



Root surface strain during canal shaping with single or multi file systems and its influence on apical crack development

(An in vitro study)

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By

Sara Elbarrani Abdullah Eshkal

B.D.S.

Faculty of Dentistry
(GharianUniversity, Libya, 2008)

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Ain Shams University
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SUPERVISORS

Prof. Dr. Shehab El-Din Mohamad Saber

Professor of Endodontics

Faculty of Dentistry

Ain Shams University

Dr. Mohamed Mokhtar Nagi

Associate professor of Endodontics

Faculty of Dentistry

Ain Shams University

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LIST OF ABBREVIATION

<i>Abbreviation</i>	<i>Term</i>
<i>NiTi</i>	Nickel Titanium
<i>St St</i>	Stainless Steel
<i>XPS</i>	XPendo Shaper
<i>HCM</i>	HyFlexCM
<i>CM</i>	Controlled Memory
<i>Max Wire</i>	Martensite-Austenite-electropolish-fileX
<i>VRF</i>	Vertical root fracture
<i>RSS</i>	Root Surface Strain
<i>ESEM</i>	Environmental Scanning Electron Microscope
<i>RCL</i>	Root Canal Length
<i>CL</i>	Canal Length
<i>NaOCL</i>	Sodium hypochlorite
<i>AF</i>	Apical foramen
<i>ISO</i>	Standardization of instruments
<i>CEJ</i>	Cementoenamel Junction

INTRODUCTION

In any successful root canal treatment, the shaping of the canal is the most important step that provides optimum space for cleaning with irrigant. Instrumentation of root canals alone significantly weakens the roots. The loss of tooth tissue, altered physical properties of dentine, and altered proprioceptive /nociceptive properties. These factors probably interact all together to influence stress distribution. The manner of tissue loss influences the magnitude of induced strain.

Conventionally, the shaping of root canal was performed by the use of stainless steel (St St) hand files. However, the use of nickel-titanium (Ni-Ti) instruments offers a significant number of benefits over conventional (St St) files. The preparation of canals using rotary (Ni-Ti) instruments instead of (St St) instruments results in increased cleanliness, and better shaping.

Recent advancements in Ni-Ti instruments have introduced a new era to the root canal treatment. The latest generations with different designs of rotary Ni-Ti files have been released to the market. Nonetheless, during canal instrumentation with a rotary Ni-Ti instrument, the development of the apical stress and strain concentrations of the canal wall at or near the tip of the instrument is inevitable. Therefore, it may influence the generation of cracks.

Attempts have been made to modify and improve the metallurgical and mechanical characteristics of the Ni-Ti instruments. Nowadays, there are so many instruments with innovative metallurgical properties. Because of the variations in the properties of the different phases of Ni-Ti alloy, manufacturers introduced several proprietary manufacturing procedures including thermal, mechanical and surface treatment. A change in the transformation temperatures of the utilized Ni-Ti alloy is the most important tool for manufacturers to alter the phase composition and consequently the mechanical properties of the Ni-Ti alloy.

A number of researchers found that there were differences between the multiple instrument rotary system and a single instrument rotary system. In this study, single and multi-file systems were used.

XP-endo Shaper (*XPS; FKG Dentaire, La Chaux-de-Fonds, Switzerland*) instrument is a Single-file system which can be used to simplify the sequences of the endodontic treatment. It was made of MaxWire (Martensite-Austenite-electropolish-fileX) alloy, which provides extraordinary flexibility, and super elasticity. In addition, it is equipped with the Booster Tip in which the instrument has six cutting edges at the tip that follow the canal track. It is used in a traditional continuous clockwise rotation at

high speed (800 rpm) and minimal torque. In contrary to single file systems, Hyflex CM rotary instruments (*Coltene-Whaledent, Allstetten, Switzerland*) were made of a CM wire, which is a new type of Ni-Ti wire, with (controlled memory).

A considerable number of studies were performed on root surface strain and dentinal microcrack development during canal shaping. However, examining whether the XPendoS and HyFlex CM have any effect on the apical strain development has not been done yet. There is a limited information available regarding their effect on the apical microcrack. Therefore, observing the apical root surface strain generated and microcrack developed by canal shaping with these files, in vitro, would provide more relevant data to be utilized clinically.

REVIEW OF LITERATURE

THE ROOT SURFACE STRAIN:

*Saw and Messer (1995)*¹ evaluated the influence of different obturation techniques (lateral condensation, Obtura, and Thermafil) on root strains in 27 upper central incisors using strain gauges mounted on the coronal and apical one-thirds of the root surface. The vertical load applied with each obturation technique was also measured. Authors found the technique of obturation significantly influenced the root strains, with the Obtura generating the highest strains. The Thermafil group showed significantly less strain than the Obtura or lateral condensation groups. Thermal expansion of dentin was an unexpected finding. A large proportion of strain in the Obtura and Thermafil groups was found to be thermal strain. The mean load required to cause vertical root fracture was five to six times higher than the load used in obturation.

*Ricks-Williamson et al (1995)*² This study is an application of a three-dimensional Finite-Element Method to investigate the changes in stress characteristics of a prepared maxillary central incisor. The purpose of this study was to analyze stress distributions in this tooth after simulated canal preparation and static loading. A maxillary central incisor was embedded in acrylic, sectioned, photographed, and digitized. A

three-dimensional finite-element model was generated by a computer and appropriately modified to simulate canal preparation. Data identified the highest stress magnitudes to be located between the middle and coronal thirds of the root; an area clinically observed to be prone to fracture during treatment. In addition, the magnitude of generated stresses was directly correlated with the simulated prepared canal diameter. The development of a validated three-dimensional finite-element method could identify areas that may predispose a tooth to structural failure during condensation loads.

*Lertchirakarn et al (1999)*³ assessed the vertical loads and root surface strains in extracted teeth during lateral condensation using finger and hand spreaders and compared with loads and strains at fracture. Six groups each of 10 teeth were tested: maxillary central incisor, premolar and molar; and mandibular incisor, premolar and molar. Root strains were measured using strain gauges mounted on the apical and middle third of the buccal root surface. Authors found the maximum loads and strains generated by finger spreaders were significantly lower than those generated using a hand spreader (D11T). These loads and strains were also significantly lower than the values at fracture. Most fracture lines were in a buccolingual direction, but maxillary premolars with two separate roots and the mesiobuccal root of maxillary molars showed more variation in fracture site. The

results suggest that lateral condensation alone should not be a direct cause of vertical root fracture. The use of finger spreaders, however, is associated with lower risk.

*Asundi and Kishen (2000)*⁴ examined the nature of stress distribution from the tooth root surface to the supporting alveolar bone. Such studies help in understanding the behavior of dental supporting structures under physiological function. In the strain gauge experiment, the mechanical strains were measured on the supporting bone surface and the root surface of the tooth under applied bite force. It was found that higher strains were distributed along the cervical region of the supporting bone and the root surface. The photoelastic study was also done to evaluate the stress distribution pattern from the root surface to the supporting bone under clinical conditions. The stress patterns were found to decrease from the cervical to the apical region of the root surface.

*Simet al(2001)*⁵ examined the null hypothesis that sodium hypochlorite irrigation of root canals does not alter the properties of dentine and contribute to the weakening of root-treated teeth. The effect of two concentrations (0.5%, 5.25%) of sodium hypochlorite (NaOCl) and saline on (i) the elastic modulus and flexural strength of machined dentine bars, and (ii) changes in strain of 'whole' extracted human teeth were evaluated. One hundred standardized plano-parallel dentine bars (> 11.7'0.8'0.8

mm) were randomly divided into the three groups, immersed for 2 h in the respective solutions and then subjected to a three-point bend test. Changes in strain of each of 10 teeth on cyclical nondestructive occlusal loading were measured using electrical resistance strain gauges bonded to the cervical aspects. Each tooth had its crown and enamel reduced, and root canal prepared. These were irrigated sequentially in a series of four separate, 30-minute regimes; initial-saline, 0.5% NaOCl, 5.25% NaOCl and final-saline. The changes in strains after each irrigation regime were compared. Authors found the null hypothesis was rejected, 5.25% NaOCl reduced the elastic modulus and flexural strength of dentine. Irrigation of root canals of single, mature rooted premolars with 5.25% NaOCl affected their properties sufficiently to alter their strain characteristics when no enamel was present.

*Goldsmith et al (2002)*⁶ determined the effect of root-canal irrigation with different concentrations of sodium hypochlorite (3%, 5.1%, 7.3% NaOCl) on the mechanical properties of teeth. Root canals of 13 extracted, premolars, denuded of enamel, were prepared with nickel-titanium rotary instruments to a standard size by using saline irrigation. An electrical strain gauge was bonded to the cervical aspect of each tooth. The 10 experimental teeth were subjected to five successive, 30-minute periods of irrigation. The irrigants were used in the following order: (a) saline; (b) 3.0% NaOCl; (c) 5.1% NaOCl; (d) 7.3% NaOCl; (e) saline. Three

control teeth were irrigated with saline only for all five periods. After irrigation, the teeth were cyclically loaded to 110N while the surface strain was measured. Changes in strain of the test teeth after each irrigation regimen followed broadly similar patterns that were different from the control teeth. The authors found there was no difference, however, in the strain recorded after irrigation by the different irrigants within the experimental group.

*Lertchirakarn et al (2003)*⁷ investigated , using FEA, the stress distribution generated in maxillary incisor and mandibular incisor root models by forces applied within the canal; and to use strain-gauge techniques to validate the root surface strain results obtained from FEA. The combination of modeling and strain-gauge measurement should yield more information regarding the mechanism of VRF. Finite element analysis indicated that circumferential tensile stresses were concentrated on the buccal and lingual surfaces of the canal wall, corresponding to areas of greatest canal wall curvature. Surface stresses were much lower and were consistently tensile on the proximal root surfaces but variable on the buccal and lingual surfaces. The measurement of root surface stresses does not provide a reliable picture of internal stresses in the root. Canal wall curvature is a major factor in stress concentration and hence in the pattern of fracture.