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DOCTORAL STUDIES IN STABILIZATION AND ARTHROPLASTY OF LUMBAR SPINE

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***Summary**: The thesis studies both lumbar stabilization implants and total lumbar disc arthroplasty (TLDA), in order to improve the anatomical integration using modern procedures and technologies. The main treated topics are: synthesis of the state-of-the-art research in the interest field, study of lumbar spine biomechanics, 3D modeling of the lumbosacral segment starting from CT images, design constructive solutions of both vertebral and intervertebral stabilization implants, simulating of different functional spinal units, implant manufacturing using modern technologies, and implant endurance testing. The doctoral studies benefit of properly equipped laboratories for completing the expected tasks.*

***Key words:** lumbar spine implant, 3D modeling, biomechanics, manufacturing, endurance testing.*

DOKTORSKE STUDIJE U OBLASTI STABILIZACIJE I ANTROPLASTIKE LUMBALNE KIČME

***Rezime**: Ovaj rad proučava kako stabilizaciju lumbalnih implantanata tako i potpunu antroplastiku lumbalnog diska (TLDA), kako bi se pospešilo anatomsko sjedinjavanje korišćenjem savremenih tehnika i tehnologija. Glavne obrađivane teme su: sinteza savremenog istraživanja u polju interesovanja, proučavanje biomehanike lumbalne kičme, 3D modelovanje lumbar sakralnog dela počev od CT slika, osmišljavanje konstruktivnih rešenja pršljenastih i međupršljenastih implantanata za stabilizaciju, simulacija različitih funkcionalnih delova kičme, proizvodnja implantanta korišćenjem savremenih tehnologija,i testiranje izdžljivosti implantanata. Za adekvatnu realizaciju doktorskih studija neophodne su dobro opremljene laboratorije.*

***Ključne reči:** implantant lumbalne kičme, 3D modelovanje, biomehanika, izrada, test izdržljivosti.*

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1. INTRODUCTION

The human spine, an element which influences our everyday life, both as a basic biomechanical component and as a metaphor of one's personality, has been the subject of various researches, due to the increasing rate of back pain, especially in the lumbar segment of the spine.

Statistics nowadays show that 75-85% of people suffer from spine disorders at some point in their lives, back pain representing the second most common reason for seeing any doctor, the third most common reason given for surgery and the fifth most frequent cause of hospitalization. The age group with the most reported symptoms is adults age 45-64. Behind all these numbers are the factors that produce back pain coming from either accidental injuries, everyday activities or even from obesity.

Considering a human body in an orthostatic position, experimental data shows that the lumbar vertebrae, L1-L5, carry the most amount of body weight being subjected to the largest forces and stresses along the spine.

One justification for choosing this research subject stands in the bachelor theme continuity, where the modeling of an implanted functional lumbar unit was the main goal. During the project, the synthesis of the state-of-the-art research in the interest field began and several constructive solutions of spinal implants were achieved from modeling and simulating.

The main treated topics are: synthesis of the state-of-the-art research in the interest field, study of lumbar spine biomechanics, 3D modeling of the lumbosacral segment starting from ct images, design constructive solutions of both vertebral and intervertebral stabilization implants, simulating of different functional spinal units, implant manufacturing using modern technologies, and implant endurance testing.

2. STATE-OF-THE-ART RESEARCH

On whether the vertebral segment mobility is missing or restored, two categories of implants are known in literature: stabilization devices (placed either exteriorly or interbody) and preserving motion devices (total disc replacements or interspinous spacers).

Lumbar stabilization implants placed onto the spine are considered temporary devices because their function stops once fusion occurs, and thus the implants may be retracted (as an explant) or not, depending on the case. The role of the stabilization implants is to help restore and maintain normal alignment of the lumbar spine and to keep the spine fixed (stable) during the fusion process *(fig. 1)* [1].

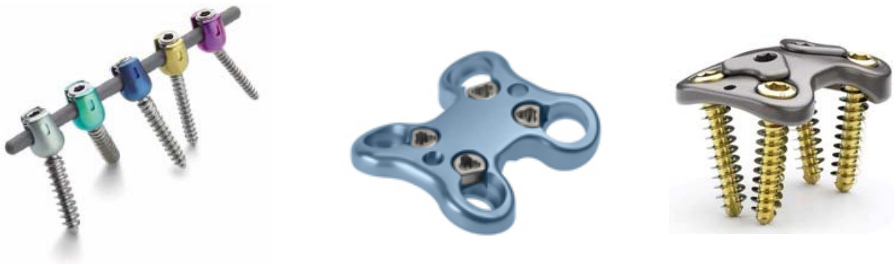

Figure 1: *Lumbar exterior stabilization implants*

Lumbar interbody implants are devices used by surgeons to decompress and stabilize the spine. Decompression consists in surgically removing tissues pushing or pinching a nerve while spinal stabilization involves fusing two or more vertebrae together. Such devices, combined with bone graft, restrict all the movement between vertebral bodies *(fig. 2)* [1].

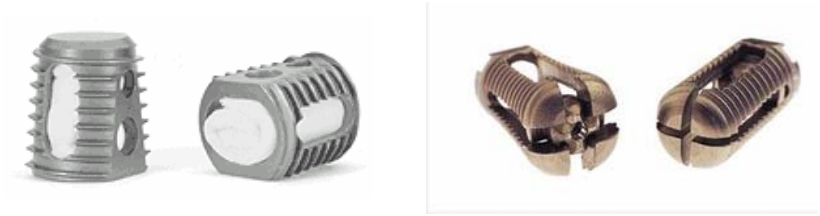

***Figure 2**: Lumbar interbody stabilization implants*

The total disc replacement device is intended to advanced degenerative disease patients. Nowadays it comes in different designs, but generally consists of two plates bounded by a motion system (fig.3). Despite the positive clinical results, there is a continuous debate between specialists concerning the efficiency of using TLDA rather than spinal fusion [2].

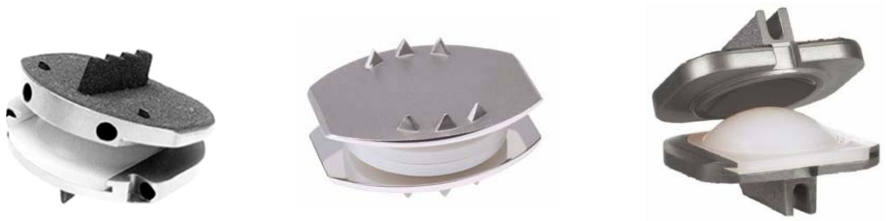

***Figure 3:** Total lumbar disc replacements*

Interspinous spacers (*fig. 4*) are designed for treating lumbar spinal stenosis and disc herniation. They mode of action is to distract an affected spinal segment by placing it in a slightly flexed position, thus decompressing the nerve root to relieve pain [2].

***Figure 4:** Interspinous spacers*

Regarding the biomechanics of lumbar spine, during any type of movement, ligaments, groups of muscles, intra-abdominal pressure and body weight determine forces and torques influencing the motion between vertebrae and discs. It is very difficult to determine the exact amount of load bearing the lumbar segment, neither the corresponding forces and torques [3], [4], [5].

3. METHODS AND RESOURCES

The doctoral research is developed in the Mechanical Engineering Faculty, one of the "Politehnica" University of Timisoara faculties, benefiting by the infrastructure of the *Centre for Modeling the Prosthetic Appliances and Surgical Operations on Human Skeleton* – a Multiple User Research Centre. The centre laboratories are highly equipped being able to support the achievement of the thesis goal, both experimental and technological.

The Medical Imaging Laboratory uses computer tomography (SIEMENS SOMATOM Plus 4 Power), providing image acquisition and processing of the necessary anatomical elements.

The Modeling and Design Laboratory contains performance computers with specialized software for the doctoral study. Thus, the CT images achieved are processed, in order to obtain 3D entities of the corresponding images, following numerical analysis simulations to take place on the reconstructed embodiments. Constructive solutions for implants are designed, and then tested as an anatomical functional lumbar unit, in assembly with the scanned elements, in various situations depending on the type of loads, movement, exterior forces, materials, etc.

Achieving positive results from the simulations, encourages one to proceed in creating the selected implant in a high quality design. The Manufacturing Laboratory includes classical machines processing, CNC machines processing and unconventional processing (EDM fabrication, rapid prototyping using both metal and plastic powder).

In vitro mechanical tests and measurements will be realized in the CIDUCOS Testing Laboratory. Different lumbar functional units derived from cadavers are studied with and without implants, determining the most efficient way to a future successful implant design.

Using the Zebris system from the Motion Analysis Laboratory, implanted patients will be analyzed, in order to obtain a substantial database for future in vivo/in vitro comparisons. The investigations imply triangulation in ultrasonic field, a non-invasive technique.

4. CONCLUSIONS

The thesis studies both lumbar stabilization implants and total lumbar disc arthroplasty (TLDA), in order to improve the anatomical integration using modern procedures and technologies. The infrastructure of the CMPICSU Research Centre assures the best conditions to solve all the proposed subjects. The results obtained during the research, will be published in articles, professional journals and national and international conference proceedings.

5. AKNOWLEDGEMENT

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