Why we need bone quality

Loss of bone mass, measured clinically as change in bone mineral density (BMD), is considered an important risk factor for bone fragility. However, BMD is not the sole predictor of whether an individual will experience a fracture [1, 2], and there is considerable overlap in BMD between populations that do and do not develop fractures [3–5]. It has been demonstrated that for a given bone mass, an individual's risk to fracture increases with age [6]. Consistent with these findings, numerous investigators have shown that mechanical variables directly related to fracture risk are either independent [7] or not totally accounted for bone mass itself [8–12]. Epidemiological evidence also shows considerable overlap of bone density values between fracture and non-fracture groups suggesting that low bone quantity alone is an insufficient cause of fragility fractures [13–15]. It is becoming evident then, that in addition to BMD, bone quality should also be considered when assessing bone strength and fracture risk. Bone quality is a broad term encompassing a plethora of factors such as geometry and bone mass distribution, trabecular bone microarchitecture, microdamage, increased remodeling activity, along with genetics, body size, environmental factors, and changes in bone mineral and matrix tissue properties [4, 5].

One of the obstacles to be circumvented when assessing mineral and matrix tissue properties is tissue heterogeneity at the microscopic level. In normal humans, cortical bone constitutes approximately 80% of the human skeletal mass and trabecular bone approximately 20% [16]. Bone surfaces may be undergoing formation or resorption, or they may be inactive. These processes, which can be visualized microscopically, occur throughout life in both cortical and trabecular bone [16]. Bone remodeling is a surface phenomenon and in humans occurs on trabecular and cortical surfaces [16–19]. The rate of cortical bone remodeling, which may be as high as 50% per year in the mid-shaft of the femur during the first 2 years of life, eventually declines to a rate of 2–5% per year in the elderly. Rates of remodeling in trabecular bone are proportionately higher throughout life and may normally be five to ten times higher than cortical bone remodeling rates in the adult [16]. This information is critical when evaluating bone at the microscopic level; thus, tissue age should be considered as well.

Fourier transform infrared spectroscopy

Molecular bonds are not stationary, but rather undergo motion such as twisting, bending, rotation, and vibration. When irradiated with infrared

radiation, these vibrational motions absorb at specific wavelengths, characteristic of the overall configuration of the atoms, and representative of specific functional groups. Moreover, through detailed analysis of the absorption wavelengths, information may be deduced on the subtle interactions with the surrounding moieties of a molecule. Fourier transform infrared spectroscopy (FTIR) spectra provide information on all tissue components. The protein and mineral constituents produce intense, structure sensitive IR modes. FTIR microspectroscopy and imaging have proven to be powerful tools in the establishment of parameters contributing to bone quality and thus bone strength.

FTIR major outcomes

The most frequently reported outcomes of FTIR spectroscopy are (1) mineral to matrix ratio, (2) mineral maturity, and (3) collagen maturity, and specifically the ratio of two of the major type I bone collagen cross-links.