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OPTIMAL SHAPE REPRODUCTION OF AN INTERVERTEBRAL PROSTHESIS "COFLEX" FOR ADDITIVE MANUFACTURING

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ABSTRACT

The coflex Interlaminar Technology is an interlaminar stabilization device indicated for use in one or two level lumbar stenosis from L1-L5. It is used in skeletally mature patients with at least moderate impairment in function who experience relief in flexion from their symptoms of leg/buttocks/groin pain, with or without back pain, and who have undergone at least 6 months of non-operative treatment. Our study is focused on the evaluation and biomechanical analysis of osteosynthesis implants and in particular the Corflex-F implant to redefine a new approach to the "Coflex" interspinatus implant using particles swarm optimisation for additive manufacturing, then to study these biomechanical performances.

Keywords: Corflex, PSO optimization, spine, biomechanics.

INTRODUCTION

The spine is the base of the skeleton. It is composed of a set of elements containing the intervertebral discs. The latter are cartilages with little innervation and little vascularity, located between the vertebrae of the spine. Their ability to deform gives them a major role: to give flexibility to the spine by allowing the body to take different postures and act as an energy shock absorber, by transmitting various mechanical stresses related to weight along the body's spine and muscle activities. These functions require discs on a daily basis and cause wear and tear that predisposes the individual to a set of pathologies [1]. Degenerative pathologies of the intervertebral discs are related to the high and repetitive stresses to which the spine is subjected.

Our study is focused on the evaluation and biomechanical analysis of osteosynthesis implants and in particular the Corflex-F implant. One of the dynamic interspinatus implants (called "dynamic" because they contribute to the treatment of lumbar pathologies by restoring, in part, the natural mobility and damping of the spinal segments) is the CoflexTM device (Paradigm Spine, LCC, New York, NY), formerly Interspinous'U'. A titanium U-shaped compressible device is placed between the thorny process after decompression surgery. The objective of this interspinatus system is to unload the joint veneers, restore the height of the foramen and ensure stability after decompression surgery in order to improve clinical outcome. The objective of this study is to redefine a new approach to the "Coflex" interspinatus implant using performances of particle swarm optimization (PSO), then to study these biomechanical performances and finally to realize them by additive manufacturing.

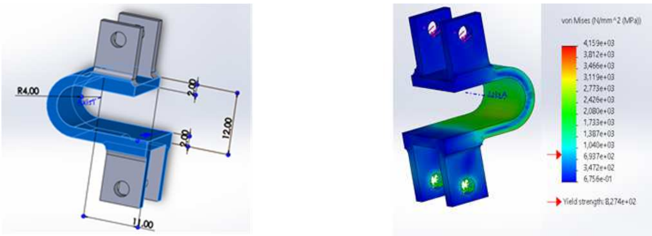
In its basic version, PSO algorithm begins by defining a number of group individuals, called particles, the search space and an optimality criterion. The particles are randomly distributed over the search space, their fitness functions are initialized, given this situation, the best particle of the swarm and the best local particle, are defined according to a neighborhood policy. Each particle is then moved toward a new position taken into consideration its current position and the best local and global positions. The amount of the displacement is called velocity, see equations (Eq. 1) and (Eq. 2).

$$v_i = v_i + c_1.rand().(P_{lbest} - x_i) + c_2.rand().\left(P_{gbest} - x_i\right) \quad (1)$$

$$x_i = x_i + v_i \quad (2)$$

RESULTS AND CONCLUSIONS

We applied the conditions of limits, totally fixed the lower part and applied a moment of 10 N.m (bending - extension), we noticed that the concentration of Von-mises stresses at the level of the semi-circle are high, Figure 1(b). To remedy this we proposed a shape optimization using PSO method of optimisation for determine the optimal model, than validate with the Solidworks software.



(a) 3D model

(a) Constraints of Von Mises

Fig. 1 - Coflex F interspinatus implant

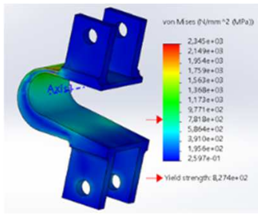


Fig. 2 - Optimal model for the Coflex F interspinatus implant

The solution to the optimization problem is given by a set x to which the objective function has a minimal value, within the constraints of equality, inequality and scope:

f (x): objective function, minimize Von-Mises constraint:
min Fobj= min F (σvon)= minF(σvon(d1,e1,e2)

- 3mm ≤d1≤ 5 mm, d1 internal diameter
- 1mm≤e1≤3mm, thickness e1
- 1mm≤e1≤3mm thickness e2
- 7 mm ≤h≤ 9 mm.

SolidWorks allows to optimize our design on the basis of criteria that we have defined, we can reduce the use of materials or the weight of our design using the optimization of shapes technology. The aims of our study was to define the diameter and thickness of Interspinous implant (Coflex) in objective to reduce the Von-Mises stress. This implant replaces the damaged interspinous ligament and ensures the mobility between the vertebrae.

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