Dehydration Induces Cracking in Root Dentin Irrespective of Instrumentation: A Two-dimensional and Three-dimensional Study

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Abstract

Introduction: Water loss strongly affects the mechanical behavior of dentin. Micro–computed tomography (μCT) studies exploring the influence of endodontic procedures on root cracking often lack information on the hydration state of the scanned samples. This study explores the relationship between dehydration and crack formation in root dentin with and without endodontic instrumentation. **Methods:** Fifty-three extracted teeth were used. Thirty canals were not instrumented, and 23 canals were instrumented with ProTaper files until F3. All teeth were imaged with visible light or x-rays, both moist (100% relative humidity) and after dehydration, thus allowing every tooth to serve as its own control. The presence of cracks was determined both before and after dehydration by microscopy on two-dimensional (2D) slices and in by μCT in three dimensions (3D). The μCT data were used to determine the total surface area of newly formed cracks after dehydration, which was correlated with dentin cross section. **Results:** Both 2D and 3D data revealed cracking with increasing dehydration. Drying led to damage in >50% of roots, with a significant number of cracks appearing within 24 hours of ambient air-drying at 35%–55% relative humidity. Some cracking was occasionally observed even within minutes. More cracks were identified in 3D by μCT as compared with 2D microscopy. A correlation was found between dentin cross section and the total newly formed crack areas. **Conclusions:** Dehydration may induce cracks in dentin regardless of canal instrumentation. The *in vitro* observed correlation between root dentin mass and newly formed cracks implies that dehydration engenders stresses that may significantly damage roots. *(J Endod 2017;■:1–6)*

Key Words

Crack, dehydration, dentin, instrumentation, μCT

Significance

Spontaneous cracking of dentin might have influenced previous studies using destructive or μCT methodologies to investigate the effects of endodontic procedures on the root dentin. The humidity in which samples are stored and scanned for damage analysis studies is an important contributor to crack formation.

Instrumentation is a critical and delicate step during root canal treatment. Its impact on the dentin canal walls is a subject of much concern (1, 2) because damage may propagate and manifest itself clinically only years later (3). Various *in vitro* studies demonstrated formation of cracks and dentinal defects, citing excess tissue removal or mechanical stresses as plausible causes (4, 5). Yet some reports suggest that root integrity may be compromised because of effects of dehydration (6). It is therefore important to consider possible implications of sample preparation, because many *in vivo* studies use both destructive (two-dimensional [2D], slicing) and nondestructive (three-dimensional [3D], tomography) imaging methods for analysis. Cracks might appear during study data acquisition, resulting in sample preparation artifacts. Such artifacts superimpose onto any previously existing damage, eg, cracking during tooth extraction or due to aging (7).

A major contemporary debate questions the relationship between instrumentation and tooth structural integrity. De Deus et al (8, 9) used micro–computed tomography (μCT) to contend that previously reported 2D microscopic evaluations (4) were unreliable in assessing damage after root canal instrumentation. Indeed, they and others showed how μCT is helping to better understand success and failure in endodontics. Specifically, cracks are elusive because they may or may not be visible by classic 2D imaging, as they propagate in 3D. Such propagating damage is therefore best studied in intact (non-sectioned) tooth segments. However, μCT scanning requires acquisition of large numbers of radiographs, necessitating significant measurement time that typically cannot capture fast processes, requiring faster imaging, which is available by optical microscopy (10). Furthermore, the resolution and contrast of conventional μCT scans are not always sufficient to detect all cracks and fractures (11, 12) because of limited signal-to-noise ratios. Even advanced high-end (eg, synchrotron radiation) μCT setups are limited in this respect, although they offer exquisite details (10). For example, Pop et al (13) used synchrotron radiation μCT to image different roots before and after instrumentation and concluded that crack number and length increased. Unfortunately, resolution and sample environment conditions were not fully described, and it seems that data were collected under dry conditions.

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Changes in water content have a marked effect on dentin. Jameson et al (14) demonstrated that dehydrated samples fracture at significantly lower strains than hydrated dentin. Kahler et al (15) reported that dehydrated dentin has lower resistance to the propagation of cracks. Concomitantly, Kruzic et al (16) showed that with hydration, dentin exhibited increased fracture resistance as compared with dehydrated dentin. Kishen and Rafique (17) reported significant increase in strain in dehydrated samples of dentin that were measured nondestructively. A more recent study (18) showed that dehydration of root dentin produces extremely high stresses up to 20 times those encountered during hard food mastication. Such high stresses (~300 MPa) exceed the strength of dentin (>100 MPa) (19); thus, unintentional dehydration may potentially cause severe damage to dentin, irrespective of care taken during endodontic instrumentation.

The aim of this study was to evaluate the effects of dehydration on the development of cracks in roots in connection with root canal instrumentation by using a combination of nondestructive high-resolution laboratory μCT and conventional time-lapse optical microscopy.

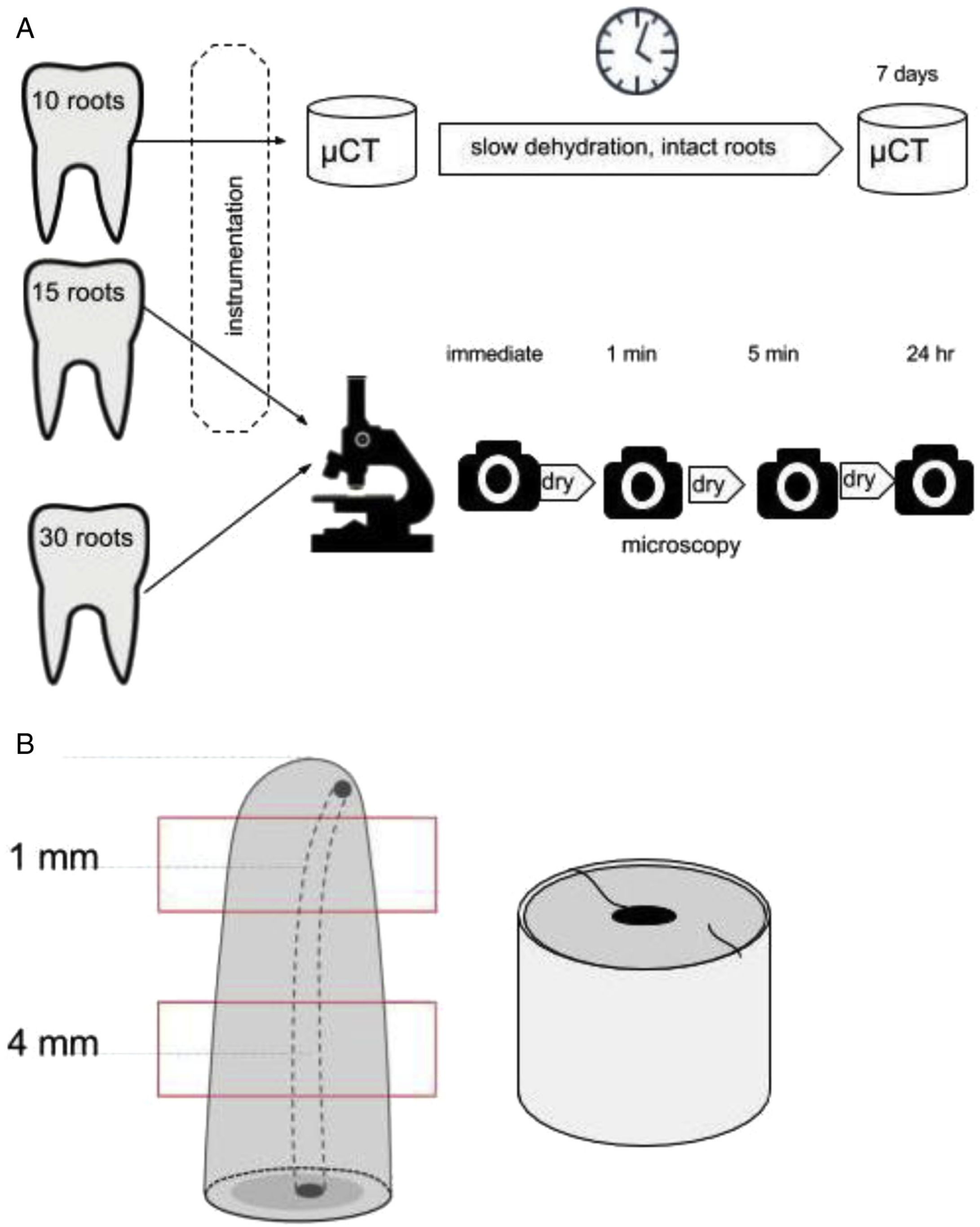

Figure 1. (*A*) Schematic representation of the experimental protocol. Twenty-five instrumented roots and 30 non-instrumented roots were analyzed under increasing degrees of dehydration either after sectioning observed under a microscope or by μCT. (*B*) Scanned and analyzed regions of interest in the 3D data. Two specific areas were evaluated: 1 mm and 4 mm from the apex (spanning $\pm$ 500 μm). Most cracks observed were radial cracks (depicted graphically on the right), which are defects originating in the external dentin surface/cementum, extending into the dentin with or without extension to the root canal.