Type of article: Original Title of the article: Evaluation of different root canal filling materials in Endo-Perio lesions: An Finite element analysis study

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Abstract

Background: Dental problems are mostly multifactorial in nature and, thus difficult to diagnose and treat. Another fact which makes these problems complex is that it is difficult to restrict the disease progression to one particular structure if not checked at an initial stage. Endo-perio Lesion (EP) is a complex disease entity which involves the tooth structure as well as the supporting periodontium **Aim:** This study was conducted with an aim to assess the effect of different root canal filling materials viz. gutta-percha, mineral trioxide aggregate (MTA) and Biodentine on EP Lesions using computational modeling. Thus, enabling the clinician in making an informed decision for treatment planning of EP **Materials & Methodology:** In the present work, mandibular molar human tooth with lesion has been precisely modelled in consultation with a clinician. Then, four different finite element models representing different filler materials were developed. Next, the finite element models were validated with experimental data for a normal tooth under a defined (300N) masticatory load. Highly refined structured mesh with high fidelity second order elements was generated and ANSYS was used to perform the structural analysis **Results:** It was observed that stresses at the peri-apical area changed with change in filler material type with best result on usage of biodentine. To the best of our knowledge, Biodentine as the filling material has not been investigated for its performance in a simulated study. However, Biodentine was suggested as an alternative to MTA and was reported to have significant regenerative capacity**. Conclusion:** In this perspective, our study intends to provide clinical inputs to dentists regard-ing use of Biodentine as filling material. The insights from this investigation can be used for therapeutic purpose by clinicians.

Keywords: 1.Endo-perio Lesion, 2.root canal filling materials, 3.finite element models, 4.structural analysis

Introduction:

Dental problems are mostly multifactorial in nature and, thus difficult to diagnose and treat. Another fact which makes these problems complex is that it is difficult to restrict the disease progression to one particular structure if not checked at an initial stage. The tooth, the pulp tissue within it and its supporting structures (periodontium) should be viewed as one biologic unit. The interrelationship of these structures influences each other during health, function and disease.

The relationship between the periodontium and the pulp was first discovered by Simring and Goldberg in 1964[1]. The periodontium and pulp have embryonic, anatomic and functional interrelationship.

Ectomesenchymal cells proliferate to form the dental papilla and follicle, which are the precursors of the periodontium and the pulp respectively. This embryonic development gives rise to anatomical connections, which remain throughout life.

Endodontic- Periodontal Lesions (EP) are complex disease entities which involves the tooth structure as well as the supporting periodontium. These lesions present challenges to the clinician as far as diagnosis and prognosis of the involved teeth are concerned. The interrela-tionship between periodontal and endodontic diseases has aroused much speculation, confusion and controversy. Etiologic factors such as bacteria, fungi, and viruses as well as various contributing factors such as trauma, root resorptions, perforations, and dental malformations play an important role in the development and progression of such lesions[2].

The periodontal-endodontic lesion develops by ex-tension of either periodontal destruction apically combining with an existing periapical lesion or an endodontic lesion marginally, combining with an existing periodontal lesion. From the diagnostic point of view, it is important to realize that as long as the pulp remains vital, although inflamed or scarred, it is unlikely to produce irritants that are sufficient to cause pronounced marginal breakdown of the periodon-tium[3]. Thus, a close relationship exists between disease of the den-tal pulp and periodontal disease, and it expresses itself in several ways. The most commonly used classification was given by Simon, Glick and Frank in 1972[4] .

Treatment and prognosis of endodontic–periodontal diseases vary and depend on the cause and the correct diagnosis of each specific condition. Many studies in the literature indicate that combined periodontal and endodontic therapy is essential for successful healing of a perio-dontal-endodontic lesion. It has been said that either endodontic or periodontic treatment alone would not lead to a satisfactory prognosis, if both disease entities are present and that both must be considered together[5]. However, the problem arises over which lesion came first and which caused or perpetuated the clinical problem.

It is generally agreed that pulpal disease could initiate or perpetuate periodontal dis-ease; the opposite theory is controversial[3]. Hence, for all the 4 classes of EP Lesion except for Primary Periodontal Lesion the primary treatment modality suggested is endodontic therapy followed by periodontal surgery, if required. Endodontic therapy consists of root canal therapy which is instituted immediately and the cleaned and shaped root canal is filled with different root canal filling materials such as, calcium hydroxide paste, gutta-percha and mineral trioxide aggregate (MTA) and Biodentine. Assessment of the best root canal filling material in terms of stress caused by it in the apical area in each of the 4 classes of EP lesions is nearly impossible to do clinically. With this perspective, we have carried out this investigation to assess the effect of different root canal filling materials viz. gutta-percha, mineral trioxide aggregate (MTA) and Biodentine in Endo-Perio Lesion using computational modeling. Thus, enabling the clinician in making a better and more informed decision to deliver treatment for Endo-Perio Lesions.

Materials and Methodology:

In the present work, mandibular molar human tooth with lesion has been precisely modelled in consultation with a clinician. Then, four different finite element models representing EP lesions with selection of 4 different filler materials have been developed. After the geometric modeling, the tooth along with surrounding cortical bone has been meshed using ANSYS 15 using 10 noded tetrahedral elements (SOLID187). The contact of tooth components and the surrounding the bony region were meshed finer (element size 0.1mm) than the tooth (element size 0.5 mm) and rest of the mandible (element size dependent on curvature from 0.1mm to 3mm). The number of elements generated each tooth component are for the material properties (i.e density, Young's Modulus and Poisson's Ratio) of bone were assigned ANSYS based on the material of each tooth layer.

Materials used in the study have been assumed to be homogenous and isotropic. Corresponding elastic properties, such as Young's modulus (E) and Poisson's ratio, were determined. Because the authors could not find any FEA study simulating EP lesions and considering the structure of peri-apical lesions and bone defects, the lesions were considered as having the same elastic modulus as pulp tissue.

Next, the finite element models were validated with experimental data for a normal tooth under a defined (300N) masticatory load. To calculate stress distributions, a 300-N static load was applied to the con-tact area at the buccal cusp of the crown with a 135 angle with the tooth longitudinal axis[13] . Results are presented considering von Mises criteria. To better visualize mechanical phenomena in the models, calculated numeric data were transformed into color graphics. Sections obtained from the 3D models were used to present the stress distributions, and the color scale was limited between 0–3+MPa. Exterior nodes of the models' root structures were fixed in all directions as the boundary condition.

Results:

Table 2 denotes the value of stress at 3 sites on the root and 3 sites on the surrounding cortical bone. The stress is observed to be maxi-mum at apical and coronal third on the root surface and also on the cortical bone. The same is depicted in the FEA model of healthy tooth and alveolar bone (Fig 3)

After filling the root canal of infected teeth with biodentine it is found that the stress level is significantly less at the apical and middle third of the infected root when compared to the middle third of the root. Whereas, the minimum stress in cortical bone was found at the apical third (Table: 1, Fig :1)

On filling the root canal with gutta-percha the stress on the root is found to be minimum at the coronal third, followed by apical third, followed by middle third of the root. On the cortical bone, stress is observed to be more or less similar at all the three sites with margin-ally higher stress values at the middle third of the cortical bone surrounding root structure (Table:2, Figure:2)

The stress is noticed to be having the least value at coronal third of the tooth when root canal was filled with MTA with almost similar values at middle third and apical third. At the cortical bone, the stress values are lowest at apical third and almost same at middle and coronal third. (Table 3, Figure 3)

Usage of Biodentine shows the least amount of stress in apical region of the root, whereas teeth restored with MTA shows similar stress as the ones restored with biodentine in coronal and middle third (Table 4)

Least stress at all the three sites are observed on utilisation of bio-dentin filler material, with significantly less stress at the apical third of the sorrounding cortical bone.(Table 5)

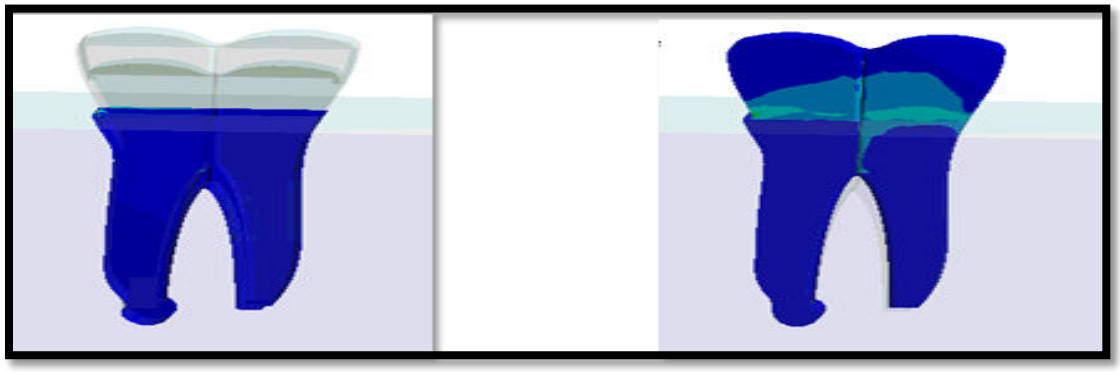

Fig 1: Stress distribution on tooth and surrounding bone in tooth with root canal filled with biodentine

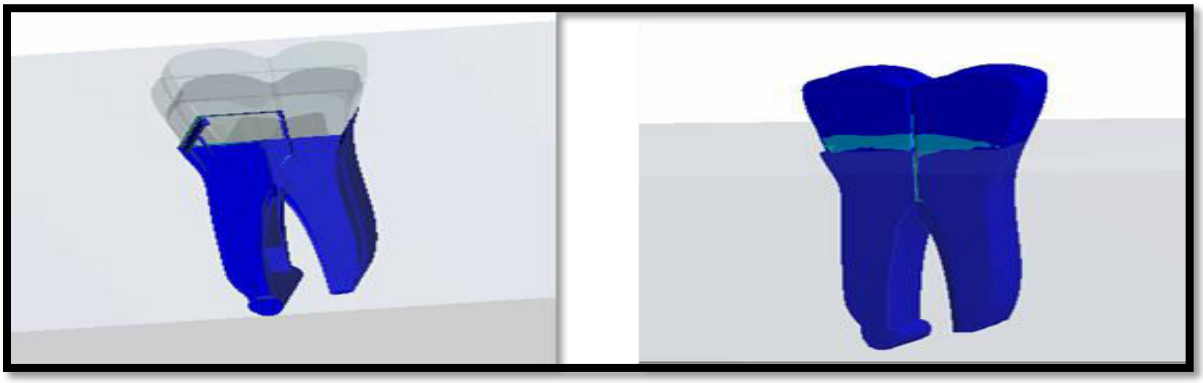

Fig 2: Stress distribution on tooth and surrounding bone in tooth with root canal filled with gutta-percha

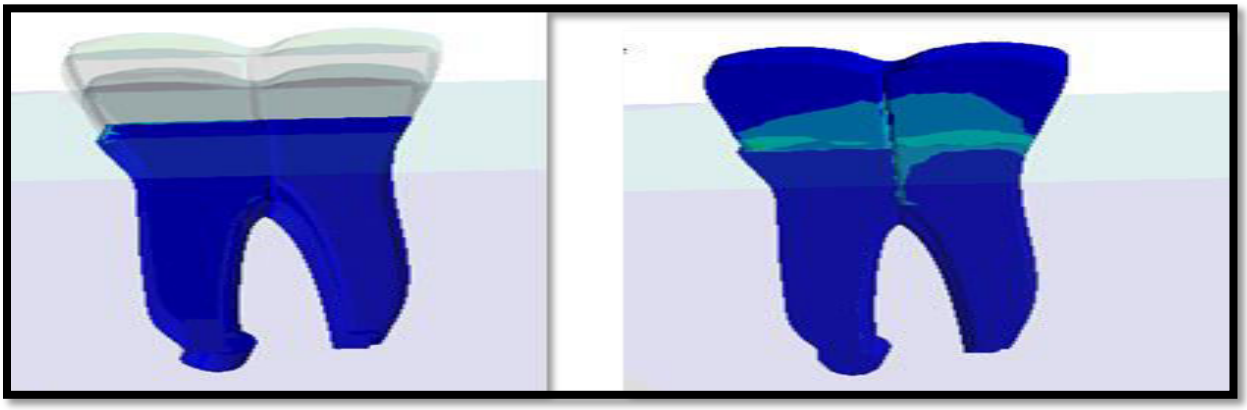

Fig 3: Stress distribution on tooth and surrounding bone in tooth with root canal filled with MTA

	Tooth Root	SorroundingCortical bone
Apical Third	0.1	1.0
Middle third	0.8	2.3
Coronal Third	0.1	2.5

Table 1: Stress distribution in root canal filled with biodentine on ap-plication of force

	Tooth Root	SorroundingCortical bone
Apical Third	0.6	2.1
Middle third	1.5	2.8
Coronal Third	0.3	2.5

Table2: Stress distribution in root canal filled with gutta-percha on application of force

	Tooth Root	SorroundingCortical bone
Apical Third	0.7	1.5
Middle third	0.8	2.3
Coronal Third	0.1	2.7

Table 3: Stress distribution in root canal filled with MTA on applica-tion of force

	Gutta-Percha	Biodentine	MTA
Apical third	0.6	0.1	0.7
Middle third	1.5	0.8	0.8
Coronal third	0.3	0.1	0.1

Table 4: Comparison of Stress distribution on tooth rooth on applica-tion of force after filling the root canal with different filler materials

	Gutta-Percha	Biodentine	MTA
Apical third	2.1	1.0	1.5
Middle third	2.8	2.3	2.3
Coronal third	2.5	2.5	2.7

Table 5: Comparison of Stress distribution on sorrounding cortical bone on application of force after filling the root canal with different filler materials

Discussion:

Highly refined structured mesh with high fidelity second order elements was generated and ANSYS was used to perform the structural-analysis. The defect created for FEA analysis simulated true combined lesion (Class of Endo-Perio Lesion). This class of endo-perio lesion shows endodontic as well as periodontal involvement of the tooth.The same was simulated was a periapical circular defect (endodontic) and defect in the alveolar bone along the root surface, extending and fusing into the peri-apical defect (periodontal). The different filler material utilised in the study are Biodentine, MTA and guttapercha. Bio-dentine is a new bioactive cement that is similar to the widely used Mineral trioxide with enhanced regenerative properties. It has dentine like mechanical properties, which may be considered a suitable material for clinical indications of dentin-pulp complex regeneration such as pulp capping[6].

MTA(Mineral Trioxide) is a restorative material which prevents microleakage, is biocompatible, and promotes regen-eration of the original tissues when placed in contact with dental pulp or per-radicular structure [7].GuttaPercha is one of the oldest root canal filling material but it has been found to demonstrate a few microscopic inadequacies such as, many irregularities in form and condensation, inadequate sealer dispersion,lack of demonstration of canal variations, such as fins and lateral canals,lack of correlation with radiographs, and roughness and pitting[8]. It was observed that stress reduced on the root and bone surface post root canal treatment. Also stresses at the middle third of the root were consistently higher when compared to apical third and coronal third in filled root. This was in contrast to clinical studies which reported markedly decrease in fracture strength with restoration[9].

However, filling of the root did not affect stress distribution. This study proves the highest efficacy of biodentine compared to MTA and gutta-percha in treatment of endo- perio lesion, followed by MTA and gutta-percha .This was in accordance with a study which concluded that Biodentine composition resulted in enhanced chemical properties relative to MTA[10]. On the other hand, another study comparing biodentine and MTA stated that Biodentine had a similar efficacy in the clinical setting and may be considered an interesting alternative to MTA in pulp-capping[6]. The results of another study also suggested that the new calcium-silicate-based endodontic cement i.e. biodentine provides improvement in sealing ability as well as clinical manageability of dental filling materi-als compared to any other root canal filler material[11]

Conclusions:

Within the limitations of this FEA study, it is plausible to suggest that filling root canal with any filler material reduces the stress at root and sorroundingbone.Maximum stress in a filled tooth is consistently found to be at the middle third of the root. Biodentine can be declared the best root canal filler material in endo- perio lesions as it showed least stress on root as well as the cortical bone structure post- treatment especially in the api-cal

region. Although, Guttapercha is the most inferior root canal filling material in terms of stress produced by the same on root and bone, it is indeed the most cost effective material.

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