Computer Aided Modeling of Lombosacral Vertebra for Lower Back Pain

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ABSTRACT

Vertebral column is an important part of human body. Body posture depends on the vertebral column. It bears the load of human body & helps human being to perform day to day activities. It also acts as shock absorber. Any injury to the vertebral column leads to the vertebral wedge fracture, cervical pain, lower back pain or spondylysis etc. The literature study shows that, most prone part of the vertebral column for the lower back pain is the lumbosacral region. The paper discusses the technique to generate the accurate 3-D model of lumber vertebra with the aim to strengthen the present practice of the orthopedic surgen. The 3-D model is generated from the slices of computer tomography (CT) scan images. Actual physical 3-D model is prepared by using rapid prototyping machines, it helps to minimize the problems during implantation or surgery. Doctor can plan the process of operation on the actual physical model. The development of actual physical model can reduce the need of MRI.The advanced engineering technique like FEM is used for the operated part to obtain the stress distribution & deformation under the various loading conditions. The decision capacity of doctors to suggest the proper prevention & precaution to the patient can be enhanced.

Keywords: Vertebral Column, Computer Tomographic, Rapid prototyping, Material Non-linearity, F.E. Model, Magnetic Resonance Image (M.R.I.), Biomechanics.

Introduction:

Vertebral column is a vital part of the human being. The whole posture of the body depends on it and its presence make it possible for the human being to perform the important movement of the various activities.

The vertebral column is made up of series of bones called vertebrae. Vertebral column is mainly divided into five regions : cervical , thorax, lumber , scral and coccygeal .The cervical or neck region is normally made up of seven bones, the thorax or chest region has twelve bones and the lumber or lower back regions is made up of five bones. The scral region consists of five fused bones & the coccygeal region three to five tiny bones. However variation in the number of vertibra can vary in few cases. The vertebral column bones are joined with each other by facet joint & in between the vertebral body a vertebral disc exist.

The vertebral column is curved in profile look like and elongated 'S' in shape as shown in fig. 1 The cervical & lumber region has a forward curve ,whereas thoracic region has a backward curve when viewed from the side.

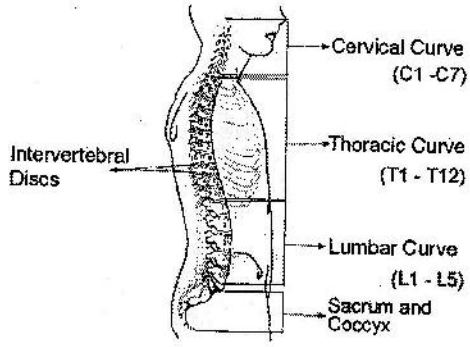


Fig: 1 : Side view of vertebral column

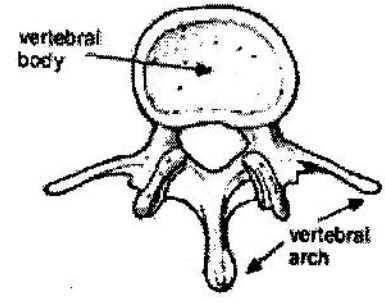


Fig.2 : Top view of vertebral body

Each vertebrae of the vertebral column is subjected to the various types of load and moments. These includes the load from the weight of body segment as well as from the weight being handled. The pattern of injury to vertebral column is the function of the type and size of the forces present at the time of injury.

SPINAL BIOMECHNICS:

There are four types of the forces acting on the vertebral structures.

1. Compression: A downward force on vertebrae compresses the disc and cause it to bulge and widen. The lifting of the excessive heavy load may cause the injury due to compressive force.
2. Tension: Tension pull apart the structures being loaded. The lower back pain is usually because of the tensile pull.
3. Shear: Shear force involves the application of load parallel to vertebral surface. Shear force are most commonly experienced in the lumbo- sacral region, because of forward and backward bending of body.
4. Torsional: The twisting movement of the spine causes soft tissues strain through the generation of large muscular force & load on the vertebral disc.

During manual handling a combination of compression, torsional, tension & shear forces occurs. Any abrupt change in the force may cause the diseases like vertebral wedge fracture, survical pain , lower back pain, spondylosis.

The literature review and discussion with various orthopedic surgeon reveals that most common site of the injury in the vertebral column is of lower back between L 4 / L 5 and L 5 / S 1 because of the rigidity of the pelvise and sacrum. These parts of vertebral column takes most of the strain during bending, twisting, & lifting action. Because of it Lower back pain, vertebral wage facture occurs. Doctor adopts X-Ray, CT - scan, MRI technique to locate the position of fault. But along with this information if a 3D model of the injured part is available with doctor. It helps greatly to decide line of action for the post treatment. In this paper an attempts is made to elaborate the approach to generate exact 3D model from the information of 3D CT scan images.A case study of a female patient suffering from lower backpain is illustrated to generate exact 3D model from the CT scan images .It helps doctors to visualise the post status of the operated part for better understanding.A physical model is prepared by using rapid prototyping technique[5].Advance engineering technique like FEM is adopted on geometrically similar feature model of single vertebra and in vertebral disc to determine the the stress bearing capacity [2].

BACKGROUND & LITERATURE REVIEW :

Earlier finite element models of Vertebral Column is treated as simple rigid masses connected by beam and spring element representing the invertebral dics, ligaments; Facet joints and muscles. Simple rigid masses do not produce realistic responses.

Ashrafivan H and Colbert R [1] presented paper " Modelling of deformable manikin neck for multibody dynamic simulation." In this paper author consider the human body as a rigid body for dynamic analysis. This model is used to predict the kinematic response of human body in the different environment.

Kumaresan S. , Joganandan Narayan, pintar Frank A [2] Studied "Finite Element analysis of cavical spine. A material property sensitivity study" with the objective to determined the effect of variations in the material properties of the cervical spinal components under physiologic load vector.

Yogannndan N., Kumaresan S.C. Voo Liming , pintar F.A. and Larsen S. J. [3] studied "Finite element Modeling of the C_4-C_6 cervical spine unit." To develop a detailed, three dimensional, anatomically accurate finite element model of the human cervical spine structure using close-up computed tomography scans and to validate against experimental data.

Tobias P, Dieter M and Wolf I [4] presented paper "Posterior element injury and cervical spine flexibility following anterior cervical fusion and plating". In this paper author had proposed linear material properties of bones and ligaments for the analysis.

Mcgurk M,Aimis A.A, Potamianous P and Goodger N.M [5] presented paper on , "Rapid prototyping technique for anatomical modeling in medicine",with the objective to highlight the procedure to generate 3D medical model for implant.

Need of Computer Aided Modeling:

Complete visualization of the damaged part can not be possible by the present technique. X-ray , CT-scan , MRI locate the position of the fault. Doctor required their skill , experience and judgment to decide the line of action to handle the problem. It may cause the difference in opinion way to handled the problems and many a times it does not focus on how much part gets injured or damaged. Hence it is felt that if a 3D model of the damaged part is available with the doctor, the precise treatment can be given to the patient. The generated 3D model can be cross checked by Rapid Prototyping Machine. From the physical model ,doctor gets clear idea of the fracture part and can precisely plan the surgery well in advance. The implantation can be very easily possible by selecting the proper shape and size of the damaged part [5].

The paper mainly focuses on the case study to generate the exact 3D model of the damaged part of lumbo scral region of vertebral column for the female patient suffering from lower back pain.

Computer Modeling of Lumbo scral Vertibra:

The 3D model of lumber vertebra can be developed from the literature available in the hand book. It is possible to scan the existing 2D image from the different position and angles and map its co-ordinate to build the 3Dmodel [1]. To get more accurate result the cloud points are generated from the old cadaver specimen using co-ordinate measuring machine (CMM) [3]. From these cloud points model can be prepared with the help of drawing software. The draw back of these method is that it can prepared only the reference model which may not be helpful during the operation & surgery of the injured patient. It is desired to generate the model of the injured person from the information which is available with the doctor. Doctor can have the information in the form of X - Ray , CT - scan and MRI. The CT-scan images are stored in the diacom form. These diacom form CT-scan images required to be transferred either into DXE , STL or IGES format from which the 3D model can be generated by using modeling software. The method is explain by considering a case study of a female patient 57 years old whose facet joint are fracture from L-3 to L-5 and is suffering from the problem of lower back pain.The 3D CT- scan images of lumber vertebra along with scram are taken in the form of slices 1.5 mm increment [2] , from the central Indian Institute of Medical Science. The common information about the patient is as given in table. 1

Table 1. Showing Information of Patient.

Patient Information

Name: TEST --- 1		Age:	57
ID: 00		Sex:	F

CT scan information

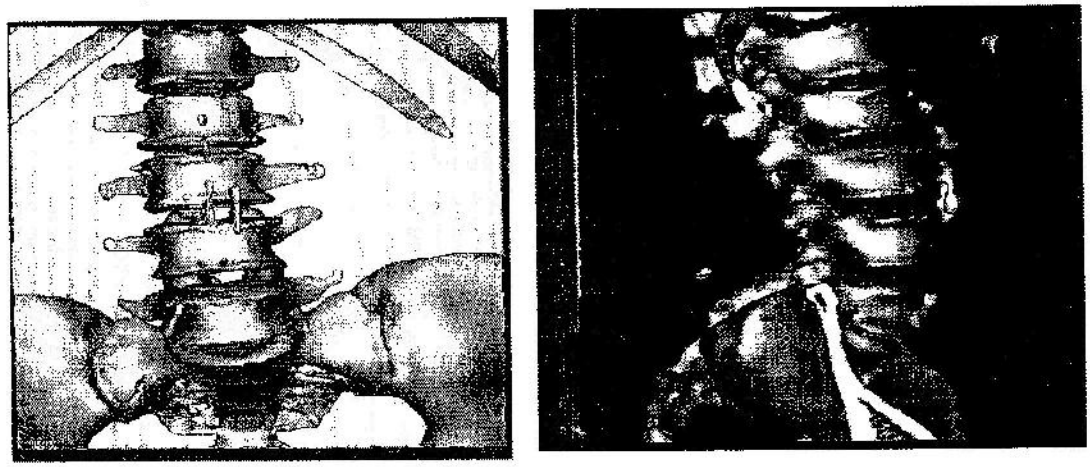
Hospital name:			
Radiologist:			
Referring:			
Created:	2004/07/24 00:00:00	Field of view:	18.20 cm
Scanner:	Emotion Duo / SIEMENS		
Algorithm:	B30s		
Exam:	1	Voltage:	130.00 kV
Slice increment:	1.50 mm	Dose:	96.00 mAs
Slice thickness:	3.00 mm	Image res.:	512

Reformatted Study Information

File:	lumbar		
Created:	25-Jan-2005 12:08 (AM)	Parallel incr.:	1.00 mm
Anatomy:	Mimics	Cross-sect. incr.:	1.00 mm
Parallel:			

These CT- scan images are processed by MIMICS software to generate exact 3D model. The mimics software convert the diacom form images into DXF , STL , IGES format.

The 3D model generated by mimics software is shown in figure 3.



(I) (II)

Figure3 (I) 3-D Model Front view (II) 3-D model Side view

The complete data thus obtained is stored in binary STL form and is processed by catalyst software to generate actual physical model by rapid prototyping machine of dimension bst make.The technique used to develop this model is non laser base fused deposition modeling with ABS material.The model developed by the rapid prototyping machine shows the same feature as that of the model generated by MIMICS software.The actual physical model is as shown in figure 4.

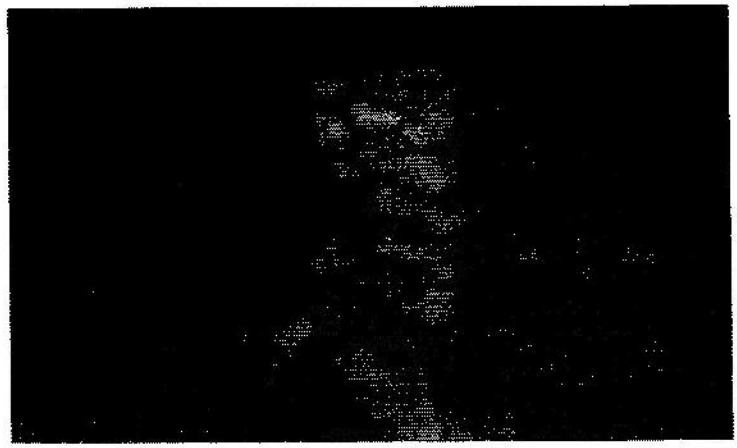


Figure 4 - Actual physical model from RP.

F. E. Analysis of lumber Vertebra:

It is desired that the solid model thus developed from the CT scan images need to be analyzed by using advanced engineering techniques like FEM to get the behavioral response of lumber vertebra for different loading conditions. It is observed that data loss occurs while transferring the data from modeling software to the analysis software .Lot of repair work is required to get accurate solid model .Considering these difficulties ,a generalized geometrically semi symmetrical model is prepared by using the information from the research paper and handbook for single vertebra and invertebral disc [2].Considering complexity of non linearity ,linear material properties are assumed for analysis.FE analysis is carried out by considering solid-92 tetrahedral element having total number of elements generated are 4066 freemesh and linear young's modulus 10000 MPa [4]and poisson's ratio 0.2. A semi symmetrical mesh model is as shown in figure 4.

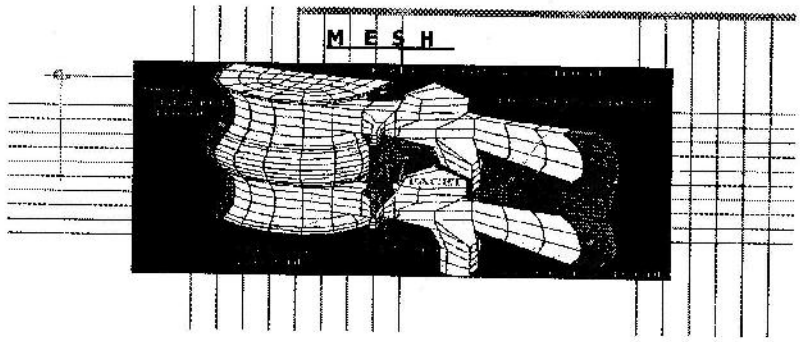


Figure 4 - Semi symmetrical mesh model .

Stress distribution and displacement result for 400 N force and 8 Nm bending moment is shown in figure 5 and 6

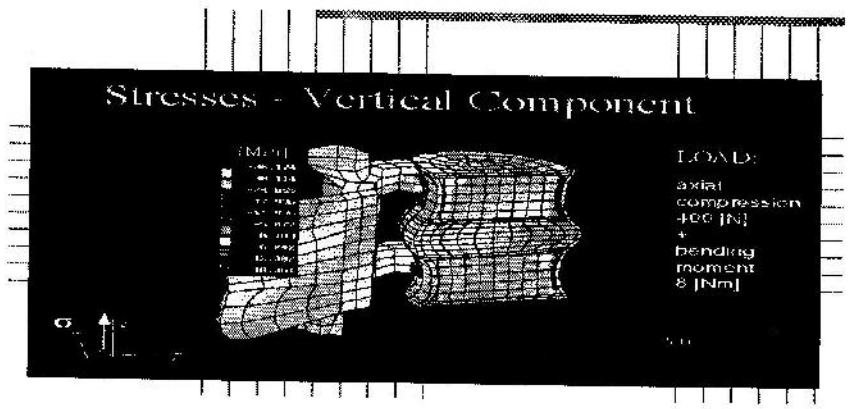


Figure 5- Stress distribution

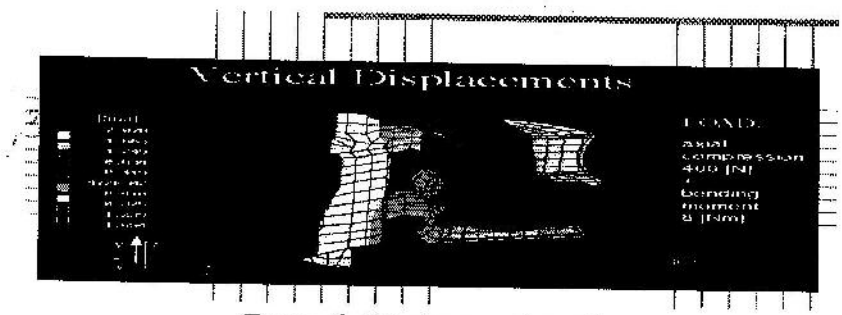


Figure 6- Displacement result.

Conclusion:

Earlier, the 3-D model of the vertebral column was generated from the cadaver specimen of human being. The CMM (coordinate measuring machine) was used to generate the cloud points & these cloud points where processed by the modeling software to generate 3-D model of the vertebral column. Adoption of this method results in only one single reference model. The technique was not universal, and can not be used to plane the prócess of operation.

For the patient suffering from the injury, model is prepared by using the technique of CT scan images in the form of slices & processed it with the modeling software to convert 'Dicom' format files into the IGES, DXL, or STL files. The developed 3-D model by this method is accurate in features & gives clear understanding of the injured part and hence precise treatment can be given to the patient. Ambiguity in the opinion to analyzed the problem can be minimized.

RP technology makes significant impact in the field of biomedical engineering application and surgery. A physical model enables correct identification of the abnormalities, accurate understanding of

anatomical structures, it also helps in implant design of body organs.A precise model facilitates the pre-operative planning of an optimal surgical approach and enables selection of correct and appropriate implants.

The integration of technologies such as medical imaging,RP and FEM is important in medical field to reduce the cost and risk as it helps orthopedic surgeons to suggest proper prevention and precaution to the patients.

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