

# Trabecular bone structural units (BSU) in the lumbar spine decrease in size with age and bone volume fraction

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## OBJECTIVES

Age-related fractures are common at skeletal sites with high proportions of cancellous bone. Measures of *bone quantity* (i.e. BMD) are imperfect predictors of fracture risk, so recent studies have focused on *bone quality* (e.g. 3-D architectural parameters).

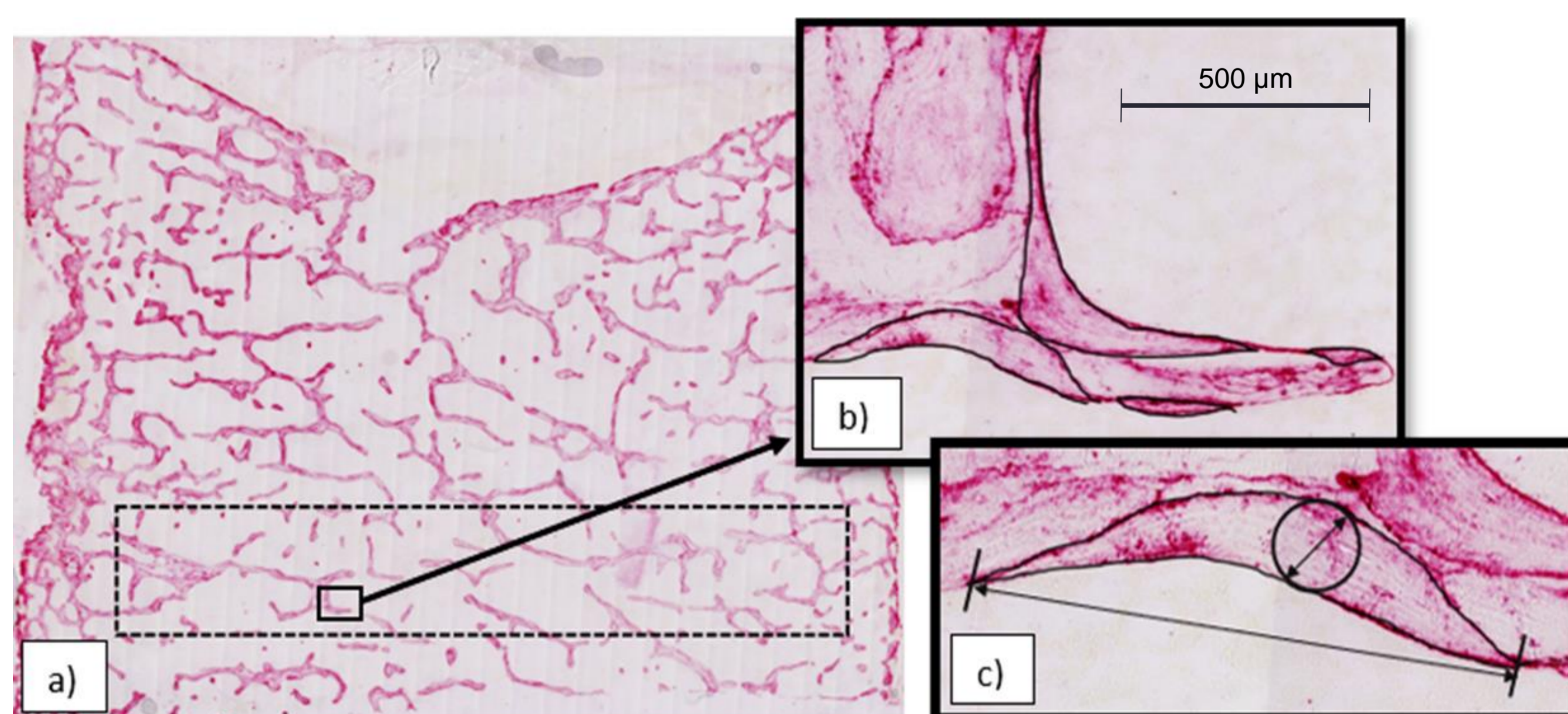
One aspect of bone quality that has received little attention is the size and distribution of bone structural units (BSU). A patchwork of new and old bone regions that form the trabeculae, BSU are created through the remodeling process and are separated by the cement lines. Any changes in BSU morphometry with age may affect the failure behaviour of cancellous bone.

The objective of the current study was to quantify age-related changes in the area, thickness, and length of the most recently formed BSU in the human lumbar spine. The relationship between BSU size and 3-D architectural descriptors were also investigated.

## MATERIALS & METHODS

L2 from **8 young** (aged 18-38 years), and **8 old** (aged 69-96 years) Caucasian women were  $\mu$ CT scanned<sup>(1)</sup>. Half of the vertebra was embedded, and frontal 7.5- $\mu$ m-thick sections were obtained.

The sections were immunohistochemically stained for osteopontin to identify the osteopontin-rich cement lines separating the BSU.



The sections were digitized using a Hamamatsu high-resolution scanner. From these scans:

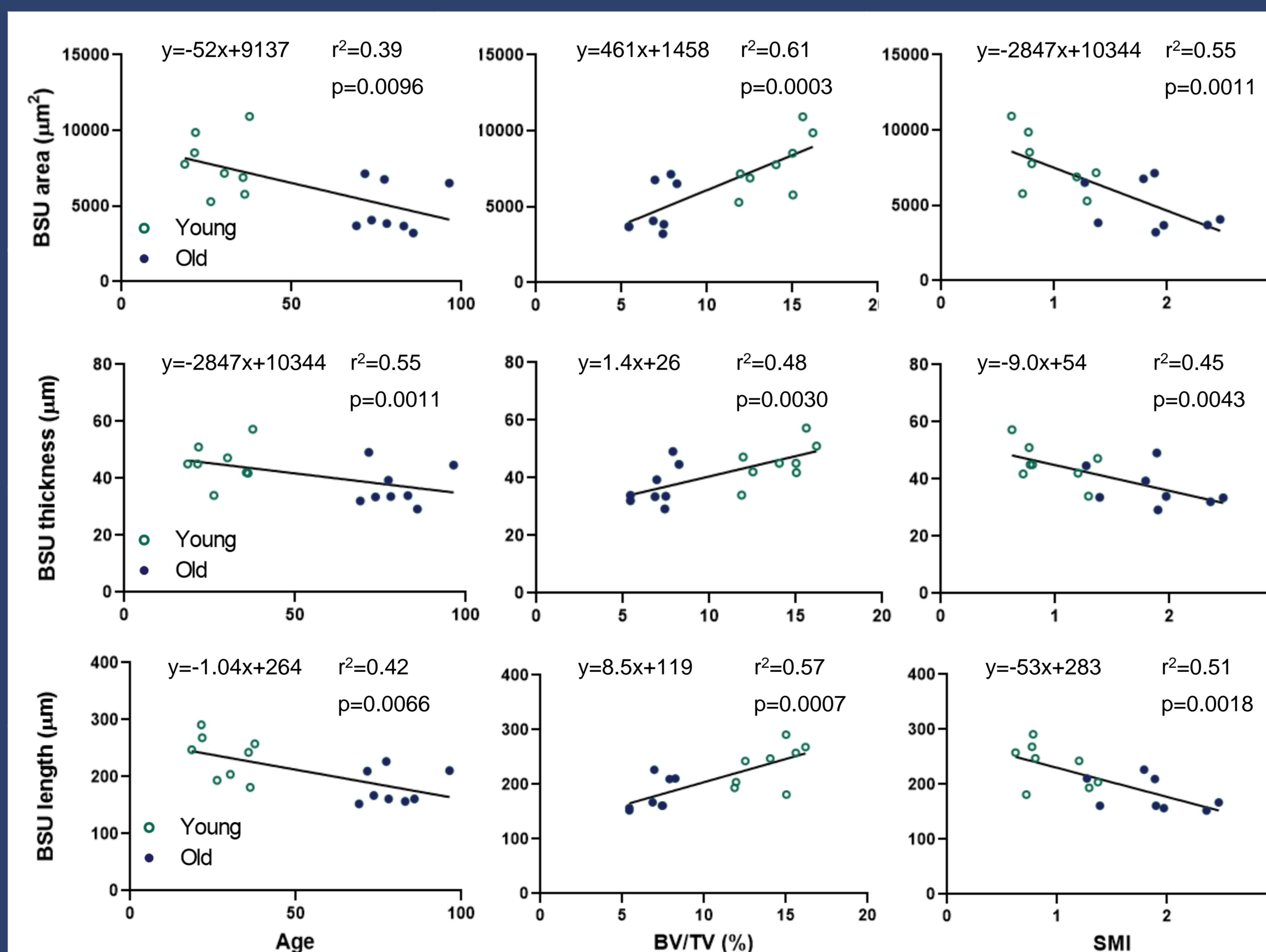
- a 75 mm<sup>2</sup> mid-vertebral region was selected for analysis,
- surface BSU not yet altered by subsequent remodeling events were manually traced in ImageJ
- the area, thickness, and direct length of these BSU were recorded.

Polarized light was used to visualize the lamella, when the cement line staining was ambiguous.

## SUMMARY

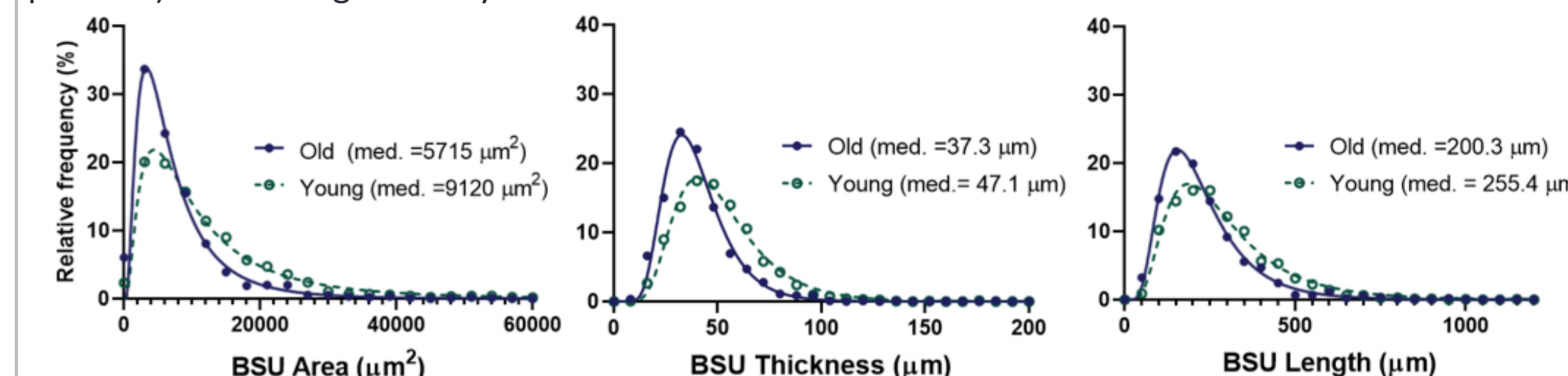
A total of 4,228 recently formed trabecular BSU were examined. It was observed that:

- BSU area, thickness, and length were significantly smaller in the old individuals compared to the young
- 2-D BSU area, thickness, and length exhibit right-skewed distributions
- The median BSU measurements were negatively correlated with age
- Median BSU measurements were more highly correlated to bone volume fraction (BV/TV) and structure model index (SMI) than to age



## RESULTS

The distribution of BSU area, thickness, and length of the young and old individuals were first compared using a gamma mixed-effect model, which accounts for the nested nature of the data. It was found that **BSU area** ( $z = 2.91$ ,  $p = 0.004$ ), **thickness** ( $z = 2.81$ ,  $p = 0.005$ ), and **length** ( $z = 3.07$ ,  $p = 0.002$ ) were all significantly smaller in the old individuals.



Linear regression revealed that:

- Median **BSU area** ( $p = 0.0096$ ), **thickness** ( $p = 0.0496$ ) and **length** ( $p = 0.0066$ ) decrease with **age**

BSU morphometry was significantly correlated to BV/TV and SMI:

- Median **BSU area** ( $p = 0.0003$ ), **thickness** ( $p = 0.0030$ ) and **length** ( $p = 0.0007$ ) increase with **BV/TV**
- Median **BSU area** ( $p = 0.0011$ ), **thickness** ( $p = 0.0043$ ) and **length** ( $p = 0.0018$ ) decrease with **SMI**

No other architectural parameters (Conn.D, Tb.N, Tb.Sp, Tb.Th) was significantly correlated to BSU morphometry.

## DISCUSSION AND CONCLUSIONS

The observed decrease in the size of BSU with age is consistent with prior findings, which investigated changes in mean wall thickness with age<sup>(2-4)</sup>.

BSU area, thickness, and length were more highly correlated with BV/TV and SMI than with age. It is unclear whether a reduction in the size of BSU is a cause, or a consequence of reduced bone volume and a shift from plates to rods.

The high correlation of BSU morphometry to BV/TV and SMI, as well as the mechanical implications of smaller BSU, require further investigation.

## REFERENCES

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