Effect of Different Treatment Options on Biomechanics of Immature Teeth: A Finite Element Stress Analysis Study

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Abstract

Introduction: Immature teeth (IT) can be managed by using several treatment options, depending on the vitality of the tooth. The aim of this finite element stress analysis study was to evaluate the effect of different treatment procedures on the stresses in three-dimensional IT models. **Methods:** Three-dimensional finite element stress analysis premolar tooth model was created as control (model 1), modified to simulate IT. Eleven models were created to simulate IT filled with (model 2) calcium hydroxide (CH), (model 3) mineral trioxide aggregate (MTA), (model 4) Biodentine (B), (models 5 and 6) MTA plug and B plug without root-filling, (models 7 and 8) MTA plug and B plug with root-filling with composite restoration, and amputation by using (model 9) CH, (model 10) MTA, and (model 11) B. Materials and structures were assumed to be homogenous and isotropic. A 300 N load was applied to the models from the functional cusps and central fossa with a 135° angle. Cosmosworks structural analysis program was used. The results were presented considering the von Mises criteria, and the scale range was limited to 0–10 + MPa. **Results:** CH use in comparison with temporary filling increased the stresses within the root. MTA filling showed less stresses when compared with B filling. MTA and B plug increased the stresses at apical and root; however, when the roots were filled using gutta-percha and the crowns were restored with composite resin, the stresses at the coronal side of the roots were reduced. The stresses were distributed more favorably in the models simulating CH, MTA, or B amputation. Amputation by using MTA and B showed similar stresses with natural tooth model. **Conclusions:** CH is not a favorable dressing material for IT when compared with MTA and B. MTA or B plug increases the stresses at apical, whereas root-filling reduces the stresses within the root. Amputation by using CH, MTA, and B in combination with composite resin restoration may save both the coronal and root structure of IT. *(J Endod 2017;■:1–5)*

Key Words

Apexification, biodentine, immature, mineral trioxide aggregate, partial pulpotomy

Significance

Calcium hydroxide is not a favorable dressing material for IT when compared to MTA and Biodentine. IT with an MTA or Biodentine plug should be immediately obturated and restored. Amputation by using calcium hydroxide, MTA, and Biodentine in combination with composite restoration may save both the coronal and root structure of IT.

In permanent teeth, root formation is not completed until 1–4 years after eruption into the oral cavity; meanwhile, therapeutic efforts can be directed toward preserving the vitality of the pulpo-dentinal complex to facilitate complete root formation (1). If pulp necrosis occurs before root maturation, the affected tooth can still be preserved by using non-vital endodontic strategies (2).

Treatment of immature teeth (IT) may vary according to the status of the pulp and clinical situations. Root development and dentinal wall thickening can be provided after the removal of damaged coronal pulp tissue through a treatment method known as exogenesis (3) or in a Cvek partial pulpotomy procedure where 2 mm coronal pulp tissue is removed (4). Apexification procedures can be applied if the pulp is necrotic or if there is irreversible pulpitis (5). In this technique, calcium hydroxide (CH) and/or mineral trioxide aggregate (MTA) are generally used to stimulate mineralization within the apical root canal to prevent toxins and bacteria from entering periradicular tissue and to help disinfect the root canal (3, 5, 6). Revascularization processes (blood revascularization from the periapical tissues through the open apex to accomplish tissue formation) can also be used to disinfect the root canal with antibiotics and to revitalize new tissue formation (7). The new tissue formation can mineralize the dentin and help foster continuous root development and maturation.

CH is a predictable material and can be used safely to induce apical closure (3, 6). With a number of favorable characteristics such as biocompatibility, antimicrobial activity and prevention of bacterial leakage, no cytotoxicity, and stimulation of cytokine release from bone cells, MTA is a preferable alternative material (8). Biodentine (Septodont, St Maurdes-Fosses, France) was introduced later, with the advantage of remarkable biological properties of Portland cement (9). Biocompatibility (10) and potential for pulp regeneration of both MTA and Biodentine have been proven (9).

The CH apexification procedure requires multiple treatment sessions, and because of the presence of thin roots or prolonged exposure (nearly 8 months) of root dentin to CH (11), the tooth will be more susceptible to root fracture (3, 12). Because of this, clinicians consider single-visit apexification by using MTA

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as an osteoconductive apical barrier to be a better choice (13). Although this procedure may not prevent the risk of root fracture after treatment (14), high rates of complete healing have been observed with this technique (13, 15). Biodentine has been suggested as a potential apical plug material to overcome some of the disadvantages of using MTA such as long setting time, high cost, potential for discoloration, poor handling characteristics, and unpredictable antibacterial properties (14).

Several laboratory studies were done to investigate the fracture strength of IT after numerous treatment procedures. Fracture resistance tests have allowed analysis of tooth behavior under loading (16). However, stress analysis studies are more informative because they analyze stress distributions and facilitate understanding of the failure patterns (17). Finite element analysis (FEA) is the most widely used method.

The aim of this FEA study was to evaluate the effect of different treatment protocols and materials on stress patterns in simulated three-dimensional (3D) IT models. The hypothesis tested was that different treatment protocols and materials have different effects on stress patterns in simulated IT models.

Materials and Methods

A 3D FEA method and SolidWorks 2007 9.0.3 structural analysis program (Solid-Works Corp, Waltham, MA) was used in this study. Linear elastic FEA was performed by using the CosmosWorks Program (SolidWorks). A 3D FEA mathematical model simulating a mandibular premolar tooth with supporting tissues based on the geometry previously described by Wheeler (18) was created first. The anatomic dimensions of the supporting tissues were generated according to data in the literature (19). This model was then modified to simulate an IT. Apices of the models were shortened for 3 mm first, and the apices were simulated as open. This model was kept as a control. Eleven more models were then created on the basis of this model by simulating the following conditions (Fig. 1):

Model 2: Four fifths of the root canal of IT model was assumed to be filled with CH and sealed temporarily (TF).

Model 3: IT model was assumed to be filled with MTA as in model 2 and sealed temporarily.

Model 4: IT model was assumed to be filled with Biodentine (B) as in model 2 and sealed temporarily.

Model 5: apical one third of the root of IT model was assumed as filled with MTA plug, and the rest of the model was kept unfilled but sealed temporarily.

Model 6: apical one third of the root of IT model was assumed as filled with B plug, and the rest of the model was kept unfilled but sealed temporarily as in model 5.

Model 7: apical one third of the root of IT model was assumed as filled with MTA plug; opposite to model 5, the rest of the root was assumed as filled with gutta-percha, and the access cavity was restored with composite resin (CR).

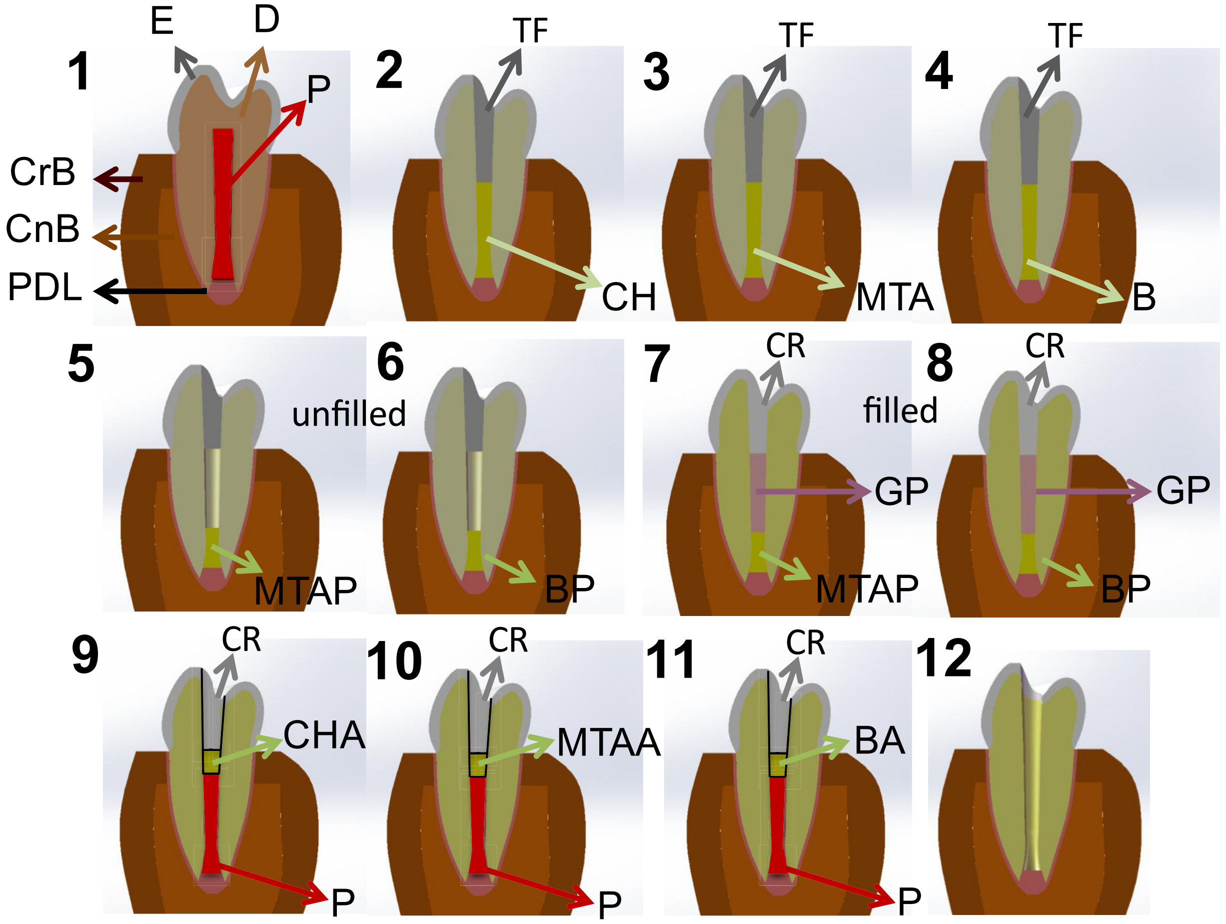

Figure 1. Schematic overview of models prepared for the study. A sound tooth model (1) was used for comparison, and a model with access cavity but without root-filling or restoration was used as control (12). BA, amputation with Biodentine; BP, Biodentine plug; CHA, amputation with CH; CnB, cancellous bone; CrB, cortical bone; D, dentin; E, enamel; GP, gutta-percha; MTAA, amputation with MTA; MTAP, MTA plug; P, pulp; PDL, periodontal ligament.