# Biomechanical Properties of First Maxillary Molars with Different Endodontic Cavities: A Finite Element Analysis

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## Abstract

**Introduction:** The aim of this study was to compare the biomechanical properties of first maxillary molars with different endodontic cavities using the finite element method. **Methods:** Three finite element analysis models of a maxillary first molar were designed and constructed with 3 different types of endodontic cavities: a traditional endodontic cavity, a conservative endodontic cavity, and an extended endodontic cavity. An intact tooth model was used for comparison. Each model was subjected to 3 different force loads directed at the occlusal surface. The stress distribution patterns and the maximum von Mises (VM) stresses were calculated and compared. **Results:** The peak VM stress on all models was at the site of the force load. The occlusal stresses were spread in an approximate actinomorphic pattern from the force loading point, and the stress was much higher when the force load was close to the access cavity margin. The peak root VM stresses on the root-filled teeth occurred at the apex and were significantly higher than that on the intact tooth, which appeared on the pericervical dentin. The area of pericervical dentin experiencing high VM stress increased as the cavities extended and the stress became concentrated in the area between the filling materials and the dentin. **Conclusions:** The stress distribution on the occlusal surface were similar between the conservative endodontic cavity, the traditional endodontic cavity, and the extended endodontic cavity. With enlargement of the access cavity, the stress on the pericervical dentin increases dramatically. *(J Endod 2018;■:1–6)*

## Key Words

Endodontic cavity, finite element analysis, minimally invasive, stress

**Significance**

Minimal invasion endodontic treatment is a novel concept that recently has been adopted by an increasing number of dentists. The aim of this study was to compare the biomechanical properties of first maxillary molars with different endodontic cavities.

The first maxillary molar is the largest tooth in total volume and is generally considered the most anatomically complex tooth (1). The maxillary molar is the second most frequently endodontically treated tooth (2, 3). Successful root canal treatment depends on the adequate debridement and filling of the entire root canal system (4). For this purpose, in the clinical context, dentists usually prepare a much larger endodontic cavity to detect and clear the root canal. However, removal of much of the tooth structure can undermine its resistance to fracture under functional loads (5). Traditional endodontic cavities (TECs) involve straight-line pathways into the canals to enhance the efficacy of instrumentation and prevent procedural errors (6). The consequent removal of the tooth structure, coronal to the pulp chamber, along the chamber walls, and around the canal orifices, is the most frequent cause of fracture in endodontically treated teeth (7, 8) because the removal of a large amount of dental tissue can threaten the integrity of the dental structure, facilitating fracture. A previous study reported that the first maxillary molar most frequently fractured after endodontic treatment (9, 10). Therefore, it is extremely important to determine how to protect the first maxillary molar and avoid destroying much dental tissue during endodontic treatment.

Minimally invasive endodontics (MIE) aims to improve traditional endodontic treatment by designing precise access cavities and pulp chamber finishing. Protecting the cingulum, the oblique ridge, and the pulp chamber roof, which play very important roles in the chewing function, can enhance the tooth fracture strength (11). Conservative endodontic cavities (CECs) have recently been designed to minimize the removal of the tooth structure. By combining cone-beam computed tomographic (CBCT) imaging and dental operating microscopy, some dentists have used this contracted access cavity design during clinical endodontic treatments (12, 13). In previous *in vitro* studies, several authors have found that compared with TECs, CECs improved the fracture strength under a continuous load (14, 15). However, other studies have shown no obvious difference between CECs and TECs in maintaining fracture strength (16, 17). The aim of this study was to compare the biomechanical properties of the first maxillary molar containing different endodontic cavities using the finite element method (FEM) and to check the hypothesis whether teeth with a minimally invasive endodontic cavity would relieve the stress distribution.

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## Materials and Methods

### FEM Model Generation

An intact, noncarious, mature first human maxillary molar was obtained and scanned with the SkyScan 1072 high-resolution Micro-CT scanner (SkyScan, Aartselaar, Belgium) with a voxel dimension of 20 $\mu$m. An interactive medical image control system (MIMICS 16.0; Materialise, Leuven, Belgium) was used to identify the different hard tissues visible. Three-dimensional (3D) objects (enamel and dentin) were automatically created in the form of masks by growing a threshold region on the entire stack of the scans. These files were refined with reverse engineering software (Geomagic Studio 10; Geomagic, Inc, Research Triangle Park, NC). The software SolidWorks (Dassault Systems SA, Concord, MA) combined the enamel and dentin. The periodontal ligaments (0.25-mm thick) (18) surrounding the roots and the cortical and cancellous bones were established. The endodontic access cavities were then designed on the solid model with SolidWorks.

### Cavity Design

The tooth was modeled with its enamel and dentin structures. Four 3D models were generated: the intact (IT) model, the TEC model, the CEC model, and the extended endodontic cavity (EEC) model. A traditional access opening in the TEC model was designed so that the entire roof of the pulp chamber was removed, and a straight-line path was created from the access opening to the coronal part of the canal (Fig. 1*A3*). As reported by Eaton (19), the conservative access outline was determined with a line drawn from the center of the root canal furcation level landmarks through the central canal orifice at the level of the floor of the pulp chamber and extrapolated onto the occlusal surface (Fig. 1*A1* and *A2*). The extended access cavity was designed based on the traditional cavity in which the remaining dentin thickness was 2.0 mm (Fig. 1*A4*).

### Set Material Properties

The models were cross-linked to 3D FEM models with ANSYS14.5 software (ANSYS, Inc, Canonsburg, PA). Consistent with previous studies, the teeth and materials were considered homogeneous, linear, elastic, and isotropic (20). In the endodontic treatment models (the CEC, TEC, and EEC models), the roots were filled with gutta-percha. The area extending from 2 mm beneath the canal entrance to the level of the pulp horn was filled with flowable composite resin, and the cavity was restored with composite resin. The cement layer was 0.04-mm thick (21). The material properties (elastic modulus and Poisson ratio) are presented in Table 1.

The contact conditions between the structures of the FEM models were defined as follows: fixed composite resin–adhesive, adhesive–enamel, adhesive–dentin, adhesive–flowable composite resin, enamel–dentin, dentin–pulp (or gutta-percha), dentine–periodontal ligament, periodontal ligament–cortical bone, periodontal ligament–cancellous bone, and cortical bone–cancellous bone.

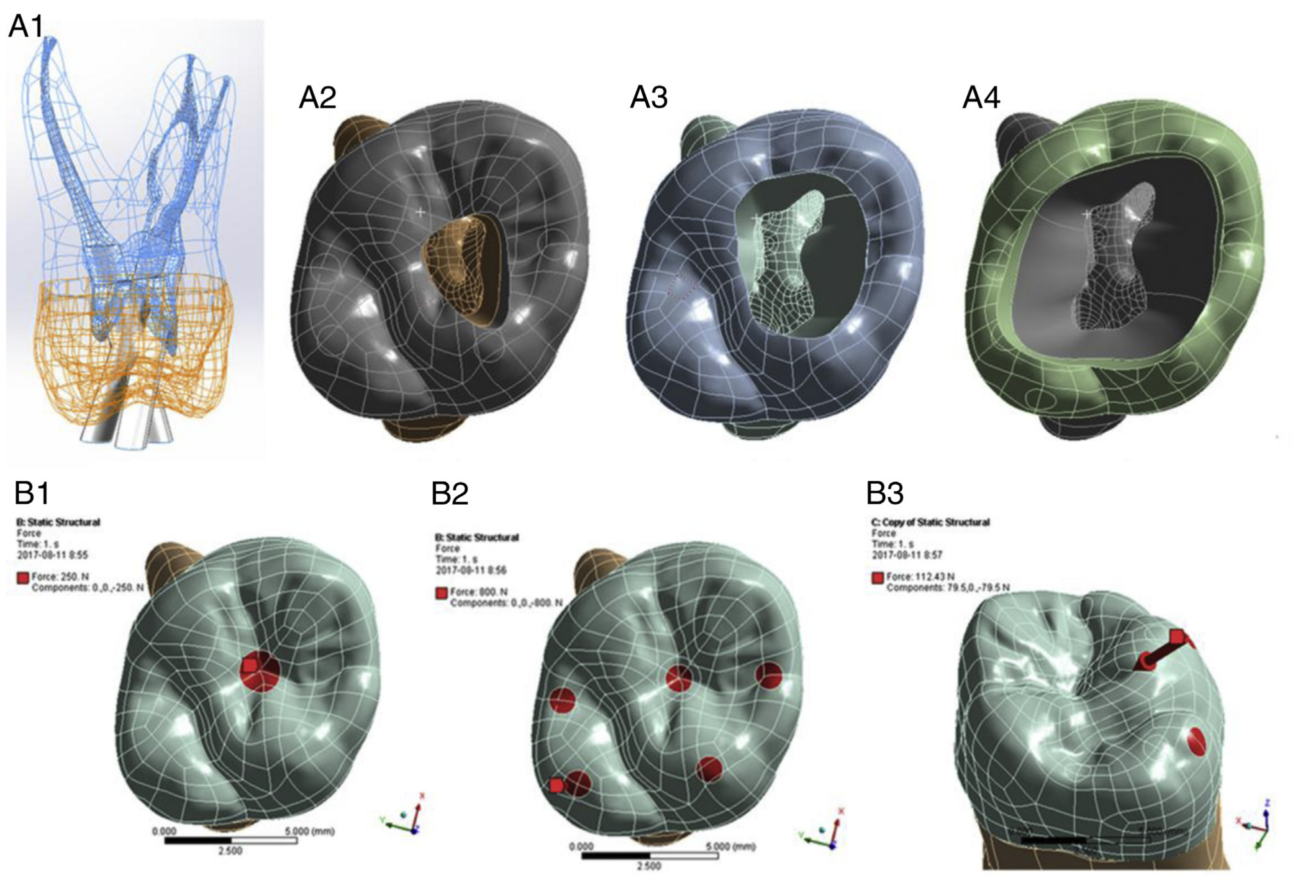


**Figure 1.** The cavity design and force load. (*A1* and *A2*) The conservative access cavity. (*A3*) The traditional access cavity. (*A4*) The extended access cavity. (*B1*) A vertical force of 250 N was applied to the central groove area of the model. (*B2*) A total force of 800 N was applied to 5 points. (*B3*) A force of 225 N was applied to the lingual plane of the lingual cusp at 45° to the longitudinal axis of the model.