Influence of Apical Root Resection on the Biomechanical Response of a Single-rooted Tooth: A 3-dimensional Finite Element Analysis

Youngjune Jang, DDS, Hyoung-Taek Hong, MS,† Byoung-Duck Roh, DDS, MSD, PhD,* and Heoung-Jae Chun, MS, PhD†*

Abstract

Introduction: Apical root resection is a biologically essential component in endodontic microsurgery. However, because it reduces the total root length and supported root surface, it changes the biomechanical response of the tooth. The purpose of this study was to analyze the biomechanical effect of apical root resection and to compare apical root resection with periodontal bone loss from a biomechanical standpoint. **Methods:** Finite element models of the maxillary central incisor were reconstructed. First, preoperative and surgically treated models were generated to assess the factors altering the biomechanical response of the tooth. Then, apically resected models with different amounts of resection (3, 4, 5, 6, 7, and 8 mm) were created to estimate the clinically applicable limit of apical root resection. Periodontally destructed models with varying degrees of bone loss (0.5, 1, 1.5, 2, and 3 mm) were also created to compare the effect of apical root resection with periodontal bone loss. Stress distribution, tooth displacement, and effective crown-to-root ratio (α) were analyzed for each condition. **Results:** Apical root resection did not significantly alter the maximum von Mises stress or tooth displacement until it reached 6 mm (α = 0.67) when the tooth was supported by normal periodontium. In contrast, periodontal bone loss had a greater impact on biomechanical response change compared with apical root resection. **Conclusions:** For a tooth supported by normal periodontium, 3 mm of apical root resection (α = 1.07) appeared to be mechanically acceptable. The biomechanical influence of apical root resection was weak compared with that of periodontal bone loss. *(J Endod 2014;40:1489–1493)*

Key Words

Alveolar bone loss, apicoectomy, biomechanics, crown-to-root ratio, endodontic microsurgery, finite element analysis

Apical root resection is one of the most essential components in endodontic microsurgery because it removes the majority of anatomic variations located at the apical one third of the tooth (1–4). The procedure also allows for the repair of mistakes from previous endodontic treatment including apical transportation and endodontic perforation. With this method, apical root resection provides biologically favorable conditions for periapical healing (4, 5).

However, because apical root resection reduces the total root length and supported root surface, it alters the biomechanical response of the tooth, which may result in unfavorable stress distribution and increased tooth mobility (6). Therefore, it is important to assess apical root resection not only in the biological aspect but also in the biomechanical aspect in order to ensure the long-term prognosis of endodontic microsurgery.

The crown-to-root ratio (CRR) has been 1 of the primary variables for the biomechanical evaluation of fixed partial denture abutments (7). Generally, a 1:1.5 CRR is suggested as the optimal value, with a 1:1 CRR as the minimum value for fixed partial denture abutments (8). However, it is unreasonable to directly apply such a guideline to an apically resected tooth because the value is based on investigations of normal or periodontally damaged teeth, not apically resected teeth (9, 10). When considering the fact that apically resected teeth have different properties compared with periodontally damaged teeth in terms of supported root surface and stress distribution (11), the influence of apical root resection should be assessed in a different manner. More qualitative methods are necessary to properly compare the different natures of apical root resection and periodontal bone loss.

The purpose of this study was to assess the biomechanical effect of apical root resection in endodontic microsurgery and to compare apical root resection with periodontal bone loss from a biomechanical standpoint using 3-dimensional finite element analysis. The following hypotheses were tested: (1) apical root resection does not alter the biomechanical response of a single-rooted tooth, and (2) the same amount of apical root resection and periodontal bone loss induce the same degree of biomechanical change of a single-rooted tooth.

From the *Department of Conservative Dentistry and Oral Science Research Center, College of Dentistry, Yonsei University, Seoul, Republic of Korea; and †School of Mechanical Engineering, Yonsei University, Seoul, Republic of Korea.

Address requests for reprints to Dr Heoung-Jae Chun, School of Mechanical Engineering, or Dr Byoung-Duck Roh, Department of Conservative Dentistry and Oral Science Research Center, College of Dentistry, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul 120-749, Republic of Korea. E-mail address: hjchun@yonsei.ac.kr or operatys16@yuhs.ac

0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2014.03.006

Materials and Methods

Development of Finite Element Models

A 3-dimensional geometric model was reconstructed from cone-beam computed tomographic images of an intact human maxillary central incisor and surrounding bone structures using modeling software (Mimics 14.1; Materialise, Leuven, Belgium; Unigraphics NX 7.0, Siemens PLM Software, Torrance, CA). The total length of the tooth was 21 mm, with 9 mm of crown length and 12 mm of root length. The alveolar bone crest was located 1 mm below the cementoenamel junction, supporting 11 mm of the root. The periodontal ligament was simulated with 200-μm thickness (12). This basic geometric model was modified according to the test conditions and then meshed by linear tetrahedron (C3D4) elements in finite element analysis software (ABAQUS 6.10; SIMULIA, Providence, RI).

Model Group 1

Four different models were developed following the course of treatment to assess the influence of predisposing factors and in-treatment factors on the biomechanical response of the tooth (Fig. 1*A–D*). The basic model was used as an intact model. From the intact model (Fig. 1*A*), an apical periodontitis model (Fig. 1*B*) was generated, simulating bone resorption with a 6-mm diameter around the root apex. Subsequent root canal treatment and apical root resection were simulated in the surgically treated model (Fig. 1*C*). Round root canal enlargement (master apical file #50, 0.06 taper), gutta-percha obturation, and resin core restoration were performed, and a 3-mm apical root resection without a bevel angle, retropreparation (cylinder shaped cavity with a 1.5-mm diameter and 3-mm depth), and MTA retrofilling were conducted on the surgically treated model. The completely healed model (Fig. 1*D*) simulated complete resolution of the periapical bone lesion after surgical intervention, with recovery of the inner cortical bone (0.5-mm thick) and periodontal ligament layer.

Model Group 2

From the completely healed model (Fig. 1*D*), 5 more models were developed with different apical root resection lengths (4, 5, 6, 7, and 8 mm). After including the intact model and completely healed models (Fig. 1*A* and *D*), a total of 7 models were classified into model group 2 to assess the effect of amount of apical root resection. Complete resolution of the periapical lesion was supposed for this group (Fig. 2*A*).

Model Group 3

From the intact model (Fig. 1*A*), 5 more models with different periodontal bone loss amounts (0.5, 1, 1.5, 2, and 3 mm) were developed. After including the intact model (Fig. 1*A*), a total of 6 models were classified as model group 3 to compare the effect of apical root resection with that of periodontal bone loss (Fig. 2*B*).

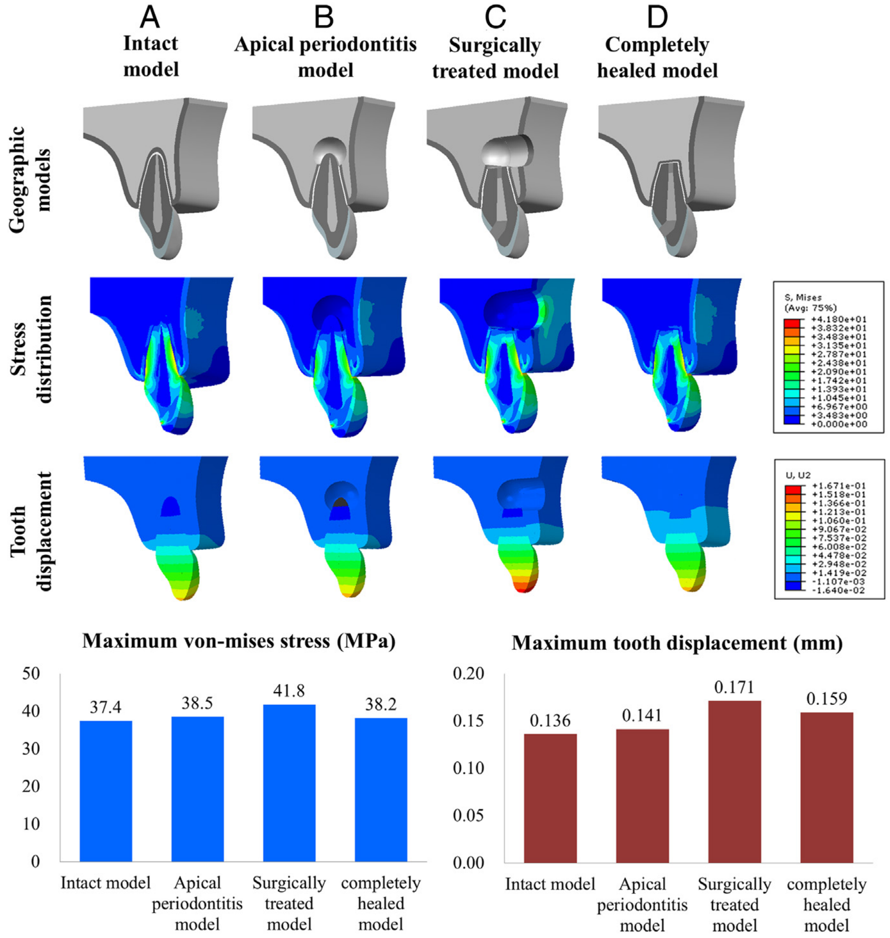

Figure 1. Stress distribution and tooth displacement pattern of models following the course of treatment: (*A*) intact model, (*B*) apical periodontitis model, (*C*) surgically treated model, and (*D*) completely healed model.