A Study of Root Fracture Susceptibility Following Two Canal Preparation Techniques and Two Different Filling Materials "A finite element analysis"

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Dedicated to My dear Mother and Father

Without you I would never be the person who I am now.

Thank you,

My Son, My Husband

My Brother and Sister

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Table of Contents

List of Figures

List of Tables

Introduction

Vertical root fracture is a serious complication of endodontic treatment, which may extend throughout the entire thickness of dentin and cementum along the whole length of the root. Such type of fractures have poor prognosis and usually result in extraction of the tooth or resection of the affected root.

It is known that endodontic treatment negatively affects the fracture strength of teeth [1, 2]. Biomechanical preparation, use of different irrigating solutions, and dentin dehydration are among the causative factors that weaken the tooth structure [3, 4]. Adhesive obturation materials that can bond to the root canal dentin surface are claimed to strengthen the remaining tooth structure [5]. It is thought that the adhesion and mechanical interlocking between the material and the root canal dentin prevens microleakage and reduces the risk of fracture [6].

Advances in rotary nickel-titanium (NiTi) instruments over the last decade have led to innovative instrument design concepts and more efficient and easier techniques of canal preparation. Numerous studies emphasized the superior performance of NiTi rotary preparation of canals in terms of; better cleanliness and centralization, and minimal risks of straightening, apical transportation, perforations [7–11]. The greater flexibility and the specific design features of NiTi instruments [12], allowed the natural canal curvature to be maintained.

Gutta-percha is the most commonly used core filling material for endodontic obturation. Although it is not the ideal filling material, it has been used in conjunction with a sealer as the material of choice for over

100 years. The objectives of the canal space obturation are to prevent leakage from the oral cavity and the periradicular tissues into the root canal system and to deprive microbial remnants any chance to re-flourish.

Glass ionmer and epoxy resin based sealers were evaluated as regarding their chemico-mechanical bond to the dentin [13-15]. The Epiphany/Resilon obturation system is claimed to form a monoblock that bonds to the dentinal walls when the Resilon points are used in conjunction with the Epiphany dual-cured resin sealer [16–19] .Several studies revealed that root canal obturation with this type of sealers significantly strengthened the roots [13, 20, 21] others contradicted this assumption [14, 15].

Finite element analysis is a numerical method for solving differential equations. The geometry of the structure is built and subdivided into small elements. For each of these elements, an equation is formulated according to the relationship between the displacement and loading. The global equations are then solved using computer software. The parameters of the structure geometry, material properties, and load (direction and magnitude) can be changed with a significant advantage of Finite element over the experimental method.

Review

2.1 Optimal Canal Shape after RCT

The successful root canal instrumentation cleans the root canal system off organic debris and provides a canal shape that is apt for the three-dimensional hermetic obturation. The optimal canal shape has been defined by Schilder [22] as "a tapering funnel that follows the original shape and direction of the canal, while retaining the position and size of the apical foramen". Apical enlargement is performed to ensure cleanliness and improve obturation. In accordance with the ultimate goals of other restorative dentistry branches, instrumentation should be balanced with minimal destruction and weakening of remaining tooth structure.

2.2 Innovative Endodontic Instruments and Procedural Errors

Traditionally, stainless steel endodontics files have been used for cleaning and shaping root canals. The stiffness of the files, which rises with increasing sizes, causes straightening in naturally curved canals and results in apical over-enlargement and problems such as ledging, apical transportation, zipping and elbows. Rotary nickel-titanium instruments were developed as an attempt to eliminate the drawbacks of the stainless steel files. Nickel-titanium files are more flexible and durable than stainless steel files and are reported to be able to adapt to curved canals and maintain the original canal curvature. [23, 24, 25]

2.3 Methods to Assess Fracture resistance of Endodontically-Treated Teeth

Several methods were used to assess the fracture resistance of root canal treated teeth. Vertical compressive force and shear could be applied with a universal testing machine, and the force needed to fracture each tooth, was recorded [15, 26].

Photoelastic studies used materials that change its optical properties when subjected to force. The amount of change is direct proportional the stresses developed. The material becomes "birefringent" and a colourful interference pattern is observed when the polarized light that passes through the stressed material splits into two beams. A fringe was defined as a line separating the red and green color bands. The zero fringe order is black and indicates no stress. Stress can be quantified and localized by counting the number of fringes and density. The closer the fringes, the steeper the stress gradient, indicating an area of stress concentration. [27]

2.4 Finite Element Analysis

Finite Element Analysis (FEA) uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

The advantage of FEA is modeling new designs and concepts to determine its behaviour under various load environments, and may therefore be refined prior to the application, when changes are inexpensive. Once a detailed CAD (computer-aided design) model has been developed, FEA can analyze the design in detail, reducing the number of prototypes required. An existing product which is experiencing a field problem, or is simply being improved, can be analyzed to speed an engineering change and reduce its cost. In addition, FEA can be performed on increasingly affordable computer workstations and personal computers; however, professional assistance is required. [28]

FEA has been applied to investigate; fracture susceptibility of root canal treated teeth [29, 30], torsional and bending stresses of rotary nickel-titanium instruments [31], and forces generated during root canal shaping[32].

2.5 Root and Canal Geometry and Stress Distribution

Lertchirakarn et al 2003 [21] tried to explain why the non uniform tensile-stress distribution is predominantly in a buccolingual direction, although dentin is thicker in this direction than in the mesiodistal direction. The study also investigated which factors play the greatest roles in stress distribution. A series of FEA models were constructed, beginning with a simple, thick-walled cylinder. Changing the inner and outer surface shapes and reducing the proximal dentin thickness, the final model resembled an idealized, single-canal mandibular incisor. Canal shape and its radius of curvature were found to strongly influence stress concentration. Changing the outer root shape from round to oval, with a round canal, resulted in a slight increase in maximum tensile stress than changing the inner canal shape from round to oval. The highest stress concentrations occurred when both inner and outer shapes were oval. The less the proximal dentin thickness, the greater the stress buccolingually. They concluded that; canal shape, root shape, and dentin thickness significantly affect tensile-stress distribution. The root with a combination of the three factors was the most susceptible to Vertical Root Fracture.

2.6 Manual versus Rotary Canal Instrumentation

Chen et al 2002 [(33)] evaluated hand and rotary NiTi instrumentation in terms of canal shape, centering and procedural errors using a sequential silicone Impression technique to assess root canal morphology. Pre-operative canal impressions were obtained from 24 extracted single-rooted premolars.

Canals were instrumented with stainless steel K-type files and rotary nickel-titanium instruments (Profile), then further apically enlarged with rotary nickel-titanium instruments (Profile or Lightspeed). Post instrumentation impressions were taken and digitally photographed Images were inspected for procedural defects, changes in canal curvature, canal enlargement and canal rounding at 1, 3 and 7mm from the working length. Hand instrumentation incurred more errors than rotary nickel-