of metabolic processes related to the comparisons of bone thickening and bone thinning in the corticalis with high and low density. The main objective has been to derive the fundamental theorems related to the influence of mechanical/biomechanical stress changes on accelerating/retarding the bone thickening/thinning. Resultant rate (speed) $\mathbf{k_j}$ of the **j**-th biochemical reaction (for example the processes concerning the mineralization of osteoid) is the *exponential function* of dominant volume changes (of molecular mixtures) and the stress changes *dp*. Derived function has the following form: $\mathbf{k_j} = \mathbf{A_j} \exp[-(\eta_{jch} + \eta_{jm}) \cdot dp]$. The density of bone can be increased when the stress changes in bone have the *positive signum* (with regard to zero in the "theoretical" steady state). The bone with a higher density responses more fast on the stress changes than the bone with a lower density. The bone with a higher density during the bone thinning has retarded reactions on the stress changes than the bone with lower density.

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7234 Mo–Tu, no. 31 (P55)

Intermittent treatment yields a slightly higher bone mass than continuous treatment, according to a simulation of bone remodeling during antiresorptive treatment

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Antiresorptive treatment is widely used in osteoporotic patients. During treatment, resorption by osteclasts and formation by osteoblasts are changed, bone mass increases and fracture risk decreases. Some anti-resorptive medicines are prescribed for very long periods. A disadvantage of years of continuous usage of these medicines could be accumulation of damage, and high costs. An intermittent treatment protocol might be preferable.

Using a previously described three-dimensional simulation model of remodeling in trabecular bone we simulated continuous and intermittent PTH and bisphosphonate treatment. The specimen, from an autopsy L4-vertebra of a male 37-year-old donor, was micro-CT scanned. A three-dimensional model of 4 4 4 mm trabecular bone (volume fraction 12.9%), with 2.9 million 14 14 14 μm voxels was made.

The remodeling process was simulated by repeating the following steps. In step 1 hemi-spherical resorption cavities of 42 μm were created, randomly distributed over the surface of the trabeculae. In step 2, a check for disconnected trabeculae was performed. Resorption cavities that disconnected trabeculae were not refilled. In step 3, all cavities that did not disconnect trabeculae were refilled. Simulated bisphosphonate and PTH treatment (5 years continuously, or 5 times 1 year and a 1 year pause) were based on remodeling changes reported in literature. During bisphosphonate treatment, bisphosphonates were built in newly formed tissue, the number of resorption cavities was decreased by 50%, the osteblasts made 5% more bone tissue. Resorption depth in bisphosphonate containing tissue was also decreased. During simulated PTH treatment, the number of resorption cavities was not changed, the osteoblasts made 10% more bone tissue.

According to the simulation results, intermittent alendronate treatment results in a 3% higher bone mass on the long term than continuous alendronate treatment. After stopping the treatment, remodeling is still slightly decreased, incorporated bisphosphonates reduce resorption depth of part of the cavities. Intermittend and continuous PTH treatment resulted in the same bone mass.

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Micromechanics modeling of trabecular bone

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Trabecular bone is studied as a hierarchical material. The paper focuses the mechanics modeling at several different structural length scales: nanoscale (under 1 ?μm, crystal/fiber level), sub-microscale (1–10 μm, single lamella level), microscale (10–500 μm, single trabecula level), and mesoscale (1 mm-10 cm, trabecular structure, random network of struts or plates). The investigation focuses on the differences between notmal and osteoporotic trabecular bone.

The experimental observations of bone's hierarchical structure are used in the theoretical micromechanics analyses of bone's mechanical properties. The calculated results are compared with the experimentally measured ones. The material properties are determined at each scale both analytically (using micromechanics theories and mechanics of composite materials approaches) and numerically (using a finite element method, a spring network, and beam network approaches). The macroscopic structure of bone is analyzed in a "descending" order by considering finer details of substructures. The computational challenges include a complex irregular, random structure at each structural level, spatial heterogeneity of bone's structure, the theoretical issues of the applicability of separation of scales' law, the size of the representative volume element, and in general the dependence of properties on specimen size and boundary conditions.

This research is of importance in the understanding of local phenomena such as bone remodeling (the loads at cellular level) and fracture processes in normal and osteoporotic bone, for example.

This is an unpublished work. The new contribution of this paper is in employing a range of micromechanics and computational tools to model the complex and hierarchical structure of trabecular bone.

5229 Mo–Tu, no. 33 (P55)

The development of a simple biomechanical model for the rotator cuff

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The deltoid and rotator cuff muscles are vulnerable structures exposed to high mechanical loads. These loads can be assessed by biomechanical models which provide a source of quantitative information on muscle forces. The majority of three-dimensional biomechanical models are complex, expensive and involve cumbersome calculations. To overcome these problems, a simple biomechanical model for the rotator cuff has been developed using saw bones of humerus and scapula to act as compression components while extension springs with nylon cables have been used to model rotator cuff and deltoid muscles. The effect of various force patterns of these muscles were studied by exerting tension in the springs in order that corresponding changes in size and location of gleno-humeral contact areas using pressure sensitive film Podotrack® could be identified. The model has been successful in analyzing muscle forces and corresponding gleno-humeral contact areas in various patterns of deltoid and rotator cuff activity. Further application of this model may aid understanding of the aetiologies of secondary arthritis and of instability. It may also assist in the improvement of surgical repairs designed to reconstruct these pathologies.

6628 Mo–Tu, no. 34 (P55)

Simulation of 3D architectural and mechanical changes in human trabecular bone during menopause

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The increase in bone remodeling after menopause is responsible for both reduced bone mass and deterioration of the trabecular bone network, leading to an increased susceptibility to osteoporosis. In this study, we simulated the dynamic and physiological process of trabecular bone remodeling, using parameters derived from recently published clinical data [1]. These simulations considered three types of microscopic bone loss in the pathophysiology of osteoporosis: perforation, breakage, and disconnection of trabeculae. The simulations were done using rigorous 3D digital topological analysis (DTA) [2]. The simulation included a bone remodeling cycle corresponded to a 200-day period (40 days resorption/160 days formation). Resorption cavities (42 μm deep and 126 μm in diameter) were created in 40 days according to the current activation frequency [1] and distributed randomly over the bone surface. Every resorption cavity was refilled in 160 days unless it caused a perforation, or breakage of a trabecula while disconnected trabeculae removed [2]. New resorption cavities were continuously created in every 40-days. The simulation was started 5 years before and ended 15 years after menopause and applied to twelve human trabecular bone samples.

The time course of the averaged bone volume fraction (BVF) of samples from two anatomical sites (spine and femoral neck) showed great agreement with the corresponding clinical data [1]. Bone with higher initial BVF showed a slower bone loss time course, which was consistent with the fact that peak bone mass is one of the important risk factors in osteoporosis. The structural transition of each sample from plate-like to rod-like during menopause can be qualitatively observed and also quantitatively confirmed by the change of plate fraction. Furthermore, the results of this study suggest that the trabecular plate perforation accounts for more than 70% of bone loss during menopause.

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