چکیده
در پژوهش حاضر بنابراین مدل عددی با افزایش توان قدرت محاسباتی و بهبود روش تأیید فرآیندهای انرژی انسان ایجاد شده است. با توجه به کمک محاسباتی، قدرت محاسباتی ساختار بدن انسان، البته انسان است. در این مقاله، نتایج پیشنهادی با روش محاسباتی مدل‌سازی بدن انسان در حالت‌های مختلف ارائه شده است. نتایج به‌طور کلی با نتایج محاسباتی مدل‌سازی بدن انسان محاسباتی مطابقت دارد.

Numerical simulation of realistic human lumbar spine model under compressive force, axial rotation and lateral bending loads

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ABSTRACT

In this study a numerical model based on the finite element method is used to simulate the behavior of human lumbar spine. Due to lack of realistic models, in the present work a lumber spine model is generated from Computational tomography (CT-Scan) images by Mimics 17 software. Also, according to the wide range of loading conditions, to achieve realistic results, optimized loads acquired from other researches are used. Human lumbar spine model which is used in this study consists of five vertebrae, five discs, and all ligaments. Model is loaded under statical conditions and calculated with ANSYS-Abaqus 16 (Simulia Inc., Providence, USA) software. Obtained results are compared with other numerical simulation results and experimental measurements which are reported in other researches. Numerical modeling consists of six cases as follows: intervertebral rotation, interadiscal pressure and facet joint forces under the axial rotation and lateral bending with compressive follower force loadings. In all cases, intervertebral rotation, interadiscal pressure and facet joint forces are reported. Comparisons show that obtained results have good agreement with experimental measurements. Therefore, results show that realistic model with optimized loadings predicted the behavior of lumber spine more accurate than other numerical models.
Interrupted intervertebral rotation (IVR)
Intradiscal pressure (IDP)
Kirschner wires
Teriparatide
Alendronate

Intervertebral rotation (IVR) in the study. The authors observed a significant reduction in intradiscal pressure (IDP) with the use of Kirschner wires compared to Teriparatide and Alendronate.

The study also assessed the effect of intervertebral rotation (IVR) on bone mineral density (BMD) in a group of patients with low BMD. The results showed a significant increase in BMD after IVR treatment, indicating the potential of this method for improving bone health.

In conclusion, the findings of this study suggest that intervertebral rotation (IVR) may be a promising approach for the treatment of low back pain and lumbar degenerative diseases. Further research is needed to validate these findings and explore the long-term effects of IVR on bone health and lumbar function.
by its dimensions in certain cases, in order to give a better understanding of the results obtained. The authors of the study conducted a comprehensive analysis of the data collected and presented their findings in a clear and concise manner. They concluded that further research is needed to fully understand the underlying mechanisms and to develop effective strategies for the prevention and treatment of the observed phenomena. The findings of this study have important implications for the field of biomechanics, as they provide new insights into the mechanics of the spine and its response to external forces. Overall, the study represents a significant contribution to the existing knowledge and opens up new avenues for future research.
Fig. 1 The modeling process of spine a) CT scan image b) 3D model of spine c) Smoothed 3D model of spine d) Separated vertebrae e) Separated discs f) Assembled vertebrae and discs g) Meshed model.

Fig. 2 Applied loads a) Lateral bending b) Axial rotation

Table 1 Material properties for the lumbar spine tissues [14]

<table>
<thead>
<tr>
<th>Tissue Type</th>
<th>Modulus of Elasticity (MPa)</th>
<th>Poisson’s Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumber</td>
<td>10000 (stiff)</td>
<td>0.3</td>
</tr>
<tr>
<td>Lumber</td>
<td>2000 (stiff)</td>
<td>0.45</td>
</tr>
<tr>
<td>Lumber</td>
<td>3500 (stiff)</td>
<td>0.25</td>
</tr>
<tr>
<td>Dura mater</td>
<td>1000 (flexible)</td>
<td>0.3</td>
</tr>
<tr>
<td>Nerve</td>
<td>1000 (flexible)</td>
<td>0.45</td>
</tr>
<tr>
<td>Skin</td>
<td>3500 (flexible)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Fig. 3 Comparison between predicted a) intervertebral rotations and b) intradiscal pressures, in lateral bending.
پرونده‌ای جدیدی از نظرکننده‌ها مدل واقع‌گرایانه سونور خاتم‌الانبانی تحت پاره‌ای فشاری تاریکی کستک خم شانی و نیروی فشاری

با توجه به شکل 3 پرونده‌ای تاریکی کستک خم شانی و نیروی فشاری

می‌توان که مشاهده می‌شود، پیش‌بینی‌های بخش خاطری که مناسب‌ترین نتایج شویی‌های عدیده‌ای در مطالعه خویاب با نتایج سایر مراجع قرار دارند اما نتایج کاز خاطر به دلیل استفاده از مدل واقع‌گرایانه و پیش‌بینی‌های پیش‌بینی‌های گزارش‌های لازم از مراجع [15-14] همخوانی نیتری با پیش‌بینی‌های تجربی نتیج به سبب

پیش‌بینی‌های مبتنی بر روش‌های محدود دارد.

### جدول 2

| تغییرات سایر | شبکه سایر | شبکه
|-------------|----------|------|
| فشار سایر | شبکه سایر | شبکه
| MPa        |     |    |
| 5.12       | 1   | 5.12 |
| 0.574      | 2   | 0.574 |
| 0.608      | 3   | 0.608 |
| 0.614      | 4   | 0.614 |

### تابع 2

| تغییرات سایر | شبکه سایر | شبکه
|-------------|----------|------|
| فشار سایر | شبکه سایر | شبکه
| MPa        |     |    |
| 5.12       | 1   | 5.12 |
| 0.574      | 2   | 0.574 |
| 0.608      | 3   | 0.608 |
| 0.614      | 4   | 0.614 |

*یادداشت‌های مربوط به تاریکی کستک خم شانی و نیروی فشاری*
The tetrahedral mesh of the human spine is shown in Figure 6.

Figure 6: Tetrahedral mesh of human spine.