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Experimental Verification of Viscoelastic Properties of Spongy Bone Tissue

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ABSTRACT: The viscoelastic properties of most biological materials are significant for the distribution and redistribution of the fields of deformation through the periods of time. The values of viscoelastic constants are not exactly defined for greater number of biomaterials. They are dependent on the age of a human being, on the intensity of loading, and on the period of time through which the loading acts. This research work has been aimed at the experimental and analytical determination of the coefficient of viscosity **λ**, and the modulus of elasticity of the time-dependent viscoelastic strain **E** in the spongy bone of human femurs.

It is Poynting-Thompson model that belongs to the most relevant mechanical models which enable us to determine the material rheological constants in the spongy bone tissue as precisely as possible. This model is made up of an elastic element characterized by the modulus of elasticity E_0, and of the Kelvin-Voight viscoelastic member that consists of an elastic element of the time-dependent viscoelastic strain E and the coefficient of viscosity λ.

In the order to determine the rheological constants, the total number of 3 male femurs and 3 female femurs were used.

KEY WORDS: spongy bone, viscoelastic properties, rheological constants

INTRODUCTION: This research work has been aimed at the experimental and analytical determination of the coefficient of viscosity **λ**, and the modulus of elasticity of the time-dependent viscoelastic strain **E** in the compact bone of human femurs.

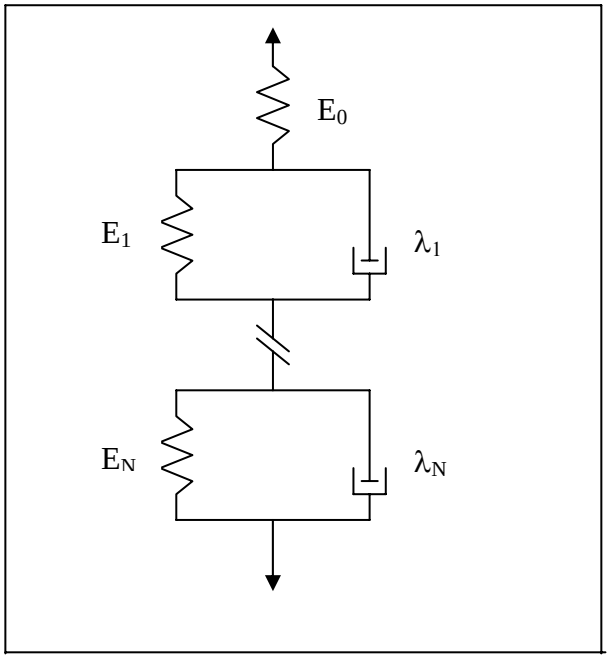
It is Poynting-Thompson model that belongs to the most relevant mechanical models which enable us to determine the material rheological constants in the spongy bone tissue as precisely as possible.

The influence of viscoelasticity on the value of relative strains of the spongy bone tissue of the femur diaphyses is a comparatively small. After a eight minute loading of the bone tissue through a load, the strains increase by about 1- 2 %.

METHODS: In the order to determine the rheological constants, the total number of 3 male femurs and 3 female femurs were used.

Samples	Sex	Age	Height (m)	Weight (kg)
1	Man	27	1,8	80
1	Man	27	1,8	80
2	Woman	30	1,58	75
2	Woman	30	1,58	75
3	Man	35	1,72	80
3	Man	35	1,72	80
4	Woman	36	1,72	80
4	Woman	36	1,72	80
5	Man	47	1,78	72
5	Man	47	1,78	72
6	Woman	47	1,74	72
6	Woman	47	1,74	72

Table 1: Samples of spongy bone



It is Poynting-Thompson model that belongs to the most relevant mechanical models which enable us to determine the material rheological constants in the spongy bone tissue as precisely as possible. This model is made up of an elastic element characterized by the modulus of elasticity E_0, and of the Kelvin-Voight viscoelastic member that consists of an elastic element of the time-dependent viscoelastic strain E and the coefficient

of viscosity λ. For the resultant bone tissue relative strain, the following equation applies:

$$\varepsilon = \varepsilon_1 + \varepsilon_2 = \frac{\sigma}{\varepsilon_0} + e^{\frac{-E^*t}{\lambda}}\left[\frac{1}{\lambda}\int_0^t \sigma(\tau)^* e^{\frac{E^*\tau}{\lambda}} d\tau + \left(\varepsilon_0 - \frac{\sigma_0}{E_0}\right) e^{\frac{E^*t_0}{\lambda}}\right]$$

in witch E_0 is the modulus of elasticity given by the stress ratio σ and the immediate elastic strain ε, E is the modulus of elasticity of the time-dependent viscoelastic strain, λ is the coefficient of viscosity, σ_0, ε_0 are stresses and strains in the initiate time t_0.

In the order to determine the rheological constants, the total number of 3 male femurs and 3 female femurs were used. The miniature beams of 10 x 10 x 15 mm were taken out of the femurs. Then the beams were placed into a loading device and exposed to stress. Strains in the damp bone tissue (that was extracted from human beings not later than twelve hours after their death) were being detected for load during the period of 10 minutes.

RESULTS: On the basis of experimental measuring and analytical solution, the following conclusions can be made: moduli of elasticity E_0 = 4,18 MPa , the modulus of elasticity of the time-dependent viscoelastic strain, and the coefficient of viscosity were verified at a value of 32 GPa, and 6,7 GPa.min respectively.

CONCLUSION: Presented results of the experimental measurements proved that:

The influence of viscoelasticity on the value of relative strains of the spongy bone tissue in the femur is a comparatively small.

After a ten-minutes loading of the bone tissue through a load, the strains increase by about 1-2 % only (!!!).

The influence of viscoelastic properties of the spongy bone tissue on the value of relative strains during the normal process of walking is insignificant and practically negligible. It becomes fully evident only after long-term loading, approximately after five minutes at the earliest.

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