ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 3, Issue – 4, July - 2020, Page No. : 494 - 502

Influence of different cervical dentin loss on stress distribution in different posts used to restore endodontically treated primary teeth under various traumatic loading: 3-D Finite Element Study

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Citation of this Article: Dr. Binita Srivastava, Dr. Malvika Panchal Sharma, Dr. Nidhi Gupta, Dr. Rashi Singh, "Influence of different cervical dentin loss on stress distribution in different posts used to restore endodontically treated primary teeth under various traumatic loading: 3-D Finite Element Study", IJDSIR- July - 2020, Vol. – 3, Issue -4, P. No. 494 – 502.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Introduction: Determination of stress distribution endodontically treated teeth restored with post and core is very difficult because of its complex system. The system has small dimensions due to which most biomechanical research was unsuccessful in explaining the internal behavior of the structures. Finite Element Analysis (FEA) is one of the upcoming methods to evaluate the stresses and strains in the living structures under various external forces.

Aim: To evaluate and compare the influence of stress distribution in different cervical dentin loss on stress distribution in different posts used to restore endodontically treated primary teeth under various traumatic loading: 3-D Finite Element Study.

Materials and Methods: A 3D finite element model of an endodontically treated deciduous maxillary central incisor tooth was generated and geometric models were developed using pro/engineer which were meshed into elements. Vertical, horizontal, and oblique loads of 150 N were applied on the crown to simulate horizontal traumatic impact, ideal primary occlusion and vertical traumatic impact respectively. Von-mises stresses in dentin, posts, cores and crowns were determined using ANSYS Software.

Results: During all the three loading condition maximum stress noticed was with 0 mm dentin loss in Zirconia post, whereas with the increase in cervical dentin loss models stress values decreases in the posts. Dentin Post has shown the least values of stress distribution. This concludes that maximum value of stress are exhibited with horizontal loading followed by Oblique loading and vertical loading showed the least values of stress. Hence zirconia post bears more stress within and least stresses are transferred to the root dentin.

Conclusion: Thus it is concluded that, the high elastic modulus post (Zirconia Post) showed maximum stress with all the types of dentin loss.

Keywords: Finite Element Analysis, Stress distribution, Glass-fiber post, Zirconia post, Ribbond post, Dentin post

Introduction

Early childhood caries (ECC) is a devastating condition for both the child undergoing the dental treatment and the concerned parent[1]. It is characterized by affecting the maxillary anterior teeth followed by molars. The early loss of primary teeth results in problems such as decreased masticatory efficacy, development of Para-functional habits, speech, esthetic-functional problems, and psychological problems that may intervene in personality and behavioral development of child[2].

Restorations of decayed primary maxillary anterior teeth mainly at the cervical third of the crown are usually a clinical dilemma for every Pediatric dentist.[3] As a consequence of the extensive carious decay with pulpal involvement and endodontic intervention, there is severe loss of the coronal structure[1]. Several attempts have been made by clinicians to restore grossly decayed anterior primary teeth with strip crowns, polycarbonate crowns, veneered stainless steel crowns, and art glass crowns[4]. Carious teeth with sufficient tooth structure are being restored esthetically so that the primary teeth are retained until they are replaced by permanent teeth[5]. But these restorations have failed to withstand the occlusal and external forces. Hence, the innovative intra-canal posts and core systems such as modified Omega shaped orthodontic wires[3,6], biological posts[7,8], fiber core posts, Polyethylene Fiber-Reinforced Posts (PFR)[9] and glass reinforced fiber composites have been introduced to overcome the problem of fracture of restoration of such teeth with extensive loss of tooth structure.[2, 4]

The biomechanical conditions that result in fracture are characterized by the stress development in a tooth[10]. Various mechanical investigations have been used to determine stress, behavior and mechanical properties of the tooth structure, but are limited in their assessment of stress distributions in the internal structures[11]. To completely understand the complex mechanisms of post-core application, a more comprehensive analysis of stress is needed to determine the optimal procedures for reconstructing these endodontically treated teeth[12].

Stress analysis has been popular in determining stresses in the dental structures and improvement of the mechanical strength of these structures[13]. Being a complex biomechanical system oral cavity has limited access. Due to this, most biomechanical research has been performed in-vitro and in-vivo studies, but were unsuccessful to explain the internal behavior of the structures[14]. Finite Element Analysis (FEA) makes it possible to evaluate the stresses and strains in the living structures under various external forces[13].

Finite Element Analysis (FEA) is a modern, powerful and a valuable analytical tool for complex biomechanical analysis in biological research[14]. The finite element method (FEM) comprises of a series of mathematical computational procedures to evaluate the load distribution in each element. The results obtained can be visualized using visualization software to view a variety of parameters, and to fully identify implications of the analysis[12]. FEA has various advantages compared with studies on real models like understanding the biomechanics of fracture under simulated traumatic loads [14]. Presently in various fields of engineering: civil engineering, mechanical engineering, nuclear engineering, biomedical engineering, the finite element method (FEM) is considered to be one of the well-established and convenient technique for the computer solution of complex problems[15].

Aims And Objectives

- To evaluate and compare the influence of various cervical dentin loss on stress distribution in different posts under various traumatic loading.
- The objective was to attain an extensive knowledge of the mechanical performance of the post restored endodontically treated teeth with varying cervical dentin loss.

Materials & Methods

The in-vitro study would be carried out in collaboration with **"Le-Logix Design Solution Private Limited"** in Greater Noida.

The following Computer Characteristics will be used: **ANSYS 14.0 Version**

Source of Data: Three-dimensional finite element models of an endodontically restored Deciduous Maxillary Central Incisor tooth using different post and core combinations will be subjected to loads in three different loading directions. The mechanical properties (Young's modulus of elasticity and Poisson's Ratio) will be collected from the literature and Finite element analysis will be done.

General Steps of Finite Element Analysis (FEA)

Preprocessing: Pre-processing involves constructing the **"Model".**

The model will consist of the geometrical representation, the definition of the material properties, and the determination of the load and site of loading.[10]

A. **Construction of the Geometric model:** The objective of the geometric modeling stage is to describe geometry in relation to points, lines, areas, and volume. Complex, as well as smooth objects, are described by geometrically simple elements.[12]
B. **Conversion of the Geometric model to Finite Element Model:** Discretization is the procedure of dividing problem into numerous small elements, connected with nodes. All elements and nodes have to be numbered to ensure the building of matrix connectivity. This significantly will influence the computing time period. The elements would be in various shapes and are usually one, two or three-dimensional. It is important that the elements should not be overlapping but are connected just at the key points, which are referred to as nodes. The elements will be joined at the nodes and will eliminate duplicate nodes termed as 'Meshing'.[12] The resultant group of elements is known as the finite element mesh. The finite element mesh will constitute spatial coordinates characterized by quadrilateral elements combined and organized to generate various geometric shapes – triangles, tetrahedrons, and hexahedrons. More the number of quadrilaterals used to generate the mesh, higher are the accuracy and reliability of FEA.[18]
C. **Assembly / Material Property data representation:** The stresses and strains distribution in a structure are significantly influenced by material properties. These properties are generally modeled in FEA as isotropic, transversely isotropic, orthotropic, and anisotropic.

Isotropic materials are those materials which display similar properties in every direction, Anisotropic materials show different properties along the directions and Orthotropic materials exhibits same properties in two directions and different in the third.[18] Equations will be produced for each element in the FEM mesh and assembled into a set of global equations that design the properties of the entire system. Poisson's ratio, Young's Modulus and Density of the material are the minimum properties required to generate the Mesh.[3] All these factors will give the information to the software on how a given material will behave when subjected to a force application taking into account its deformation capability, elasticity, and behavior under tension or compression.[18]

D. **Defining the Boundary Conditions:** The boundary conditions define the external influences on a modeled structure, usually loading and constraints.[10] It signifies that if an element is designed on the computer and a force applied to it, it will behave like a free-floating rigid body and will go through a translatory or rotatory motion or a combination of the two without undergoing deformation. To analyze its deformation, certain degree of freedom must be restricted (movement of the node in each direction x, y, and z) for some of the nodes. Such restrictions are referred to as boundary conditions.[12] To ensure an equilibrium solution, a zero displacement constraint must be placed on some boundaries of the model. The constraints would be placed on nodes which are far away from the region of interest to prevent the stress or strain fields associated with reaction forces from overlapping with each other.[18]

E. **Loading configuration:** The application of loads in an FEA model must also represent the external loading situations to which the modeled structure will be subjected. These loads can be tensile, compressive, shear, torque, etc.[10] Application of force will be at various points of geometry and its configuration. The word "loads" as used in the ANSYS program includes boundary conditions as well as other externally and internally applied loads. The majority of loads can be applied either on the solid model (key points, lines, and areas) or the finite element model (nodes and elements). A load step is simply a configuration of loads for which a solution will be obtained.

Processing: In this step the system of linear algebraic equation are solved. After SOLVE command, the results will be calculated using ANSYS program by taking model and loading information from the database. The stresses will be determined from the strains by Hooke's law. Strains will be derived from the displacement functions within the element Combined with Hooke's law.[12]

H. **Post-Processing:** After gaining the solution, the ANSYS post-processors are used to review the results. The output achieved from the Finite Element Analysis is basically in three forms: Graphical-output, Numeric-output, and Animated-output.[13] The numerical form is primarily used. Graphic outputs and displays are definitely more informational. The output is usually in the form of color-coded maps. The quantitative analysis is determined by interpreting these maps.[12] The colors vary from red to blue. Red denotes the area of maximum tensile stress and blue signifies the area of maximum compressive stress. The numeric output will display the amount of principle stress/strain into the given material. In the animated output, the results will be shown as animations.

Materials used in study

1. A Model of maxillary deciduous central Incisor tooth
2. Computer with a Finite Element Program

(ANSYS, Version 15.0)

3. Zinc Oxide Eugenol Cement

(Deepak Enterprise, India)

4.Glass Ionomer Cement Type 2

(3M ESPE, USA)

5. Bonding agent

6. Tetric flow

7. Zirconia Crown

Material properties: Young's Modulus of Elasticity & Poisson's ratio of:

- Restorative materials are given in **(Table: 1),**
- Tooth are given in **(Table: 2),**
- Posts are given in **(Table: 3),**

4-Different Posts Materials
1. Glass-fiber Post
2. Zirconia Post
3. Ribbond Post
4. Dentin Post

Material	Young's Modulus of elasticity (MPa)	Poisson's Ratio	Reference
Enamel	80350	0.33	Gurbuz et al
Dentin	19890	0.31	Gurbuz et al
Pulp	2	0.45	Gurbuz et al
Cortical Bone	14700	0.30	Gurbuz et al
Spongiose bone	490	0.30	Gurbuz et al
Periodontal ligament	69	0.45	Gurbuz et al

Table 1: Mechanical Properties of Tooth

Material	Young's Modulus of elasticity (MPa)	Poisson's Ratio	Reference
Enamel	80350	0.33	Gurbuz et al
Dentin	19890	0.31	Gurbuz et al
Pulp	2	0.45	Gurbuz et al
Cortical Bone	14700	0.30	Gurbuz et al
Spongiose bone	490	0.30	Gurbuz et al
Periodontal ligament	69	0.45	Gurbuz et al
Cementum	18600	0.3	Desai et al
Gingiva	0.019	0.3	Adanir et al

Table 2: Mechanical Properties of Restorative Materials

Material	Young's Modulus of elasticity (MPa)	Poisson's Ratio	Reference
Glass-fiber Post (G.P)	45000	0.24	Adanir et al
Zirconia Post (Z.P)	210000	0.23	Adanir et al
Ribbond fiber + bonding agent + Tetric flow (R.P)	23600	0.32	Gurbuz et al
Dentin Post	18600	0.31	Memon et al

Table 3: Mechanical Properties of Posts

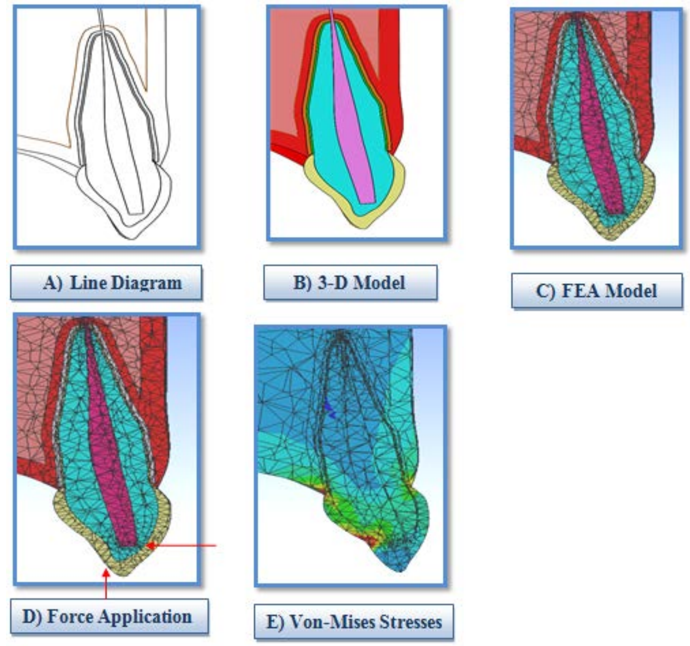


Figure 1: Creation of Geometric Model, FEM Model and Force Application

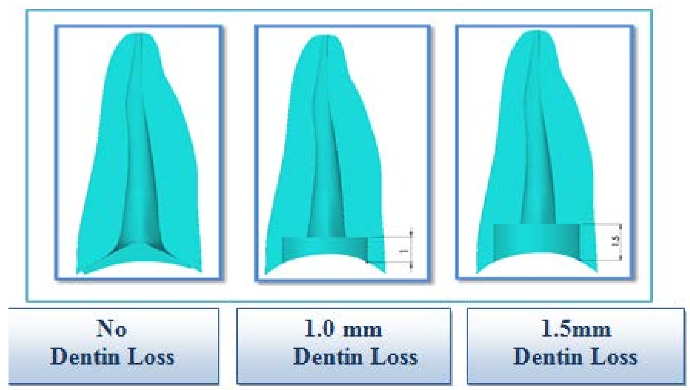


Figure 2: Different Cervical Dentin loss

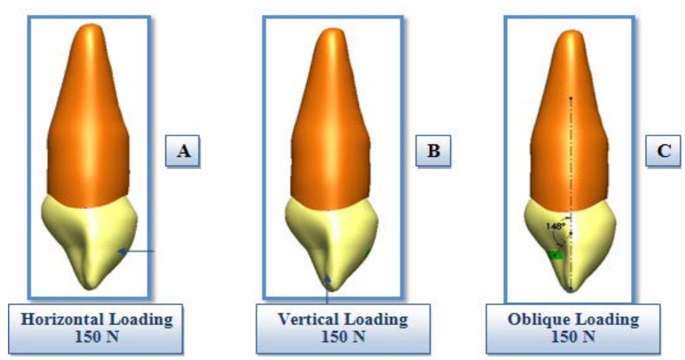


Figure 3: Loading Condition

Results

Table 4: Maximum Von- Mises Stress values in different post materials with various cervical dentin-loss under **Horizontal load**

Cervical dentin loss	Glass-Fiber Post	Zirconia Post	Ribbond Post	Dentin Post
0 mm	13	48	9.7	9
1.0 mm	12.5	42	9.6	8.5
1.5 mm	12	41	9.5	8

*Mega Pascal: (1 MPa = 1,000,000 Pascal)

Graph 1: Comparison of Maximum Von- Mises Stress values in different post materials with various cervical dentin-loss under Horizontal load

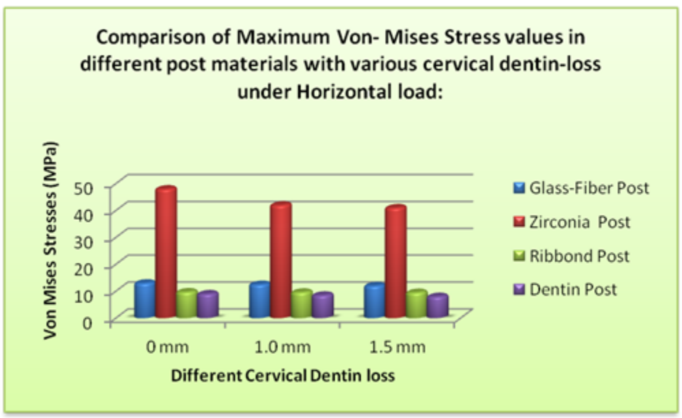


Table 5 : Maximum Von- Mises Stress values in different post materials with various cervical dentin-loss under Oblique load

Cervical dentin loss	Glass-Fiber Post	Zirconia Post	Ribbond Post	Dentin Post
0 mm	20	45	16	15
1.0 mm	15	35	12	11
1.5 mm	13	32	10.5	9.5

*Mega Pascal: (1 MPa = 1,000,000 Pascal)

Graph 2: Comparison of Maximum Von- Mises Stress values in different post materials with various cervical dentin-losses under Oblique load:

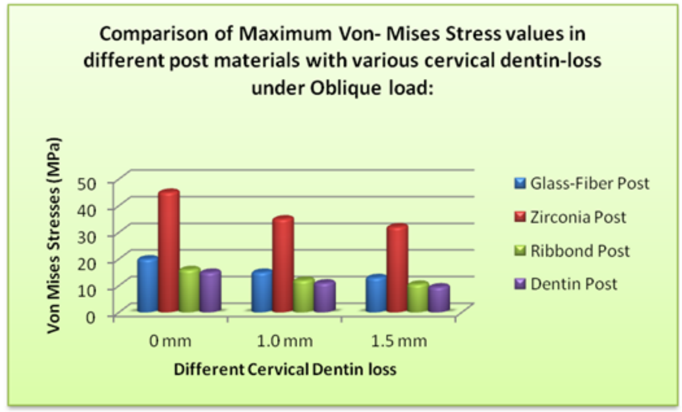
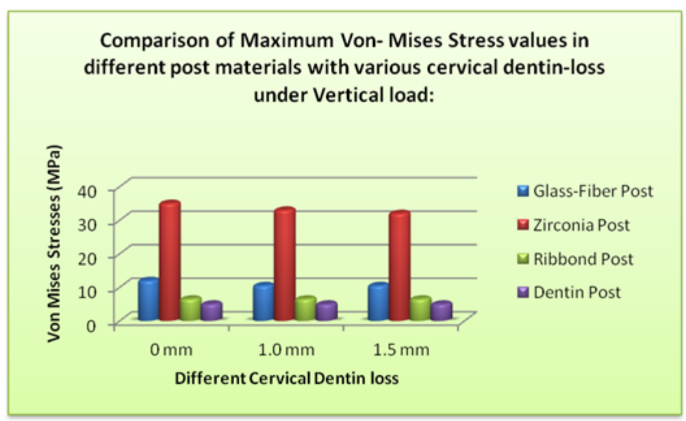


Table 6: Maximum Von- Mises Stress values in different post materials with various cervical dentin-loss under Vertical load

Cervical dentin loss	Glass-Fiber Post	Zirconia Post	Ribbond Post	Dentin Post
0 mm	12	35	6.5	5
1.0 mm	10.5	33	6.5	5
1.5 mm	10.5	32	6.5	5

*Mega Pascal: (1 MPa = 1,000,000 Pascal)

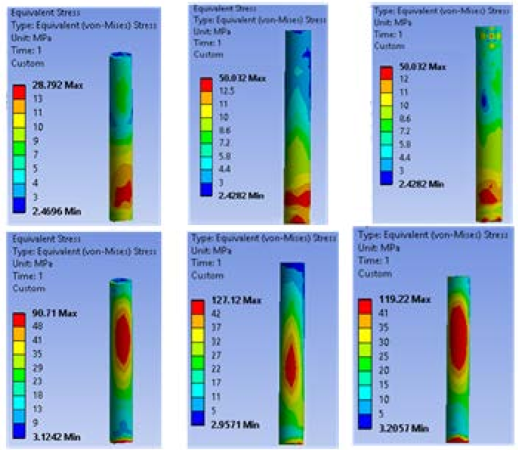
Graph 3: Comparison of Maximum Von- Mises Stress values in different post materials with various cervical dentin-loss under Vertical load:



Horizontal Load

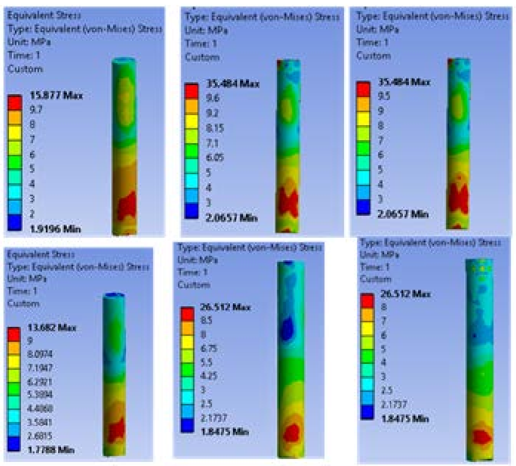
Glass fiber Post

Zirconia Post



Ribbond Post

Dentin Post



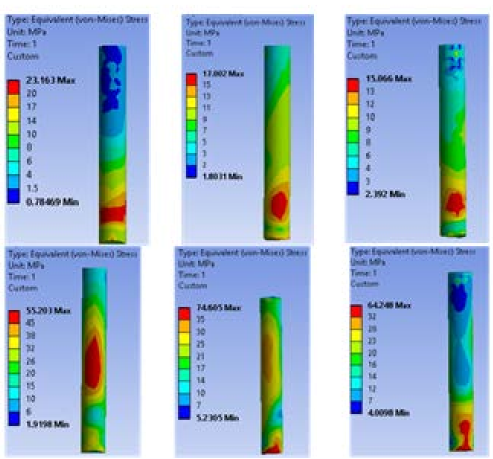
No loss 1.0 mm 1.5 mm

Cervical Dentin Loss

Oblique Load

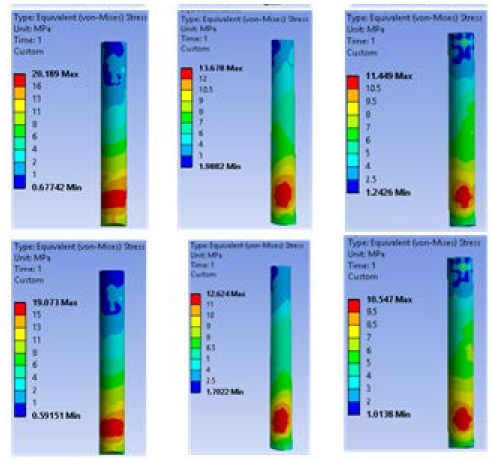
Glass fiber Post

Zirconia Post



Ribbond Post

Dentin Post



No loss 1.0 mm 1.5 mm

Cervical Dentin Loss

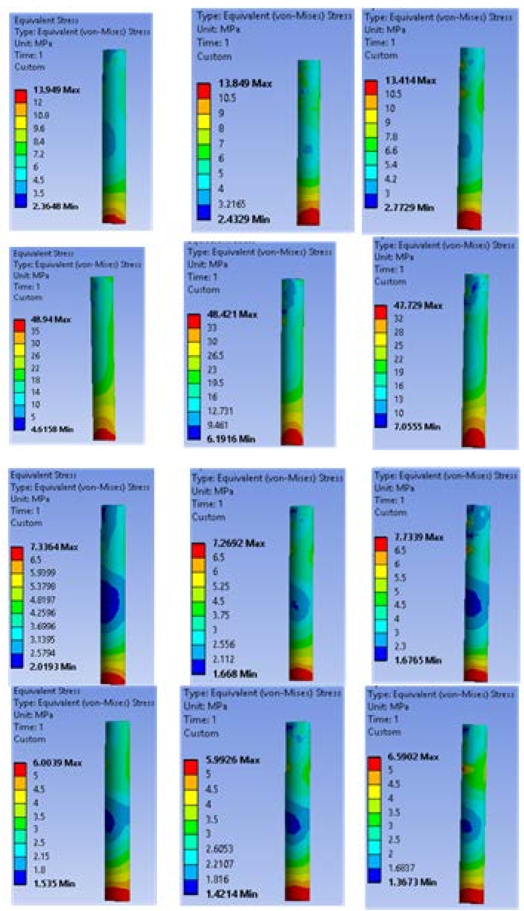
Vertical Load

Glass fiber Post

Zirconia Post

Ribbond Post

Dentin Post



No loss 1.0 mm 1.5 mm

Cervical Dentin Loss

Conclusion

Effect of cervical dentin loss on the stress distribution in root dentin is important and has been investigated in this simulation. The depths varied from *no dentin loss, 1mm dentin loss and 1.5 mm dentin loss.* Irrespective of the loading condition Zirconia Post is showing the maximum stress values when compared to other posts.

- During all the three loading condition ***(horizontal loading, oblique loading*** and ***vertical loading)*** maximum stress noticed was with 0 mm dentin loss in Zirconia post, whereas with the increase in cervical dentin loss models stress values decreases in the posts. Dentin Post has shown the least values of stress distribution.
- This concludes that maximum value of stress are exhibited with horizontal loading followed by Oblique loading and vertical loading showed the least values of stress. Hence zirconia post bears more stress within and least stresses are transferred to the root dentin.
- Thus it is concluded that, the high elastic modulus post (Zirconia Post) showed maximum stress with all the types of dentin loss. This concludes that more of the loading is supported by the posts having below or equal elastic modulus that of dentin.
- The material with high Young's modulus of elasticity exhibits less stress distribution in teeth and restoration.

References

1. Council R. Policy on Early Childhood Caries (ECC): Classifications, Consequences, and Preventive Strategies. 2016;(6):52–4.
2. Verma L, Passi S. Glass Fibre-Reinforced Composite Post and Core Used in Decayed Primary Anterior Teeth: A Case Report. Case Rep Dent [Internet]. 2011;2011:1–4.
3. Article R. Methods of Intracanal Reinforcement in Primary Anterior Teeth — Assessing the Outcomes through a Systematic Literature Review:48–54.
4. Toksavul S, Zor M, Toman M, Güngör MA, Nergiz I, Artunç C. Analysis of Dentinal Stress Distribution of Maxillary Central Incisors Subjected to Various Post-and-core Applications. Oper Dent. 2006;31(1):89–96.
5. Rajesh R, Baroudi K, Reddy KBK, Praveen BH, Kumar VS, Amit S. Modified Anchor Shaped Post Core Design for Primary Anterior Teeth. Case Rep Dent. 2014; 2014 (Figure 1):1–4.
6. Gupta P, Bhatnagar P, Bais PS, Bhatnagar A. Case Report Management of Mutilated Primary Anteriors : A challenge to pediatric dentist. 2017;4(1):45–7.
7. Botelho AM. "Biological Restoration": Root Canal and Coronal Reconstruction. 2010;22(3):168–77.
8. Swarupa C, Sajjan GS, Bhupathiraju VL, Anwarullah A, Sashikanth Y V. Biological dentin post for intra radicular rehabilitation of a fractured anterior tooth. J Clin Diagnostic Res. 2014;8(2):242–3.
9. Shetty N. Types of post and core systems. J Int Oral Health 2016;8(12):1136-1139.
10. Soares CJ. Finite element analysis in Dentistry – improving the quality of oral health care. Finite Elem Anal - From Biomed Appl to Ind Dev. 2012;25–50.
11. Andressa M, Piccioni R V, Campos EA, Roberto J, Saad C, Ferrarezi De Andrade M, et al. Application of the finite element method in Dentistry. Comput Methods Biomech Biomed Engin. 2006;9(4):257–70.
12. Mehta Falguni JH. Finite Element Method: An Overview. IOSR J Dent Med Sci. 2016;15(Issue 3 Ver. III ,):PP 38-41.
13. Desai H MS. Basic Concepts of Finite Element Analysis and its Applications in Dentistry: An Overview. J Oral Hyg Heal. 2014;2(5).

14. Trivedi S. Finite element analysis: A boon to dentistry. J Oral Biol Craniofacial Res. 2014;4(3):200–3.
15. Nikishkov G. Introduction to the finite element method. Univ Aizu. 2004;1–70.
16. Lodaya SD. Orthodontic Force Distribution : A Three-dimensional Finite Element Analysis. 2010;1(December):159–62.
17. Peters MCRB, Poort HW, Farah JW, Craig RG. Stress Analysis of a Tooth Restored with a Post and Core. J Dent Res. 1983;62(6):760–3.
18. Chopade S, Madhav V, Palaskar J. Finite element analysis: New dimension in prosthodontic research. J Dent Allied Sci. 2014;3(2):85.
19. Adanir N, Belli S. Stress analysis of a maxillary central incisor restored with different posts. Eur J Dent. 2007;1(2):67–71.
20. Gurbuz T, Sengul F, Altun C. Finite element stress analysis of short-post core and over restorations prepared with different restorative materials. Dent Mater J. 2008;27(4):499–507.
21. Memon S, Mehta S, Malik S, Nirmal N, Sharma D, Arora H. Three-dimensional finite element analysis of the stress distribution in the endodontically treated maxillary central incisor by glass fiber post and dentin post. J Indian Prosthodont Soc 2016;16(1):70.
22. Prabhakar AR, Chakraborty A, Nadig B, Yavagal C. Finite element stress analysis of restored primary teeth : A comparative evaluation between stainless steel crowns and preformed zirconia crowns. 2017.