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Evaluation of Stress Distribution in Teeth with Angulated Cast Posts: Fem Analysis

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Abstract

Aim: To evaluate and compare the stress distribution pattern of simulated endodontically treated maxillary central incisors restored with cast post and cores with different core angulations.

Materials and Methods: An intact maxillary central incisor was decoronated 3mm above the CEJ, endodontically treated and restored using cast post and core and metal ceramic crown. The sample was scanned using 3D white light scanner and FEM models were generated by angulating the cast core to the post and were divided into 4 models : cast post restored central incisor with 0^0 core angulation , 10^0 angulation , 20^0 angulation , 30^0 angulation . A force of 75N was applied at an angle of 135 degrees to the long axis of crown on palatal side and stress distribution was analysed.

Results:

- At 30 degrees, highest stress concentration was seen at cervical region of the tooth
- Upto 20 degree change in core angulation, there was not much of increase in stress distribution under normal loading conditions

Conclusion: Upto 20 degrees, the cast post and cores had no much detrimental effects and beyond that the stress levels increased drastically and stresses accumulated at the cervical 3rd of the tooth.

Keywords: Custom cast post and cores, Finite element method, Von misses stresses

Introduction

Malaligned Proclined maxillary central incisors are most prone to fracture following trauma to orofacial region which is usually seen due to a fall or road traffic accidents[1]. Rehabilitating such teeth to normal alignment not only improves the esthetics, but also increases the long term success rate of the treatment outcome by preventing further fractures in the future.

Orthodontic treatment remains the best method for aligning the malposed teeth, as the tooth movement is similar to physiologic tooth movement with bone remodelling taking place. However, for those patients not willing for orthodontic treatment due to time constraints, economic reasons, needing immediate esthetics-restorative treatment can be saught as an alternative[2]. A slight change in the tooth's angulation can be obtained by modifying the access cavity preparation during root canal treatment followed by tooth preparation appropriately to receive a crown. But this may lead to undue loss the natural tooth structure, especially on the labial side - necessitating placement of post and core restoration.

Various Post and core systems are available in the market, from the pre-fabricated metal posts- to the custom cast metal/Ceramic- and Fibre posts. However, they are not indicated for teeth requiring more angulation correction, as they cannot be bent and would debond easily from the core. This is where, traditionally used custom cast posts have a role to play. The cast cores can be suitably angled to the post[3-4], unlike the fibre post without the question of debonding of core from the post as they act as single assembly[5-8]. In addition, they provided good fracture strength and cervical strengthening effect to flared roots even in very thin sections.Cast post and cores have been used for changing core angulation, since decades with good success rate[9]. The fracture resistance and stress distribution pattern in teeth with angulated cast posts is certainly different from a normal tooth and may vary with varying degrees of core angulation.

However, there is no conclusive evidence in the literature depicting the fracture resistance and stress distribution of root canal treated teeth with angulated post and cores.

Hence this study is designed to analyse the stress distribution in endodontically treated maxillary central incisors restored with cast posts at varying core angulations using FEM- a newer and meticulous method of stress analysis[10-12].

Materials and Methodology

Source of Data

An intact upper central incisor was carefully examined for any existing enamel crack or fractures. The coronal portion of tooth was sectioned transversely 3mm coronal to the cemento-enamel junction using a diamond disk ensuring the remaining root length was 14 ± 1 mm and was subjected to root canal treatment.

Root canal treatment & Post Space Preparation

The root canal treatment was done using step back technique with hand K files 21 mm long to the Master apical file size of 60 using 3% Sodium hypochlorite &17% EDTA solution. The canal was obturated by lateral compaction technique using gutta-percha points and AH plus root canal sealer. Post space preparation was done the following day. Gutta-percha was removed using Peeso reamers corresponding to a diameter of 1.1mm, leaving behind 5mm of gutta-percha at the apex ensuring 1mm of root dentine at its thinnest portion.

Cast post fabrication and cementation

Tooth preparation was done using a flat end tapered diamond bur ensuring 1.2mm shoulder labially and a torpedo bur for lingual Chamfer. A 2mm of crown ferrule is maintained for all the specimens without any core ferrule to avoid any disparity in the crown preparation as the cores are being angulated since crown ferrule is more important than core ferrule[13]. The finish line was placed 1mm coronal to the CEJ for PFM Crowns.

Post pattern was done using a 25 mm no.60 K file cut 5mm from the tip using type 2 inlay wax. After the post pattern was obtained, the core was built and shaped such that the total height of core was 8mm .Wax pattern was casted using Non precious gold alloy (NPG, Albadent.co)[14] .The cast post and core was luted using type I Glass Ionomer cement, following which PFM crown was cemented using the same cement.

Step Model: (Fig :1)

The tooth sample was subjected to 3D white light scanning for step model generation. The model was then imported to ANSYS version 10.0 for modelling and analysis.

Following the construction of the control model in which the core has zero degree angulation with the post, the other 3 models were generated by angulating the core to the post at an angle of

- 10^0 for model 2
- 20^0 for model 3
- 30^0 for model 4

Materials:To construct the model, the following materials were simulated using their physical properties such as Young's Modulus and Poissons ratio. (Table :1)

Material properties: Table 1

Mesh Generation: The scanned model was represented in ANSYS version 10.0 software in which the other 3 models were also generated upon modifications required for the angulation change. At the same time, bone and periodontal ligament was built for the required depth and width. The root portion was embedded in the bone and the bone was constrained in all directions.

The Models were generated using 4 noded tetrahedral element solid 45 for mesh generation. 903776 elements and 180138 nodes represented the problem.

Load application: A static load of 75N was applied at an angle of 135 degree to the long axis of the crown on the palatal surface and the resultant Von Misses stresses were evaluated.

Results: (Fig : 2), (Table :2)

Model 1: **Over all stress pattern** : For model 1, the stress concentration was found to be highest along the length of the post on the labial side .The magnitude of peak stresses was 15.33Mpa

Model 2: **Overall stress pattern**: For model 2 , the highest stress concentration was observed along the length of the post on the labial side. The magnitude of peak stresses was found to be 16.36Mpa.

Model 3:**Over all Stress pattern**: For model 3, the peak stress magnitude was 18.30 Mpa and was higher than first and second models. Stress concentration was highest along the length of the post on the labial side, but was slightly lesser when compared to the first and second models. Also in model 3 , peak stresses started accumulating at the cervical region of the tooth on the palatal side.

Model 4 : **Over all Stress pattern**: For model 4, the peak stress magnitude was 20.92Mpa and was higher than first three models.Stress concentration along the length of the post was relatively lower on the labial side than other three models and peak stresses were seen in the cervical region of the root on the palatal side

Discussion

The stresses seen in endodontically treated teeth with cast posts along the long axis of the tooth may not be same as with angulated posts. In a study where maxillary central incisors restored with different post systems were fracture tested at 110,130,150 degree load angulations, higher mean fracture load was required to fracture endodontically treated teeth with cast posts along the long axis of the tooth, inferring that the fracture resistance of the tooth decreased as the cast cores angles differed from the long axis of the tooth[15].

When a tooth is subjected to normal functional loading, there will be areas of compression and tension around the tooth in the periodontal ligament. In intact teeth under eccentric loading conditions, the compressive stresses will be substantially higher compared to tensile stresses due to the shape and angulation of the tooth or due to bone remodelling taking place[16]. The stress distribution pattern in a tooth with post, core and crown will be distinctly different to that of an intact tooth where whole assembly flexes as a single unit due to masticatory forces. This change in the 'flexing pattern' of a post–core restored tooth when compared to a normal intact tooth results in bone loss due to periodontal reasons.

Unlike the intact teeth, where compressive stresses predominate, in post restored teeth, tensile stresses will be higher and are seen to increase as the load angle deviated from the long axis of the tooth[17]. Hence, stress distribution pattern seen with cast posts that are stiffer by nature varied for different core angulations, although the magnitude and direction of load application remained the same.

It was observed that, as the angulation of core to the post increased, the principal stresses decreased along the length of the post and shifted to the cervical part of the tooth on the palatal side. Force being a vector, can be resolved as having horizontal and vertical components.

Since the load applied in the present study was at an angle of 135^0 to the long axis of the tooth crown, Model 1 with core along the long axis of the post, would have the same amount of compressive and tensile stresses acting along the post but in opposite directions and would get nullified without stresses being concentrated at any particular area in and around the tooth.

However, with a change in core angulation, there was an increase in the resultant horizontal component of stresses and a decrease in the vertical component-leading to accumulation of stresses at the cervical region of the tooth. Our FE analysis has also shown that model 4 with 30 degree core angulation exhibited higher stress values with a mean of 20.92Mpa as against other models. The findings of our study is in accordance to an FEM study comparing, the stress distribution in various posts to horizontal, vertical and oblique loads which concluded that horizontal loads resulted in highest stresses within the post and surrounding structures followed by vertical and oblique ones[18].

In our study, there was very minimal increase in stress concentration areas as the core angulation changed from 0 degrees to 10 degrees and then to 20 degrees. However, there was a significant increase in stress concentration areas at 30 degree core angulation.

From these observations it can be inferred that, under normal loading conditions, angulating cast posts upto 20 degrees can be considered safe for Endodontically treated teeth. However, any increase in the core angulation beyond 20 degrees needs to be done cautiously, as it would result in a lot of stress accumulation areas in the tooth, especially for patients with parafunctional habits. One has to be cautious before attempting any angulation change for such patients, as it would ultimately fracture the tooth unrestorably. Helkimo E Ingervall et al has opined that the individuals with abnormal clenching and grinding habits showed higher stresses in incisors compared to molars[19]. During eccentric jaw movements, the envelope of motion is dictated by anterior guidance and if this is not taken into consideration while rehabilitating proclined anterior teeth, abnormal forces act on them- leading to fracture of these teeth. a change in the angulation of the tooth crown should be attempted only after cessation of habits and correction of occlusion in parafunctional habits, presence of trauma from occlusion etc. Also to ensure predictable longevity of any restoration, one must identify the signs of occlusal instability within the masticatory system, satisfy the requirements of anterior guidance, envelope of function and distribute the forces of occlusion equally[20].

The present study is an invitro study with computerised simulation of clinical conditions, hence further long term invivo studies are essential to determine the clinical implications and deleterious effects of such angulated restorations to the tooth before they can be routinely used as an alternative to the conventional treatment options available.

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Legends Table and Figure

Table 1 : **Material properties**

MATERIAL	MODULUS OF ELASTICITY (GPa)	POISSON’s RATIO
Dentin	18.6	0.31
Periodontal ligament	0.0689	0.45
Bone	1.37	0.30
Gingiva	.003	.45
Gutta percha	.00069	.45
Non precious gold alloy	109.08	.33
Glass ionomer cement	5.1	0.28
Porcelain	68.9	0.28

Table 2 : Stress magnitudes of models

Description	**Core 0 Degree**	**Core 10 degree**	**Core 20 degree**	**Core 30 degree**
Overall Stress(Mpa)	15.3348	16.3647	18.3067	20.9261
Overall Displacement(mm)	0.016982	0.018908	0.020381	0.022005
Cortical Bone(Mpa)	9.96695	11.0791	12.1721	13.2039
Cancellous Bone(Mpa)	3.1521	3.44215	3.64122	3.78036
Dentine(Mpa)	7.90499	10.5182	10.6138	10.7825
Peridontium(Mpa)	3.16621	3.39587	3.51792	3.61177
Post(Mpa)	15.6734	15.9173	16.0046	17.3133
Cement(Mpa)	5.00241	4.87301	4.63094	4.33064
Guttapercha(Mpa)	0.005107	0.004278	0.003423	0.002496
Crown(Mpa)	3.2689	4.1259	6.2582	8.7826

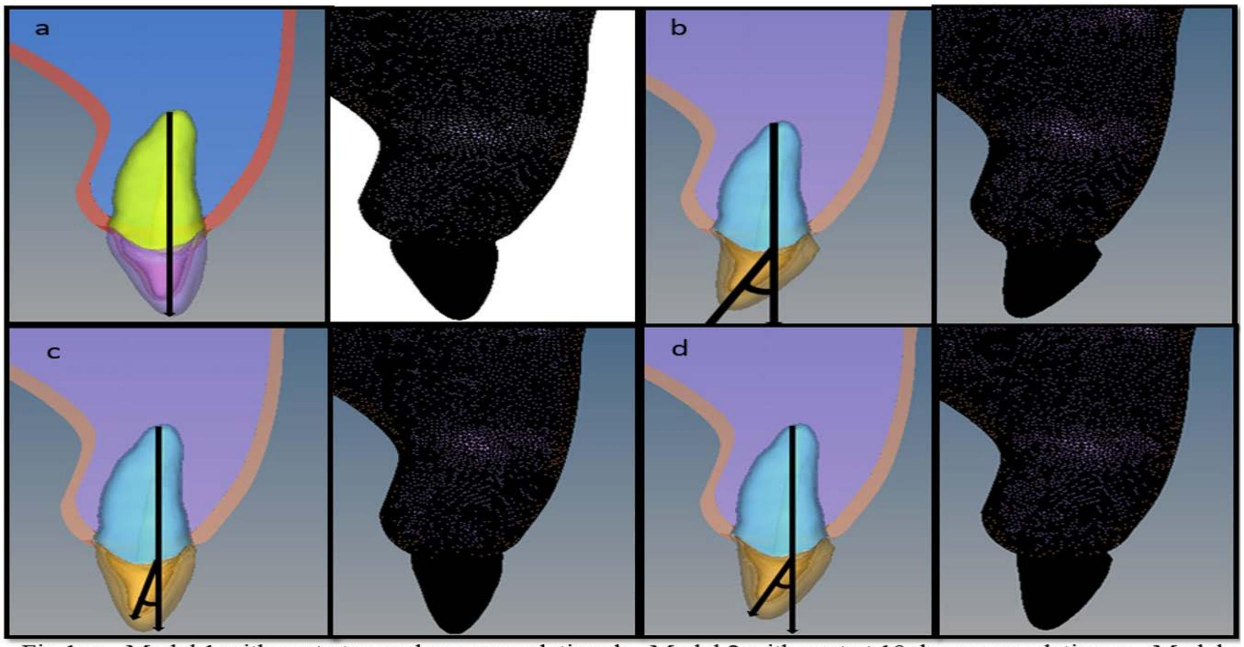

Fig 1: a - Model 1 with post at zero degree angulation; b - Model 2 with post at 10 degree angulation; c - Model 3 with post at 20 degree angulation ; d - model 4 with post at 30 degree angulation

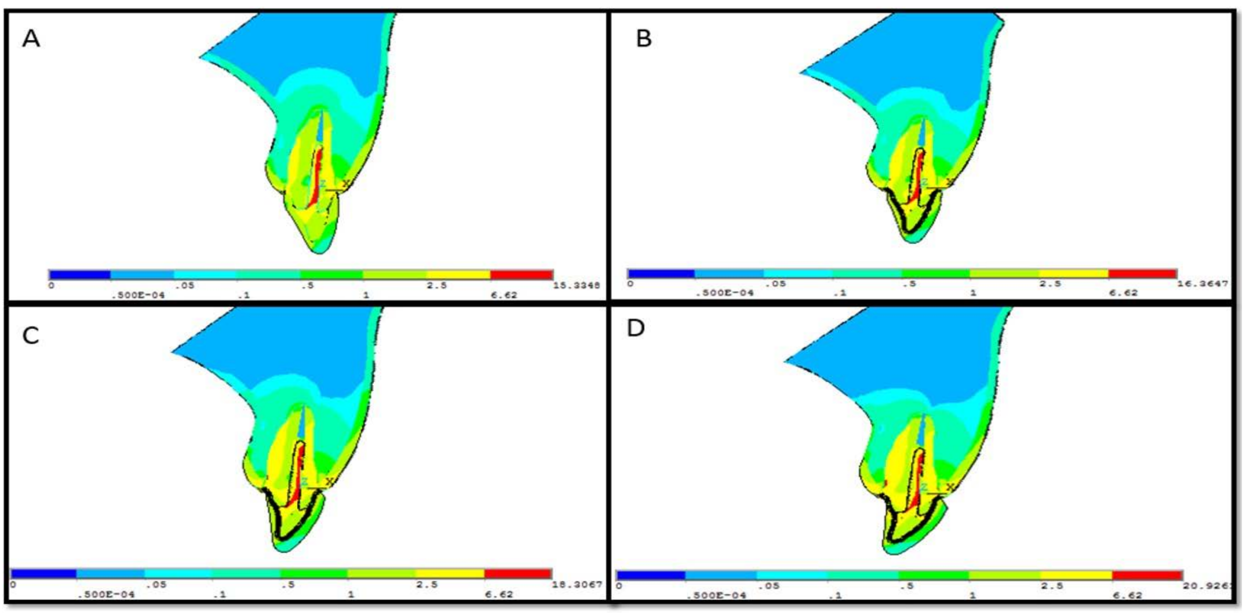

Fig 2: A - Stress pattern of post at zero degree angulation; B - Stress pattern of post at 10 degree angulation; C - Stress pattern of post at 20 degree angulation ; D - stress pattern of post at 30 degree angulation