Finite Element Analysis Of Different Spinal Cage Designs For Posterior Lumbar Interbody Fusion

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Abstract: *The study on spinal cage designs for their implementation in the medical field is developing over the years. Currently, many designs have been studied varying from the biomaterials and the designs. This study aimed to determine the best design structure of an annealed titanium spinal cage with the integration of porous holes and to attain its mechanical performance under different loadings before topology optimization. 8 specimens were designed and analyzed based on porosity percentage, MIT, and FEA before undergoing topology optimization. The analysis was conducted on two loadings applied simultaneously to resemble the human body weight and the motion of the lumbar column. Results showed that the stress concentration of all specimens increased accordingly as the porosity volume increases, thus specimen 2 was selected due to it having the second-lowest stress concentration but also the more adequate pore volume for the bone graft filling.*

Keywords: PLIF, Lumbar Cage, Stress Analysis, Topology Optimization

1. INTRODUCTION

Lumbar or spinal cage fusion is a method of treatment that is required to treat a specific disease called disc spondylosis or degenerative disc disease. Methods of surgery include the Posterior Lumbar Interbody Fusion (PLIF), Anterior Lumbar Interbody Fusion(ALIF), Transforaminal Lumbar Interbody Fusion(TLIF), etc. Disc spondylosis refers to the degeneration of an intervertebral disc that sits between two adjacent vertebrae, thus an external implant is required to be fused into the lumbar column for the fixation of the vertebrae. The spinal cage has to serve its purpose in terms of an implant replacement of the actual intervertebral disc, as well as being able to serve its purpose of a connecting medium between two vertebrae. Various designs of lumbar cages are being applied in the medical field up till today yet it has still been improvised as the technology and resources develop.

The two main factors that give an immediate effect to the biomechanical performance of the spinal cages are the biomaterials and the spinal cage designs. PLIF spinal cages are mostly manufactured using Polyetheretherketone (PEEK) and titanium alloy [1]. Each material undoubtedly has its unique material properties that would give different outputs of stress and strain analysis. Despite PEEK having its term of being used as the most common material, titanium alloy is rather more favourable in terms of clinical outputs such as the cage subsidence, and the complication rates mostly yield towards titanium.

On the other hand, cage designs have always been a confusion in the current industry. Several criteria are commonly found among the commercialized designs such as the cylindrical, threaded, biconvex and biconcave designs as well as porosity integrated cages[2]. Porous holes are required to be implemented in the spinal cages. It serves the significant purpose of being a medium for the filling of bone graft material, which helps to aid the fusion rate and allowing the transport of fluid into the cages. However, only limited studies showed that with the alteration of porosity volume, the performance of the cages is affected[3].

Therefore, this study was conducted to analyze the designs of spinal cages in terms of porosity volume and their stress analysis that includes Von Misses Stress and Maximum Principal Stress, using Finite Element Analysis under two loading conditions, force and moment. Then, using the topology optimization, comparison are to be made. The material used in this study was annealed titanium alloy and the pore volumes were varied in terms of holes and slots integration on 8 different cages including the control study.

2. MATERIALS AND METHOD

2.1 Modelling of Lumbar Cage

The whole 3D sketching of the lumbar cage implant is sketched using the SolidWorks software, and the whole process of sketching will be detailed in the following orders [4]. The sketching began by selecting the top view of the plane in the XY views and is followed by a 2D square sketching with a dimension of 32 mm in length and 12 mm in height. The sketching was then extruded to a 3D model by extruding it with a thickness of 28mm. These dimensions were referred from a previous study and a generalization assumption was done referring to previous research papers. The cuboidal spinal cage was selectively filleted on the 12 edges, with a curved dimension of 0.65 mm with a purpose of softer and less sharp corners and edges that do not disrupt the lumbar column once it has been placed into the human body. The diameter of the porous holes is 3 mm with uneven spacing between the holes whereas the height of the slots is kept constant at 6mm.

Figure 1 and 2 below shows the reference images for the porous holes and slots at the side surface of the cages, while the larger hole in the front surface is called the insertion that is used for the implementation to the surgical tool during the surgical process.

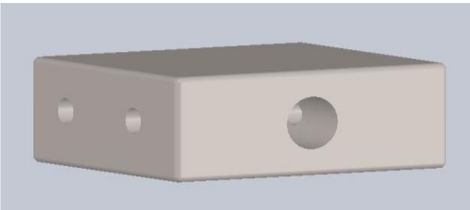

Fig.1. Spinal Cage with Holes