IMPLICATIONS OF PRESSURE AND RANGE OF MOTION ON POSTERIOR FIXATION OF THORACOLUMBAR BURST FRACTURES

By:

NUR AIMI AMANINA BINTI MOHD MARZUKI

(Matric no.: 131598)

Supervisor:

Dr. Mohd Sharizal Abd Aziz

May 2019

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfilment of the requirement to graduate with honors degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed...
(NUR AIMI AMANINA BINTI MOHD MARZUKI)

Date ....

Statement 1

This thesis is the result of my own investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

Signed...
(NUR AIMI AMANINA BINTI MOHD MARZUKI)

Date ....

Statement 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available outside organizations.

Signed...
(NUR AIMI AMANINA BINTI MOHD MARZUKI)

Date ....

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest gratitude and special thanks to my research supervisors, Dr. Mohd Sharizal Abdul Aziz for his kind supervision, constructive criticism and valuable time in guiding me throughout the entire duration during my completion of final year project. His continuous support, guidance, and encouragement with enthusiasm are much appreciated to allow me to handle this project with care. Without his guidance and persistent help, this final year project would not have been possible. Thank you for the tremendous positive feedbacks given along with the continous support received. Special thanks to the authorities of Universiti Sains Malaysia (USM) especially to School of Mechanical Engineering for providing me with all the facilities needed to complete this project. I would like to use this opportunity to express thank to Dr. Ikhwan and Dr. Hafifi who never tired in teaching and giving guidence on how to handle my final year project. Lecture on thesis writing help me a lot and give much valuable information for thesis writing. Finally, my utmost gratitude especially to my parents, Mohd Marzuki Bin Hashim and Fatimah Binti Harun, my family and friends for their continuous support and motivation. With their support and advice when I feel down were helpful and valuable that I will remember forever. In short, thank you for being a part of my life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASIA	American Spinal Injury Association
CT	Computed Tomography
FE	Finite Element
ISNCSCI	International Standards for Neurological Classification of Spinal Cord Injury
MRI	Magnetic Resonance Imaging
ROM	Range of Motion
RPC	Radial Posterior Construct
PC	Posterior Construct
RC	Radial Construct
STL	Stereolithography
USM	Universiti Sains Malaysia

IMPLICATIONS OF PRESSURE AND RANGE OF MOTION ON POSTERIOR FIXATION OF THORACOLUMBAR BURST FRACTURES

ABSTRAK

Rawatan pembedahan menggunakan kaedah binaan pituitari sering digunakan bagi kes patah tulang belakang di kawasan tulang toraks dan lumbar. Terdapat pelbagai kaedah rawatan bagi kes-kes kecederaan tulang belakang mengikut tahap keseriusan masing masing. Namun begitu, kesan daripada rawatan-rawatan tersebut masih kurang diketahui bagi sudut biomekanik. Tujuan kajian ini dijalankan adalah untuk menganalisa kesan daripada tekanan terhadap rawatan pembedahan yang melibatkan kawasan toraks dan lumbar dari tulang toraks yang kesepuluh sehingga tulang lumbar yang kelima. Lingkungan pergerakan pesakit juga diselidik agar kesan daripada rutin seharian atau aktiviti lasak yang mampu menjejaskan rawatan pembetulan tulang belakang dapat dikenal pasti. Model 3 dimensi tulang belakang di bahagian toraks dan lumbar dihasilkan untuk mengenalpasti sebarang perubahan biomekanik terhadap bahagian tersebut. Model tersebut dihasilkan menggunakan imej pemeriksaan imbasan CT pesakit. Kemudian, model tersebut dimasukkan ke dalam perisian Ansys bagi tujuan kajian. Model tulang belakang itu dikaji melalui tekanan dan lingkungan pergerakan.

Hasil kajian menunjukkan bahawa bahagian tulang toraks mempunyai ketahanan yang rendah kepada tekanan yang dikenakan berbanding bahagian tulang di lumbar. Berdasarkan binaan pituitari, lingkungan pergerakan yang selamat untuk pesakit adalah kurang daripada 30° bagi memelihara kadar hayat binaan tersebut. Di samping itu, pada daya 650 Pa menyebabkan lebih tekanan bertumpu pada bahagian binaan dan menyebabkan gangguan kepada struktur binaan tersebut berbanding pada daya 450 Pa.

IMPLICATIONS OF PRESSURE AND RANGE OF MOTION ON POSTERIOR FIXATION OF THORACOLUMBAR BURST FRACTURES

ABSTRACT

The surgical treatment for thoracolumbar burst fracture by using posterior construct is commonly practised respect to certain cases. Different cases have different spine fixation treatments which suitable to the patient condition and injury levels. Despite that, the consequence of those constructs is still less known on the biomechanics side. The purpose of this study is to analyse the effect of pressure on thoracolumbar spine fixation specifically on the tenth thoracic (T10) to the fifth lumbar (L5) due to implantation using posterior construct. Range of motion of the patient is studied to prevent excessive daily routines or activities that may affect the construction of the spine. A 3D model of thoracolumbar spine from thoracic 10 to lumbar 5 (T10 - L5) was used to evaluate the changes in the biomechanics of the spine segments. First, the model is obtained from the DICOM file of a patient which then extracted leaving the specified segments. Next, the model is imported in Ansys Transient Structural to analyse the changes. The model is validated on the von misses stress generated on the segments and the range of motion.

The result showed the thoracic part of spine segment has low resistance towards pressure applied than lumbar area. According to pedicle construct, burst facture patient need to restrict the movement less than 30° of flexion to prolong the implantation life. Additionally, the pressure of 650 Pa exerted on the affected area has higher stress concentration and deformation than pressure at 450 Pa.

CHAPTER 1

INTRODUCTION

1.1 Overview

Over the years, researches have been carried out actively to find the solution or ways to reduce the trauma caused by spine injuries. Before any further details about treatment are discussed, the levels of injury need to be examined. According to American Spinal Injury Association (ASIA), there about five types of classified injuries such as ASIA A, B, C, D, and E. The spine injury may cause by some segments of bone fracture that affect the nervous system or spinal cord. Patient's injury will be evaluated based on the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) (American Spinal Injury Association , 2011).

Spine fractures usually resulted from blunt injuries, which can cause other long bones fractures too. A high index of suspicion must be maintained with palpation of all joints and bones during the examination. Full neurological examination such as sensation, motor, anal tone and signs of sacral sparing incomplete paraplegia should be done and documented repeatedly to look for and pick up neurological deficits and deterioration (R. W. J. Dashti et al., 2005).

Burst fracture or any other spine fractures can be examined by radiography, computed tomography (CT scan), magnetic resonance imaging (MRI) and X-ray. There are many types of spine fixations to tackle each problem such as interbody grafts and implants, total disk replacement, pedicular screws, posterior lateral fusion, and anterior lateral fixations.

Human spine as known as vertebral column consists of 26 bones separated by cartilage, adding with five sacrum bone and four coccygeal. The spine is divided into 5 region parts which are cervical, thoracic, lumbar, sacrum and coccygeal. As mention before, there are cartilages between the bones in the spine. It is known as an intervertebral disc. Intervertebral discs have two types of characteristics, one known as annulus fibrosus located at the outer shell and nucleus pulposus located in the middle which has a soft, pulpy area. Tough fibrocartilage that made the annulus fibrosus is to attach the vertebrae together and at the same time flexible to allow the movement. Besides, the nucleus pulposus functions like a shock absorber to bear the body’s weight and protect the vertebrae from painfully colliding or sliding into each other while under strain.

There are 5 main regions of the spine mention above and the name of vertebrae is taken from the first letter of them. Starting from cervical which consists of 7 vertebrae in the neck area to support the skull known as C1-C7. Next, the thoracic has 12 vertebrae (T1-T12) in the chest which form unique support of building the rib cage. The thoracic is less flexible even though it is larger and stronger than cervical vertebrae. Then, the 5 vertebrae of lumbar (L1-L5) form in the lower back which support all the upper body weight resulting in many back pains. It is larger, stronger and more flexible than thoracic. The sacral region consists of sacrum, is a bone that fused of 5 smaller vertebrae (S1-S5) happen during adolescence. It is located at the lower back between two hip bones and has a flat, triangular shape. The coccygeal region has coccyx, also a single bone made of the fusion of 4 vertebrae (C1-C4) during adolescence. The coccyx is referred to as human tailbone and it withstands our body load when we are sitting.

1.2 Problem Statement

The insertion of the pedicle screw limits the patient motion in everyday life. The patient may have difficulties to bend down at a certain angle. Furthermore, active lifestyle will affect the position and the strength of the screw as it will have a high chance of screw losing as it is placed on the weakest point of posterior fixation. Screw implementation may cause infection such as bacteria if it is not well treated and sterile. The pedicle screw also has a chance of the causing breakage because of load and pressure exerted on it

1.3 Objective

- To investigate the effect of a range of motion to pedicular screws, rods, and anterior cage from Thoracic 10 (T10) to Lumbar 5 (L5) level.
- To analyse Von-Misses stress and displacement of the thoracolumbar spine using finite element method
- To validate the maximum value of the range of motion (ROM), distribution of the implant stress, and the stress in the facet joint using the simulation data and comparison with the established database from the journal.

1.4 Scope of Work

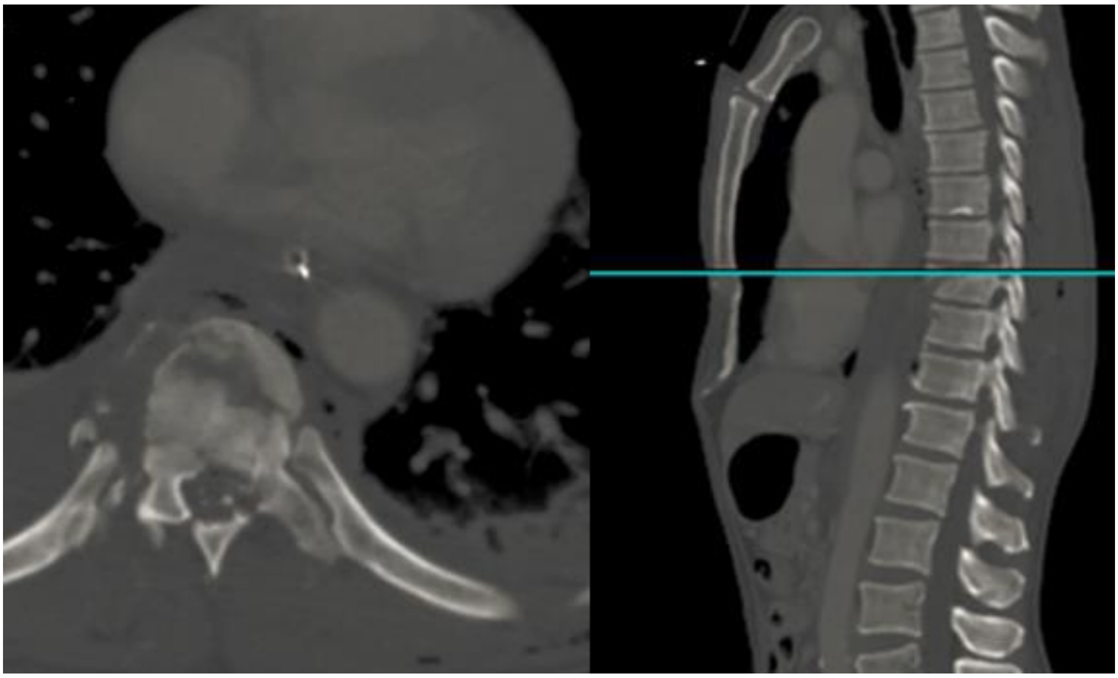
In this project, the implication of the pedicle screw to fix the thoracolumbar burst fracture will be studied. A 3D model of the thoracolumbar segment extracted from a CT scan will be generated by using Invesalius 3.1 and Autodesk Meshmixer. Next, it will be transferred to Ansys Structure software to study the finite element (FE) based on the different amount of pressure exerted on the screw. The maximum amount of stress and range of motion (ROM) will be determined. Results will be validated through the data from the simulation of Ansys structural software and compare with established data from the journal. Therefore, a solution will be estimated by applying pressure on the 3D model of the thoracolumbar segment in Ansys structure software to evaluate the von-Mises stress and range of motion (ROM) of the transpedicular screw.

CHAPTER 2

LITERATURE REVIEW

2.1 Burst Fracture

Burst fractures occur due to an axial loading force or blunt injuries causing in failure to support anterior, middle column and posterior which contribute approximately 20% of thoracolumbar fracture (J. C. Liao et al., 2017). Figure 2.1 shows a CT scan of a patient experiences thoracolumbar burst fracture where the fracture's segment is underlined (Orthobullets.com , 2018). Thoracolumbar burst fracture may happen along the spine between thoracic and lumbar bone segments such as from T10 to L4 referred to Figure 2.2 showing a 3D visualisation of the respective area (Tyndyk et al. 2007). In order to treat the injury, surgical correction with corpectomy and subsequent fusion of neighbouring levels is a commonly practised treatment for burst fracture injury (S. Elmasry et al., 2016). Short-segment pedicle screw instrumentation is an option widely used clinically to stabilize spine fractures (G. Xu et al., 2014). Among many implants available for posterior fixation, pedicle screws have proved their superiority as it is possible with their use to engage all three columns of the spine and effect reduction with a short segment to construct (N. Jindal and S. S. Sankhala. , 2012).



(a) Axial View (b) Sagittal view

Figure 2.1 Thoracolumbar Burst Fracture (Orthobullets.com , 2018)

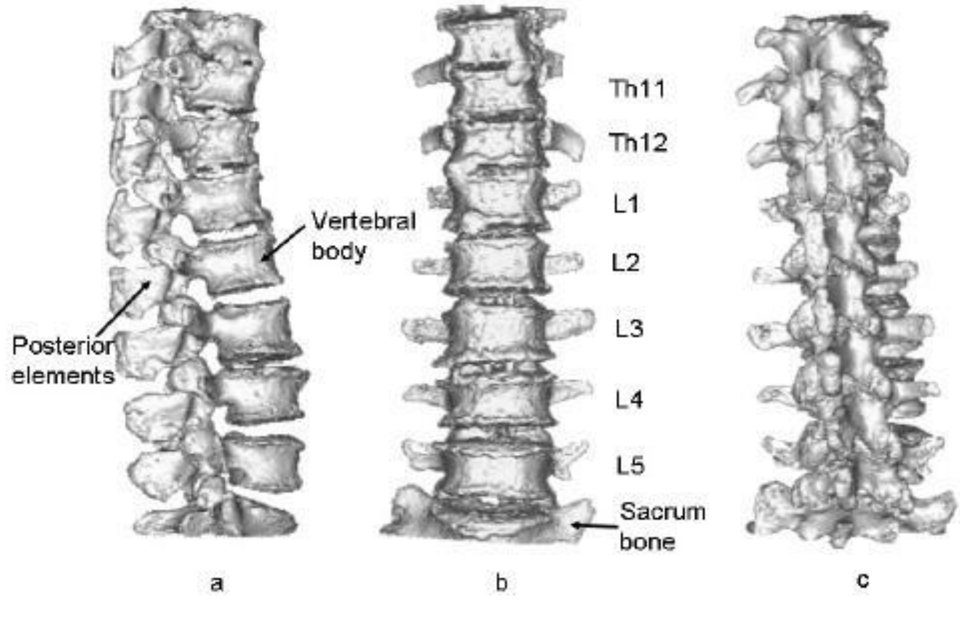


Figure 2.2 3D Visualisation of the Thoracolumbar Spine (Tyndyk et al. 2007)

Based on studies, spinal fractures majority occurs in thoracolumbar section and about 10- 20% of the injuries are burst fracture (A. A. Patel , 2010). A thoracolumbar burst fracture is synonyms to spine fixation using pedicle screw. The application of pedicle screw has been widely used in the clinical area of spine injuries such as fracture, tumour, and deformity. The use of the pedicle screw in treating unstable thoracolumbar burst fracture has been studied. As a result, short segment fixation with fracture level screw incorporation provided better correction and maintenance (O. Guven et al., 2019). However, the optimal use of the pedicle screw is understudied as the trajectory is still undetermined. Three trajectories of the pedicle screw and start points have been discovered which are anatomic, straightforward and straight ahead (A. Dhawan et al., 2008). Thoracolumbar burst fracture could affect on anterior, middle column and posterior segments. The anatomic and straightforward trajectories are studied to determine the optimal trajectory used in spine surgery specifically on thoracolumbar burst fracture. Both screws trajectories will be inserted on the sagittal plane to be investigated (R. A. Lehman et al., 2012). This surgery is meant to promote stability of the spine, the correction of sagittal deformity and neural. Nowadays, posterior rods, expandable cage, and transverse plate are chosen to insert with pedicle screws as they increase the chance of treating spine injuries (M. Sasani and A. F. Özer. 2009) , (M. Eleraky et al., 2011). Pedicle screw and posterior rods increase the ability in promoting bony purchase until the fusion mass stabilizes. Whereas, expandable cage helps to maintain anterior column reconstruction (M. Eleraky et al., 2011).

2.2 Experimental Study

In the previous study, the analysis for von-misses stress level and range of motion (ROM) on the pedicle screw was carried out and was written in an article by Shibab Asfour in 2016. A 3D model of the thoracolumbar segment was constructed from the CT Scan of a healthy male by using an image processing software called Mimics. Different fixations of pedicle screws were developed on the targeted segment such as (a) 2RPC construct; (b) 1RPC construct; (c) PC construct; (d) 2RC construct;

(e) constructs integrated with the intact lumbar spine. Each construct was replaced the intact spine levels (T12-L2) to generate the studied FE models referred to Figure 2.3 (S. Elmasry et al., 2016). Each of them was equipped with an expandable cage and transverse plate. The constructed segments were simulated with a flexion-extension moment to record the stresses exerted on them. Next, the constructed models were validated by comparing the range of motion (ROM) (J. P. Gjolaj et al., 2016). Von-Misses stress at all adjacent segments of the transpedicular screws was evaluated.

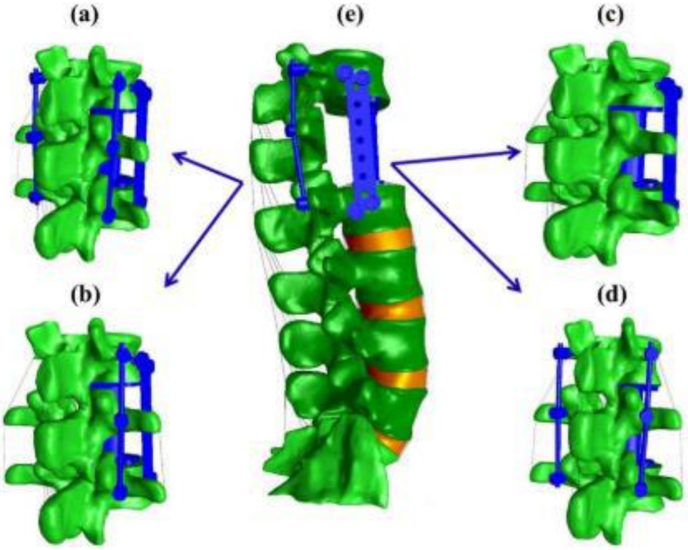


Figure 2.3 Thoracolumbar FE with different fixation constructs (S. Elmasry et al., 2016)

2.3 Material and Properties

Pedicle screw and the expandable cage are made of Titanium. Titanium has been used since the 1960s in the medical implant to replace stainless steel. Titanium is used to recover of biological tissue, dental implants, vascular stent implantation in cardiology and mostly used in screw implantation especially pedicle screw in spine fixation (A. Bergmark, 1989). Titanium is made of aluminium and vanadium or the aluminium and niobium combination which normally applied for the manufacturing of rods and spinal clamps (K. Kaur, 2013).

In comparison to stainless steel and Titanium, Titanium has better metal properties to be used in medical implantation. Stainless steel consists of nickel which may affect the body immune system as it will give adverse reaction (T. M. Stories, 2015). Hence, Titanium is the best replacement for it. Titanium is bacteria resistant, lighter in weight yet harder than steel, durable and has greater longevity (Supraalloys.com, 2018).

Titanium has 4.5 x 106 g/m3 of density. The ultimate strength, the elastic modulus of titanium is 220 MPa and 1.1600 x 1011 Pa. The Poisson’s ratio is 0.34. Thermal conductivity and specific heat capacity of titanium is 17 W/m K and 528 J/kg°C respectively as has been automatically setup in the material library in Ansys Structural.

For the thoracolumbar segment, the material needs to be added manually as the data did not occupy in the Ansys material library.

2.4 Computational Work

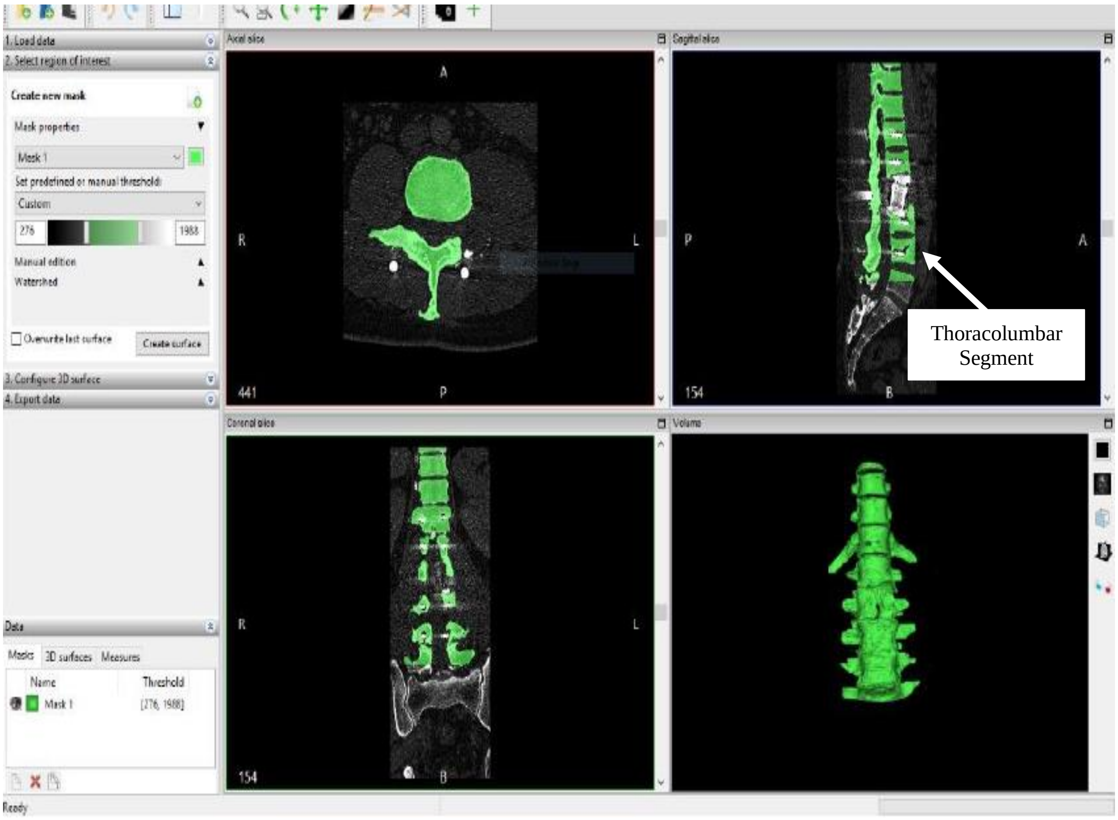
The transient structural analysis involves load function in time. In Ansys transient structural, varies mechanical can be used such as ABAQUS, Ansys Mechanical APDL to perform dynamic or rigid structure analysis. In Mechanical APDL Solver, the analysis is carried out to study the structural dynamic response of any general time-dependent load. Stress, strain and force can be determined through transient load. In computational, dynamic methods and stiffness methods take account to geometry stress. Finite element method evaluate the mechanical properties, the geometry and boundary conditions (V. Alic, 2018).

CHAPTER 3

METHODOLOGY

3.1 Experiment Setup

The model of a thoracolumbar segment, pedicle screw, and expandable cage are needed to be designed. The models were developed from a CT – Scan of a male patient in Dicom file. By using Invesalius Software, the scanned part was extracted to be a 3D part. There were about 800 layers of the scanned part which needed to be extracted one by one according to the needed region of the targeted segment, pedicle screw, and expandable cage. According to the figure below, three different slices of view. (1) Axial Slice (2) Sagittal Slice (3) Coronal Slice. Axial slice was referred to the top view, while the sagittal slice was the side view and coronal slice was the front view. The combination of these three slices has created a 3D surface of the respective parts as shown in Figure 3.1 and Figure 3.2. In Figure 3.1 shows the coloured region in CT of thoracolumbar from thoracic 10 to lumbar 5 (T10-L5). From the CT scan of a male patient's backbone, only the affected thoracolumbar section was extracted. Meanwhile in Figure 3.2, the pedicle crew and expandable cage area were coloured in the same CT scan to form 3D models.



Mask 1

Set predefined or manual threshold: Custom

276 – 1988

☐ Overwrite last surface

Name	Threshold
Mask 1	[276, 1988]

Figure 3.1 CT Scan of Thoracolumbar Segment

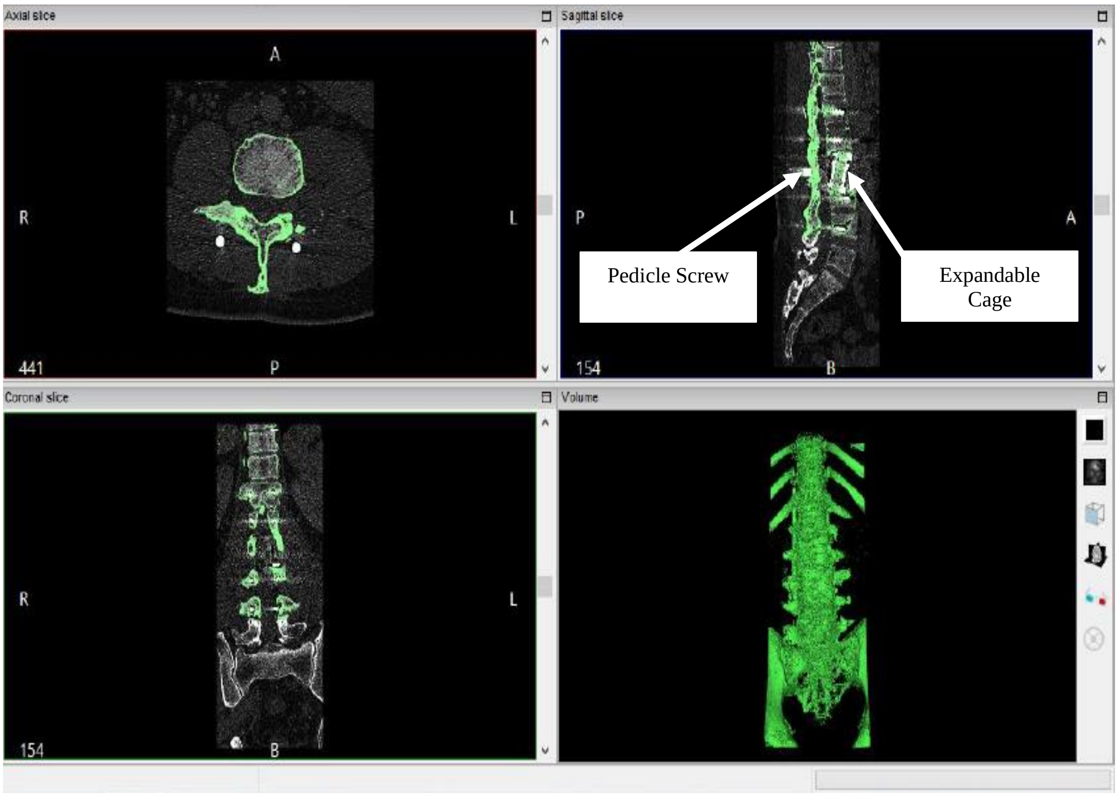


Figure 3.2 CT Scan of Pedicle Screw and Expandable Cage

The targeted segment, pedicle screw, and expandable cage were transferred to Meshmixer Software after completing the 3D models. Figure 3.3 illustrates the Meshmixer Software was used to fill the holes and to smooth the surfaces of bones. By using analysis features and select the inspector, meshmixer automatically check the hole and fill it. Same steps were repeated to the implant screw and the cage part. Some parts may need manual inspections and fill to generate. The completed file is saved in STL.

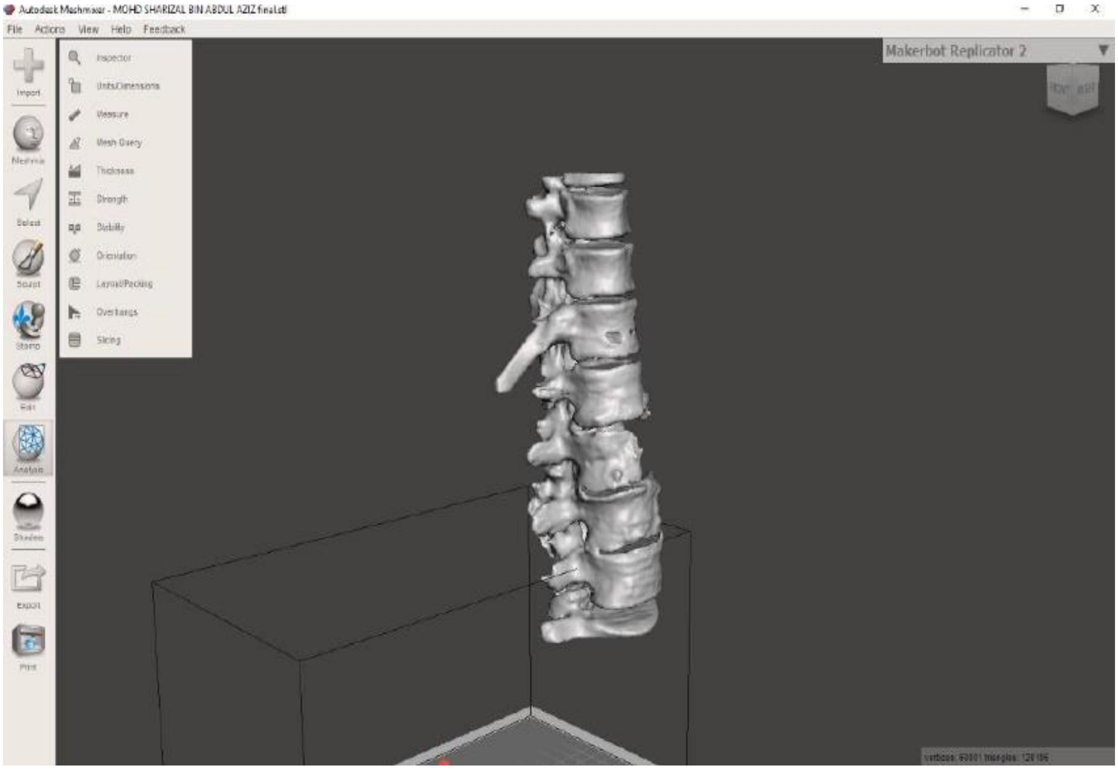
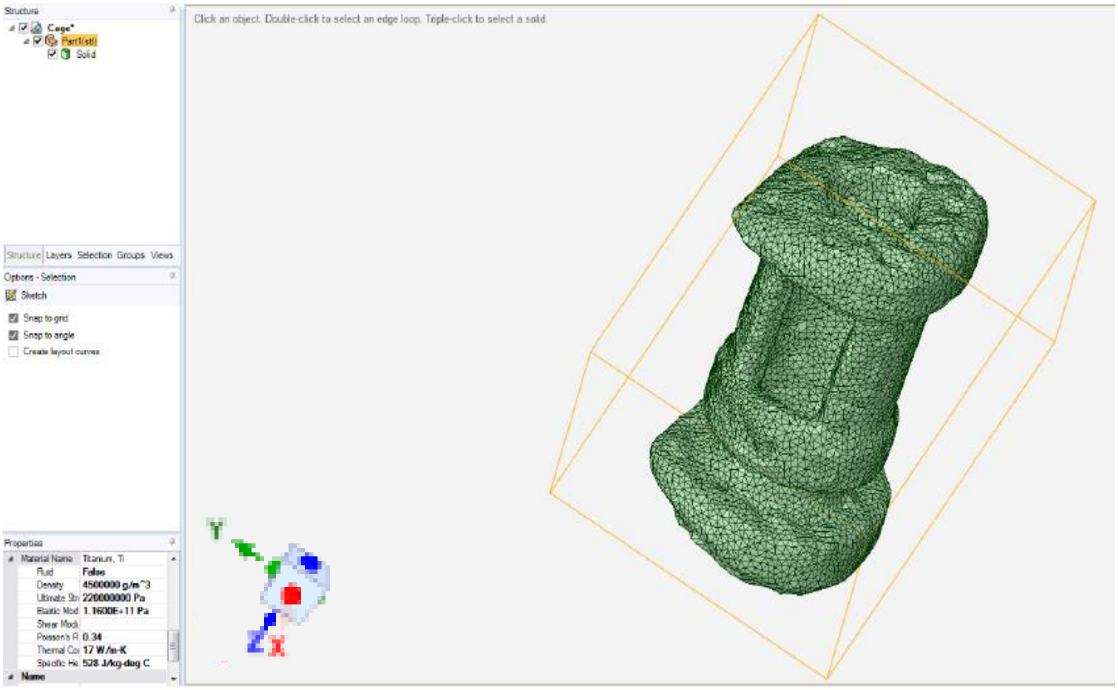


Figure 3.3 Filled and Smoothed Thoracolumbar Segment

Next, the STL parts of the thoracolumbar segment, pedicle screw, and expandable cage were opened in SpaceClaim to assemble. Each part was solidified before assembled to be one component. Figure 3.5 shows the assembled 3D solidified parts which has been combined to be a component.The parts were converted to solid to reduce the time for meshing and the error. Different orientation of loading applied to the spine such as flexion-extension, lateral bending and axial rotation moment in Ansys Structural by using the mechanical solver might cause a change of result on the model without spinal muscle (D. Mihov and B. Katerska, 2010). Next, the solid parts were then subjected to change the material properties.The material used for implant screw and cage is Titanium, while the material properties for bone was manually inserted according to research data. Engineering data in Ansys also was completed. Figure 3.4 displays the material properties of expandable cage which has been selected in the material library. For the thoracolumbar segment, the type of bone selected is cortical bone. The properties of the cortical bone are tabulated as below :

Properties	**Value**	**Unit**
Density	1.85E+00	g/cm^3
Ultimate strength		
• Longitudinal loading		
o Tensile strength	130	MPa
o Compressive strength	190	MPa
•Transverse Transverse loading		
o Tensile strength	50	MPa
o Compressive strength	130	MPa
Elastic Modulus	18.6	GPa
Shear Modulus	4.0 ± 0.4	GPa
Poisson’s ratio	0.3	
Thermal Conductivity	0.68 ± 0.01	W/mK
Specific Heat Capacity	1260	J/kgK

Table 3.1 Properties of Bone (Feldmann et al. 2018)

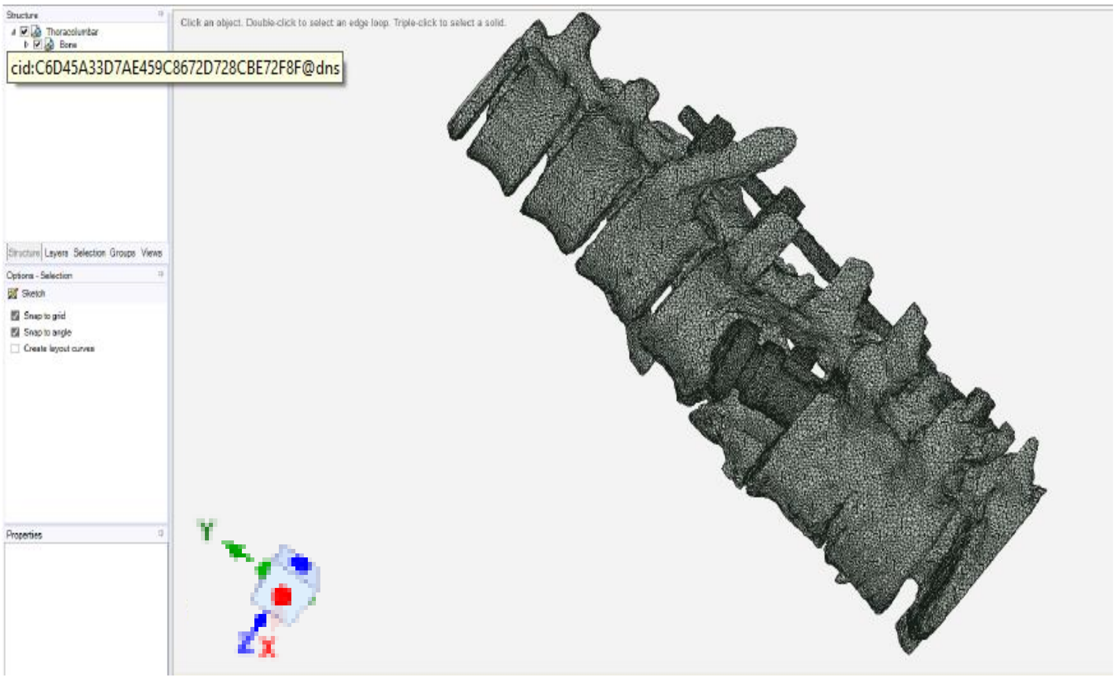


Click an object. Double-click to select an edge loop. Triple-click to select a solid.

☑ Snap to grid
☑ Snap to angle
☐ Create layout curves

Material Name	Titanium, Ti
Fluid	False
Density	4500000 g/m^3
Ultimate Str	220000000 Pa
Elastic Mod	1.1600E+11 Pa
Shear Mod	
Poisson's R	0.34
Thermal Co	17 W/m-K
Specific He	528 J/kg-deg C
Name	

Figure 3.4 Properties of Expandable Cage



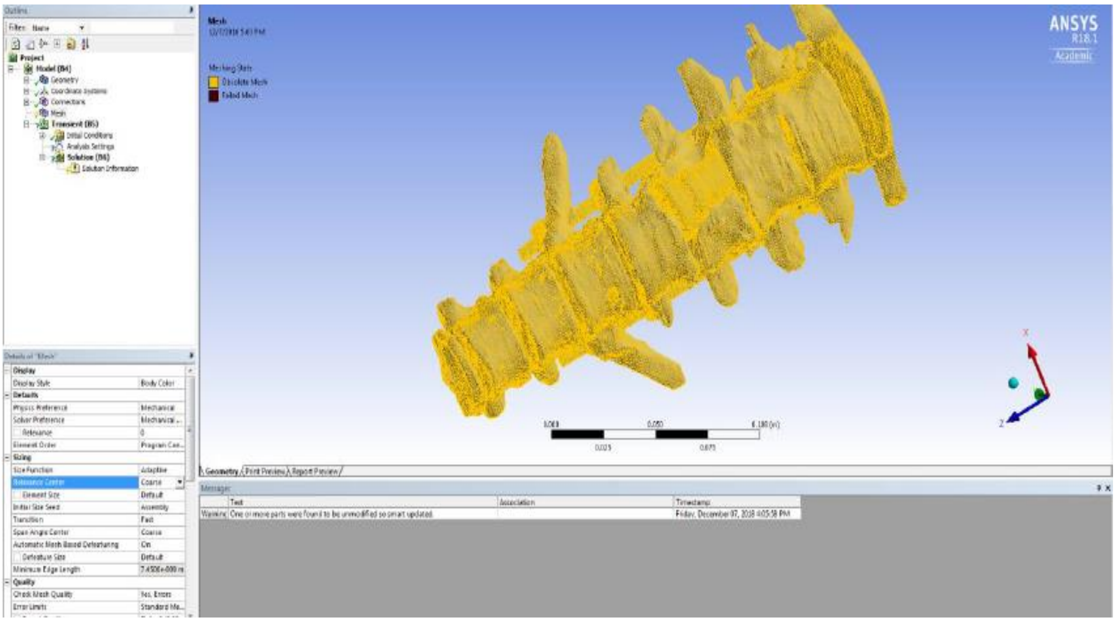
cid:C6D45A33D7AE459C8672D728CBE72F8F@dns

Click an object. Double-click to select an edge loop. Triple-click to select a solid.

☑ Snap to grid
☑ Snap to angle
☐ Create layout curves

Figure 3.5 Assembled Part

After assembling was completed in SpaceClaim, Ansys Workbench was launched, transient structural was chosen. The geometry of the assembled part was uploaded again by SpaceClaim. The modal was selected and the progress of opening the part taken place. The assembled part was then beginning to mesh. Meshing completed with 546643 elements without any changes setting in detail of mesh as the pre-step. The course mesh was choosen for the pre-step and hexahedral quadratic elements was choosen due to stability and influenced to the degree of refinement of the mesh (A. Ramos and J. A. Simões, 2006).

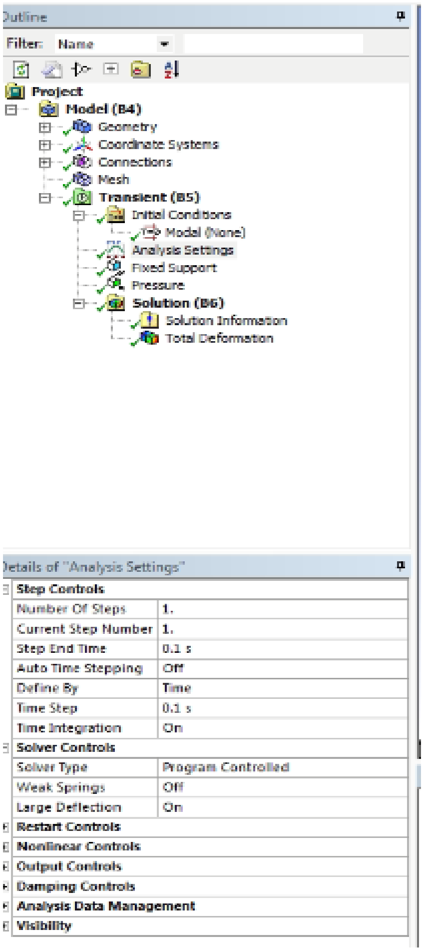


Display	
Display Style	Body Color
Defaults	
Physics Preference	Mechanical
Solver Preference	Mechanical ...
Relevance	0
Element Order	Program Con...
Sizing	
Size Function	Adaptive
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Assembly
Transition	Fast
Span Angle Center	Coarse
Automatic Mesh Based Defeaturing	On
Defeature Size	Default
Minimum Edge Length	7.4506e-009 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Me...

	Text	Association	Timestamp
Warning	One or more parts were found to be unmodified so smart updated.		Friday, December 07, 2018 4:05:58 PM

Figure 3.6 Thoracolumbar Meshed Model

The next step was setting up the analysis setting in the model (Mechanical) as shown in Figure 3.7. This setup was crucial to determine the result as the simulation would run according to what it has been set. If the setup was unsuitable or couldn’t be run, there were errors would be pop up in the message box. For this experiment, the fixed support was placed at the bottom of L5 as shown in Figure 3.9 and pressure load was assigned at the side of the thoracolumbar such as in Figure 3.8 . To apply the fixed support and pressure load, the specified faces on the geometry need to be selected. Then, the setup was run at the solution which total deformation and von misses were selected. When the simulation has completed, total deformation and von misses were selected again to view the result as shown in Figure 3.10.

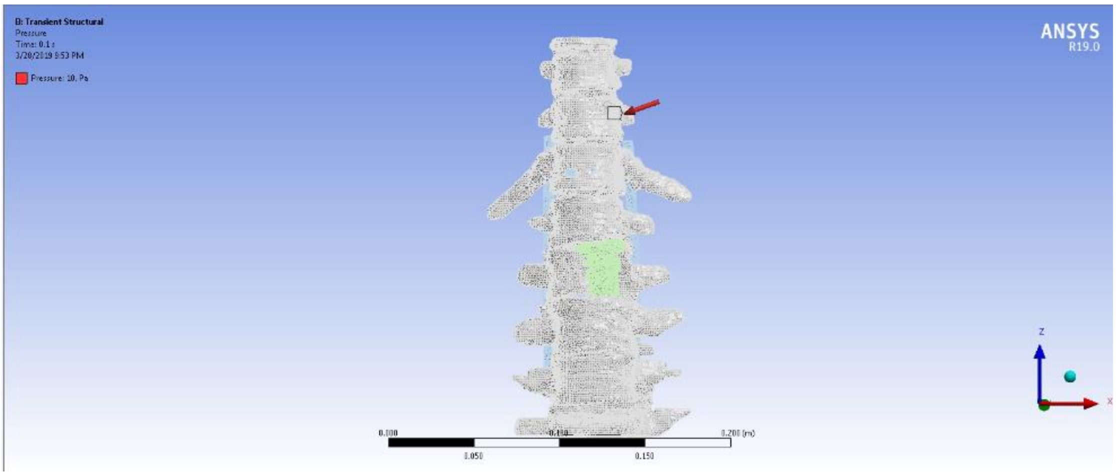


- Project
  - Model (B4)
    - Geometry
    - Coordinate Systems
    - Connections
    - Mesh
    - Transient (B5)
      - Initial Conditions
        - Modal (None)
      - Analysis Settings
      - Fixed Support
      - Pressure
      - Solution (B6)
        - Solution Information
        - Total Deformation

etails of "Analysis Settings"

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	0.1 s
Auto Time Stepping	Off
Define By	Time
Time Step	0.1 s
Time Integration	On
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Large Deflection	On
Restart Controls	
Nonlinear Controls	
Output Controls	
Damping Controls	
Analysis Data Management	
Visibility	

Figure 3.7 Setup of Analysis Setting


B: Transient Structural
Pressure
Time: 0.1 s
3/20/2019 9:53 PM

🟥 Pressure: 10. Pa

Figure 3.8 Pressure Applied at Thoracolumbar Segment

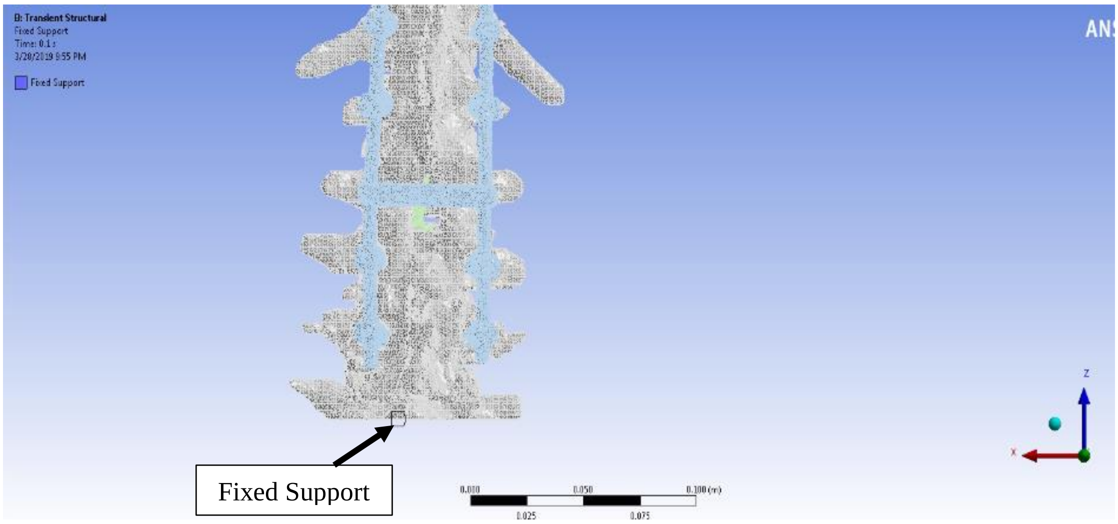


Figure 3.9 Fixed Support

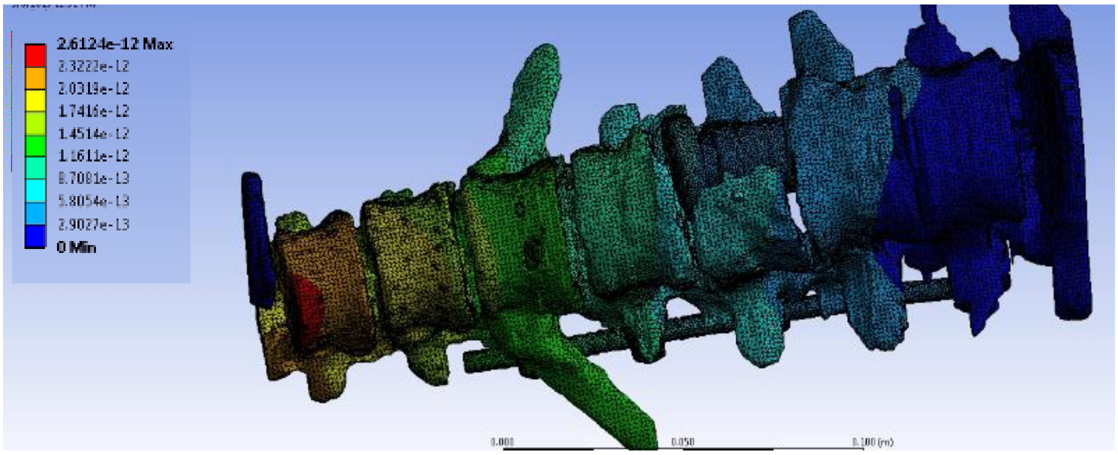


Figure 3.10 Result

As mention above, setting up the analysis would affected the results. Every simulation run need proper set up as the load was applied at various positions. Improvement in setting up the analysis has been done with respect to the different positions and load applied to have a converge and better result. In pre-step, the step end time was set to 0.1 s yet it was unsuitable setup to run the simulation as it involved multiple pressure and time variant. So, define by time in analysis setting was changed to substep and the step end time was changed from 0.1 s to 100 s. The pressure from 4.5 Pa, 5 Pa, 5.5 Pa, 5.5 Pa, 6 Pa and 6.5 Pa were applied at 5 selected positions on the thoracolumbar as shown in Figure 3.11.

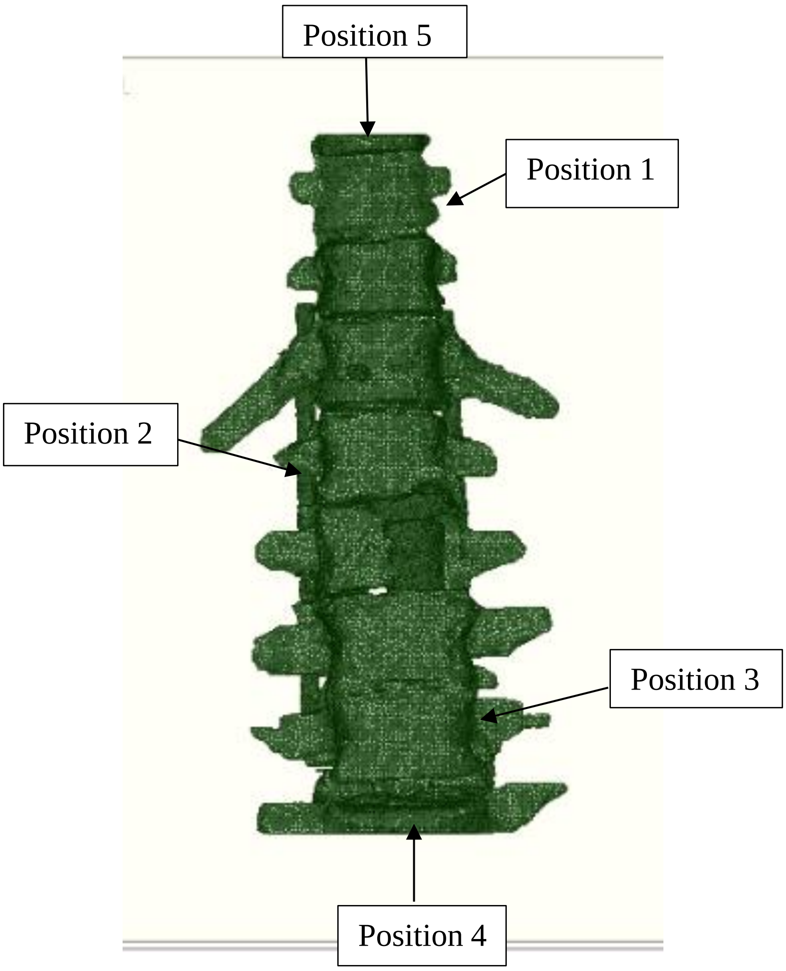


Figure 3.11 Positions on Thoracolumbar

The pressures were set varied to time in tabular. The 5 positions which pressure applied were at T10, T11, L1, L3, and L5 along the thoracolumbar segment. Then, the simulation was run 5 times for each position respected to a variant of time and pressure. The results of von misses and total deformation were recorded after each simulation completed. For a range of motion setup, the pressure was exerted on position 2 with 5 different angles. The angles were 5°, 15°, 30°, 45° and 60° with a fixed pressure of 6.5 Pa for 10s each. Phythagoras theorem theory was applied to set the angle. Figure 3.12 illustrates the range of motion to achieve 30° angle was setup where a fixed pressure of 6.5 Pa applied on Y-axis while 3.75 Pa was applied on Z-axis. So, the tension resulted a 30° angle. Y-axis is set to constant pressure of 6.5 Pa, while Z-axis is varied to get certain angles. The direction of movement set was forward bending at Lumbar 1 (L1).

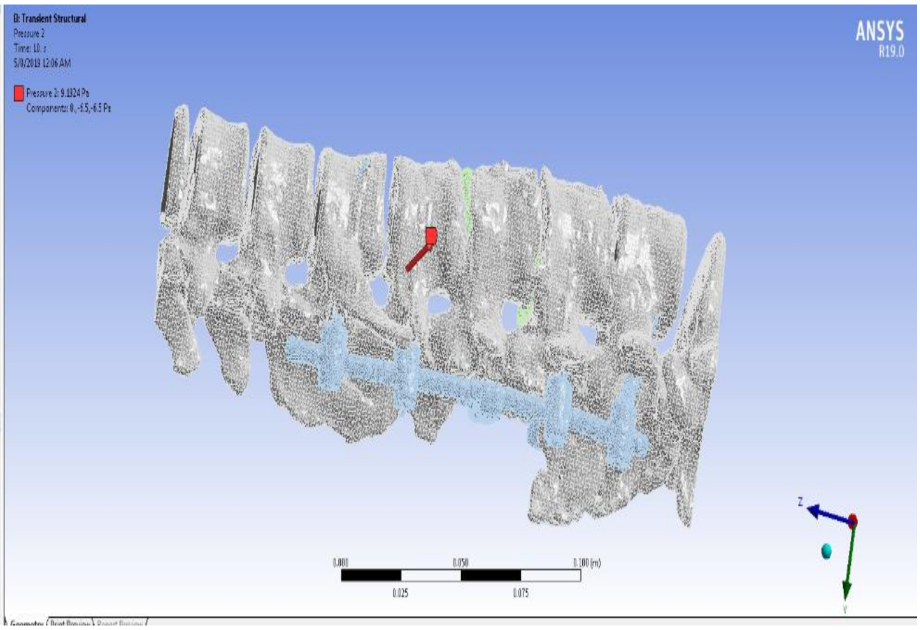


Figure 3.12 Range of Motion Angle Setup in Forward Bending

For a better result, the pressure values have been increased to 450 Pa, 500 Pa , 550 Pa, 600 Pa and 650 Pa which were more suitable than before as the previous pressure derive low result in von misses and deformation. All the simulations were carried before is set again by using the latest pressure values for better result.

3.2 Mesh Dependancy Study

Mesh dependancy study was tested by using different type of mesh and different number of elements. There were five number of elements being setup with 3 different type of meshes which started with course, medium and fine. The test was started with course mesh and ended with fine mesh at position 2 with various pressure applied. The element sizes are set from reducing the element size of 559645 to increase it by 70,000.

3.3 Flow Chart

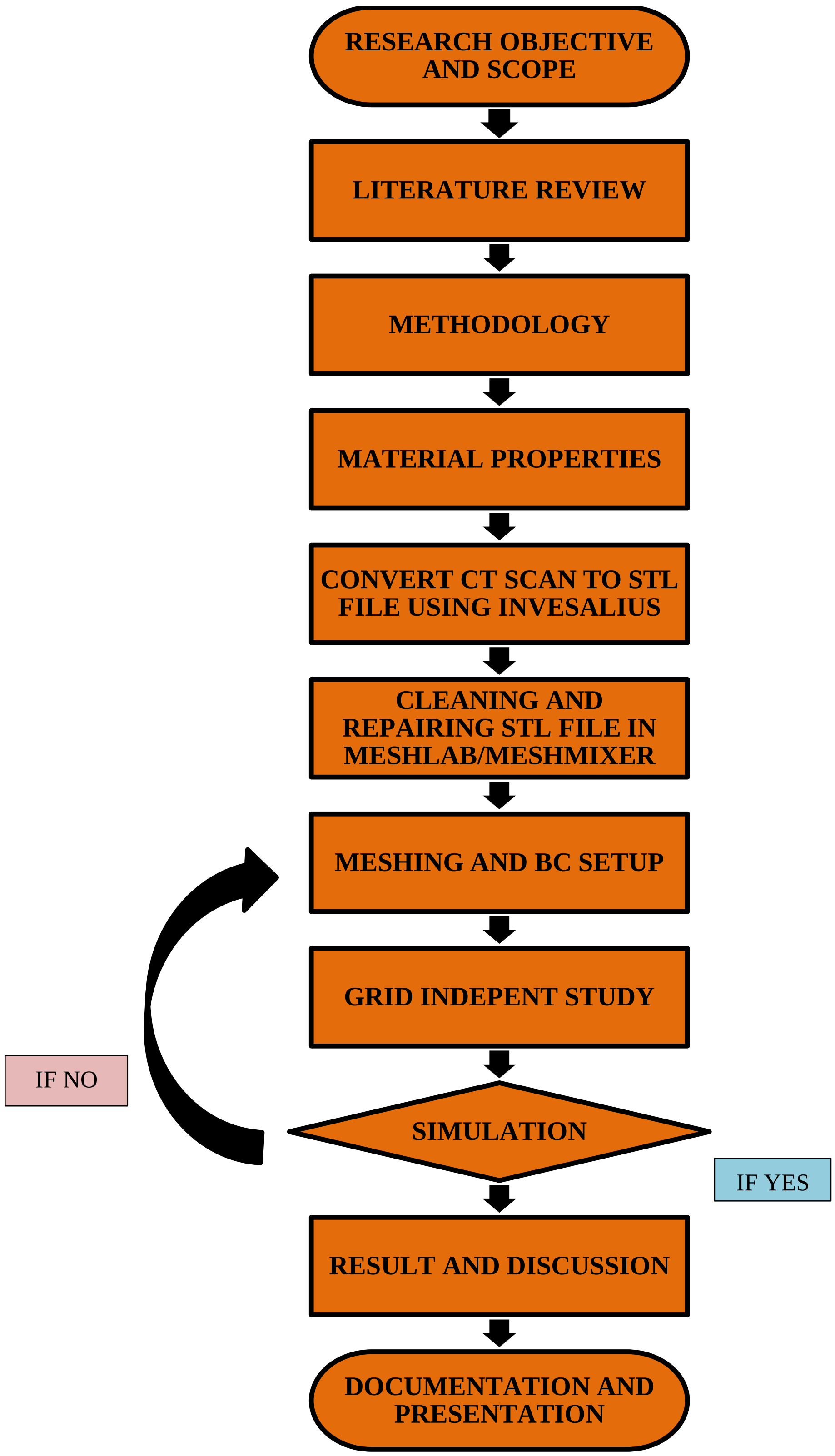


Figure 3.13 Flow of the progress

For this project, Ansys Transient Structural is used as for the thoracolumbar structure solver. The analysis consists of five steps :

I. Geometry : CT Scan is converted to STL file. Only specified part of thoracolumbar from T10 – L5 is selected.
II. Meshing : The type of mesh is selected where the division of the domain in a number of points where the solution is calculated.
III. Material properties and boundary condition is defined
IV. Perform and monitor the simulation for completion
V. Post processing and validation of results.

The structural of thoracolumbar segment, the properties of bone and the material properties of implantation are defined. The grid generation involved defining the structure which affected the accuracy of the solution and the calculation time. Pressure was exerted on some parts on the thoracolumbar and boundary conditions is set to simulate stress and deformation distribution on the selected areas.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Mesh Dependancy Study

Mesh dependancy study is carried out to decide the most suitable grid to use for the simulation. As mention before, different type of mesh with different number of elements is used for this study. The elements are tabulated as below :

Element	Element numbers
E1	419 645
E2	489 645
E3	559 645
E4	629 645
E5	699 645

Table 4.1 Number of Elements

These are the elements used alternately with different type of mesh starting with course, medium and fine mesh. C1-C5 are for course mesh using element 1 (E1) until element 5 (E5). Next, continue with medium mesh (M1-M5) and lastly fine mesh (F1-F5).

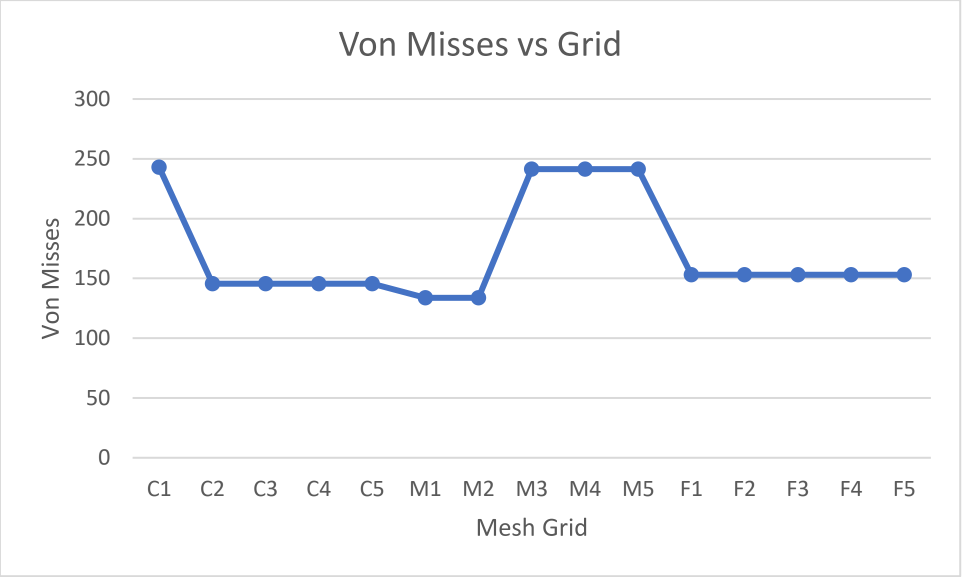


Figure 4.1 Graph of Von Misses vs Grid

For Figure 4.14 graph von misses against grid, course mesh and fine mesh is constant for some elements. For course mesh, from element 2 until element 5 has shown a constant value of 145.43 N/m. Meanwhile, by using fine mesh, all elements used has shown constant value of 153.02 N/m.

From graph result, by increasing the grid size across different types of mesh grid, the values reach the most stable in fine mesh where all elements tested obtained a constant result. Both course and fine mesh shows constant result but fine mesh is choosen. This is because high density mesh, produce in high accuracy result. The fine mesh has better coverage on critical area and suitable for non-linear structure.

4.2 Position on thoracolumbar

There are about 5 positions chosen to evaluate the effect of a pressure on different positions on the thoracolumbar. The first position (P1) is at the side of thoracic 10 (T10), the second position (P2) is at the side of lumbar 1 (L1) which located above the implant cage while the third position (P3) is at the side of lumbar 4 (L4). The fourth position (P4) is at the bottom of lumbar 5 (L5) and lastly, the fifth position (P5) is at the upper part of thoracic 10 (T10). Figure 4.1 illustrates the details about positions as stated above. Figure 4.2 shows the stress concentration at the affected parts of thoracolumbar which has been enlarged.

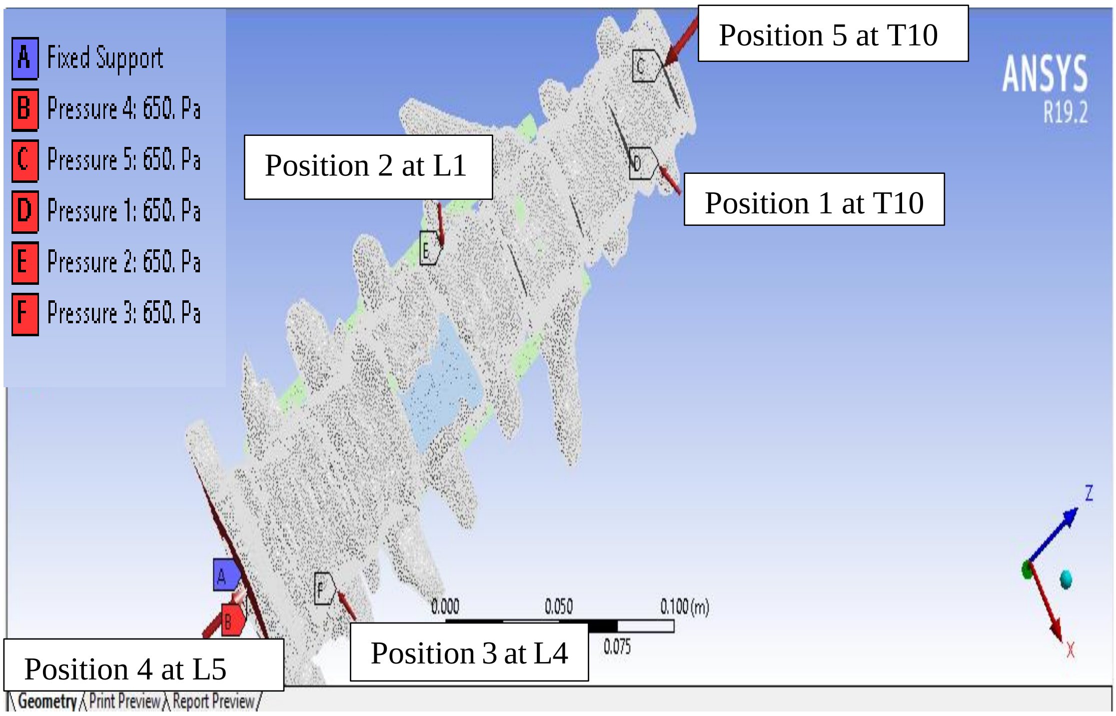


Figure 4.2 Position on Thoracolumbar with Pressure