

Femoral Bending Strength is well Correlated with DXA-Derived Strength Measures



Alexander M. Baker¹, and Gary S. Beaupre^{1,2}

¹VA Palo Alto, Musculoskeletal Research Laboratory, Palo Alto CA, USA

²Department of Mechanical Engineering, Stanford University, Stanford CA, USA

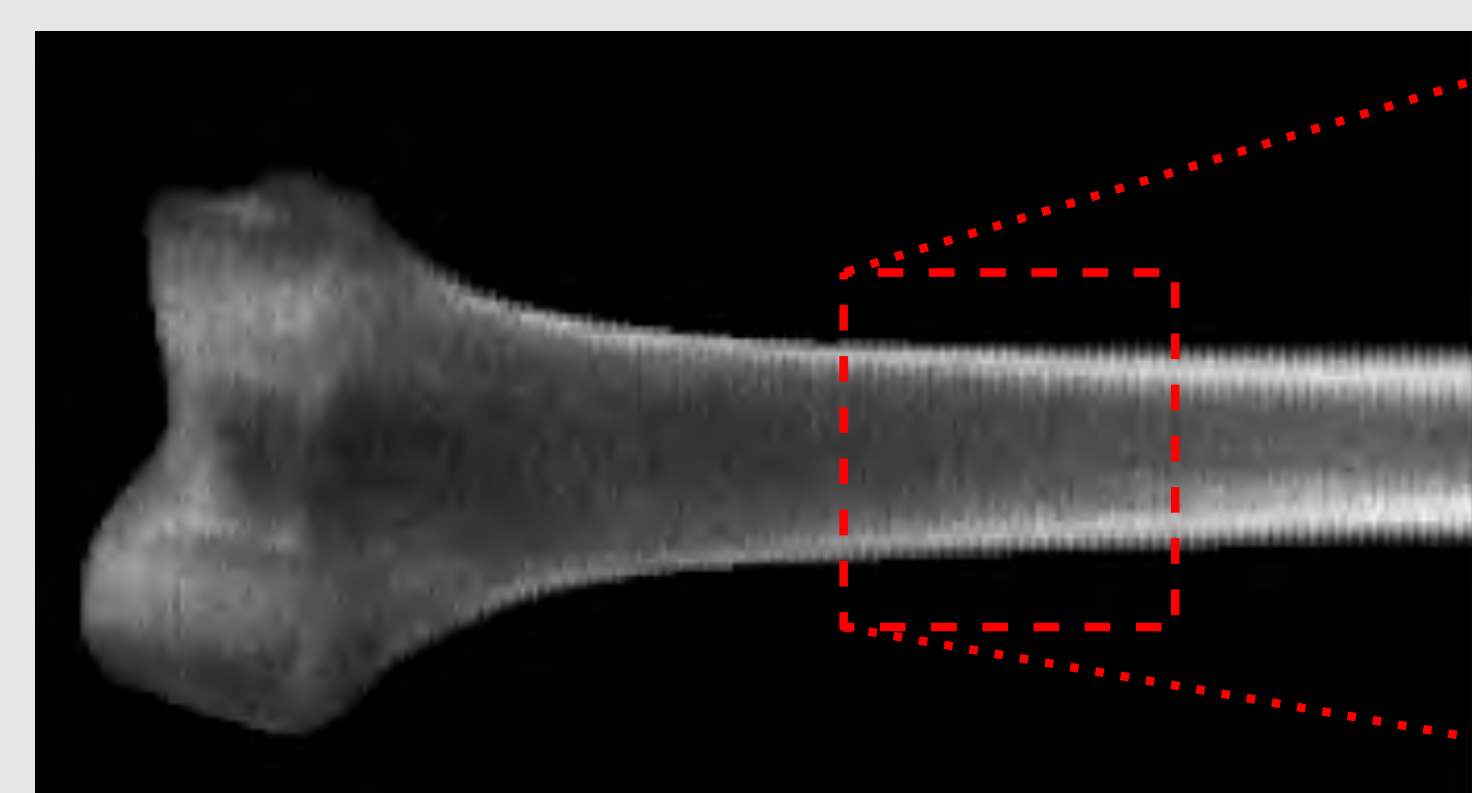
Introduction

- Fracture in individuals with a spinal cord injury can lead to a variety of complications including: extended hospital stays, infection, pressure sores, increased risk for subsequent fragility fractures, mal-union, or increased mortality. [1,2]
- Bending in distal femur is thought to be most dominant loading mechanism during fracture.

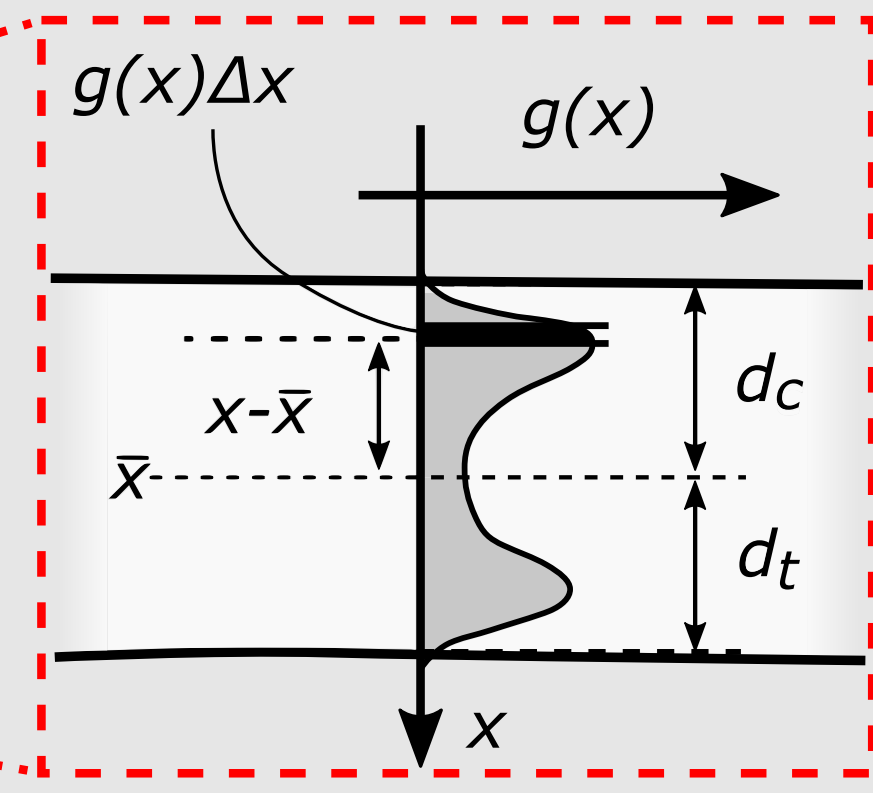
Research Aim

How well can DXA-derived engineering strength parameters cross sectional moment of inertia (**CSMI**) and Section Modulus (**Z**) predict strength properties of the distal femur?

Materials and Methods



DXA scans acquired with QDR-1000W



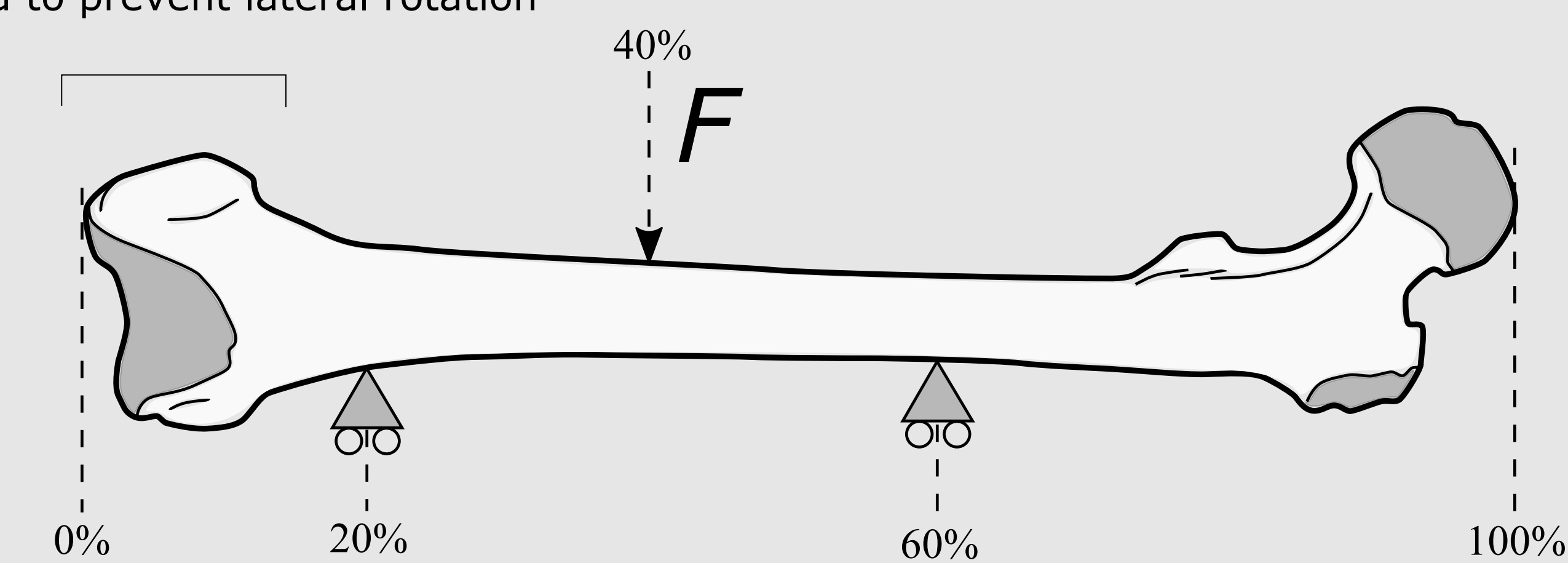
$$CSMI [3] = \sum \frac{(x-\bar{x})^2 g(x) \Delta x}{\rho_a} + \frac{g(x) \Delta x^3}{12\rho_a}$$

$$Z = CSMI/d_t$$

where:
 $g(x)$ is the pixel intensity,
 Δx is the pixel width,
and ρ_a is the assumed bone density

Gripped to prevent lateral rotation

N = 51



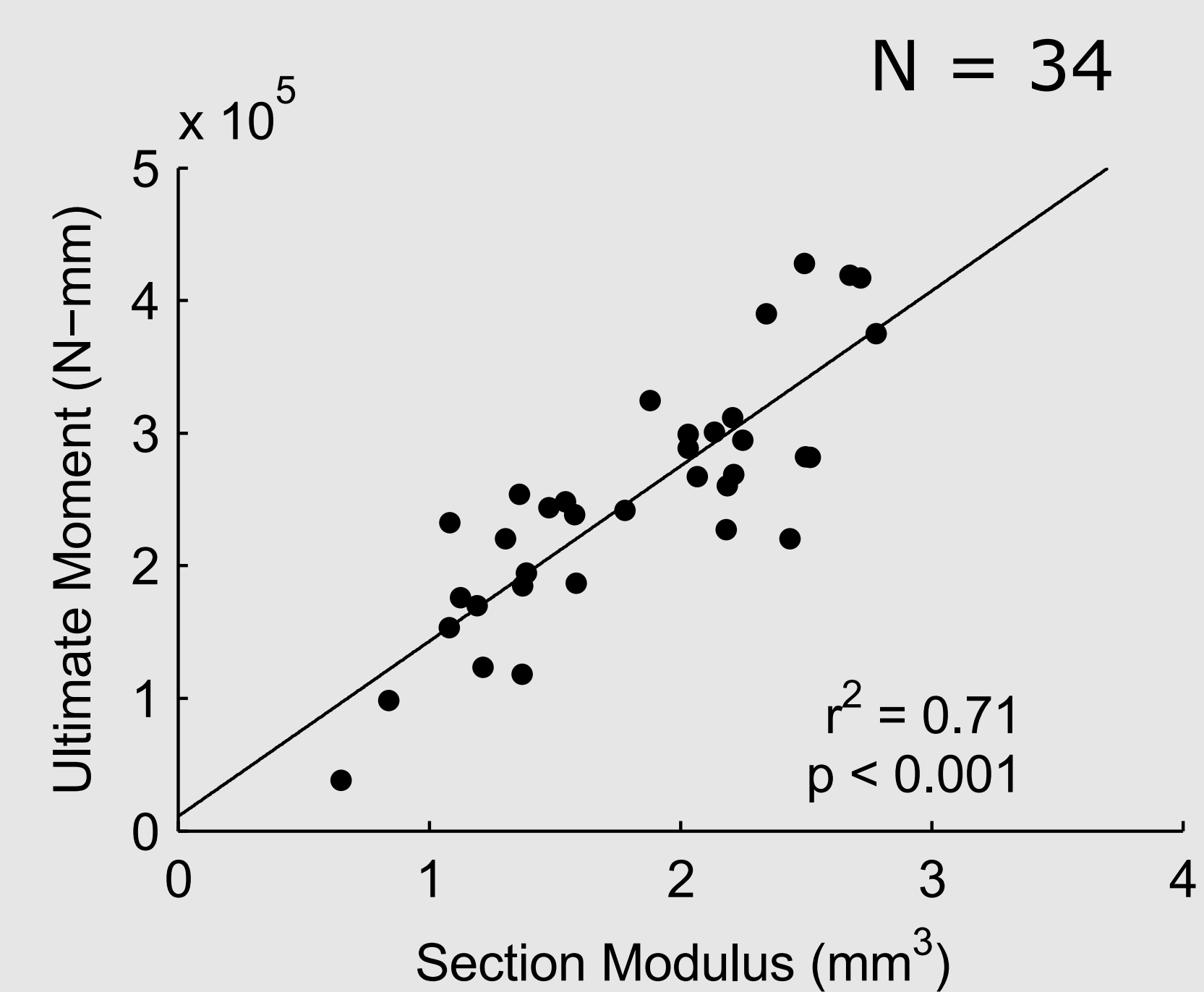
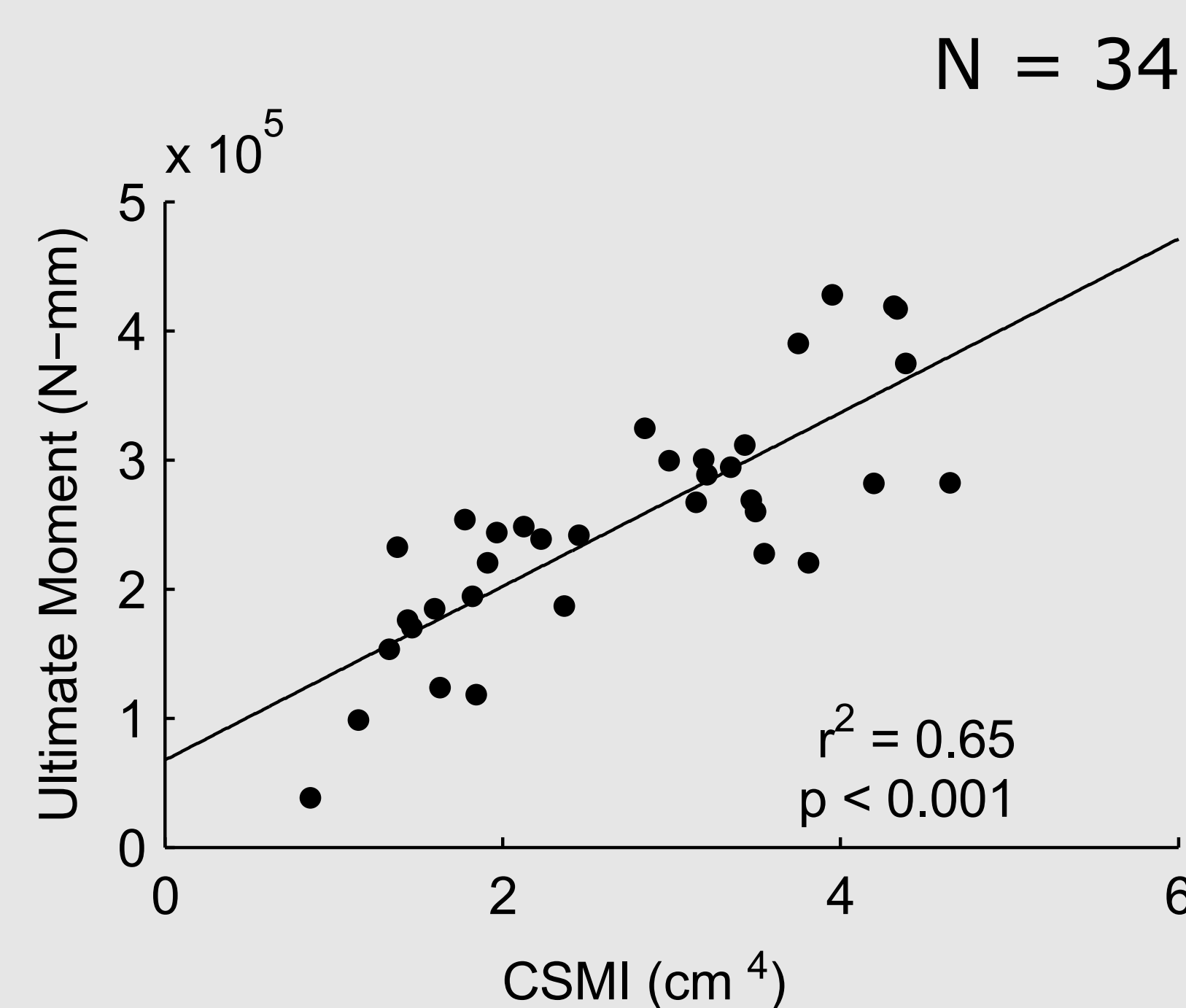
Bending strength measured using a 3-point bend test

Results

Three fracture patterns observed:



- Transverse (39.2%) — N = 34
 - Oblique (27.5%) — N = 34
 - Boundary (33.3%) — N = 17
- ↳ These were discarded due to boundary effects



Discussion

- DXA-derived strength measures **CSMI** and **Z** correlate well with femoral bending strength.
- Both **CSMI** and **Z** are engineering based measures and better represent the underlying mechanics.
- While correlations are good, fracture patterns indicate that additional loading mechanisms may be at play.
- Future DXA-derived strength measures can incorporate shear resistance and may better correlate with three-point-bend experimental results.
- Boundary fractures indicates that current experimental setup may be too aggressive in boundary condition application.
- This study excludes boundary fractures which ensures fracture results are not directly affected by boundary condition application.

Conclusions

- DXA-derived strength measures **CSMI** and **Z** are well correlated to ultimate moment.
- Fracture exhibits evidence of shear loading under three-point bend test.
- Future DXA-derived strength measures may correlate stronger with bending strength by incorporating shear fracture resistance.

References

- [1] Streubel, P. N., Ricci, W. M., Wong, A. & Gardner, M. J. Mortality after distal femur fractures in elderly patients. Clin. Orthop. 469, 1188–1196 (2011).
- [2] Ingram, R. R., Suman, R. K. & Freeman, P. A. Lower limb fractures in the chronic spinal cord injured patient. Paraplegia 27, 133–139 (1989).
- [3] Martin, R.B., and Burr, D.B. (1984). Non-invasive measurement of long bone cross-sectional moment of inertia by photon absorptiometry. J. Biomech. 17, 195–201.