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Stress Analysis of Human Molar Tooth by Utilizing CAD And FEM

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Abstract: *Dental wisdom, like much of the elaboration of mortal civilization, progresses in the way that are frequently the result of the complex relationship between wisdom, empirical knowledge, and advances in technology. Computing has modified our perception, sense, use and interpretation of time and enabled scientists to perform being procedures far briskly and more directly than ever. It has allowed them to make a reality of effects they had only pictured of ahead and maybe of lesser consequence and further excitingly. It has frequently stimulated them to perceive and concentrate on their subject with new eyes to see it on a different scale from a fully different perspective. mortal tooth is a critical and most important part of mortal to survive.*

Keywords: Human molar tooth, axial stress, bending stress, Biomedical, Dentistry

I. INTRODUCTION

Dental science, like much of the evolution of human civilization, progresses in the steps that are often the result of the complex relationship between science, empirical knowledge, and advances in technology. Computing has modified our perception, sense, use and interpretation of time and enabled scientists to perform existing procedures far faster and more accurately than ever. It has allowed them to make a reality of things they had only dreamed of before and perhaps of greater consequence and more excitingly. It has often stimulated them to perceive and focus on their subject with new eyes to see it on a different scale from a completely different perspective. Human tooth is a critical and most important part of human to survive.

1.1 Relevance

Biomechanics is fundamental to any dental practice. To anatomize and study the functional loads created within the natural systems, " Biomechanics " is nearly related to Mechanical engineering which uses traditional engineering ways analogous as Applied mechanics, utmost especially mechanical engineering disciplines analogous as continuum mechanics, medium analysis, structural analysis, kinematics and dynamics. These styles play prominent places in the study of stress and strains induced in mortal is an important part of mortal body which plays important part of tool for surviving. During eating process, while eating various kinds of foods various functional loads produce stresses and strains inside mortal tooth. Stress at any point in the construction is critical and governs failure of the tooth.

II. LITERATURE REVIEW

May et al. measured the precision of fit of the crown fabricated with CAD/CAM technology for the premolar and molar teeth fit to a die and found that the mean gap dimensions for marginal openings, internal adaptation, and precision of fit for the crown groups were below 70 μm. These findings showed that the crowns studied can be prescribed with confidence knowing that the precision of fit will consistently be less than 70 μm. To remain within this generally accepted precision the accuracy and reproducibility of the first step of surface digitization needs to be considerably lower than this value.

Toparli M et al. investigated the stress distribution which was the resultant of the stresses which come from the mastication force and those resulting from the contraction and expansion of restorative materials. They carried out calculations using the finite element method and found that the modulus of elasticity was four times that of composite resin and the tensile stresses were larger in enamel than those when composite resin had been used.

Vijay K Goel et al. analyzed the stresses at the dentin enamel junction of human teeth using a finite element method. They observed that normal and shear stresses were markebly affected by the contour of dentinenamel junction and concluded that mechanical interlocking between the enamel and dentin in the cervical region were weaker than in other regions of dentinenamel junction.

D Parle in his study created three-dimensional CAD model from DICOM images and converted to STL format to use it further in FE analysis. Stress analysis using Hypermesh and Radios on exact 3D model of premolar tooth created using medical imaging tools with the help of Computerized Tomography (CT) scanned images. Such FEA based studies help in improved understanding of biomechanics for dental structures and to produce artificial tooth with improved mechanical strength. He carried out 3D stress analysis of premolar tooth and concluded that stress during mastification is higher as compared to loading due to distalization.

Ausiello P et al. studied the cusp movements in a human upper premolar, restored with adhesive resin-based composites using a 3D finite element analysis and concluded that premature failure due to stress arising from polymerization shrinkage and occlusal loading can be prevented by proper selection and combination of materials. Due to the flexibility and adaptability to model even the most complex of geometries it has been used in almost all the fields of dentistry and quiet expensively in prosthodontics and endodontics and implantology.

III. METHODOLOGY

To carry out stress analysis of real live tooth of human poses a challenge, but the systematic and straight forward methodology executed as mentioned below, helped a lot to cover practical aspects of experimentation.

3.1 Obtaining CT scan of tooth

CT scans are widely used in dentistry for various purposes. For this work CT scan of woman's actual tooth will be obtained from radiologist for further use in this study.

3.2 Image processing and CAD modeling

CT scan images are typically in layers. These images not only contain tooth information but also lot of other unwanted information. First step involves image processing to extract tooth information using suitable medical imaging software like 3D Doctor followed by dimensional calibration and exporting tooth in IGES/STL format. To ensure correctness of CAD model, dimensions will be compared with actual tooth.

3.3 Stress analysis

Stress analysis for mastication load will be carried out using commercial FEA tool such as ANSYS. CAD model will be imported, meshed and applied with material properties obtained from literature. After successful meshing, mastication loads and boundary conditions on tooth root will be applied to obtain stresses in tooth. These results will be compared with analytical results. Analytically stress will be computed by using formulae from solid mechanics. One can compare tooth structure with beam or axially loaded structures.

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IV. EXPERIMENTATION

4.1Fixture for support to tooth as an actual tooth support

Figure 4.1: Fixture for support to tooth as an actual tooth support

4.2 Tooth holding fixture

Figure 4.2: Tooth holding fixture

The experimentation is carried out for two different age groups; Adult and Teenager.

4.3 Loading of Molar Tooth

With the help of fixture and UTM the axial and bending load is applied on tooth as shown in figure 4.3 & 4.4.The load is then gradually applied and all values of stress, load, and strain are measured in lab.

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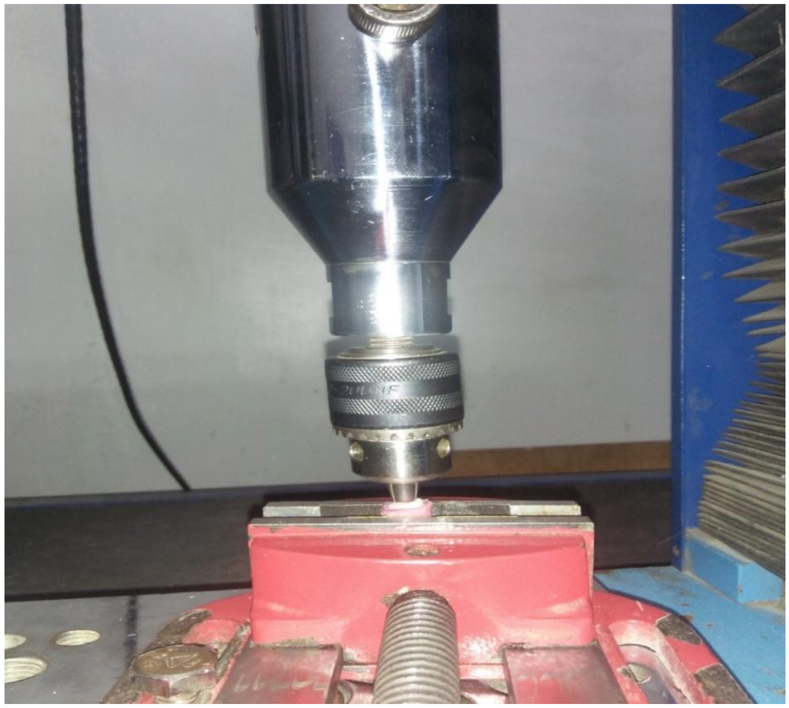

Figure 4.3: Loading of molar tooth

Figure 4.4: Loading of molar tooth

As per above methodology, the axial stress and bending stress is calculated which expresses sort of experimental base as the inputs are considered of real time human tooth.

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FINITE ELEMENT ANALYSIS OF MOLAR TOOTH

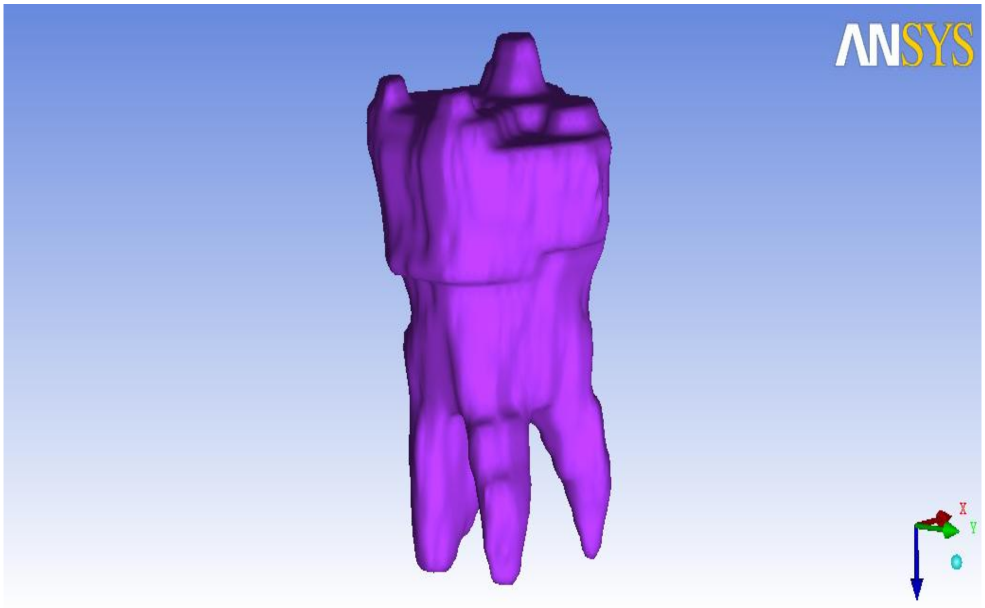

Figure 5.1: 3D CAD Model of Molar Tooth in ANSYS-ICEM

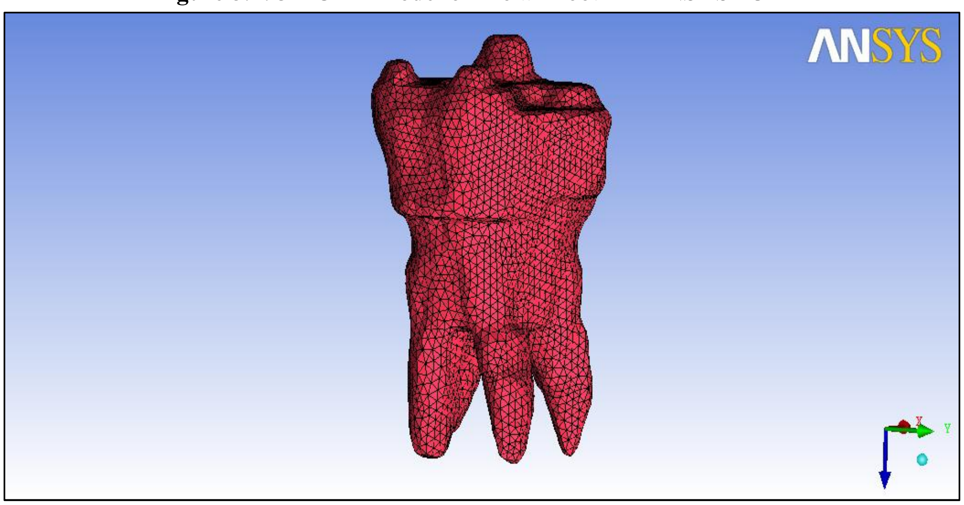

Figure 5.2: Meshed model of molar tooth in ANSYS-ICEM

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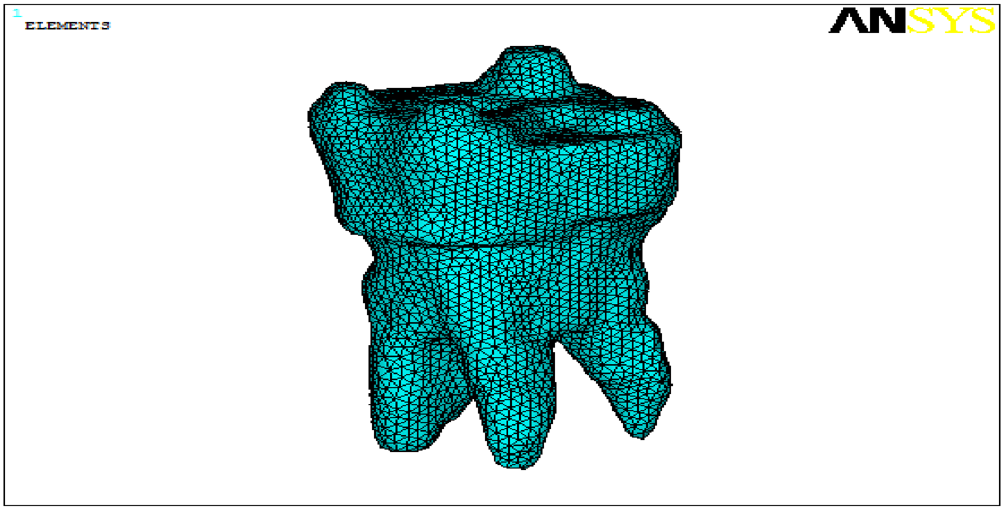

Figure 5.3: Meshed model of molar tooth in ANSYS MAPDL

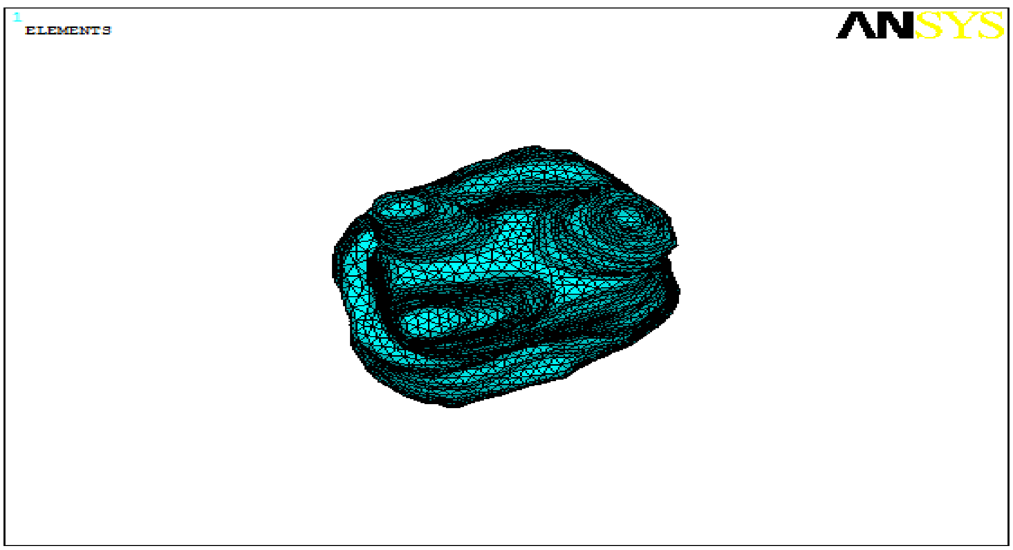

Figure 5.4: Molar tooth - meshed model (bottom view)

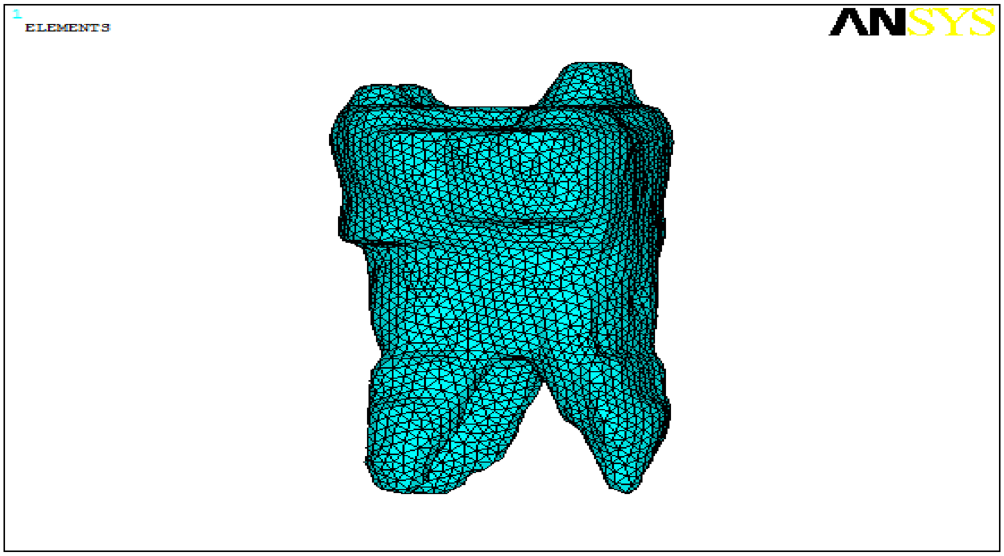

Figure 5.5: Molar tooth - Meshed model (Front view)

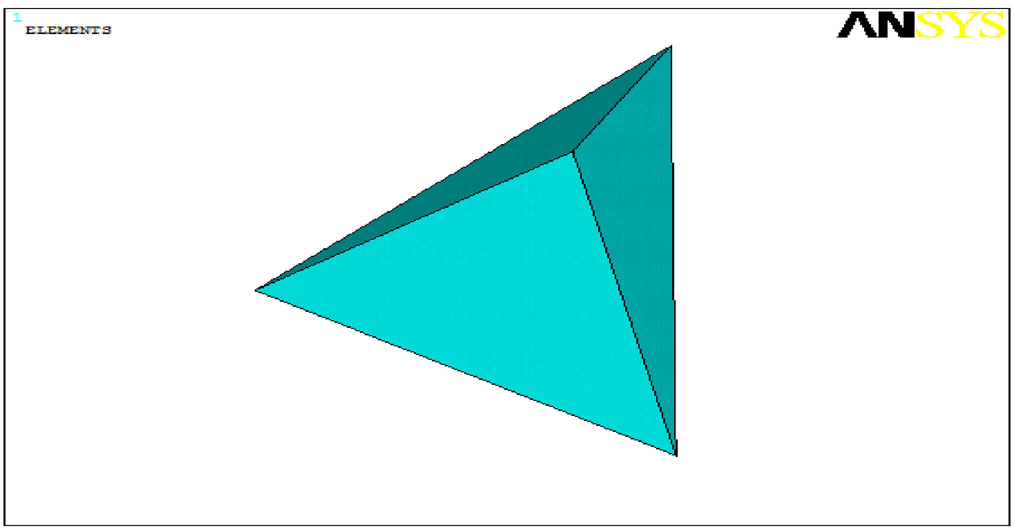

Figure 5.6: Structure of solid tetrahedron element

Table 5.1: Mesh Statistics

Sr. No.	Element Type	Solid Tetrahedron
1	Number of Elements	91504
2	Number of Nodes	17286

Table 5.2: Mechanical properties of premolar tooth

Sr. No.	Material Property	Young's Modulus (GPa)	Poisson's Ratio
1	Enamel	84.1	0.3
2	Dentine	13.7	0.3

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3	Cementum	18.6	0.31
4	Pulp [24]	0.002	0.45

VI. RESULTS AND DISCUSSION

6.1Analytical Result for Axial stress

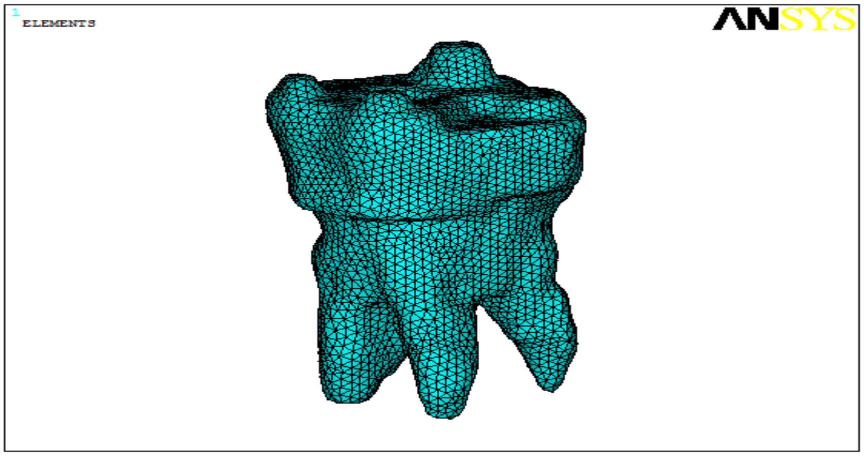

Figure 6.1: Axial stress in molar tooth by analytical approach

Area for the plane X-X calculated form 3D doctor software considered as 61.19 mm^2.

$$Stress = \frac{Force}{Area}$$

$$\sigma = \frac{Fa}{A}$$

$$\sigma_{axialx-x} = \frac{3140.90}{61.19}$$

$$\sigma_{axialx-x} = 50.50 N / mm^2$$

Value of force is taken from experimental results and area is calculated by 3D doctor for molar tooth.

6.2 Analytical Result for bending stress

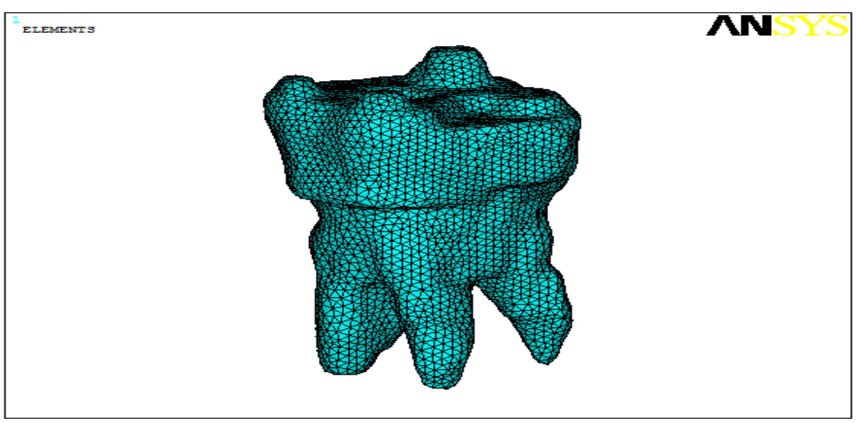

Figure 6.2: Bending stress in molar tooth analytical approach

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Area at X-X calculated form 3D doctor software considered as 61.19 mm^2.Fb = 816 N, A = 61.19 mm^2.

$$R = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{61.19}{3.14}} = 4.41mm$$

$$I = \frac{\pi}{4} R^4 = 297.1mm^4$$

$$\sigma_x = \frac{M}{Z_{x-x}}$$

$$Z = \frac{I}{y} = \frac{297.1}{4.41} = 67.36mm^3$$

$$\sigma_{bending\ x-x} = \frac{816x10.96}{67.36} = 132.82MPa$$

As per above methodology, the axial stress and bending stress is calculated which expresses sort ofexperimental base as the inputs are considered of real time human tooth. These calculated results are validated with FEA results.

6.3 FEA Result for Axial stress

FE analysis of molar tooth is performed by applying only axial component separately.

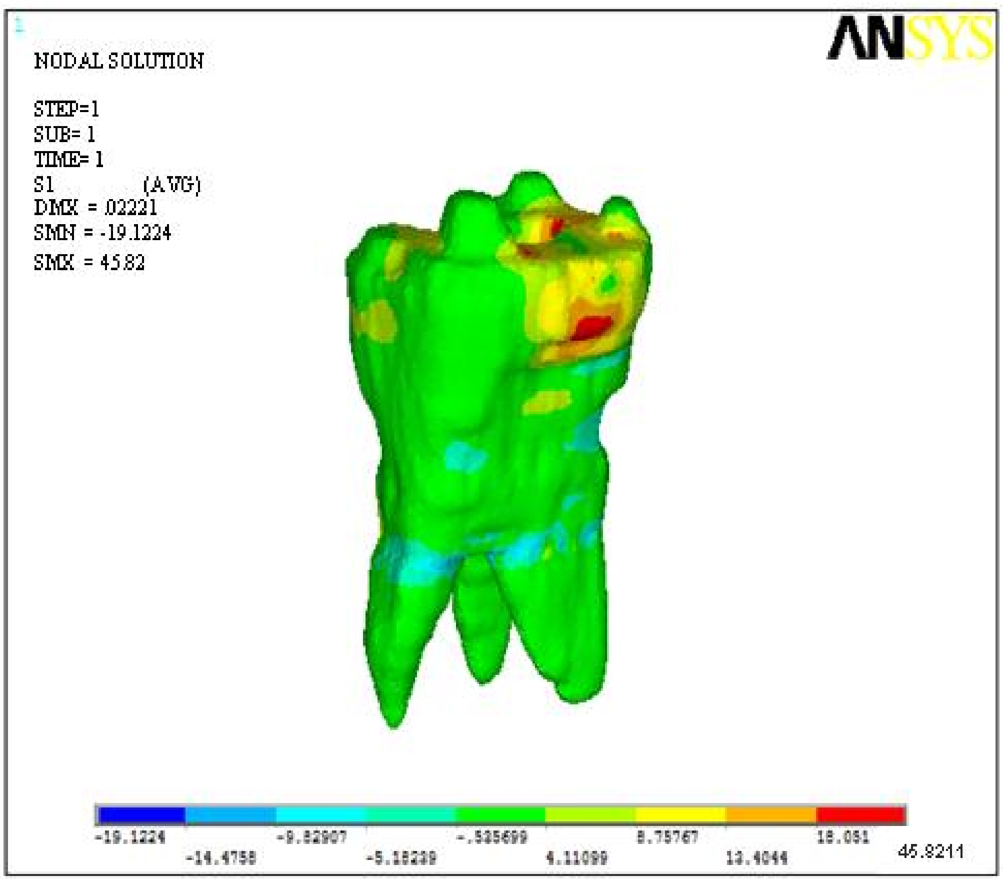

Figure 6.3: Axial stress in molar tooth by FEA approach

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6.4 FEA Result for Bending stress

FE analysis of molar tooth is performed by applying only bending component separately.

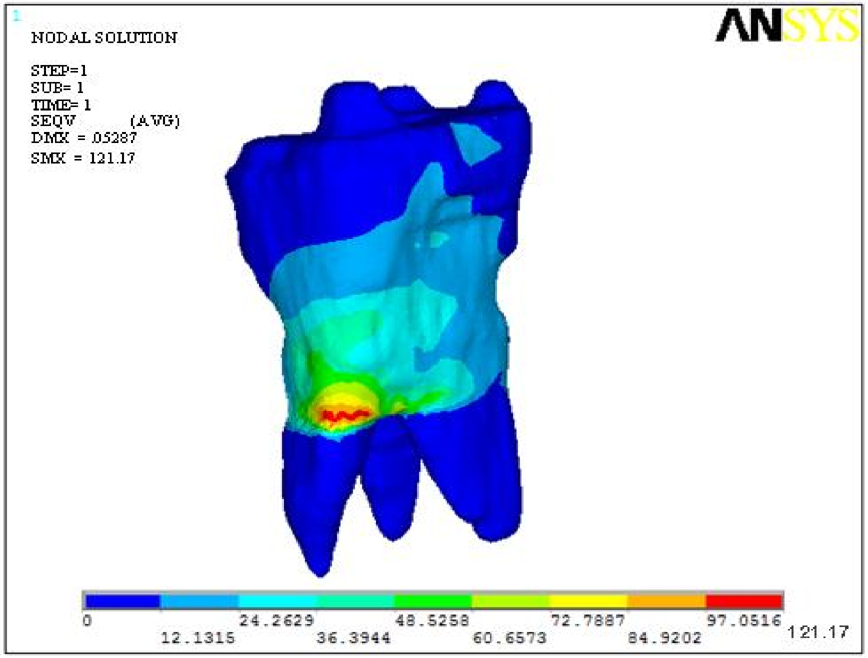

Figure 6.4: Bending stress in molar tooth by FEA approach

6.5 Experimental Results

Experimentation which has carried out on human molar tooth has results as given below. The computerized UTM has produced the results.

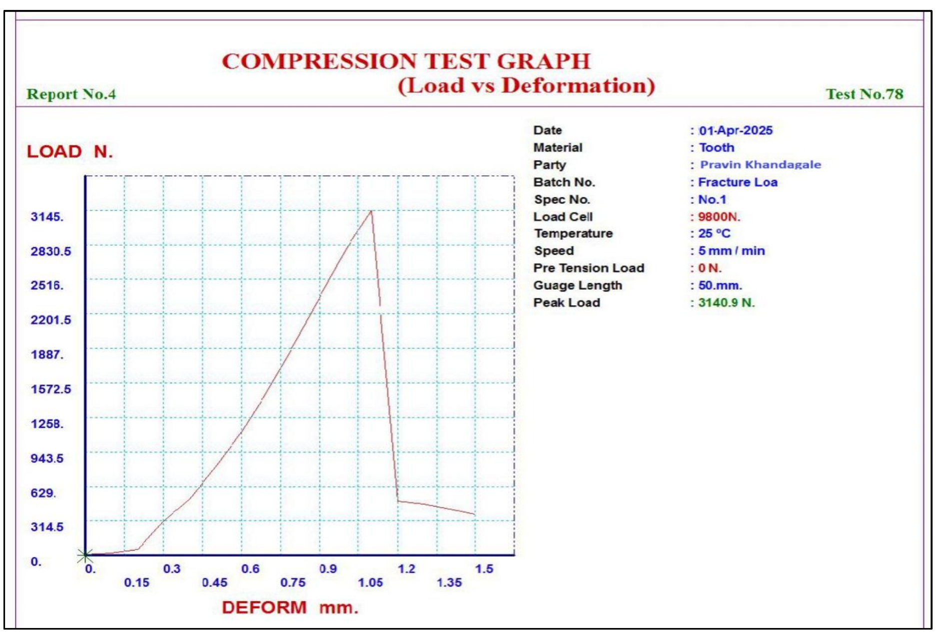

Figure 6.5: Axial Load Results

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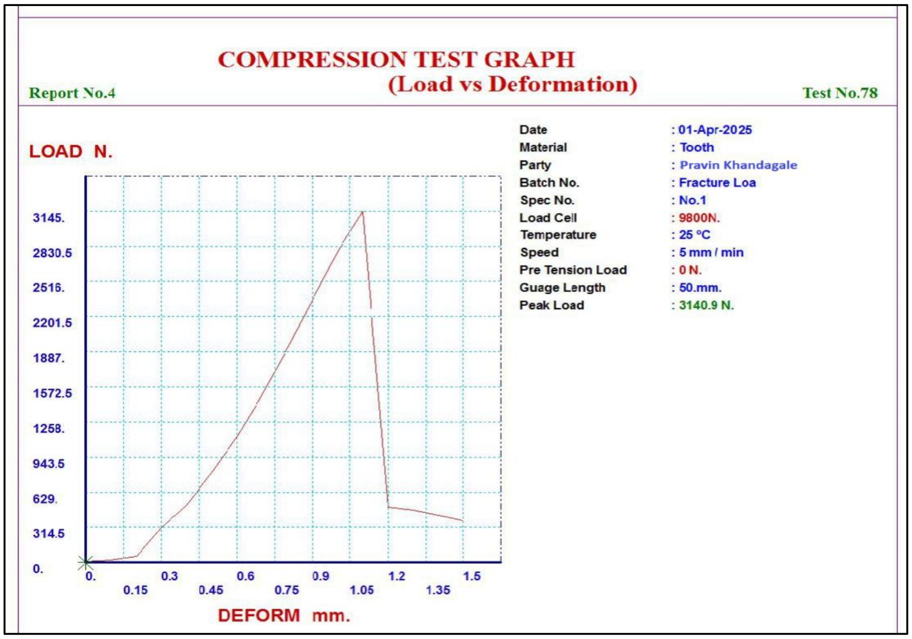

Figure 6.6: Bending Load results

Table 6.1: Comparison of Analytical, ANSYS And Experimental Results

Sr. No.	Type of Result	Analytical	ANSYS	Experimental
1	Bending stress (MPa)	132.85	121.17	128.70
2	Axial Stress (MPa)	50.50	45.82	48.74

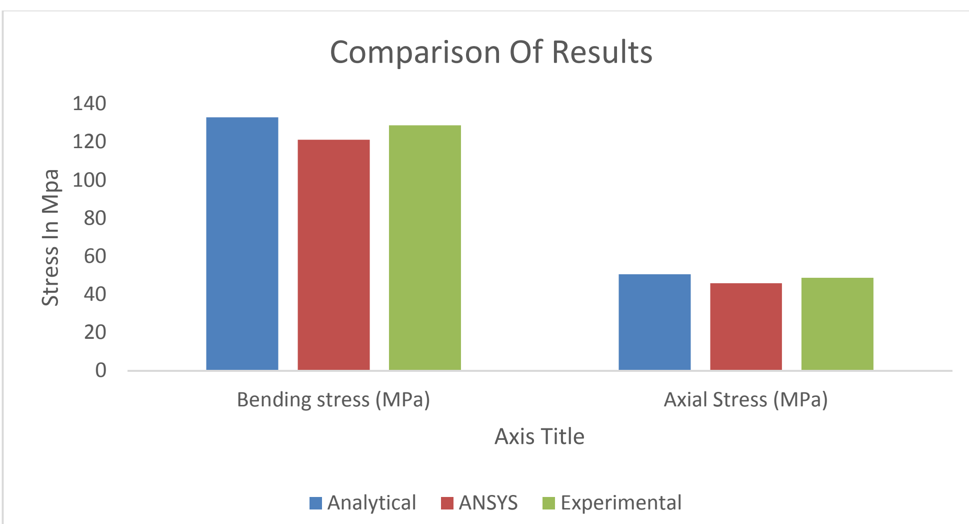

Figure 6.7: Comparison Of Results

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Summarizes the comparison of various results there is a small difference in analytical Experimental and FE results. The difference is potentially related to assumptions in analytical formulations, load approximation etc. Since difference is small so results are considered as authentic. Alsographical comparison shows of stress values and stress values calculated by three methods nearly matches to each other.

VII. CONCLUSION

Conclusions of this study and outlines scope for future work. The main conclusions of the current study are

3D stress analysis of molar tooth is successfully carried out on molar tooth modeled using FEA tool – ANSYS under mastication loading conditions. The FEA model neither simplifies geometry nor makes any assumptions in material. Hence, the developed FEA model is most accurate.

Approximate analytical calculations have been performed for axial and bending stress comparison in molar tooth. Difference in analytical and FE results doesn't exceed 10% so results and method considered as authentic and valid.

From stress distribution it appears that stress due to bending is higher as compared to loading due to axial component although bending component is lower than axial component.

Use of FEA tool for such complex geometry and complex approaches used for stress analysis overcomes the limitations of experimental and analytical methods.

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