Subendosteal Resorption and Periosteal Compensation During Age-Related Cortical Bone Loss

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Introduction: Osteoporosis, a disorder of low bone mass, is generally considered the result of excessive bone loss of the cortical and trabecular envelopes. It has been widely proposed that cortical bone loss with age is primarily due to resorption occurring along the endosteal surface and this is accompanied, in certain populations, with a compensatory periosteal expansion. Recent histological evidence from our laboratory has shown that this resorptive process occurs subendosteally and that the inner ring of endocortical bone is preserved (Figure 1) until late in life (>70 yrs). This particular mechanism of resorption has significant biomechanical implications when compared to the mechanism widely held of endosteal resorption.

To further explore subendosteal bone loss we conducted a clinical evaluation using plain film radiography to assess these age-related changes of bone and their relationship to fracture incidence. The distal radius, the most common upper extremity fracture in individuals aged 65 and older, and the first site in which osteoporotic fractures occur, was chosen for this study.

Methods: Individuals were recruited through the orthopaedic department at our institution with IRB approval (GC08 02-0883). Participants were required to be 18 years of age or older and not pregnant. All those who met these criteria were included in the study. Informed consent was obtained from all individuals prior to participation. Anteroposterior radiographs were taken according to standard radiographic techniques. An acrylic calibration device, which contains two steel spheres spaced precisely 100mm apart, was placed next to the forearm being examined. The dominant arm was chosen for evaluation unless a fracture had occurred at that site, in which case, the contra-lateral forearm was used. Plain radiographs were digitized on a Lumiscan 75 medical digitizer, (Lumisisy CA, USA) and imaged using Efilm Workstation 1.5.3 (Merge eFilm Inc., Milwaukee WI, USA). Images were magnified to 300% their original size to allow proper visualization of the cortex (Figure 2). Based on insight gained through previous histological evidence produced by our laboratory, subendosteal intracortical resorption was radiographically identified by the presence of radiolucent canals within the radiopaque area of cortical bone. Radiolucent canals found on the inner one-third to one-half of the cortex and parallel to the endosteal surface were determined to represent subendosteal resorption (open arrow in Fig 2). Endosteal and periosteal diameters were measured at 30% of the radial length using a semi-automated system on a custom-built Matlab interface (The Mathworks Inc., Natick MA, USA). Endosteal width was measured across preserved endocortical bone (if present) to the outer edge of the intracortical resorption space as shown in Figure 2 (a = endosteal width, b = periosteal width).

Results: Of the 114 men and women radiographically imaged, 41% showed evidence of intracortical resorption at the distal radius. Radiolucent canals were noted in both women (42%) and men (39%) and the percentage of those with positive findings on x-ray increased with age in both groups. Women in their seventh decade showed the greatest percentage, as shown in Figure 3 (men not shown). This percentage decreased in women >80 yrs consistent with our histological evidence showing the late loss of the endosteal bone.

To assess the clinical relevance of these findings, Caucasian women were further analyzed due to their high incidence of fracture. Fifty-two percent of all Caucasian women were positive for porosity. Segregating these women on the basis of fracture history revealed that 67% with history of wrist fracture (mean age = 53.2 yrs; n=15) showed evidence of intracortical resorption compared to 40% with no history of fracture (mean age = 48.6 yrs; n=15).

Examination of endosteal and periosteal diameter for these women revealed endosteal width increased with age as shown in figure 4. This was consistent with qualitative observations of both increased pore size and number. Periosteal width did not increase in the initial sample of Caucasian women. However, when the sample was segregated on the basis of fracture history, those that did not fracture had increases in periosteal width with age that paralleled the increase in endosteal width, whereas those that did fracture did not have increase of periosteal width.

Discussion: Subendosteal intracortical resorption of bone results in porous cavitations that can be readily observed by plain film radiography. The incidence of intracortical porosity increases with age in both males and females and appears to be a normal age-related phenomenon for a large percentage of individuals. The geometric trends seen in Figure 4 support previous reports that bone loss occurs from the inner region of the cortex and “endosteal” diameter increases with age. Of significant note however, is the ability of some women to add bone on their periosteum to compensate. The fact that those who do not compensate are more likely to have a history of fracture suggests that the combination of subendosteal intracortical bone loss and lack of periosteal compensation may lead to decreased bone strength and contribute to fracture risk.

These findings have significant implications for the diagnosis and treatment of osteoporosis. New strategies to decrease fracture risk should include ways to increase bone mass around the periosteal surface in addition to those already in use to decrease the amount of bone lost.


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