# Heat transfers to periodontal tissues and gutta-percha during thermoplasticized root canal obturation in a finite element analysis model

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***Objectives.*** The aim of this study was to measure the temperature distributions on the periodontal ligament and apical gutta-percha during thermal obturation with different plugger activation time.
***Study design.*** The multirooted model of mandibular first molar development and root canal treatment were performed by finite element analysis. The apical thirds of canals were obturated by continuous-wave condensation technique, with 3 seconds and 4 seconds of activation time. The remainder was backfilled with injected gutta-percha in 2 segments (Obtura II).
***Results.*** The highest temperatures on the periodontal ligament reached 46.914°C and 48.887°C, in the "dangerous zone" between the root canals, when activation times were 3 seconds and 4 seconds, respectively. The greatest temperature rise within the apical gutta-percha was only 0.859°C.
***Conclusion.*** With 3 seconds of activation, the temperature elevation reached almost 47°C, so one should be careful not to extend the activation time beyond 3 seconds, which is clinically difficult to control. The apical gutta-percha temperature was always below the desired level to achieve proper thermoplasticity. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:257-263)**

The complete, homogeneous, and 3-dimensional (3D) filling of the root canal system to working length (WL) is the ultimate goal of obturation. Compared with cold lateral compaction of gutta-percha (GP), thermoplasticized GP techniques have been shown to provide better sealing at apical foramina and for lateral canals.[1,2] For thermoplastisized technique, the temperature of apical GP should be increased to 40-42°C to ensure good plasticity for obturation, and it should not exceed 45°C to avoid the volume shrinkage.[3,4] Thermoplasticized GP produces temperature rise (TR) on the external root surfaces, which may cause potential damage to the periodontal tissues.[5,6] It has been reported that a TR of 10°C on the outer root surfaces over body temperature (37°C) caused permanent damage to the supporting structures of the tooth.[5,7,8]

Thermocouples and infrared cameras have been widely used to measure TR in pulp and tooth surfaces in in vitro studies.[6,8-10] The data revealed that root canal obturation using System B Heatsource might cause different thermal effects on the surrounding tissues under various temperature settings. Some reports suggested that System B heat obturation technique induced injury to the periodontal tissues,[6,11] whereas other studies showed that the same condensation technique produced TR to <10°C, the critical temperature causing potential tissue damage.[12,13] However, these temperature measurements encountered difficulties in sample standardization, and the limited consistency of the thermal loads applied in a same study complicated the interpretation of the results. High cost of equipment is another concern.

Finite element analysis (FEA), which has been widely used in analyzing the distribution of stress and temperature in vitro, is considered to be a fast and reliable alternative.[13-17] One of its advantages is that longitudinal temperature changes of the entire model can be monitored as a dynamic process under the simulated working condition.[18] An FEA maxillary canine model was first developed by Er et al.[13] to evaluate the temperature changes at the periodontal ligament induced by a warm GP technique, namely System B heat

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Received for publication Jan 10, 2010; returned for revision Mar 26, 2010; accepted for publication Apr 5, 2010.
1079-2104/$ - see front matter

doi:10.1016/j.tripleo.2010.04.005

obturation technique. The peak temperature was found to be 43.5°C. However, during the simulated obturation using System B Heatsource, 5 mm GP at 200°C was assumed to be placed in the apical region in 1 block, in contrast to the clinical practice of continuous-wave condensation technique.

The mandibular first molar is most likely the first permanent tooth to erupt, making it susceptible to dental caries and usually in need of endodontic treatments.[19] Thermoplasticized techniques producing a 3D obturation are often favored, because of a high prevalence of isthmus in the mesial root of mandibular first molar.[20] However, few studies have analyzed the thermal effect on a multirooted tooth and its surrounding ligament, especially at the "dangerous zone," the area between root canals and the root furcation. Therefore, an FEA study, modeling a mandibular first molar from the apex to the cementoenamel junction (CEJ), was used to evaluate the temperature distribution on the periodontal ligament and apical GP during warm GP obturation, using System B with Obtura II combined technique in a manner similar to clinical practice.

## MATERIALS AND METHODS

### Development of the FEA model

A mandibular permanent first molar with typical morphology, extracted for periodontal reason, was collected. The tooth was scanned by a microscopic computerized tomography system (GE Explore Locus SP; GE Healthcare, Waukesha, WI) from the apex to the CEJ, using a voxel size of 15 × 15 × 15 μm. Seven hundred 2D slices were saved in the Digital Imaging and Communications in Medicine format and then used to generate a 3D view using 3D reconstruction software (MicroView 2.0$^{+}$ ABA, GE Healthcare).

The thin cementum layer was neglected and the hard tissue of the roots was assumed to be dentin only. A periodontal ligament was modeled as a 250-μm-thick shell surrounding the roots up to the CEJ.[14] A cube of alveolar bone was modeled around the periodontal ligament (Fig. 1). The thermal characteristics of these elements involved in FEA were taken from the literature (Table I).[21]

All of the dental elements in the tooth model were assumed to have an average body temperature of 37°C as the baseline, and the temperature of ambient air was assumed to be fixed at 22°C.

### Simulation of root canal treatment

A simulation of root canal preparation and obturation procedures was conducted by using Ansys (Pera Global Corp., Canonsburg, PA). Root canal preparation was performed to a final apical size of 30 with 0.04 taper, followed by root canal obturation, where the apical thirds of the root canals were obturated by GP using the continuous-wave condensation technique using System B Heatsource at 200°C as described by Buchanan.[22] Following the manufacturers' instruction, a #30 0.04 taper master GP cone was assumed to be placed to 0.5 mm short of WL in mesiolingual (ML) root canal. The temperature of the GP was originally 22°C; 200°C heat was applied to the GP at the level of canal orifice, proceeding to a distance at 5 mm short of the WL. Times of 3 seconds and 4 seconds were allowed for

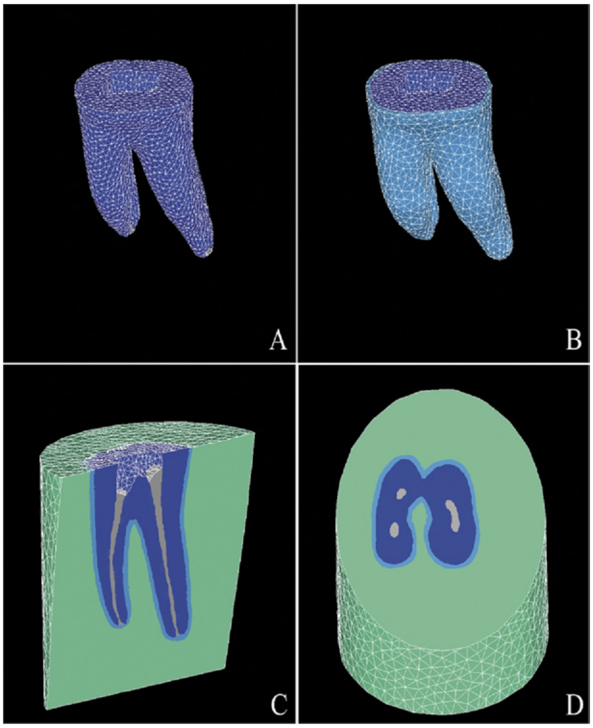


Fig. 1. Development of the finite element analysis (FEA) model. Color plots show the development of a residual multirooted model of a mandibular first molar by FEA, including dentin (**A**, blue), a 250-μm thick shell surrounding the roots representing the periodontal ligament (**B**, cyan), and a cylinder of alveolar bone (green) around the periodontal ligament (**C**). **D,** A cross-section of the combined model. The canals were colored gray (*C* and *D*).

**Table I.** Thermal characteristics of dental materials

| *Dental element* | *Specific heat J/(g·°C)* | *Thermal conductivity, J/(mm·s·°C), ×10$^{-4}$* | *Density, g/mm$^3$, ×10$^{-3}$* |
|---|---|---|---|
| Dentin | 1.172 | 6.28 | 4.00 |
| Periodontal ligament | 4.817 | 5.86 | 1.00 |
| Alveolar bone | 1.842 | 5.86 | 1.30 |
| Gutta-percha | 1.828 | 1.53 | 0.97 |