Intersomatic Cervical Fusion Modelling and Analysis

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Abstract – In this thesis a three-dimensional finite element model of the lower cervical spine is developed to compare its biomechanical behaviour before and after a cervical fusion.

The geometric model, composed by the C5 and C6 cervical vertebrae and their adjacent intervertebral discs, is obtained from Computed Tomography images using a pipeline of image processing, geometric modelling and mesh generation software. The pipeline steps in the model construction were: the medical images up-sampling; their segmentation; the surface mesh processing and, finally, the finite element model construction.

The second stage of this work was the finite element analysis. Firstly, there were studied parameters which may influence the model in terms of its range of motion. These parameters were the material properties and the contact conditions between the vertebrae. After it, a stress finite element analysis was taken, comparing the physiological case, with some of the post-operative situations, involving: the replacement of the intervertebral disc by a bone grafts and a cage and the use of anterior plates. This stress comparative analysis was aimed to understand the stress distribution changes at the spine and their influence on this surgical technique’s success.

Key-words - Cervical Spine, Inter-Somatic Fusion, Geometrical Modelling, Finite Element’s Analysis

I. INTRODUCTION

The inter-somatic cervical fusion is a surgical technique described for the first time in 1955 by Robinson and Smith. (Samartzir, et al., 2004). The cervical intervertebral disc replacement is used when there is a disc degeneration, leading to its collapse or spinal cords and nerves compression, due to disc herniation (McAfee, 2004). When the non-invasive treatment of these symptoms have no effect, there is necessary to use an anterior cervical decompression technique follow by a procedure as the inter-somatic fusion (Bandakidis, et al., 2003). With the establishment of this technique as a standard procedure for the spine’s stabilization after removal of an injured disc, there was a development of its instrumentation over the years, particularly in terms of bone grafts and stabilization systems. However, there are still some issues in terms of which are the best bone grafts to use and which are the stabilization system benefits (Samartzir, et al., 2004).

The use of bone graft is aimed to promote an immediate biomechanical support, maintenance of cervical spines lordosis and its canal’s height, and promotes bone growth between the vertebrae (Agrillo, et al., 2002). The geometric model, composed by the C5 and C6 cervical vertebrae and their adjacent intervertebral discs, is obtained from Computed Tomography images using a pipeline of image processing, geometric modelling and mesh generation software. The pipeline steps in the model construction were: the medical images up-sampling; their segmentation; the surface mesh processing and, finally, the finite element model construction.

The second stage of this work was the finite element analysis. Firstly, there were studied parameters which may influence the model in terms of its range of motion. These parameters were the material properties and the contact conditions between the vertebrae. After it, a stress finite element analysis was taken, comparing the physiological case, with some of the post-operative situations, involving: the replacement of the intervertebral disc by a bone grafts and a cage and the use of anterior plates. This stress comparative analysis was aimed to understand the stress distribution changes at the spine and their influence on this surgical technique’s success.

II. GEOMETRIC MODEL

The development of a model close to reality and its viability for a computer simulation are two of the main reasons that illustrate the importance of the modelling process. Each of its steps has a specific purpose and represents itself as a major contribution to the modelling performance.

The input for the model’s construction were Computed Tomography images (CT). These medical images allow the purchase of two-dimensional X-ray images in small slices acquired through the body along the transverse plane.

To improve the resolution and quality of the CT images, it was needed to resample the region of interest’s slices (ROI). This image technique allows increasing quality by interpolating the discrete images, transforming them in a continuous one, and after it, up sampling them (Lehmann, et al., 1999). The output for this technique is an increased number of slices in the ROI and therefore a quality increasement of the subsequence modelling steps.
The next modelling step is called segmentation. This medical image processing and analysis is composed by different algorithms for delineation of anatomical structures and other regions. This delimitation is based on a homogeneous characteristic such as image’s intensity and texture (Pham, 2000).

There are many different segmentation techniques, such as the thresholding and the deformable models, in particular, the contours active regions method of regions of competition. They were applied sequentially and were followed by a manual segmentation step.

After segmentation, these surface meshes are process to improve the quality and computational efficiency of the geometric model. Therefore, there were applied two different techniques: smoothing and decimation.

The smoothing process applied to the surface mesh is the adjustment of the coordinates of mesh nodes. This adjustment aims to improve the appearance of the mesh and the shape of the triangular element (Sullivan, 2000).

The decimation’s goal is to reduce the total number of triangles in a surface mesh, preserving the original topology and a mesh closer to the outcome of the original geometry. This process is iterative and has three basic stages: the characterization of the local geometry and topology, the assessment of a general decimation, the elimination of the summit and associated triangles and regeneration of the grid at this location (Schoroeder, et al., 1992).

After obtaining the solid models for each of the anatomical structures, it is necessary to generate a finite elements mesh of them, so that it can be possible to do a computational analysis of the geometrical model.

The finite element method is a powerful numerical technique developed to numerically solve a mathematical equation describing a physical phenomenon. What characterizes this method is the division of the domain in a set of simple sub domains, called finite element (Reddy, 2006).

A. Results

To the development of the geometrical model, there were used as input Computed Tomography images (CT) from a 34 year male subject without any local degeneration.

The resampling of the CT images was applied in the software MeVisLab, available freely in the academic context. There was defined the cervical spine’s C5 and C6 functional level as the ROI. Applying this up-sampling technique the discrete images number increased three times.

To perform the segmentation step it was used an open source program – ITK-SNAP. The first technique, thresholding, is applied based on the images intensity values similarity. This allows distinguishing bone tissue from the background surrounding.

It is then applied the active contours method of regions of competition. Taking into account the probabilistic map created by thresholding, there are introduced several deformable models, which will adjust to the structures borders during an iterative process (see figure 1).

![Figure 1- Iterative segmentation process (sagittal plane).](image)

Since it is necessary to apply the segmentation technique to a vertebra at a time and taking into account the proximity between the vertebrae, there are identified structures belonging to the two adjacent structures. Therefore it is necessary to use a manual segmentation technique to remove all elements that do not belong to the segmented vertebra. For intervertebral discs this was the only technique used to obtain their segmentation structures, since there is no discriminative power between the soft tissues in the CT images.

The segmentation output are surface meshes of the anatomical structures, composed by bonded triangular elements.

The use of smoothing and decimation technique was applied by the software Solidworks. It provides a surface mesh preparation and transforms them in a solid model. In this work, there was applied the semi-automatic method offer by this software.

To develop the finite element mesh of the anatomical structures, it was used the software ABAQUS. For the geometric model obtained, there was used a mesh technique with resource to linear tetraedrical elements. Among the techniques used to create the mesh, there are the virtual topology toolset, which ignores a number of characteristics that difficult mesh construction and the partition toolset in order to help defining the elements volume. The resulting mesh is presented in figure 2.
III. FINITE ELEMENTS ANALYSIS

The finite element analysis was performed by the commercial program ABAQUS, also used previously to generate volume meshes.

Initially it was analysed the models range of motion (ROM), under the effect of displacements or their corresponding forces. Another briefly studies were made in terms of the model sensitivity to some parameters, including: the influence of the contacts definition in the zygapophysial joints and the influence of the intervertebral discs material properties.

For this finite element analysis there were defined the initial material properties showed at table 1.

Table 1 – Material Properties of the models structures (Kumaresan, et al., 1999).

<table>
<thead>
<tr>
<th>Structures</th>
<th>Elasticity Modulus (MPa)</th>
<th>Poisson Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical bone</td>
<td>10000</td>
<td>0,29</td>
</tr>
<tr>
<td>Trabecular bone</td>
<td>100</td>
<td>0,29</td>
</tr>
<tr>
<td>Nucleus Pulposus</td>
<td>3,4</td>
<td>0,49</td>
</tr>
<tr>
<td>Annulus</td>
<td>3,4</td>
<td>0,40</td>
</tr>
</tbody>
</table>

A. ROM Analysis

Using data of (Panjabi, et al., 2001), which presents an in vitro cervical spine study of the mechanical properties at its different functional levels, there were applied pure rotational moments of 1Nm at the upper surface of the top’s disc. For each spines basic movement it was observed the ROM resulting from the moment application, showed in table 2.

Comparing with Panjabi data (Panjabi, et al., 2001), the ROM of this study is substantially minor. As a result, the displacements applied leads to reaction moments higher than the 1Nm, indicated in the same reference.

Comparing the use of hybrids and non hybrid models, the ROM is higher for the model with hybrid elements. Consequently the hybrid model presents closer values of those presented in the literature.

Table 2 – ROM of three functional levels after applying a 1 Nm rotational moment

<table>
<thead>
<tr>
<th>Movement</th>
<th>Thetraedrical elements</th>
<th>Hybrid elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>flexion*</td>
<td>7,86</td>
<td>8,82</td>
</tr>
<tr>
<td>extension</td>
<td>6,45</td>
<td>7,17</td>
</tr>
<tr>
<td>lateral bending</td>
<td></td>
<td></td>
</tr>
<tr>
<td>right</td>
<td>4,35</td>
<td>4,75</td>
</tr>
<tr>
<td>left</td>
<td>4,24</td>
<td>4,62</td>
</tr>
<tr>
<td>axial rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>left</td>
<td>7,52</td>
<td>8,17</td>
</tr>
<tr>
<td>right</td>
<td>7,71</td>
<td>8,39</td>
</tr>
</tbody>
</table>

* different contact conditions

B. Contact Definitions

In this section, there were studied the contact interface conditions established between the articular facets, and the interaction stabilization influence at the stress values observed in the finite element model.

In order to observe only deformations at the functional level of contact (C5-C6), the adjacent disc were set up with trabecular bone material properties.

After apply the rotation moment for lateral bending and axial rotation movement, the results are observed in terms of the maximum Von Mises stress at table 3.

There is a significant variation in the maximum stress values between the contact surfaces for lateral flexion and extension. In the first case, stress is two times higher for node-to-surface interface. For the extension motion, this variation is more significant within the same interface definitions. One possible explanation is that there are interpenetrations between the nodes of the surfaces.

Similarly, the non-convergence for flexion movement may be associated with interpenetration between various nodes of the contact surface at the initial step. However, using the contact stabilization, the excessive interpenetration is removed with the addition of dissipative forces, leading to the expected movement occurrence. The lack of solutions may also be a result of the distance between the surfaces in this movement, which may be superior to the small sliding definition in this contact interface.

The stress values obtained with and without contact stabilization are similar and this condition is essential for results convergence in some of the interface between surfaces.

It was defined that the better contact conditions in this work were the surface contact with stabilization because of its higher precision associated (Abaqus, 2007).
Table 3 – Maximum Von Mises Stress values for the different contact conditions tested.

<table>
<thead>
<tr>
<th>Von Mises Stress (MPa)</th>
<th>Contact Interface</th>
<th>Node to Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without CS</td>
<td>with CS</td>
</tr>
<tr>
<td><strong>Movements</strong></td>
<td>Thetraedrical elements</td>
<td>Hybrid Elements</td>
</tr>
<tr>
<td>Extension</td>
<td>23.89</td>
<td>-</td>
</tr>
<tr>
<td>Flexion</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Left Axial Rotation</td>
<td>12.41</td>
<td>13.36</td>
</tr>
</tbody>
</table>

Table 4 – ROM variation with the Elasticity Modulus value.

<table>
<thead>
<tr>
<th>Elasticity Modulus (MPa)</th>
<th>Flexion’s ROM (degrees)</th>
<th>Lateral Bending’s ROM (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thetraedrical elements</td>
<td>Hybrid Elements</td>
</tr>
<tr>
<td>3.4</td>
<td>2.83</td>
<td>3.10</td>
</tr>
<tr>
<td>3.0</td>
<td>3.13</td>
<td>3.44</td>
</tr>
<tr>
<td>2.0</td>
<td>4.40</td>
<td>4.88</td>
</tr>
<tr>
<td>1.7</td>
<td>5.07</td>
<td>5.64</td>
</tr>
</tbody>
</table>

Figure 3 – ROM variation with the Elasticity Modulus value.

Table 5 – Significant stress distribution values for the different model’s cases*.  

<table>
<thead>
<tr>
<th>Models</th>
<th>C5 e C6</th>
<th>Intervertebral Space</th>
<th>Plate</th>
<th>Screws</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Anterior region – body walls and pedicles; ~1-5MPa</td>
<td>Concentric; periphery: ~0.8-2 MPa; center: 100-700KPa</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AG</td>
<td>Anterior region – body walls and pedicles; ~3-7MPa</td>
<td>Concentric; periphery: maximum 2.5-5.5 MPa; centre: less than 500KPa</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PC</td>
<td>Anterior region – body walls; ~2-5 MPa</td>
<td>Concentric; cage: ~1 - 21 MPa; graft: ~90 - 200 KPa</td>
<td>Central region with maximum 10-40 MPa</td>
<td>5-30 MPa connection region with the plate</td>
</tr>
<tr>
<td>AG TP</td>
<td>Anterior region – body walls around the screws ~3-10MPa; ~1-2MPa between the screws; pedicles ~2-4MPa</td>
<td>Concentric; periphery: maximum 1.7-2.4 MPa; centre: about 100 KPa</td>
<td>Central region with maximum 10-40 MPa</td>
<td>5-30 MPa connection region with the plate</td>
</tr>
<tr>
<td>AG CP</td>
<td>Anterior region – body walls around the screws: proximal zone 15-20MPa, distal zone 7-15MPa;</td>
<td>Concentric; periphery: maximum 4.7-6.1 MPa; center: minimum 500KPa</td>
<td>Top - 100 MPa and decreasing until central region -60 MPa</td>
<td>50-100 MPa upper sews; contact interface</td>
</tr>
<tr>
<td>PC TP</td>
<td>Anterior region – body walls around the screws; ~6MPa; distal zone</td>
<td>Concentric; cage: maximum 8,3 -15 MPa; graft: ~50 - 300 KPa</td>
<td>Lateral movements 15-20 MPa and flexion/extension 5-8 MPa, centre and top</td>
<td>5-10 MPa connection region with the plate</td>
</tr>
<tr>
<td>PC CP</td>
<td>Anterior region – body walls around the screws; proximal zone more than 20MPa, distal zone 6-16MPa;</td>
<td>concentric; cage: between 5-6MPa e 39-48MPa; graft: ~100 - 700 KPa</td>
<td>200 MPa top and 60-80 MPa center</td>
<td>50-200 MPa upper sews; contact interface</td>
</tr>
</tbody>
</table>

*P – physiological model; AG – model with an autologous bone graft substitute; PC- model with a bone graft substitute and a PEEK cage; TP – model with a fixation plate tied to its screws; CP – model with a fixation plate with a contact interface with its screws.
C. Materials Properties Sensitivity

The materials properties sensitivity was tested for two distinct movements: flexion and lateral bending.

In order to test its influence in a simple functional level, the adjacent disc properties were set up as trabecular bone properties. There were used some of the conditions discussed earlier: the surfaces contact interface with the contact stabilize condition. The results are shown at table 4 and figure 3.

It is observed that the ROM increases with the decrease of elasticity modulus. For a modulus of elasticity of 1.7 MPa it is approach the 5.5º ROM value for functional unity at flexion movement (Panjabi, et al., 2001). However, the same elasticity modulus does not approach the ROM for lateral flexion movement from the article, since the value obtained is three times lower than it.

Comparing hybrid and non hybrid elements results, the ROM variation with the modulus of elasticity is identical, however, the model with hybrid elements present lower ROM values.

Since there wasn’t obtained any convergence value for materials properties, there were used the intermediate material properties presented in (Kumaresan, et al., 1999).

D. Models Variations and Comparative Results

This first step allowed the parameters definition to be used in the stress analysis. Now it is possible to compare the physiological (model with three intervertebral discs) and some post-operative cases (model with the replacement of one of the discs). The non physiological situations under study are: the use of bone grafts with or without a peek intervertebral cages and the use of components of internal fixation, the plates stabilizing, with an interaction between the plate and screws rigid (tied) or semi-rigid (in contact at the upper region and tied at the lower region).

In this analysis there were applied pure rotational moments corresponding to each of the movements to the hybrid model, and set up the contact as a surface interface with a stabilization condition.

It were observed the stress changes in the intervertebral space between C5 and C6 and at the vertebral level, which influenced had the bone graft , the cage and the plate on the stress values and finally, if there were significant differences in the model’s ROM.

Stress Analysis Results

The results at table 5 show that the stress values at the vertebral level remain closely the same. There are only some changes in the distribution values when cages and plates fixation are used. In the first case, these changes are a result of the cages support function. For the fixation plates, their insertion leads to an action from the rigid structures, the screws, into the vertebrae.

It should be notice that these stress distributions are only significantly found in the cortical bone layer. In the trabecular tissues region, the stress values are 500 KPa or less.

At the intervertebral space between the C5 and C6 vertebrae, the stress values are observed at a hundreds of KPa, both to intervertebral disc or bone grafts. It possible to say that there are no significant changes at bone’s formation induction related with this regions stress values. However, the stress values presented by the intervertebral cage are higher as expected, and influence the stress distribution at lateral vertebrae regions.

For plates stabilization system there are higher levels of stress when their screws interaction is defined as contact. This values increases especially in the upper region of the plate. The increasement is also noticed at the screws, where the stress distribution has higher values at its contact interface region.

ROM Results

At table 6 there are presented the ROM results for all of the studied models. There aren’t any significant changes at

<table>
<thead>
<tr>
<th>Movements</th>
<th>P</th>
<th>AG</th>
<th>PC</th>
<th>AG TP</th>
<th>AG CP</th>
<th>PC TP</th>
<th>PC CP</th>
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<tbody>
<tr>
<td>flexion</td>
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<td>lateral bending</td>
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<td></td>
<td></td>
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<tr>
<td>axial rotation</td>
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</tbody>
</table>

*P – physiological model; AG – model with an autologous bone graft substitute; PC- model with a bone graft substitute and a PEEK cage; TP – model with a fixation plate tied to its screws; CP – model with a fixation plate with a contact interface with its screws.
the ROM values between the physiological and postoperative situations.

The small variations observed may be linked to one of the following reasons: the ROM was measured generally for the entire model, and the movement changes between the vertebrae in physiological and postoperative are observed mostly at the fusion level. Another possible explanation is that influence on the movement is not significantly in order to be observed at the global cervical spine model displacement.

IV. DISCUSSION

The development and refinement of the model allows a computer analysis approach to cervical spine real behaviour. However, there are some developments limitations that are need to be taken into account because they can significantly influence the results.

The main limitations of geometric modelling correspond to its specific association to the anatomical structures of the CT images. The geometric model obtained will represent these structures faithfully, however there is an anatomical variability of each person, which will not be taken into account.

The images segmentation technique is one of the critical steps in the three-dimensional model development. It is a semi-automatic process that requires the operator's decision for a number of options and his experience and structures knowledge are crucial factors in the geometric model building (Drosket, et al., 2001). There was also a manual structures segmentation that brings some inaccuracies to the interface areas and that will influence the contact results.

The smoothing and decimation may reduce this inaccuracies and lead to a surface mesh simplification, but they also bring topological errors. Since these techniques are applied individually to each structure, these topological approaches may also lead to an interaction conflict between structures.

For the finite element mesh, in addition to the virtual topology errors, the types of elements also influence the results. Due to the complex anatomical structures morphology, the mesh was constructed with first order tetraedrical elements. However, these elements are not recommended for a stress and displacement analysis, since they only provide accurate results in general cases with very refined meshes.

With regard to using hybrid elements, they will bring an almost incompressible behaviour to the disc, however, this behaviour is not found in the annulus, and may induce incompressible properties to this region.

The ROM and reaction moment results obtained through the model used data from cadaveric cervical spines of (Panjabi, et al., 2001). In spite of providing a more accurate measurements of movements in a more controlled environment conditions this is an in vitro study and there is a lack of living tissues response.

It should be noted also that the movements made in the cervical spine are usually a complex combination of these basic movements. Thus, the stress and forces involved in these movements, not only depend on the person who performs them, but also will be a combination of forces associated with their basic movements.

The decision to apply pure rotational moments is linked to the sensitivity to models elastic properties. A moment application will have a more direct influence on stress values. It should be kept in mind that there was no muscular and ligaments activity’s modelling which will influence the movements of the cervical spine. Thus, there are a number of forces involved in the movement, which will not be present in the model, and this will influence the results. This modelling option was made in order to keep a model’s simplicity and therefore a more direct results dependence on the anatomical features of the spine, one of the factors that will heavily influence the cervical spine movements.

In the stress analysis held for the different cases presented, the influence of factors previously identified at the modelling stage and parameters definitions may be associated with some achievements. The stress peaks observed in the zygapophysial joints may be associated with nodes interpenetration resulting from topology and simplification errors. Due to these joints resistance role to compressive forces together with the intervertebral disc (Yoganandan, et al., 2001), changes in the intervertebral space conditions do not influence the stress results in this joint.

At the stress distributed study, factors as the bone graft, cages structure and plates and screws influence need to be taken into account in the results analysis. The simplified cage structure presented a 0.5 mm thickness, compared to 2mm (Yoganandan, et al., 2001) and the 5-7mm (Kulkarni, et al., 2007) reported in the literature. This indicates that the results show have a diminished effect of the cages influence on stress values. However, it was possible to observe its support function.

Definition of the screws approximate location and their interaction with the plate’s holes could have led to some errors results compared with the clinical reality. The absence of a direct interaction definition between the bone and fixation plate have caused some instability in results at the contact interface case, because the plate is allow to move along the upper screws.

However, there were obtained results close to the expected. The significant stress values for any of the movements are in the vertebrae anterior region, especially in its anterior wall. There is a significant change in the distribution when the stabilization plate is placed, increasing the stress values around the screws insertion region. In spite of these conditions changes, the stress values in the intervertebral space did not show strong changes. This leads to the conclusion that for the testing cases, the intervertebral cage and stabilizing plate played their role of support stabilization but they did not
significantly affect the graft stress values, which would influence the bone’s formation in the intervertebral space.

V. CONCLUSIONS

With this work it was possible to develop a tri-dimensional model from Computed Tomography medical images allowing a stress analysis of a cervical spine region in different physiological or non physiological conditions.

Its development shows that from common diagnosis images it is possible to obtain a specific model for each individual, which will allow a detailed analysis in a specific structure of interest. As this is a one individual analysis, the general conclusions on the benefits associated with each of the instrumentation used in cervical fusion surgical technique - bone graft, cages, stabilizing plate and screws, can be taken with a large error associated. However, this analysis combined with a model validation using in vivo studies, may help explain biomechanical clinical results presented.

The finite element models analysis of the contact used shows stress peaks in the region of the articular facets. However, these peaks do not have a clinical significance and are not considered in the analysis.

The results obtained in the analysis of the physiological case demonstrate that the model as a great sensitivity to the material properties of intervertebral disc, which is also stated in (Kumaresan, et al., 1999). As such, a possible future approach of this work will be a detailed experimental study of the influence of discs material properties.

When using a bone graft with or without intervertebral space and without stabilizing plate, it appears that the stress on the disc region’s periphery increases, however, these stress values still remain closer to the situation presented in physiological for the inner region, formerly occupied by the nucleus pulpos.

When stabilization plates are used in above cases, the stress values at the disc do not change significantly. However, there is a reduction of stress at anterior regions of the vertebrae, especially in the region between the upper and lower screws holes, showing a small stress shield.

But there is still a way to go in developing a similar model so that it can be possible to acquire more accurate results with greater clinical significance. The ideal for the development of a geometric model is the use of CT and MRI images of the same individual in order to obtain better information regarding the two types of tissues in the structure of the spine: the hard tissue, such as the vertebrae, and the soft tissues, especially the intervertebral discs. The use of two imaging techniques need to take into account an image alignment in order to obtain accurate locations of each of the structures of interest. The inclusion of other soft tissue such as ligaments and skeletal muscles, and their biomechanical behaviour, will also be an approximation of reality, which will bring a higher model complexity.

In order to improve the results resolution there are some factors that can be changed, such as: defining a mesh with other type of finite elements, including second order tetraedrical elements; restricting the use of hybrids elements to the nucleus pulpos, and study the behaviour of the model to different load cases.

One aspect not developed in this model was the bone remodelling study that occurs at the vertebrae and the bone graft. Through the stress analysis, it is possible to indicate that the loading conditions at the bone graft did not change significantly between the studied cases comparing to the ones presents at the physiological case. However, there are some changes in stress values and distribution at the vertebrae area, more visibly observed under the use of stabilizing plates.

Another aspect that could be developed in the study and characterization of the cervical spine after the inter-somatic fusion surgical technique will be the modelling of all structures of the lower cervical spine. It will then be possible to analyse the fusion impact that one or more levels may cause at the movement in this spinal region.

With these model improvements, is not only possible an understanding of the biomechanical factors that influence the fusion process, and the influence of the material used in surgical technique, but it can also help to indicate the best surgical approach for removal and replacement of intervertebral discs.

Thus, it is possible to combine the technological development and the challenges in medicine, with the aim of improving the patient’s quality of life.

REFERENCES


