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Monitoring of trabecular bone induced microdamage using a nonlinear wave-coupling technique

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Bone tissue contains microcracks which may affect its mechanical properties as well as the whole trabecular structure. The relationship between crack density and bone strength is nevertheless poorly understood. Efficient nonlinear (NL) ultrasound methods have been widely developed for nondestructive testing and geophysical applications to detect microdamage. Moreover it has been reported that elastic nonlinearities increase with induced damage. We propose to monitor trabecular bone microdamage using a NL wave coupling technique. Ultrasonic short bursts times of flight (TOF) are modulated as result of NL interaction with a low-frequency (LF) wave in the medium. TOF modulation (TOFM), or propagation velocity variations, are directly related to NL elasticity variations. This technique allows measuring the instantaneous TOFM as a function of the LF pressure. It is thus possible to analyze separately elasticity variations in tension and in compression, and to distinguish the tension to compression phase from the compression to tension phase (hysteresis). In several trabecular bone samples, different TOFM amplitudes in tension and in compression are observed, probably due to microdamage. For increasing damage levels progressively induced by quasi-static compression testing, linear and nonlinear ultrasound parameters are compared to biomechanical parameters.