Response of the Lumbar Motion Segment Subjected to Cyclic Loading- On the Basis of Defining a New Element.

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SUMMARY
The finite element method is used to analysis the spine’s issue invasively. In this study, a new element is defined which consists a disc (Viscoelastic Euler Beam Element) and a vertebra (Rigid Link) as a unit element. The new element leads to reduce the run time of the models. Therefore, the models, made by the new element, can be easily analyzed for long time. A lumbar motion segment’s model (L4/L5) was made by using the new element. For validating the model, prediction of it for circadian test was compared with in vivo result. After proving the model’s validation, it was subjected to short term creep loading. The result of this part was compared with in vivo result. The validated FE model was employed to investigate the biomechanical response of the disc during daily cycles of loading and unloading. The regime of loading during a day was simulated with an eight hours resting period followed by sixteen hours diurnal activities. To compare the effect of different prolonged and cyclic loadings, four different loading regimes were applied to the model.

INTRODUCTION
The finite element method is reputable, fast and cheap rather than experimental tests. Therefore, it is used to analysis of spine’s issues invasively. The used–to-analysis-of spine’s issue finite elements models can be divided to two types, namely the complicated models and simplified models.

In the complicated finite element models, the models were prepared for a region of the spine as lumbar region [4-7] or cervical region [2,4] or for a segment of motion [8-11]. These models consist the vertebrae with posterior part, the discs in two parts (annulus and nucleus) with different mechanical properties and the ligaments. They usually were used to static analysis.

In the dynamic (cyclic) boundary conditions, because of amount of equations, it is not easy to run the complicated models for long time. Therefore, simplifying the models can help to achieve the aim. One of the ways for simplifying the models is reducing the number of the elements. For this purpose, in this study, a new element is defined. A new beam element divided to two parts (a vertebra and a disc) was defined. The vertebra part was modeled as a rigid link. The disc has viscoelastic properties. A lumbar motion segment (L4/L5) was made by using the new element. For validating the model, prediction of it for circadian test was compared with in vivo results of Tyrrell et al.(1985). The validated FE model was employed to investigate the biomechanical response of the intervertebral disc during daily cycles of loading and unloading.

METHODS
2.1. The model
In this study, a new element is defined which consists a disc (Viscoelastic Euler Beam Element) and a vertebra (Rigid Link) as a unit element (Fig.1).

The model of a segment of motion of lumbar region (L4/L5) was prepared by the new element [3]. The validation of the model was determined by comparing the model’s prediction with result of circadian variation measured in vivo by Tyrrelle et al (1985) (Fig) and result of FE model by Williams et al[1].

2.3. Short term creep
In the short-term creep study conducted by Tyrrelle et al. a normal subject held a 40 kg barbell across his shoulders for 20 min, at which time the barbell was removed for a 10 min recovery period .A compressive load equaled to 400N was applied as a preload followed by and additional 400N for 20 min on the superior surface of L4, after which the load was reduced to 400N for 10 min for recovery. (Fig 6)

2.3 cyclic loading
The validated FE model was employed to investigate the biomechanical response of the intervertebral disc during daily cycles of loading and unloading. The regime of loading during a day was simulated with an eight hours resting period followed by sixteen hours diurnal activities. To compare the effect of different prolonged and cyclic loadings, four different loading regimes were applied to the model. The resting period were the same at all the four different cases consisted of an eight hours under a constant compressive load of 350 N [8].

RESULTS AND DISCUSSION
3.1. Short term creep
In the short-term creep, a normal subject held a 40 kg barbell across his shoulders for 20 min, at which time the barbell
was removed for a 10 min recovery period. A compressive load equaled to 400N was applied as a preload followed by and additional 400N for 20 min on the superior surface of L4, after which the load was reduced to 400N for 10 min for recovery. (Fig 6)

Fig: Comparison of viscoelastic model response subjected to sort-term creep loading in vivo result (Tyrrell, 1985).

The distribution of the percent loss of total stature predicted by the model closely compared to the in vivo results throughout loading as well as unloading (Fig 9). The model prediction of total stature change at the end of loading (20 min) and unloading (30 min) were also within 6% of the corresponding in vivo measurement and the total stature loss at the end of creep unloading also matched the in vivo results. (Tyrrell et al. 1985) 3.1. Short term creep

The validated FE model was employed to investigate the biomechanical response of the intervertebral disc during daily cycles of loading and unloading. The regime of loading during a day was simulated with an eight hours resting period followed by sixteen hours diurnal activities. To compare the effect of different prolonged and cyclic loadings, four different loading regimes were applied to the model. The resting period were the same at all the four different cases consisted of an eight hours under a constant compressive load of 350 N.

Fig: Comparison of viscoelastic model response subjected to cyclic loading case 1 with related prolonged loading.

The responses of FE model subjected to the mentioned four loading regimes were shown in Fig. 5 and Fig. 6. Experimental measurements by Adams et al. indicated that the intervertebral disc height loss were 1.2±0.3 mm [1] after three hours under a constant prolonged compression (1000 N). Our FE model predictions were 1.262 mm which was in reported range.

Fig: Comparison of viscoelastic model response subjected to cyclic loading test in comparison with in vivo measurements. Although complicated models of a lumbar motion segment can predict the in vivo tests’ results by high accuracy, achieving to the predictions need to run models for several hours. In this study, all of the model’s runs took less than 1 minute. The accuracy of the simplified model and complicated model are same. Therefore, using the new simplified model can save time and can predict with high accuracy.

REFERENCES