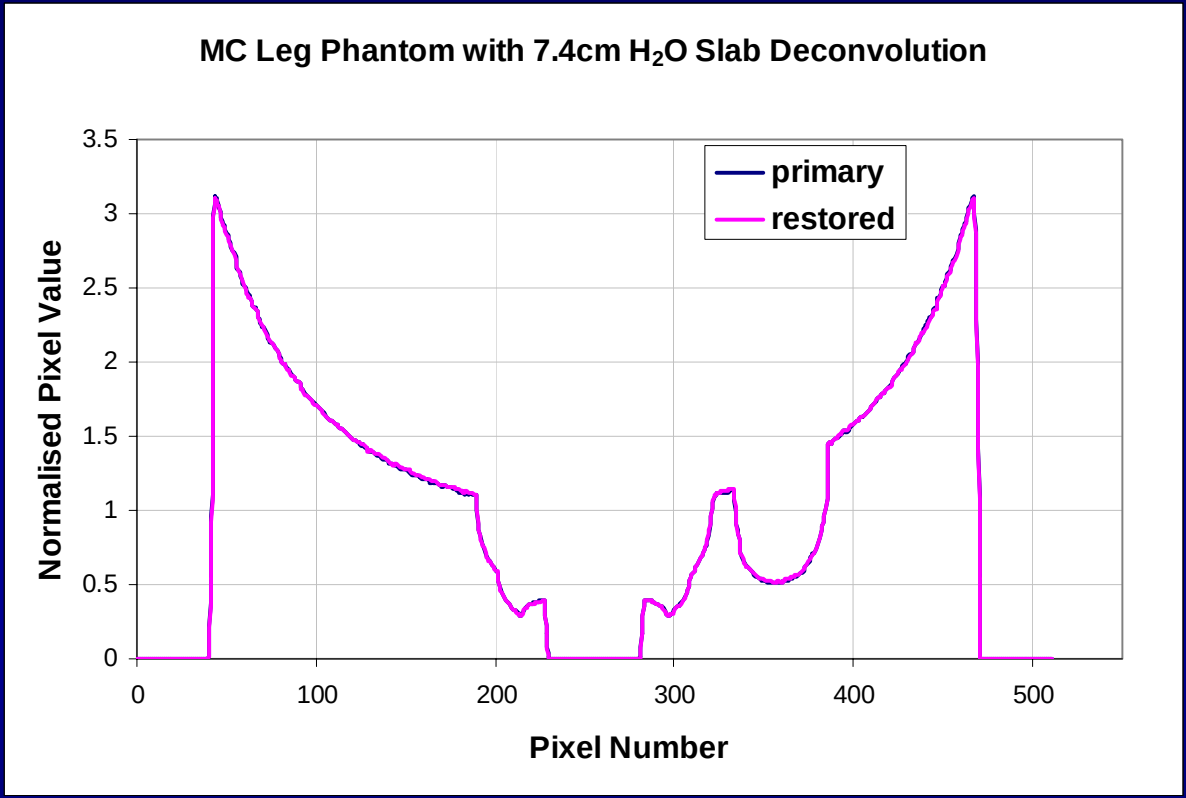
MC Approach

- PSF generated
- Original image deconvolved with PSF
- Restored image then compared with known primary image





MC Approach



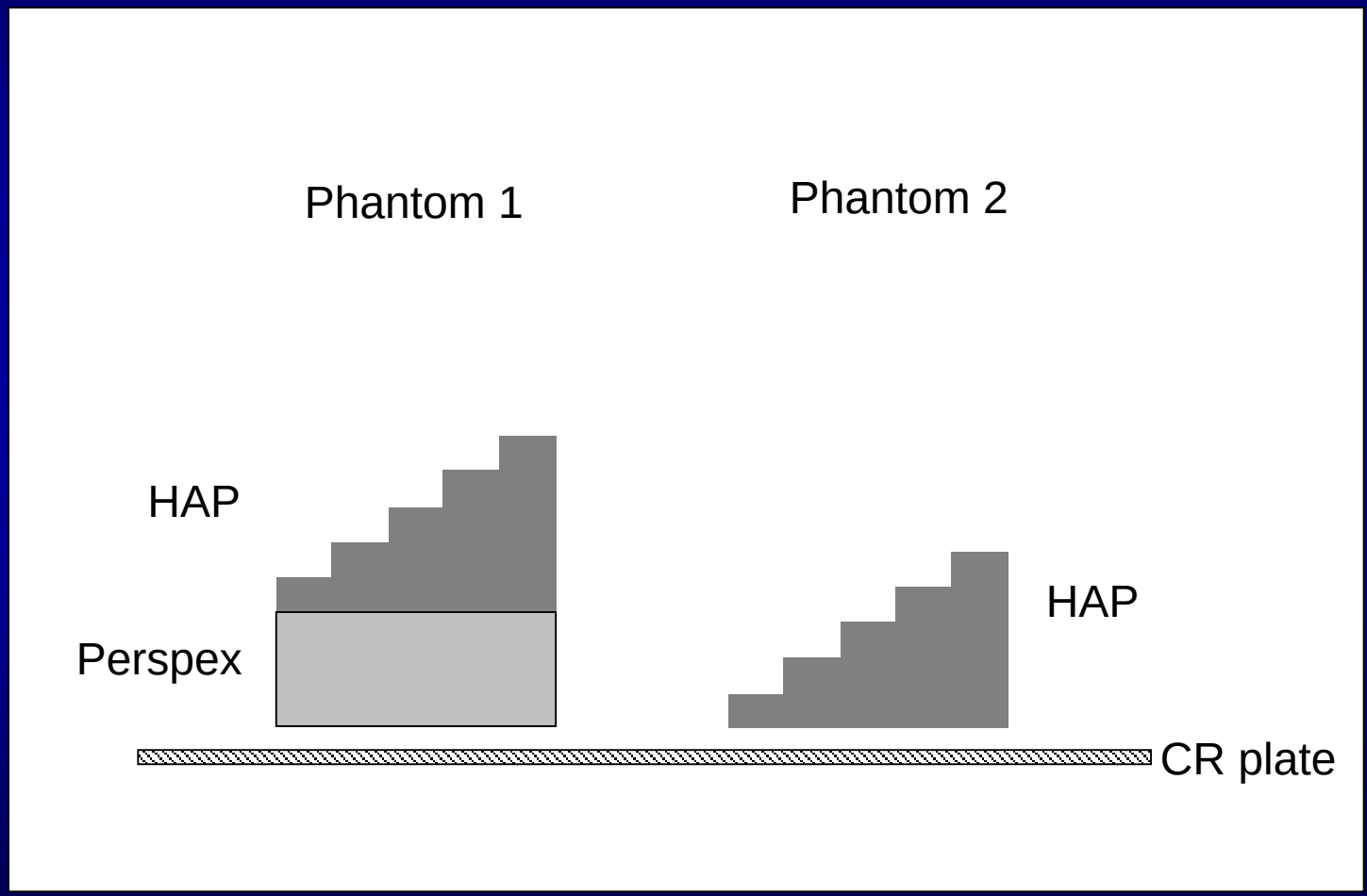
- Restored image is within ±2% of primary in bony region of interest

Analytical Scatter Model

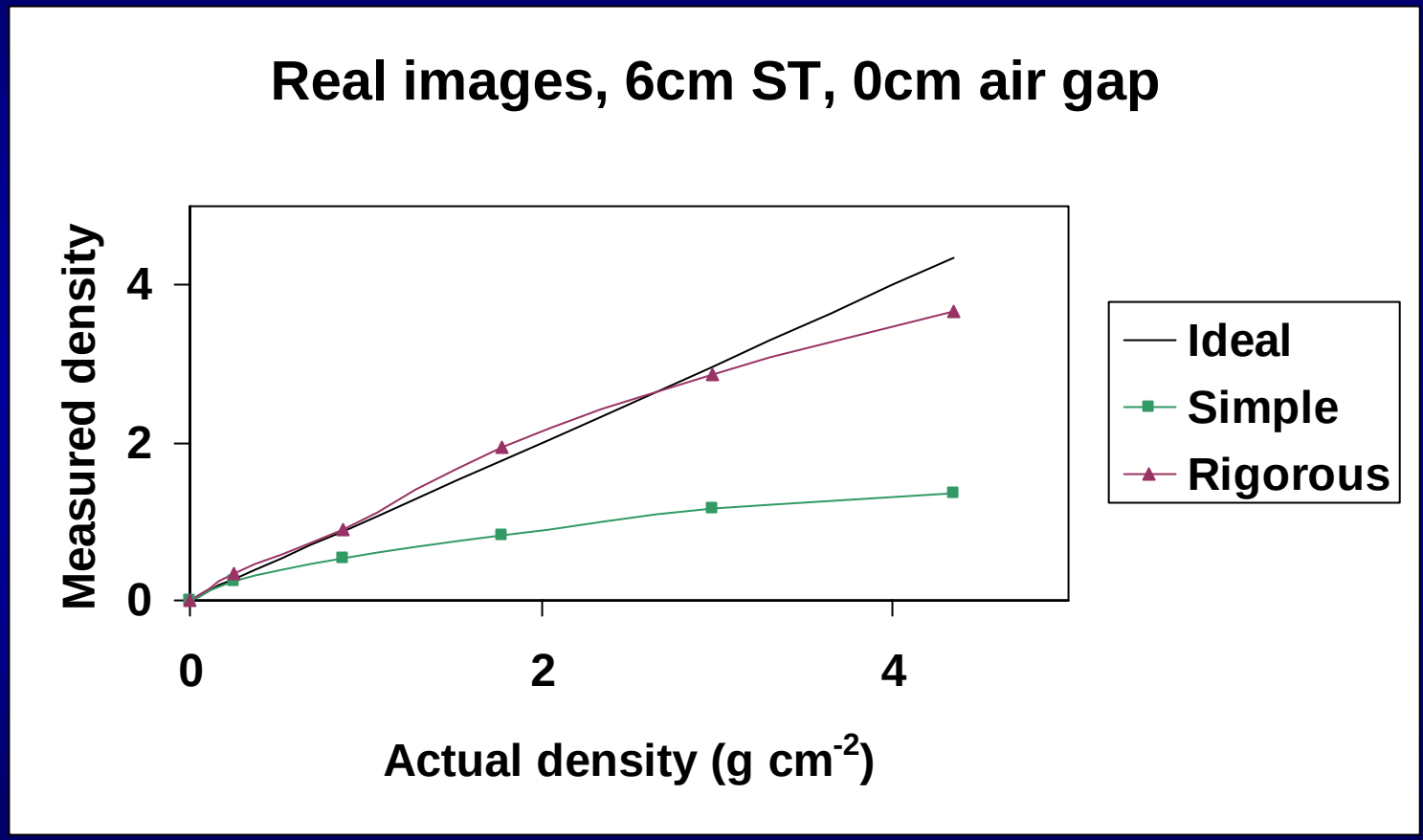
- Soft tissue thickness used as input parameter for analytical model [2]
- Facilitates restoration of actual CR images
- Verified using HAP step wedge phantom (bone) and Perspex block (soft tissue)

[2] J.M. Boone and J.A. Seibert *Med. Phys.* 15 (5) 1988

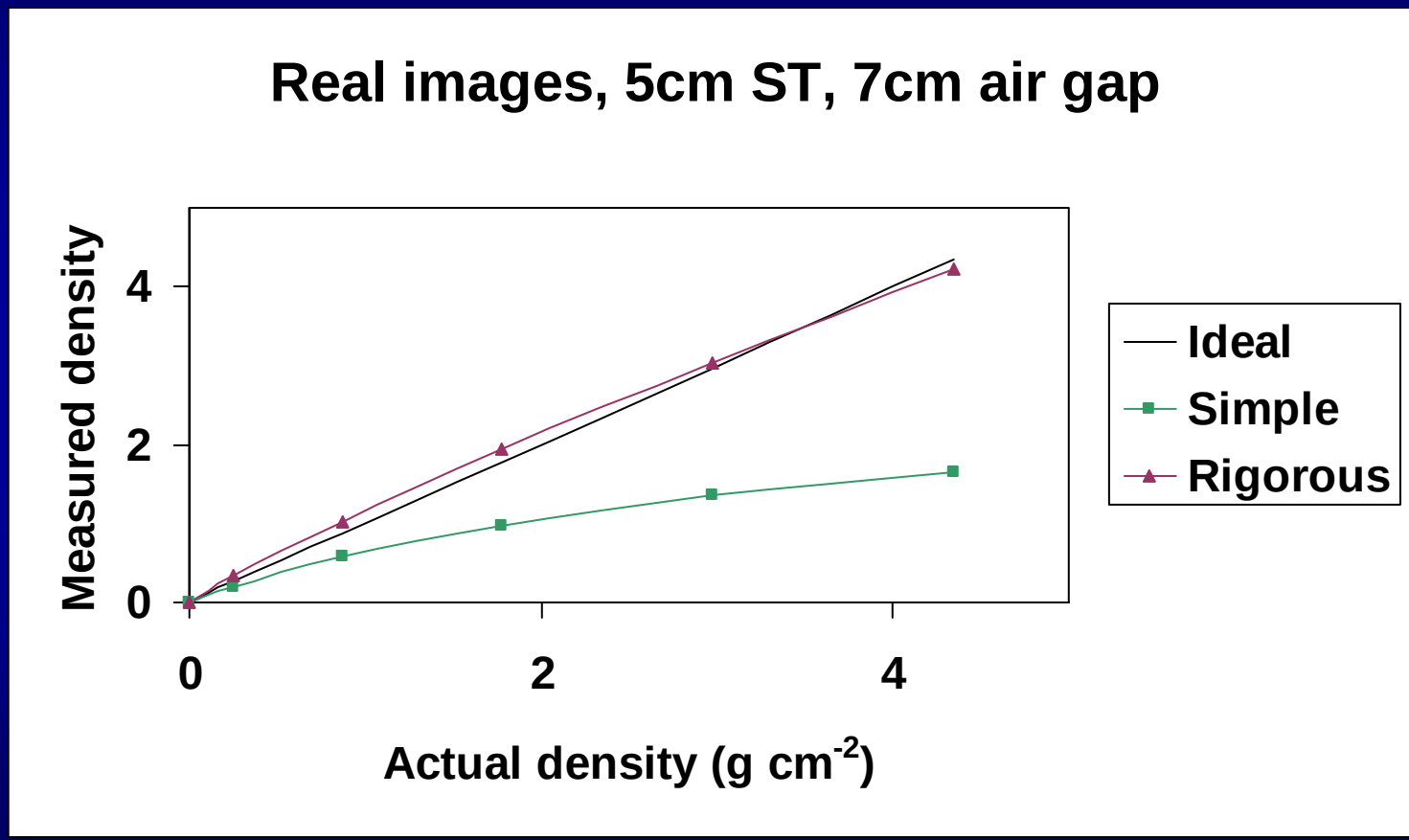
Experimental



Results


Real images, 6cm ST, 0cm air gap
Measured density
0
2
4
0
2
4
Actual density (g cm-2)
Ideal
Simple
Rigorous

Results


Real images, 5cm ST, 7cm air gap
Measured density
0
2
4
0
2
4
Actual density (g cm-2)
Ideal
Simple
Rigorous

Summary

- Need to obtain quantitative measure of fracture healing
- Removal of scatter necessary
- 3 pronged approach
  - MC
  - Analytical
  - Experimental
- Test results: HAP densities returned to within 4% of expected value (10cm soft tissue, 10cm air gap)

Future Work

- Model still undergoing refinement
- Clinical trials
- Application to other long bones e.g. femur, radius