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Stress Analysis of Second Molar Tooth

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ABSTRACT

It is well known fact that molar tooth of human being faces different loading conditions. In this paper a general model is made in Pro-Engineer to carry out analysis of second premolar tooth of human using Finite Element Analysis(FEA). Also the effect of breaking hard objects like walnut on teeth and stress distribution under this loading condition is considered. This analysis has been carried out seamlessly between CAD and FEA. As the stress distribution is an important factor for many types of dental treatments, including designing dental implants, applying restoration etc., the results of this paper will help in understanding the way in which stresses are distributed in dental structures.

Keywords: pro-engineer, walnut, CAD, FEA.
DOI: 10.3722/cadaps.2013.701-709

1 INTRODUCTION

Human dental structures, both natural and manmade, experience different internal stresses which are of great interest to both practicing dentists and researchers. Palamara et al., [10] and Topbasi et al., [13] revealed that stresses resulting from regular chewing forces will not cause any damage to regular teeth, but once the teeth are damaged due to the loss of tooth tissue on a certain area, they become more sensitive to fracture due to concentration of stresses. According to Borcic et al., [5], Ausiello et al., [4], Toparli et al., [12] and Arola et al., [1] restorations composed of various materials and the anomalous biting forces caused by hard food or anomalous chewing will make teeth more susceptible to fracture. Thus, understanding the way in which stresses are distributed in dental structures, and where the highest stresses are concentrated, is an important aspect to be taken into account.

As per the literature study, it was found that for the stress analysis of human tooth, there are basically three methods usually performed: analytical, experimental and computational methods. In analytical methods mathematical equations were used to describe the stress state of a structure. But, biological systems are too complicated for analytical treatment: human teeth are a good example of the complexity of such systems. In short, analytical methods for stress descriptions of human teeth were not critically used in previous works.

Similarly using experimental techniques many difficulties arises. Palamara et al., [10] concluded that physical stresses can be measured on human teeth using experimental methods but experimental procedures provides a solution for only one particular tooth shape for each experiment and not a general method for describing the stress in any tooth.

Many researchers for the last few years are using computational methods. Today, the primary computational method used for stress analysis is Finite Element Analysis (FEA). It can be found through literature review that in computational method a geometric model is developed and a mesh is created by subdividing the geometry into rectangular or brick-shaped elements. In all FEA studies there are four sets of parameters that completely define the model: geometry, material behavior, loading and boundary conditions. Once the model is completely defined and meshed, a stress analysis is performed to obtain the stress distributions.

Thus, understanding the way in which stresses are distributed in dental structures, and where the highest stresses are concentrated, is an important aspect to be taken into account. In this paper anomalous biting forces to break a hard object are taken in consideration to obtain the deformation and stress distribution of mandibular molar tooth of human.

2 OBJECTIVE

The objective of this paper is to carryout the stress analysis of second human molar tooth using computational method. The anatomy of molar tooth of human is represented in Figure 1. The impact of anomalous breaking forces for breaking hard objects like Walnut was taken into consideration. The maximum value of concentrated stress and deformation occurred in molar tooth has been computed under the effect of inconsistent breaking forces.

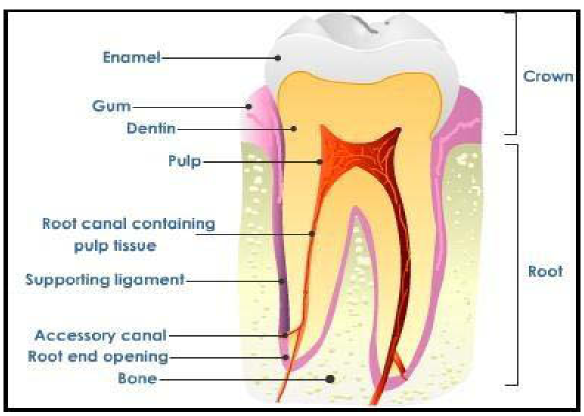

Fig. 1: Parts of human molar tooth.

3 EXPERIMENTAL DETAILS

3.1 Tools

ANSYS Workbench software is used for Finite Element Analysis (FEA) and Pro-Engineer is used for modeling of molar tooth. Pro-Engineer is a parametric software mainly used for designing purposes developed by Parametric Technology Corporation, Needham, MA, USA and ANSYS is an engineering simulation software mainly used for simulation purpose developed by ANSYS Inc., Pennsylvania, United States. Tool profile projector is used for the dimensional analysis of molar tooth. Spring testing machine is used for calculation of load required to break a walnut.

3.2 Construction of Parametric Models

According to Ash, [2]; Ash, [3]; Karring and Lindhe,[7]; Grine, [6] and Schwartz et al.,[11], the geometric model for molar tooth can be drafted if size and shape for each tooth part is known. The geometric model comprising of length of crown, length of root, diameter of crown, thickness of enamel and width of bone used in this study is represented by Figure2.

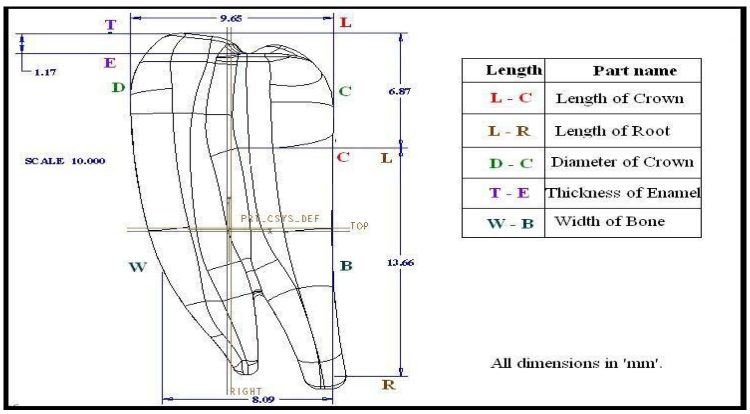

Fig. 2: Dimensions of second molar tooth.

A sequence of representative points are calculated using the parameters and description of the tooth. These representative points are traced with the help of highly magnified and sharp image produced by profile projector.

The measured dimensions of the geometric model of second molar tooth are tabulated in Table 1.

	Length of crown (mm)	Length of root (mm)	Diameter of crown (mm)	Thickness of enamel(mm)	Width of bone (mm)
Mandibular molar tooth	6.87	13.66	9.65	1.17	8.09

Tab. 1: Measurements for mandibular molar tooth of average size.

3.3 Generation of CAD Compatible Model

3-Dimensional CAD model is generated in Pro-Engineer software using splines and curves through which surfaces are generated to give a specific shape of molar tooth. The geometry of roots and enamel portion is actively made in this model according to all the dimensions provided by profile projector. A chain of representative points produced the curves which are further joined through point to point curve. These representative points are connected together using spline curves to form each part of tooth. After generating the surfaces, they all are made merge to form smooth geometry. To provide sharpness to the model, fillets are used at the end.

3.4 Calculation of Breaking Load

Spring testing machine was used to find out the value of load to break a walnut. The initial value of load was taken as zero in Spring Testing Machine and Walnut was placed in between the centre of compression plates of machine. During compression test of walnut, its position was kept longitudinally. Six samples of walnut were tested on spring testing machine under compressive loading. The mean value of breaking load was taken after calculating six set of readings. The average value of load to break a walnut was found to be 150 N. The experimental results for breaking a walnut under compression load are tabulated in Table 2.

S. No.	Load (KN)	Displacement (mm)
1.	0	95.6 (When compression plates fix the walnut at null state)
2.	0.052	96.2
3.	0.060	97
4.	0.068	97.5
5.	0.075	98
6.	0.083	98.5
7.	0.094	99
8.	0.120	100
9.	0.130	107
10.	0.150	110
11.	0.090	120

Tab. 2: Readings of compression test of walnut.

4 METHODOLOGY

The preprocessed IGES file from the CAD model was successfully imported to the FEA software. Element type selected for meshing of tooth was solid tetrahedral element available in ANSYS Workbench. For meshing and equavalencing of solid model òBy default meshingó was adopted. To carry out this analysis of molar tooth, the root portion of the molar tooth is made fixed by constraining all its degree of freedom. During practical application of force to break a walnut, it was observed that the load first comes at the top most part of enamel of mandibular tooth. After impacting this part, action of load get distributed to entire portion of the enamel. All loads on human tooth, whether from orthodontic devices, inconsistent biting forces, anomalous chewing forces and force to break a walnut can be treated as either concentrated or distributed. The load to break a walnut by molar tooth was considered to be distributed over the entire area of the enamel. This area is clearly shown in Figure 3.

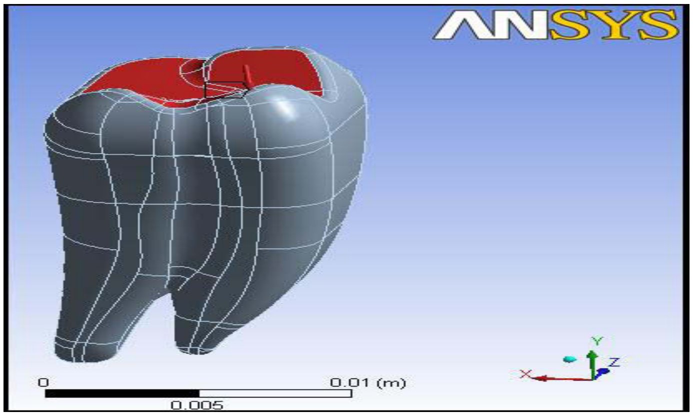

Fig. 3: Application of load over the surface of crown.

The material properties for enamel portion (which can be isotropic or anisotropic), including Elastic modulus and Poissonós ratio were taken as per literature (Li; Rubin [9]). Material properties of enamel part of molar tooth are tabulated in Table3.

Material	Property	Value
Enamel	Youngós modulus (MPa)	85000
	Poissonós ratio	0.33

Tab. 3: Material Properties used for molar tooth.

5 RESULTS AND DISCUSSIONS

The study presented in this paper is a Finite Element Analysis of human second molar tooth to identify deformation and stress concentration under the effect of breaking forces. It was found that the load 150 N get uniformly distributed over the entire area of enamel. Using computational methods the effect of load and maximum stress induced was found to determine the deformation of molar tooth. This paper emphasized on the maximum deformation occurred in molar tooth and maximum equivalent stress concentrated by irregular breaking forces to break a walnut.

5.1 Deformation of Molar Tooth

The value of maximum deformation occurred due to application of breaking force for a walnut comes out to be 1.5683×10^{-5} m. It may be observed from Figure 4 that the maximum deformation was critically occurred at top part of enamel portion of crown. This region of maximum deformation can be clearly seen and is coded with red region as shown in Figure 4.

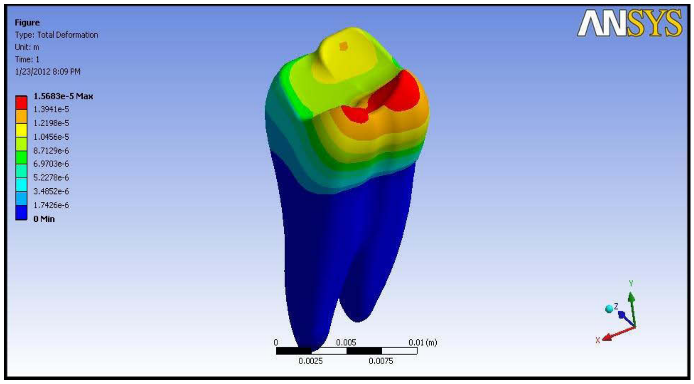

Fig. 4: Total deformation of molar tooth.

This region of maximum deformation is also found in next corresponding lower portion of enamel but this region is less affected as compared to top part of enamel. The distribution of deformation by anomalous breaking forces shows that the maximum impact of force was first produced on the upper most enamel portion, then it gets shifted to the next lower portion and then transferred to other parts of crown. Thus it may be concluded that although the value of deformation is quite small but still it is contributing to deform the molar tooth.

5.2 Maximum Equivalent Stress Distribution

Using ANSYS the maximum value equivalent stress induced by breaking force found at the enamel portion of molar tooth comes out to be 426.16 MPa. This result can be helpful for practicing dentists and researchers in estimating the value of stress which is induced during various dental implants and restorations. The variation of stress distribution is well depicted by the maximum equivalent stress (Figure 5).

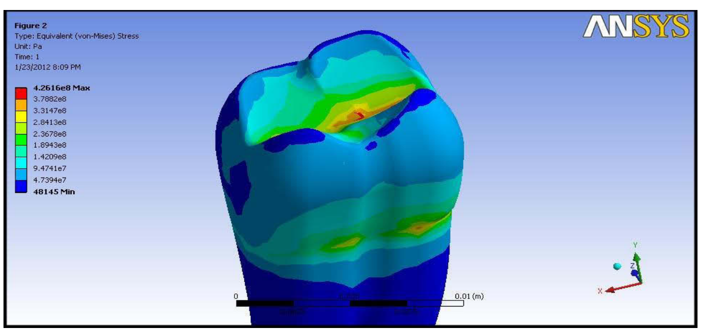

Fig. 5: Maximum equivalent stress distribution.

It may be clearly observed from the Figure 6 that the application of breaking force directly imparts maximum stress near to the middle portion of enamel. It was observed that the molar tooth starts decaying from middle portion of enamel. Regular tooth are not sensitive to fracture but once teeth get damaged by loss of tooth tissue, they become more sensitive to these stresses. The maximum stress induced by inconsistent breaking forces was found near the middle portion of enamel and then distributed to the rest of the enamel portion.

5.3 Distribution of Factor of Safety

The distribution of factor of safety was necessary to calculate. This is because to declare that whether molar tooth is safe or not under the action of breaking forces. The minimum value of factor of safety which is obtained by this stress analysis was found as 0.58663, which is quite less than 1. This shows that anomalous breaking forces can cause a damage to molar tooth. This declaration is only made on the basis of minimum value of factor of safety obtained by Finite Element Analysis of molar tooth under the action of breaking force to break a walnut. The distribution of safety of factor is shown in Figure 6.

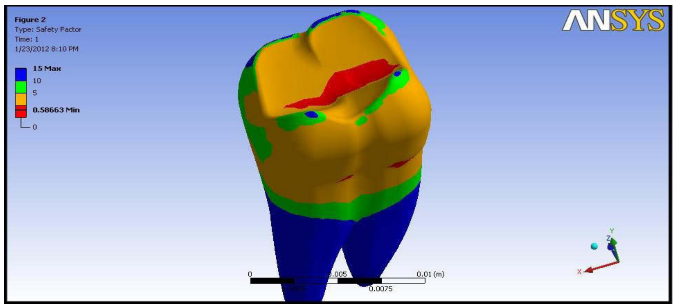

Fig. 6: Distribution of factor of safety.

It may be clearly observed from the above figure that the factor of safety is minimum at the centre of enamel portion. The variation of factor of safety with respect to unit time (in sec) has been obtained as depicted from Figure 7. It is clear from Figure8 that the factor of safety decreases with the increase in time interval. The decrease of factor of safety concludes that the effect of anomalous breaking forces increases the stress concentration in molar tooth. Hence, it can be concluded that the enamel portion of molar tooth is not safe under the action of inconsistent breaking forces.

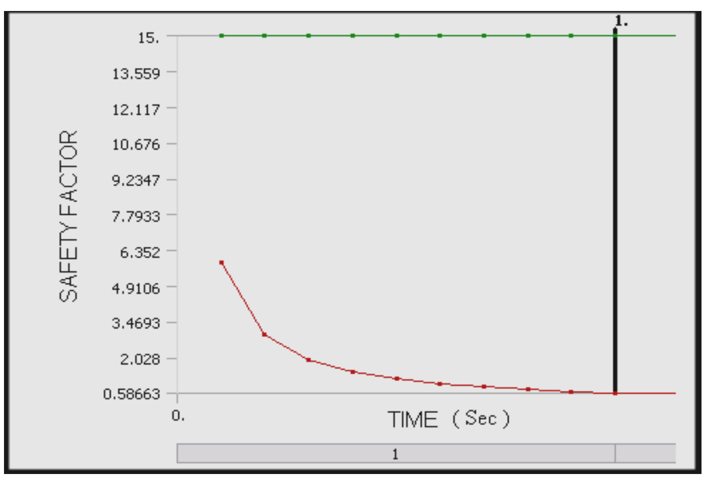

Fig. 7: Variation of factor of safety.

6 CONCLUSION

Human being generally do not give much care while eating or breaking hard objects with tooth. The study presented in this paper is a Finite Element Analysis of molar tooth which identifies deformation and maximum stress induced by the action of anomalous breaking forces (like breaking a commonly used dry food walnut). The value of maximum deformation due to breaking a walnut was found as 1.5683×10^{-5} m and maximum equivalent stress over the surface of crown of enamel comes out to be 426.16 MPa. The small value of factor of safety which equals 0.5866, reveals that the stress concentration is induced over molar tooth by breaking hard objects like walnut. Hence it may be concluded that the inconsistent breaking forces make an impact on molar tooth structure. This study will surely help practicing dentists and researchers in estimation of the range of stress concentration during various dental implants.

7 RECOMMENDATION FOR FUTURE WORK

There are several areas where more work is needed for analysis of molar-tooth. A few future recommendations for future studies aimed at achieving this study are listed below:

- Different filler materials in the cavities of the tooth can be taken into account to evaluate the life of tooth using Finite Element Analysis.
- Stress analysis of molar tooth for breaking hard objects other than walnut (used in this study).

ACKNOWLEDGEMENT

Both the authors express their sincere gratitude to Regional Director, Engg. Colleges (DAVCMC) Sh. C.L. Kochher and Dr. A.L.Sangal, Principal D.A.V Institute of Engineering and Technology for funding grant and providing lab equipments during this research. Appreciation also goes to Dr. Daljinder Singh Minhas, Dr. Navdeep Kaur (Calgary), Er. Mandeep Singh, Er. Akashdeep Goel and Er. Parminderjit Singh for their valuable guidance and suggestions about the subject. We would like to express our gratitude to our family for painstaking sacrifice. Above all, to my beloved present master, who never cease in loving us and showering his gracious blessings continuously.

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