Finite Element Analysis of Stresses Generated Within Curved Root Canals Prepared to Different Taper

Thesis

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Introduction

Vertical root fractures (VRF) have been described as longitudinally oriented fractures of the root, extending from the root canal to the periodontium. They usually occur in endodontically treated teeth; although occurrence in non-restored teeth has been described.

The vertical fracture may involve the whole length of the root or only a section of it. It may involve only one or both sides of the root, most commonly in a buccolingual direction.

Vertical root fractures can occur during different phases of root canal treatment: instrumentation, obturation or during post placement. The risk of fracture can exist during root canal space obturation in both lateral and vertical condensation techniques, particularly if too much force is exerted during compaction.

A better understanding of factors related to VRF might open the possibility of better prevention and/or management of this catastrophic entity. Dentin thicknesses, radius of canal curvature and external root morphology are factors that may potentially influence fracture susceptibility

In recent years with technological advancements, canal preparation techniques have evolved rapidly. The introduction of rotary nickel-titanium (Ni-Ti) instruments for canal preparation has changed canal shape, size, and taper compared to hand instrumentation. Canal shape after preparation with hand files can be quite irregular. Theoretically, smoothly tapering canals prepared using rotary Ni-Ti should result in higher fracture resistance.

Because the stresses predisposing to VRF are considered to be generated within the canal space, the pattern of stress distribution on the root canal surface is likely to be critical in directing crack initiation and fracture propagation. Finite element analysis (FEA) is a useful technique that can be used reliably in the analysis of stresses distribution as it’s a computer-based numerical technique for calculating the strength and behavior of engineering structures. The generated stresses during load application can be compared to strength values for the materials to be used, thereby predicting if the structure is strong enough to withstand such load.

It might thus be useful to use the finite element analysis method in an attempt to predict the stress response during root canal obturation of roots prepared with different taper, as well as to determine the effect of roots with different curvature and cross sectional root geometry.

Review of Literature

1- Stress analysis studies

Several studies aimed to investigate the stresses generated during obturation of the root canal and the influencing factors that might affect stress distribution.

Harvey et al (1981) [(1)] studied the stresses induced by lateral compaction obturation technique using photoelastic models. They compared the stress distribution of minimally tapered versus accentuated flared root canal preparation with simulation of periodontal ligament and bone. The photoelastic models had average dimension of maxillary central. Unflared root canal had dimension similar to actual root canal prepared with filling motion up to size 60. Flared root canal represented canal dimension prepared up to size 90 followed by size 2- 3 Gates Glidden burs. Lateral compaction was applied by D11 endodontic spreader. The load was applied parallel to root canal ranging from 0.5 – 3 kg. After application of each load, photographs were taken; stress location and magnitudes were recorded. Furthermore, residual stresses were evaluated. Results showed that the unflared model had localized stress with little increase of magnitude as the load increased. While flared models showed less concentration of stresses throughout the compaction. Both models showed stresses at periapical bone and apical third of canal. As the canals were filled, the stress pattern moved coronally with spreader tip.

Yaman et al (1995) [(2)] used finite element method to determine the stress distribution in endodontically treated maxillary central incisors with simulated vertical compaction. The models were developed with different cross section of root canal (normal dentin thickness and thinner dentin thickness). The simulated root canals had 8 parts that allowed vertical compaction to be applied in 8 successive steps, such that obturation started from apex to coronal direction. The simulated root canals were obturated to either apical one third or two third from apex or totally obturated. The results showed greater stresses developing in the apical one third and two thirds. While totally filled canals showed no significant difference between the models.

Ricks-Williamson et al (1995) [3] performed 3D finite element models of intact and endodontically prepared central incisors, they determined stress distribution following simulated canal preparation at two different diameters to simulate normal canal preparation and over preparation. Static vertical and lateral condensation loads were applied. The results showed that vertical compaction produced higher stresses than lateral compaction. The larger preparation led to higher stresses when vertical compaction was applied. The application of lateral compaction forces in the smaller canal preparation produced higher stresses when compared with larger biomechanical preparation.

Telli et al (1999) [4] used finite element models, representing a maxillary canines and its structure, to investigate the effect of certain pathological alternation of dental structure on stress distribution during the warm vertical compaction technique. Different pathological conditions were simulated; representing diminishing bone support, internal resorption, root perforation and periapical lesion. After vertical load application all stresses were evaluated at three levels: apical, middle and coronal. The results showed that when diminishing bone support and internal resorption were simulated, a marked increase in stress magnitudes occurred, however, these values still remained much below the most frequently reported tensile strength of dentin. They remarked that when warm vertical compaction technique was skillfully performed without inadvertent undue force, root fracture in a large rooted maxillary anterior tooth with straight root canal anatomy was not likely to occur.

Lertchirakarn et al (2003) [5] used 3D finite element analysis (FEA) to investigate the stress distribution generated in incisor roots. Furthermore they used strain gauges to determine the root surface strain. The combination of modeling and strain gauge yielded information about vertical root fracture. One upper and lower incisor FEA model was created with typical morphology. Two loading patterns were selected simulating the spreader within root canal, or spreader when surrounded with gutta percha. Different load values were applied in perpendicular direction to root canal wall in the upper root model (170 N), and in lower root model (60N). Ten upper and lower incisors were used for strain gauge measurement, where the teeth were prepared and obturated with lateral compaction technique. FEA showed that the tensile stresses were highest in inner dentin wall; the stresses were concentrated at buccal surface of canal wall followed by lingual walls. Strain gauge measurement showed greater tensile strains in proximal surfaces than the buccal and lingual surfaces.

Lertchirakarn et al (2003) [6] studied pattern of vertical root fracture and evaluated factors affecting stress distribution in root canal. Finite element models with different cross section of internal and external root canal shape with different dentin thickness were used. They related the stress patterns to actually fractured teeth. Different models were (a) cylindrical root and centrally located 1mm canal (model I). (b) Oval root with rounded canal having 1mm diameter (model II). (c) Cylindrical root