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# Analysis of soft tissue in cervical traction therapy using finite element method

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**Abstract.** Cervical traction is a therapeutic method used for treating neck pain. As of July 2016 according to the Institute for Health Metrics and Evaluation the healthy life lost per 100000 people from neck pain in India has increased by 18.7% since 1990 as a result of individuals devoting about 10 to 15 hours a day in an undesirable position. This project is an approach using a finite element method for a 30 year old male to investigate the response of soft tissue related to cervical traction therapy affecting the lordosis angle of the cervical spine. Research work is done concerning the material properties of the soft tissues to be incorporated in the model for validation. Once validated the lordosis angle of the cervical region was measured and compared against the lordosis angle of the model when exposed to traction forces. Results of the study gave evidence on the reduction of the lordosis angle and extend at which the lordosis angle is reduced. These results of the study when considered minimize the potential harm to soft tissues during cervical traction therapy and help in allocating the appropriate force on the appropriate position during cervical traction therapy and cervical traction therapy equipment design.

## 1. Introduction

Few studies have studied the response of soft tissue to cervical traction therapy. [1] An estimate of 3.5/1,000 is given as the point prevalence and an estimate of 83/100,000 is given as the annual incidence of cervical radiculopathy which initially reflects itself with a symptom of neck pain. A sample of 205 patients was treated for 10–25 years with therapeutic methods such as traction, medications and rest. The results indicated that 43% of patients had their symptoms resolved, 25% with mild pain, and 32% had severe residual pain. Cervical traction is a method of treatment which can be continuous or intermittent. The treatment with respect to cervical lordosis is responsible for restoring the normal lordosis angle thereby releasing pressure on intervertebral discs, releasing pressure on nerve roots and blood vessels to allow for improved nutrient transport and relieving neck pain. BAO Chunyu (2014) et al., [2] gave an approach of investigating the biomechanical characteristics of the cervical spine for

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clinical diagnosis. The model was checked and confirmed to simulate the structure and properties of cervical spine. A result of the biomechanical study was correlated with the experimental data. This showed that the use of the finite element model in analysing the biomechanics characteristic of the human cervical spine is capable of producing feasible results. Liqiang Dong (2013) et al., [3] reported a study of a finite element model for a paediatric cervical spine with the objective of understanding the neck injury mechanisms related to automotive crash cases for a 10-year-old human developed from CT scans. This study provided proper predictions of soft tissue failure in tensions exposed to a child's cervical spine. A study was done by Kuan Wang (2017) et al., [4] on comparing the biomechanical behaviour of soft tissue with application of traction with and without neck support. In order to simulate traction weight a 100N axial traction weight was loaded on the upper surface of C0 whilst simulation of neck support was done by additionally constraining anterior-posterior motion of the surface of the C4 vertebral lamina. For the two conditions the tension forces, the stress and the motions of the soft tissues were compared between the two conditions. The results of the study showed that for C4-C5 and C5-C6 levels the non-support traction resulted in a small decrease in the lordotic angle. For the region C4-T1 there was a decrease in the intradiscal pressure during traction therapy of the two conditions. In conclusion the study resolved that to reduce the harm of soft tissues the use of neck support traction is to be done as per the targeted level. However, few investigations have studied the effects of cervical traction on the lordosis angle when subjected to different tension loads. Therefore, the goal of this analysis is to study the mechanism of cervical traction treatment by use of a validated finite element model. Changes in the lordosis angle was analysed.

## 2. Materials and methods

### *2.1 Methodology*

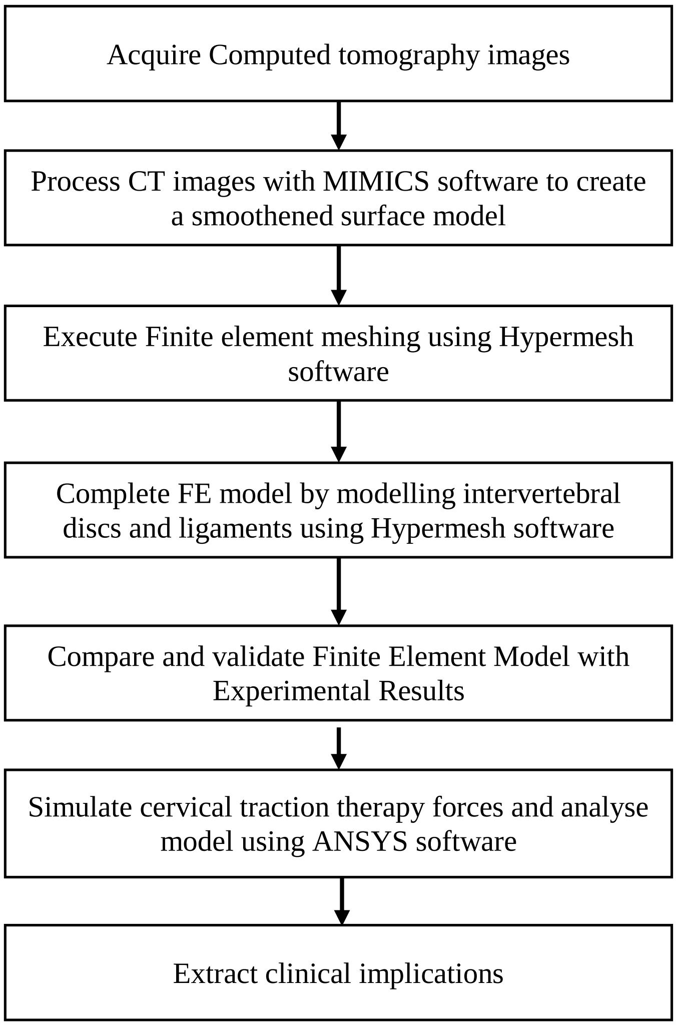



**Figure 1.** Methodology Flow chart

*2.2 Materials*

The CT images of a healthy male human subject at the age of 30 years were extracted from the skull to the L5 vertebra in standing position. Mimics 10.01 software was used to process the CT images and isolate the C3-C7 region of the spine for modelling. The Mimics extrapolation is broken up into four main views which are the coronal, axial, sagittal, and 3D view as shown in Figure 2. The axial plane is XY direction as shown by the top right section, the coronal plane is the XZ direction as shown by the top left section, the sagittal plane is the XZ direction as shown by the bottom left section and the 3D view is as shown by the bottom right section.

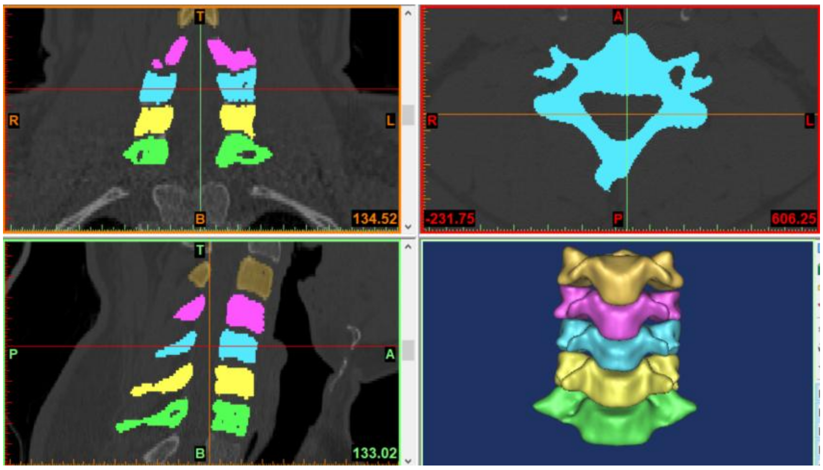


**Figure 2.** Mimics Planes.

Anatomical data from images is converted to a 3D model by segmentation. The model is then converted to inp format for exportation to Hypermesh software. The completed meshed model is as shown in Figure 3.

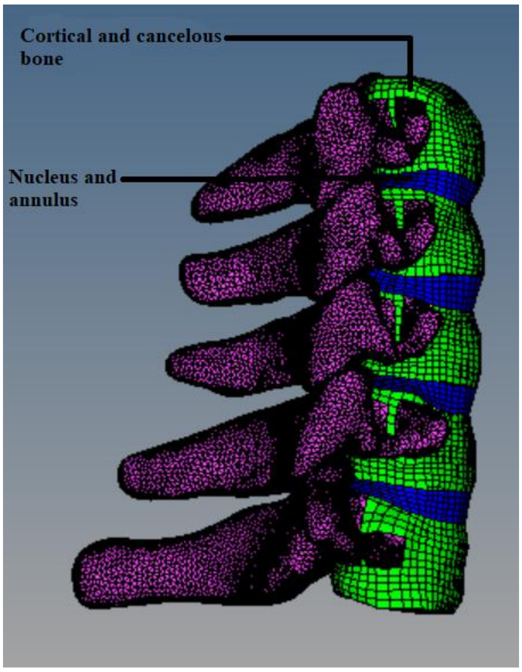



**Figure 3.** Meshed model.

After meshing process is completed the different components of the vertebrae are separated and the material properties of the model are assigned with values shown in Table 1 accordingly.

**Table 1.** Material Properties.

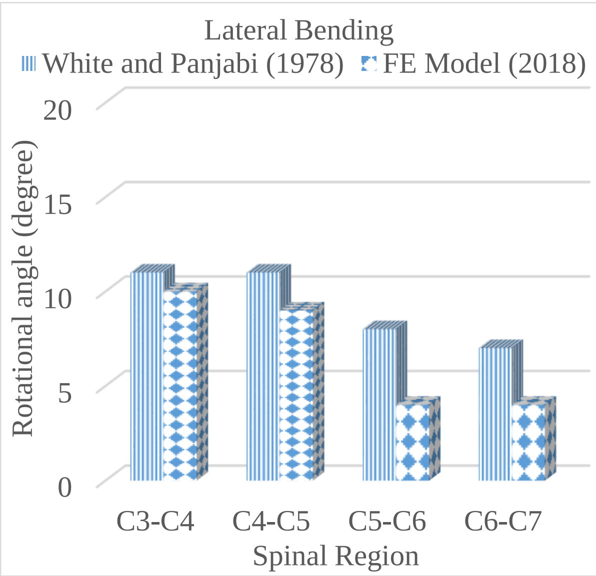
| Component | Element type | Young’s modulus(MPa) | Poisson’s ratio |
|---|---|---|---|
| Trabecular bone | Solid 45 | 450 | 0.25 |

| | | | |
|---|---|---|---|
| Cortical bone | Solid 45 | 10000 | 0.3 |
| Endplate | Solid 45 | 1000 | 0.3 |
| Nucleus | Solid 45 | 1 | 0.499 |
| Annulus | Solid 45 | 3.4 | 0.4 |

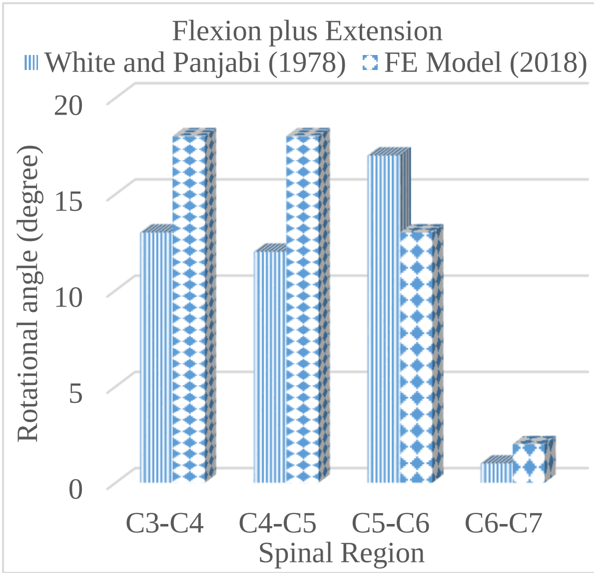
A hexahedral mesh was done on the vertebral body and anterior components of the spinal region and tetrahedral mesh was done for the spinous process and posterior components of the spinal region. A total of 74872 nodes and 213448 elements was generated. The meshed model is then transported to ANSYS software were it is analysed for validation of the model and for the behaviour of lordosis angle from C3-C7 when subjected to cervical traction forces. AutoCAD software is used for plotting and measuring the rotational angles formed.

### 3. Results and Discussion

Model validation was executed in ANSYS software. An estimation of the range of motion of the model under a pure moment of 1Nm for the FE model was compared with results already obtained by work done by White and Panjabi (1978) et al., [5] for validation. All degrees of freedom were constrained on the lower surface of C7. The x-axis rotation was for flexion and extension whilst the z-axis rotation was for lateral bending. The resultant angles of rotation for the different regions of the cervical spine and their comparisons for validation are shown in Figure 4.




(a)




(b)

**Figure 4.** Comparison of the rotation moment response against previous study and FE model under (a) Lateral bending and (b) Flexion plus extension.

The result of the rotational angle for Lateral bending under a 1Nm pure moment gave readings of 10°, 9°, 4°, 4° from C3-C7 respectively. These values indicated a correlation with work done by White and Panjabi (1978) et al., [5] giving values within a 10% error. Cervical traction forces implemented for rehabilitation in clinics are documented to be in the range 60N-120N (6-12) kg. Therefore, for model analysis traction force up to 120N was applied from 50N with increment value of 10N. The traction forces were simulated as tension forces in the +ve FZ plane. On application of each individual force the lordosis angle was measured by calculating taking two nodal coordinates in the same plane and plotting their deflexion in AutoCAD software to give the deviation and lordosis angle.

The results of the study are shown in Figure 5. Analysis shows that as the traction force is increased the lordosis angle is decreased hence curving the cervical spine into its preferable posture resulting in a relief of neck pain. Also notice a greater change is experienced in the C3-C4 region of the spine hence it is critical to monitor the traction forces applied in this region as it might result in excessive lordosis which also is a cause of neck pain. The lordosis angle of the spine under unloaded condition was also seen to be 16°, 39°, 20° and 23° for C3-C4, C4-C5, C5-C6 and C6-C7 respectively which is in correlation with work done by Gore (1986) et al., [6] which stated the range for normal cervical spine of men to be 21±14°.

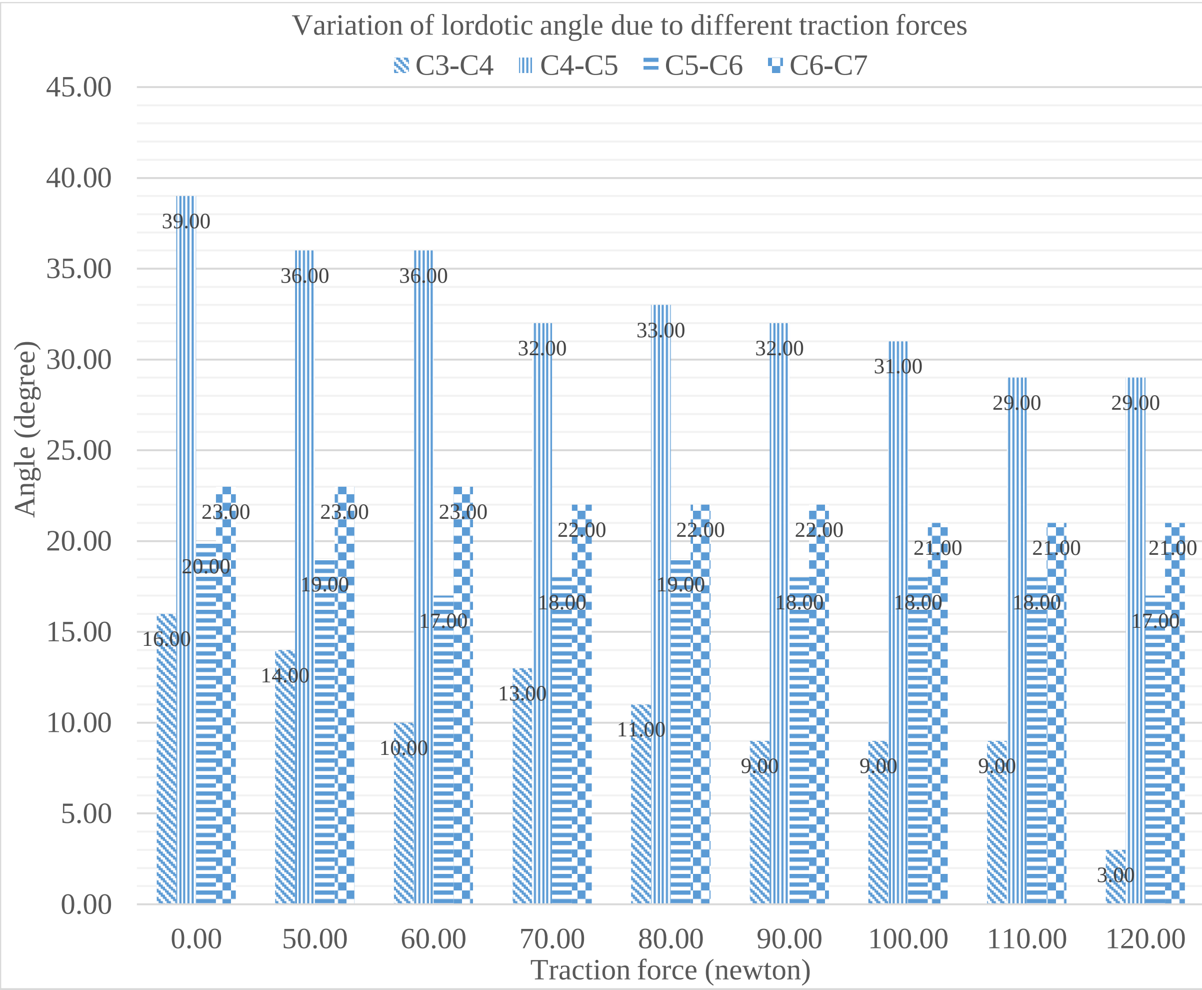



**Figure 5.** Variation of lordosis angle during traction from 50N to 120N on the (a) C3-C4 (b) C4-C5 (c) C5-C6 (d) C6-C7 region of the vertebrae.

## 4. Conclusion and future enhancements

The objective of this paper was to be able to use the finite element method to understand the behavioural response of the lordosis angle present between the C3-C7 sections of the cervical spine when subjected to traction forces currently used for treatment in outpatient rehabilitation. In summary the FE model was modelled and validated successfully. Also the analysis of the C3-C7 discs was done under different traction forces. The results obtained gave evidence that the FE model can be used to determine the appropriate force needed to relieve neck pain and shows how the force acts on the disc. Future improvements involve use of human cadaver in studying the human spine behaviour and also need to analyse the behaviour of sections of the spine which are also involved in causing neck pain like ligaments rapturing.

## 5. References

[1] Todd A G 2011 Cervical spine: degenerative conditions *Curr. Rev. Musculoskelet. Med*. **4** 168-74
[2] Bao C and Meng Q 2014 Study on cervical spine stresses based on finite element model *Spine*. **21** 1824-34
[3] Dong L, Li G, Mao H, Marek S and Yang K H 2013 Development and validation of a 10 year old child ligamentous cervical spine finite element model, *Annals of Biomedical Engineering*. **41,** 2538-52
[4] Wang K, Wang H, Deng Z, Li Z, Zhan H and Niu W 2017 Cervical traction therapy with and without neck support: A finite element analysis, *Musculoskeletal science and practice*. **28,** 1-9
[5] White A A and Panjabi M 1978 The basic kinematics of the human spine, *Spine.* **3,** 12-20.
[6] Gore D R, Sepic S B and Gardner G M 1986 Roentgenographic findings of the cervical spine in asymptomatic people, *Spine* .**11,** 521-24
[7] Cox J M 2012 Low back pain: mechanism, diagnosis and treatment. *Lippincott Williams & Wilkins*
[8] Kuo Y W, Hsu Y C, Chuang I T, Chao P H and Wang J L 2014 Spinal traction promotes molecular transportation in a simulated degenerative intervertebral disc model.*Spine* **39** E550-56
[9] Harrison D E, Cailliet R, Harrison D D, Janik T J and Holland B 2002 A new 3-point bending traction method for restoring cervical lordosis and cervical manipulation: a nonrandomized clinical controlled trial, *Arch Phys Med Rehabil.* **83,** 447-53
[10] Loeser J D 1992 History of skeletal traction in the treatment of cervical spine injuries. *Neurosurg* **33** 54-9
[11] Radhakrishnan K, Litchy W J, O'Fallon W M and Kurland L T 1994 Epidemiology of cervical radiculopathy, *Brain*. **117** 325-35
[12] Murphy MJ 1991 Effects of cervical traction on muscle activity. *Journal of Orthopaedic & Sports Physical Therapy.* **13,** 220-5
[13] Murray CJ, Abraham J, Ali MK, Alvarado M, Atkinson C, Baddour LM, Bartels DH, Benjamin EJ, Bhalla K, Birbeck G and Bolliger I 2013 The state of US health, 1990-2010: burden of diseases, injuries, and risk factors,*Jama.* **310,** 591-606
[14] Mustafy T, El-Rich M, Mesfar W and Moglo K 2014 Investigation of impact loading rate effects on the ligamentous cervical spinal load-partitioning using finite element model of functional spinal unit C2–C3, *Journal of biomechanics.* **47,** 2891-903
[15] Panjabi MM, Crisco JJ, Vasavada A, Oda T, Cholewicki J, Nibu K and Shin E 2001 Mechanical properties of the human cervical spine as shown by three-dimensional load–displacement curves, *Spine.* **26,** 2692-700
[16] Harrison DE, Cailliet R, Harrison DD, Troyanovich SJ and Harrison SO 1999 A review of biomechanics of the central nervous system Part III: spinal cord stresses from postural loads and their neurologic effects, *Journal of Manipulative & Physiological Therapeutics.* **22,** 399-410