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A BIOMECHANICAL STUDY OF SACRALIZATION IN SPINE USING FINITE ELEMENT ANALYSIS

Vamsi Krishna Dommeti and Raja Dhason
Department of Mechanical Engineering, SRM University, Chennai, India
E-Mail: vamsi.dommeti@gmail.com

ABSTRACT

Sacralization is a type of transitional abnormally observed at the lumbosacral junction. It involves fully bilateral fusion in between the fifth lumbar vertebra to first sacral vertebra (L5–S1 Transverse vertebra). Sacralization of the L5 vertebra is more commonly observed in people comparison to lumbarization of the first sacral vertebra segment, this can be present in human being from birth. The aim of the present work is to study the pressure distributions in sacralisation. For that cadaveric bones of sacralisation are used to measure geometrical data for modeling and to construct a better mesh representation for sacralization, the meshed model was analysed under compressive load to understand the load concentration on the sacralization. It is observed that the pressure distributions of the ventral - lateral and dorsal-medial sides of sacrum are slight higher when compare to ventral and dorsal sides. This stresses were mostly concentrating at the sacral ala and the s1 pedicle region. This concentration may lead to fracture in ventral – lateral region of sacralization.

Keywords: sacralisation, finite element analysis, biomechanical study.

INTRODUCTION

Sacralization of the L5 vertebra is commonly found in 33.3% population in comparison to lumbarization of the S1 sacral segment report by analyzing data by Niladri Kumar Mahato [1, 2, 3]. Sacralization of the L5 vertebra observed fully fusion between the L5–S1. Sacralization or accessory articulation between the elements of L5 vertebrae and the sacral ala are exhibits differential patterns of bone architecture as these situations are related in physiological posture. A specified study of 441 patients was performed .using MRI of spine the standard protocol for imaging of lumbar spine, lumbosacral anomaly in patients with a sacralized transitional segment is around L4/5 in 33% and at L5 in 13% [6]. The aim of the present work is to study pressure distribution in sacralization.

Figure-1. Anatomy of sacrum.

MATERIAL AND METHODS DATA COLLECTION

Five dried human sacra with completely bilaterally fused L5 vertebra were studied for the Trabecular structure, the normal sacrum and sacralization dry bones are shown in Figure-1 & 2. Each Sacralization was analyzed for bone densities and specific cortical thickness across each of the Sacralization segments by taking 1mm thickness. By tracing their path on paper and by using vernier calliper, measurements of aurticular surface areas, facet surface areas, body surface area were obtained.

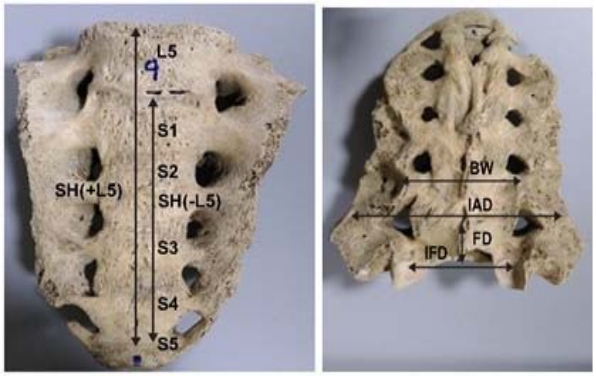

Figure-2. Anatomy of sacralisation.

MODEL CREATION

The geometric model of sacaralization was created from the values obtained from the measurement; the measured values are given in Table-1. The Sacralization model contains totally 2 components. It consists of cortical bones and cancellous bone. The solid model of sacralization was shown in Figure-3.

The model was meshed using 2D trias and collectors of 3D elements in a separate component to create tetrahedral elements. For converting 2D to 3D tetrahedral elements, SOLID92 element type was assigned was shown in Figure-4.

Table-1. Morphological details of sacralization.

SURFACE AREA	Sacra with complete and Bilaterally fused L5 (mm)
Auricular Surface Areas (ASA)	9.82 (+-1.24)
Auricular Surface Areas (left)	10.24 (+-2.00)
Auricular Surface Areas (right)	10.47 (+-1.92)
Facet Surface Areas (FSA)	1.71 (+-0.51)
Facet Surface Areas (left)	1.68 (+-0.58)
Facet Surface Areas (right)	1.73 (+-0.52)
Body Surface Areas.	10.02 (+-2.35)

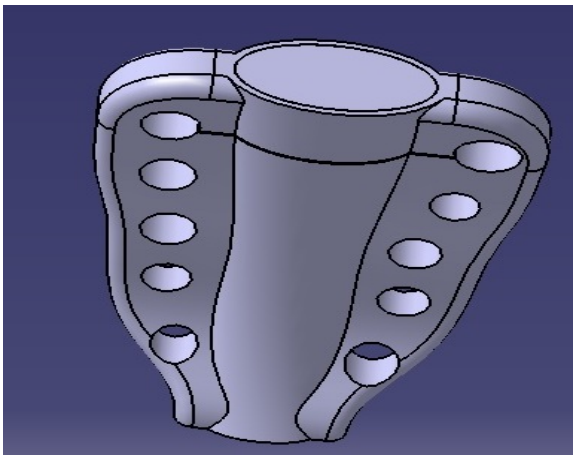

Figure-3. Solid model of sacralization.

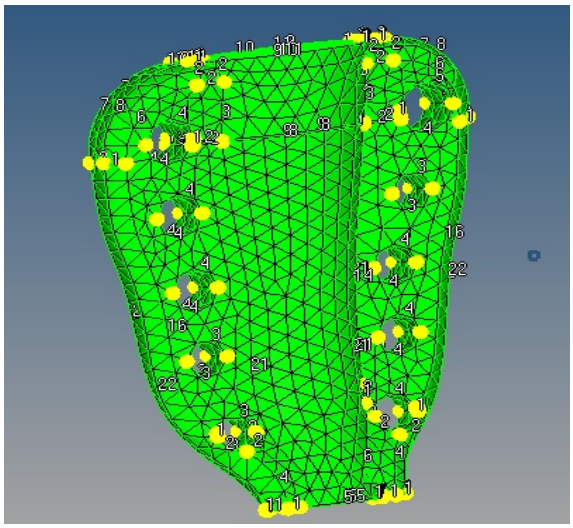

Figure-4. Meshed model of sacralization.

The material properties of the cortical and cancellous bone are Young's Modulus 8900 Mpa, Poisson Ratio 0.3, Density 1300 kg/m^3 were assigned based on the literature [7]. The boundary and loading conditions are applied on sacralization model same as loading condition stated in the literature [7]. The sacralization model was fixed at the pelvis joint region and the pressure of 10 KN was applied on the top surface of S1 intervertebral articular surface of the sacralization, by considering the weight of the person as 75 kg, according to the literature Hakan BOZKU [7].

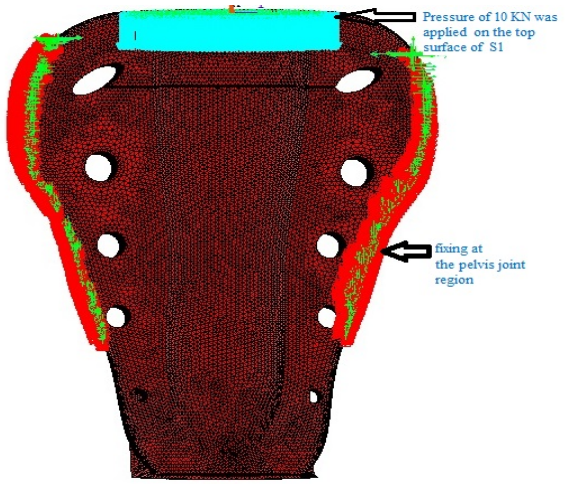

Figure-5. Boundary condition for sacralisation.

RESULT AND DISCUSSION

Detailed biomechanical behaviour of the whole Sacralization under large compressive load is presented here. The stress values are obtained from the present FE model were compared with FE model of Hakan Bozku *et al*. [7] for loading condition 10 KN for the validation of compressive loading case.

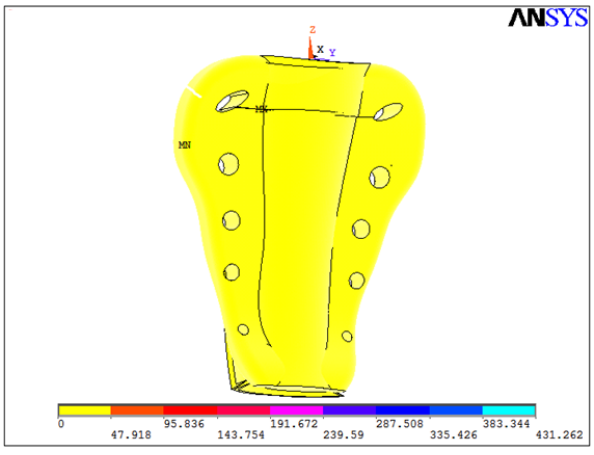

Figure-6. Stress distribution of sacralization estimated in sacrum.

The von Mises equivalent stress distribution on the sacralization for a 10kN axial compressive load as show in Figure-6, 7. The following stress values were observed at the sacral ala (min 224 mpa , max 501 mpa, median 336 mpa), the S1 pedicle (min 118 mpa , max 353 mpa, median 236 mpa),the S1 foramen ventral-lateral side(min 82 mpa , max 148 mpa, median 118 mpa), the

sacral promontory (min 22mpa , max 52 mpa, median 32 mpa) the S1 foramen dorsal-median side (min26 mpa , max 59 mpa, median 39 mpa),S1 lamina (min 0 mpa , max 33mpa, median 22 mpa).

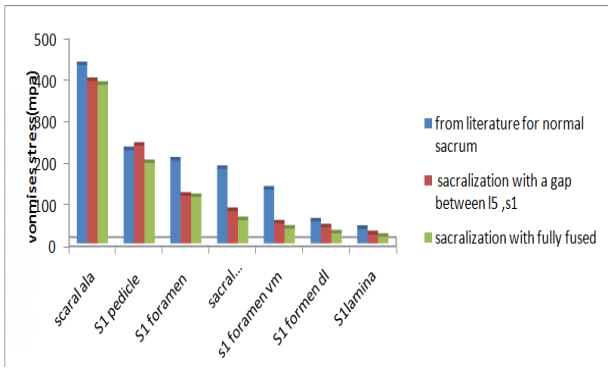

Figure-7. Comparison of stress distribution of sacralization with literature.

CONCLUSIONS

The developed model was provided necessary details about the pressure concentration due to large compressive load. it was observed that the stress values of the ventral - lateral and dorsal-medial sides were exceeding the stress values of the ventral and dorsal sides .This variations create internal architecture disturbance of the bone .The stress were mostly concentrated at the sacral ala and the s1 pedicle due to this fractures observed in zone1 region.

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