Multiscale mechanical characterization of materials

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1. **Imaging analysis :** High performance computers with customized codes and commercial software for manipulating CT and MRI images
2. **Bose ElectroForce 3230 (Minnetonka, MN) with environmental chamber**: This loading machine utilizes a high frequency linear motor system for high precision mechanical testing with a high resolution (15 nm) displacement transducer and load cells of ± 450 N (100 lb) and 45N (10lb) force capacity. The accuracy is ± 0.5% of the measurement range.
3. **Nanoindentation machine (Nano-XP, MTS):** This machine contains an x-y motorized stage, an optical microscope with a magnification of up to 1500X, and diamond tip indenter head. Indentation load and depth (up to 500 nm) are simultaneously measured to compute hardness, elastic modulus, and viscoelastic values using load-unload-displacement plots. A custom-made hydration system can allow a long-term experiment while keeping the specimen moist.

Examples of translational science

When any 3D image of micro-computed tomography (micro-CT), clinical cone beam CT (CBCT) and magnetic resonance imaging (MRI) is obtained for patients or animals, it can be digitally measured for mass, morphology, and tissue mineral density distribution at the micro- and macro-levels (Fig. 1). If the non-destructively scanned subject is a biopsy from patients or animal specimens, multiscale mechanical characterization can be conducted using the loading machine and nanoindentation. Non-destructive static and dynamic loading in an elastic range are applied to the specimen (Fig. 2). Dynamic mechanical analysis (DMA) is performed by applying non-destructive oscillatory loading or displacement. Then, the same specimen can be subjected to fracture testing. Following the fracture test, the same specimen is dissected at the non-fractured region outside of the loading jig. The dissected surfaces are polished and glued onto a polycarbonate holder with a fluid drainage system mounted on the nanoindenter. Indentation regions are determined using a light microscope incorporated within the nanoindenter. All nanoindentations are performed using a pyramidal Berkovich tip in a wet condition (Fig. 3).

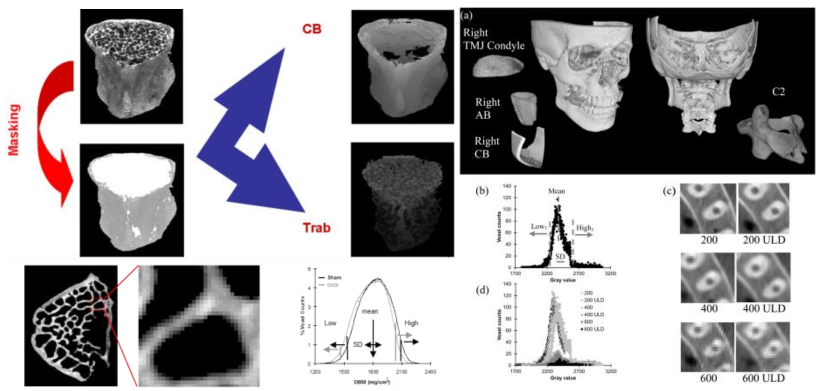

Fig. 1 Micro-CT and CBCT image based analyses.

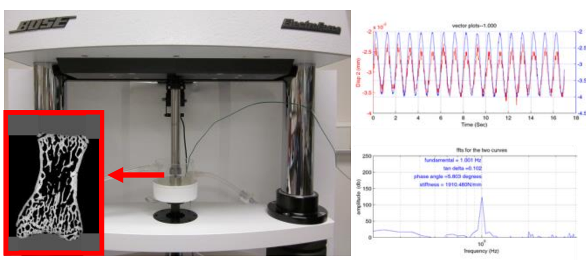

Fig. 2 Static and dynamic mechanical testing.

This multiscale characterization provides the static properties including elastic modulus and stiffness (E and K^*), and viscoelastic normalized creep (Creep/P_{max}), viscosity (η), energy dissipation (W), and plastic hardness (H), strength (F_{max}), displacement (d_{max}), toughness (U), and dynamic stiffness (K^*) and viscoelastic tangent delta (tan δ) at the nano- (nanoindentation), and macro- (dynamic mechanical analysis, DMA) levels. These properties account for the ability of bone to resist elastic, viscous and plastic deformations. As all bone quantity and quality, elastic, and viscoelastic parameters are measured by non-destructive methodologies, bone damages prior to fracture testing are minimized. The nanoindentation is also performed on the regions away from the fractured site to avoid bone tissue damages from the fracture testing.

More than 50 parameters can be assessed to diagnose bone diseases and evaluate clinical treatment results.

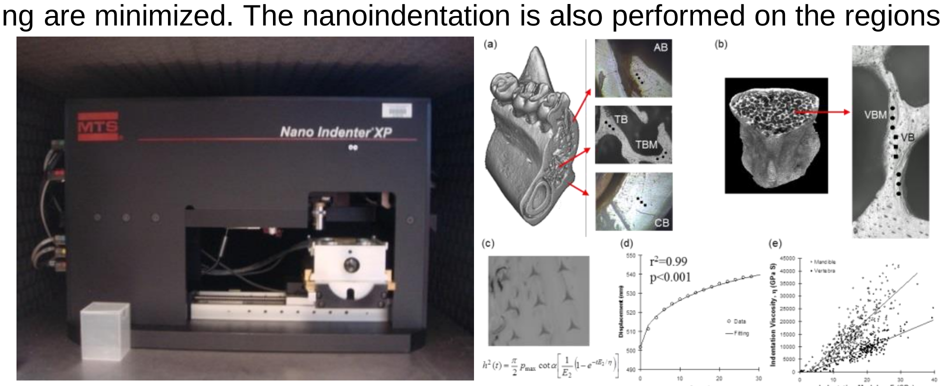

Fig. 3 Nanoindentation for oral and orthopedic bone specimens.

Fee schedule

$50/hour for any service.