FINITE ELEMENT ANALYSIS OF LUMBAR SPINE

FAIRUL IDZWAN BIN MOHD ROSNI

Report submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

N	Force
mm	Displacement
MPa	Megapascal
L1	Lumbar 1
L2	Lumbar 2

LIST OF ABBREVIATIONS

FEA	Finite Element Analysis

ABSTRACT

Three-dimensional models of the one and two vertebrae were developed to clarify the mechanical cause of low back pain. The lumbar structures produced allowed the simulation by the performance of finite element analysis of different situation movement. The purpose of this study was to analyze the highest stress concentration on lumbar spine L1 and L2. However, little information is focused on the stress concentration on the axial compression and complex movement. This study stress concentration of the lumbar spine of L1-L2 by using the commercial software MSC Patran software for pre and post processor and MSC Nastran to solve the finite element analysis. Another scope is focus on 3D solid body of lumbar spine. Along with the increase in use of the finite element method has come a corresponding increase in its potential. There are several important keys to the proper application of any numerical method. The geometry, material properties and boundary condition is a technique to solve the finite element analysis that must have in finite element method. The loading conditions were that 450 N for axial compression and 150 N with 10 Nm for flexion, extension and lateral bending respectively were imposed on the superior surface and facet joints of the L1 vertebral body. The bottom of the L2 vertebral body was fixed in all direction completely. The variable meshing also been analyze of tetrahedral 10 and tetrahedral 4 this due to get optimize result on the analysis. In the starting position, the spines were found to be relaxed without any movement. As the axial compression been applied with increase of force the spine the displacement also will increases. The data have been compared with literature that seems good agreement for the result. Then flexion, extension and lateral been analyze to get the stress concentration since tetrahedral 10 is optimize to the geometry the analysis seen was found in pedicles, laminar and spinous processes on the Von mises stress as a parameter. From the research that can be conclude is the finite element analysis has the same result with the experiment that can compare with other journal. It also can be help in the clinical to cure the patients. It easy to know which part injured happen in lumbar spine and why.

ABSTRAK

Model tiga dimensi daripada satu dan dua vertebra dibangunkan untuk mengklarifikasi penyebab sakit tulang belakang. Struktur tulang belakang dihasilkan bagi membolehkan simulasi dijalankan oleh prestasi analisis elemen hingga gerakan situasi yang berbeza. Tujuan kajian ini adalah untuk menganalisis ketumpuan ketinggian tekanan pada tulang belakang lumbar L1 dan L2. Namun, sedikit maklumat difokuskan pada tumpuan tegangan pada mampatan paksi dan gerakan yang kompleks. Tekanan tertumpu pada tulang belakang lumbar L1-L2 dengan menggunakan perisian komersial perisian MSC patran untuk prosesor pra dan pasca dan MSC Nastran untuk menyelesaikan analisis. Skop lain adalah fokus pada 3D tulang belakang lumbar. Seiring dengan peningkatan penggunaan kaedah analisis telah datang sesuai peningkatan potensinya. Ada beberapa kunci penting untuk pelaksanaan yang tepat dari setiap kaedah berangka. Sifat-sifat geometri material, dan keadaan had adalah teknik untuk menyelesaikan analisis unsur hingga yang harus ada dalam kaedah unsur hingga. Keadaan pembebanan adalah bahawa 450 N untuk mampatan paksi dan 150 N dengan 10 Nm untuk fleksi, sambungan dan bengkok ke kiri atau ke kanan yang dikenakan pada permukaan superior dan sendi tubuh vertebra L1. Bahagian bawah badan vertebral L2 itu tetap di segala arah. Pembolehubah sejaring juga telah menganalisis tetrahedral 10 dan tetrahedral 4, ini kerana untuk mendapatkan hasil analisis yang optimum. Dalam posisi awal, tulang belakang adalah dalam keadaan tanpa melakukan gerakan apapun. Apabila mampatan paksi dikenakan dan ditingkatkan berlakunya peningkatan daya dan pemindahan diantara tulang belakang. Data yang telah dibandingkan dengan berdasarkan kajian sebelum ini menampakkan hasil yang sama. Kemudian fleksi, sambungan dan bengkok telah menganalisis untuk mendapatkan tumpuan tekanan sejak tetrahedral 10 sejaring digunakan adalah optimum kepada geometri dilihat ditemui di kawasan pedikel, laminar dan proses spinouns. Manakala tekanan Von mises sebagai parameter. Dari kajian yang dapat disimpulkan adalah analisis elemen memiliki hasil yang sama dengan percubaan yang boleh membandingkan dengan jurnal yang lain. Hal ini juga dapat membantu dalam klinikal untuk merawat pesakit. Hal ini bagi memudahkan untuk mengetahui bahagian mana berlakunya kesakitan pada tulang belakang lumbar dan mengapa hal ini berlaku.

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The understanding of the positions of lumbar spine is necessary when the spinal spatial configuration, posture, motion and loading are estimated. The functions of the lumbar spine are to provide flexibility, support of the upper body weight, and protect the spinal cord and nerve roots (Chen-Sheng Chen a. 2001). With increasing costs of low back pain and spinal disorders, spinal loading during daily life activities is on the focus of present ergonomic research.

Some disease and several loads may cause compression in vertebrae and make the spine become unstable. These vertebrae of lumbar spine are carry the most amount of body weight and are subject to the largest forces and stresses along the spine. As an important human load bearing structure, the lumbar spine has a variety of clinical manifestations because of its complex physical structure. And that is mainly related to congenital physical structure of the lumbar vertebrae and its load bearing in the whole spine. The mechanical load can aggravate low back pain and disc degeneration (Videman T. 1990). Therefore, in clinic, many methods of bone fusion or non-fusion fixation are applied to achieve anatomical reduction and fixation, thus increase three-dimensional stability of the spine (Zhang and Chen et al. 2007). Using the three-dimensional numerical analysis and test the state of stress and deformation of the spine under the actual stress, is an effective way to obtain mechanical changes under a variety of force.

This study attempted to further investigate the mechanical behavior of lumbar spine by finite element method (LI Zhuo-dong. 2009).

Finite element analysis (FEA) was first proposed by Richard Courant in 1922 ironically during an era in which the method was impractical due to the laborious process of solving linear systems of equations by hand. It was not until the advent of the digital computer in 1942 that the method became practical. Indeed, John Argyris is usually credited with making the method suitable for nontrivial problems in the early 1950s when he published a series of papers outlining the technique and realized the critical role that computers would play in the viability of the method. Although the finite element method gained popularity in many engineering disciplines throughout the 1950s and 1960s, it was not until 1973 that the technique was applied to the human spine. However, little information has focused on stress alteration of the lumbar spine. (Steven and Avram 2006)

1.2 PROBLEM STATEMENT

The vertebrae are a complex shaped structure whose mechanical behavior is not clearly understood. It has been argued that a clarification of the mechanical causes of low back pain requires the knowledge of the states of stress throughout the lumber region. Therefore, in order to help explain the structural changes that accompany the degenerative process, this study proposes to analyze stress alteration of the lumbar spine by using the finite element method. The important of this study is to get some additional information of the lumbar spine, a doctor become easy to operate the patient when do the operation.

1.3 OBJECTIVE OF THE RESEARCH

The objectives of the research are to analyze the highest stress that concentration on the lumbar spine L1 and L2 (L1-L2). Also to investigate which location will be high stress concentration if the movement of axial compression, flexion, extension and lateral bending. Furthermore is to investigate the different size of meshing to get the optimum size for the accuracy result.

1.4 PROJECT SCOPE

This focus is base on the following aspect:

(i) Limited to male age between 20 until 30 years old.
(ii) Average weight for male around 63kg until 81kg.
(iii) Average height for male is 163.5cm.
(iv) Focus on 3D solid body of lumbar spine
(v) Perform a simulation test by using finite element method.
(vi) Analyze the problem by using MSC Patran software for pre and post processor.
(vii) Solve the problem by using MSC Nastran software.
(viii) Numerical method only not for the experiment.

1.5 SIGNIFICANT OF THE RESEARCH

When research is complete more information will get from the finite element analysis. From the way complex movement and variable loading been applied. Another than that, it will easy for the clinical to know which part of location that patient have problem.

References

Adams M.A., Dolan P., Recent advances in lumbar spinal mechanics and their clinical significance, Clin. Biomech. 10 (1995) 3–19.

Chen-Sheng Chen a, Cheng-Kung Cheng a,*, Chien-Lin Liu b, Wai-Hee Lo b, Stress analysis of the disc adjacent to interbody fusion in lumbar spine, Medical Engineering & Physics 23 (2001) 483–491

Christian Wong*, Martin Gehrchen P., Tron Darvann, and Thomas Kiær. Nonlinear Finite-Element Analysis and Biomechanical Evaluation of the Lumbar Spine. VOL. 22, NO. 6, JUNE 2003

Dong Suk Shina, Kunwoo Leea, Daniel Kimb, 2007, Biomechanical study of lumbar spine with dynamic stabilization device using finite element method, Computer-Aided Design 39 (2007) 559–567.

Frymoyer JW, Pope MH, Clements JH, et al. Risk factors in low-back pain. An epidemiological survey. J Bone Joint Surg Am 1983;65 (2):213-218.

Falk M¨orl a,∗, Heiko Wagner b, Reinhard Blickhan b, 2005, Lumbar spine intersegmental motion analysis during lifting, Pathophysiology 12 (2005) 295–302.

Hutton D. V., Fundamental of Finite Element Analysis (2004) p364 -368

Jaw-Lin Wang, PhD,* Mohamad Parnianpour, PhD,† Aboulfazl Shirazi-Adl, PhD,‡ and Ali E. Engin, PhD,§)Viscoelastic Finite-Element Analysis of a Lumbar Motion Segment in Combined Compression and Sagittal Flexion Effect of Loading Rate.

Jun Yaoa, Sergio R Turteltaubb, Paul Ducheynea. A three-dimensional nonlinear finite element analysis of the mechanical behavior of tissue engineered intervertebral discs under complex loads Biomaterials 27 (2006) 377–387

Jia-can SU, Zhuo-dong LI, Lie-hu CAO, Bao-qing YU, ZHANG Chun-cai and LI Ming, Three-dimensional finite element analysis of lumbar vertebra loaded by static stress and its biomechanical significance, Chinese Journal of Traumatology 2009; 12(3):153-156

Kelsey JL, Githens PB, White AA 3rd, et al. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. J Orthop Res 1984; 2 (1):61-66.

Kim-Kheng Lee, Tian-Xia, Qiu, Ee-Chon Teo) International Journal of Information Technology Vol. 8, No. 2 September 2002

Nabhani* F., Wake M. 2002, Computer modelling and stress analysis of the lumbar spine, Journal of Materials Processing Technology 127 (2002) 40–47.

Videman T, Nurminen M, Troup JD, et al. 1990 Volvo Award in clinical sciences. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation and physical loading. Spine 1990;15(8):728-740.

Stokes I.A.F., in: Proceedings of the First International Workshop on the Contribution of Biomechanics to the Prevention and Treatment of Low Back Pain, Clin. Biomech. 12 (1997) 195–197.

Steven M. Kurtz, Avram A Edidin 2006. Spine technology handbook

Stress analysis of the disc adjacent to interbody fusion in lumbar spine. Medical Engineering & Physics 23 (2001) 483–491

Shepherd D.E.T., Leahy J.C., Mathias K.J., Spinous process strength, Spine 25 (3) (2000) 319–323.

Wong* C, P. Martin Gehrchen, Tron Darvann, and Thomas Kiær, Nonlinear Finite-Element Analysis and Biomechanical Evaluation of the Lumbar Spine, IEEE Transactions on Medical Imaging, vol. 22, no. 6, June 2003

Zhang F, Chen BQ, Ju JW, et al. Biomechanical comparison of the initial stability after anterior, posterior and transforaminal interbody fusion with and without posterior pedicle
instrumentation. J Med Biomech 2007;22(3):302-305.

Zeng XL, Peng L, Bai J. Three-dimensional finite element modeling and analysis of human L3-L4 lumbar segment based on CT data. Beijing Biomed Eng 2007;26(3):266-269.

Zheng-Cheng Zhonga, Shun-Hwa Wei a, Jung-Pin Wang b, Chi-Kuang Feng c, Chen-Sheng Chena,∗, Chung-huang Yu a, 2006, Finite element analysis of the lumbar spine with a new cage using a topology optimization method, Medical Engineering & Physics 28 (2006) 90–98.

Zienkiewicz O.C and Taylor R.L. 2000. The Finite Element Method, Fifth edition, Volume 1: the basis