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Mineralization of Cortical Bone of the Lower Extremity Depends on Site

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Introduction: Previous studies have shown that microcracks in cortical bone accumulate with age [1,2]. One supposition for damage accumulation with age is that damage accumulation may be related to bone turnover [3]. Low bone turnover increases bone matrix mineral content at the microscopic level and these changes may cause bone to become more brittle and more susceptible to damage [3] although no direct cause and effect relationship has been established between bone mineralization and microdamage accumulation. In addition, decreases instead of increases in bone mineralization have been reported in femoral cortical bone with age [4-6]. The goal of this research was to examine the age-related variation of mineralization at three sites in long bones of the lower extremity in order to establish age-related changes. Such information may have important implications for treatment modalities that influence bone turnover.

Materials and Methods: Sixty-one fresh human femoral shafts were harvested from 35 male and 26 female cadavers. The male donors' ages ranged from 22 to 91 years (average age = 61.0 ± 19.0 yrs.) while female donors' ages ranged from 24 to 94 years (average age = 64.8 ± 21.0 yrs.). Tibial midshafts and femoral necks were harvested from 24 male and 14 female cadavers. The male donors' ages ranged from 22 to 90 years (average age = 58.0 ± 19.0 yrs.) while female donors' ages ranged from 24 to 94 years (average age = 71.0 ± 19.0 yrs.). Harvested bones were ashed in a muffle furnace at 600°C to determine mineral percentage. Mineral percentage was calculated from the ratio of specimen ash weight and dry weight. Simple regression analysis was used to determine significant relationships between age and mineral percentage. Significance was set at $p<0.05$. The statistical package JMP™ (SAS Institute, Cary, NC) was used to perform the analysis.

Results: Mineral percentage was found to decrease in the midshaft of the femur ($p<0.0001$) and tibia ($p<0.0001$) with age (Figure 1) but no significant variation of mineral percentage was found in the femoral neck (Figure 2).

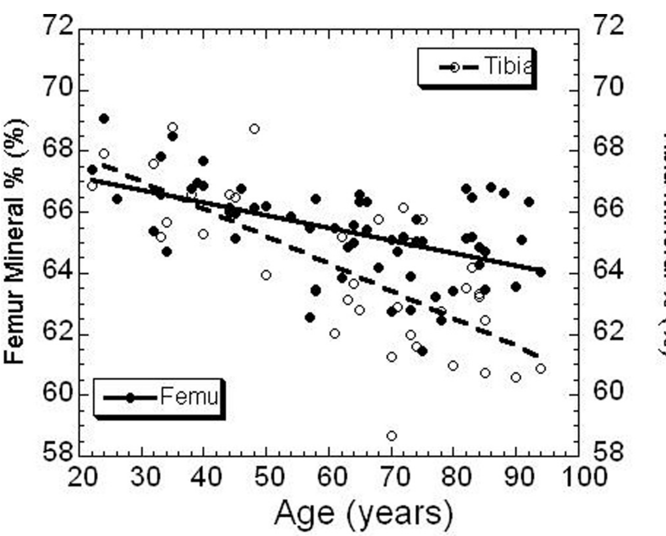

Fig. 1 Variation in mineralization with age in the femur and tibia.

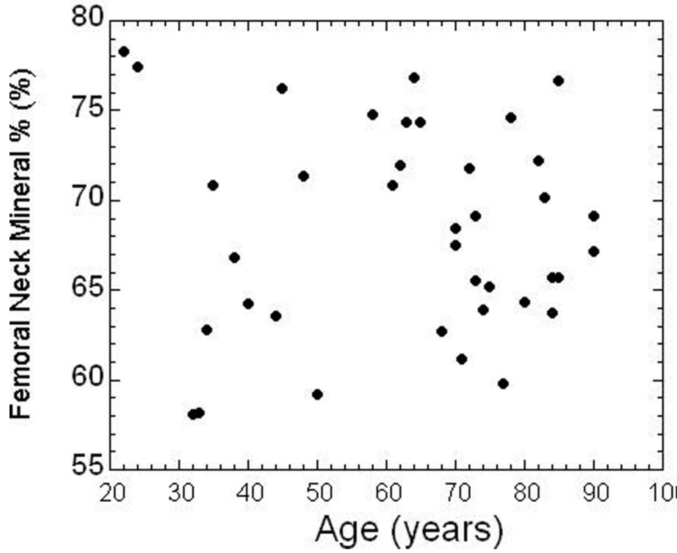

Fig. 2 Variation in mineralization with age in the femoral neck.

Discussion: Results of this study show that bone mineralization changes with location, with bone mineral percentage decreasing with age in the femur and tibia and not changing with age in the femoral neck. Our results for the femur and tibia agree with the data presented previously for adult human femoral bone that indicated a downward trend in bone mineralization with age [4-6]. A more mineralized material exhibits more brittle type fracture characteristics compared to a less mineralized material [7]. Brittle fracture occurs with minimal plastic deformation indicated mechanically by little to no post-yield deformation in the load-deformation curve (work to fracture). A decrease in bone mineralization with age should result in a more ductile fracture, increasing bone toughness. However, fracture toughness [8] and work to fracture [9] decrease with age indicative of a more brittle cortical bone. Therefore, some explanation other than mineralization must be responsible for changes in mechanical properties and microdamage with age. Changes in tissue heterogeneity [3] and compromised collagen crosslinking [10] have been implicated in previous studies. In addition, according to the results presented here, an increase in femoral neck fractures that occur with age may not be attributed to changes in mineral content.

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