Impact of Lubricant Parameters on Rotary Instrument Torque and Force

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Abstract

In the current study, the impact of lubricant parameters on simulated root canal instrumentation was investigated. Using size 30 ProFile .06 instruments in milled artificial root canals in human dentin, the effects of sodium hypochlorite (1% NaOCl) and a chelator (18% etidronic acid) in aqueous irrigants on maximum torque, full torsional load, and maximum force values were gauged using a torque testing platform. Furthermore, the impact of the time a chelating lubricant was exposed to dentin as well as its galenic form (aqueous vs. gel-type) on the above outcome variables was evaluated. Aqueous lubricants significantly ($p < 0.05$, ANOVA, Newman–Keuls) reduced all outcome variables compared to dry conditions. The incorporation of a chelator further reduced these values ($p < 0.05$), whereas hypochlorite behaved similar to water. The chelator effect was immediate and did not increase with time. An aqueous lubricant was more beneficial than a gel-type counterpart. *(J Endod 2007;33:280–283)*

Key Words

Chelation, lubrication, rotary instrumentation, torque

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Cyclic fatigue and torsional overload have been identified as the main reasons for rotary nickel–titanium instrument fracture (1, 2). It is generally believed that lubrication during root canal preparation would lower mechanical stress on rotary root canal instruments and therefore prevent instrument separation (3). However, few data exist in the literature to confirm or disprove that notion. A lubricant may exert a physical effect by floating debris away from the rotating instrument. In addition, chemical additives may act on the root canal dentin to facilitate instrumentation. Calcium-chelating moieties soften the root canal wall by the dissolution of inorganic dentin components (4), whereas sodium hypochlorite (NaOCl) attacks the organic dentin matrix (5). Consequently, both NaOCl and chelators can lower root dentin microhardness (6). Furthermore, the galenic form of a lubricant (i.e., its rheological form) appears to have a significant impact on torsional loads during rotary instrumentation (7). A paste-type lubricant containing EDTA in a carbowax base (8) showed little benefit when used in conjunction with rotary instruments (ProFile and ProTaper) in simulated root canals in human dentin (7). In contrast, torsional loads on ProFile and ProTaper instruments were reduced when the simulated root canals were filled with pure water or aqueous EDTA compared to dry conditions (7). The incorporation of the chelating agent EDTA showed scarcely any immediate effect on torsional loads compared to pure water. Whether the chemical effect exerted by the chelating agent would increase with the contact time to dentin, however, was not assessed.

Using milled artificial canals in standardized human dentin discs and ProFile instruments attached to a specifically designed torque-testing platform, the goals of the current investigation were twofold: (1) to determine the influence of NaOCl and a chelator in aqueous solution on torque and force values during simulated instrumentation and (2) to assess the impact of the galenic form and dentin exposure time of this chelator on the above parameters.

Materials and Methods

Preparation of Standardized Simulated Root Canals

Human third molars free of decay and restorations were selected from a collection of extracted teeth. Teeth had been stored in 0.1% thymol solution at 5°C. Dentin discs of 3 mm thickness were prepared as described (7), using a diamond-coated saw (SP 1600, Leica, Nussloch, Germany). All discs were inspected under a stereo dissecting microscope (Leica Wild M3Z, Wild, Heerbrugg, Switzerland) with an internal light source (Intralux 4000, SOWO-DENT, Birmensdorf, Switzerland) for possible enamel remnants; specimens showing such remnants were discarded. Four pilot holes 0.5 mm in diameter were drilled perpendicularly through the dentin discs with a stationary drill under water-cooling. These holes served as standardized simulated root canals (SSRCs) for torque testing. Using a computer algorithm (http://www.random.org/), sixty discs were then randomly assigned to three main experimental groups ($n = 20$ per group) and stored in distilled water at 5°C until further use. The experimental groups are described in Table 1.

Torque-testing Platform

Standardized simulated root canals were prepared using ISO size 30 ProFile .06 instruments (Maillefer, Ballaigues, Switzerland). A computer-controlled testing platform (9) was used to record values for torque and apically directed force. Using data

TABLE 1. Experimental groups in the current study

Group	Canal #	Lubricant in canal	Dentin contact time
I	1	∅ (positive control)	Immediate
	2	H_2O	Immediate
	3	Aqueous 1% NaOCl	Immediate
	4	Aqueous 18% HEBP	Immediate
IIa	1	∅ (positive control)	Immediate
	2	H_2O	Immediate
	3	Aqueous 18% HEBP	Immediate
	4	18% HEBP gel	Immediate
IIb	1	∅ (positive control)	10 min
	2	H_2O	10 min
	3	Aqueous 18% HEBP	10 min
	4	18% HEBP gel	10 min

from pilot experiments with manual feed, optimized feed parameters were programmed for instrument insertion speed and depth.

In brief, specimens were mounted on a specially designed holder attached to a load cell (strain gauge full bridge, LC 4101-K003, Orientec, Tokyo, Japan), which was connected to a preamplifier (CALEX Model 160, Concord, CA). A torque sensor (MTTRA 2, with amplifier Microtest, both Microtec Systems, Villingen, Germany) and a motor (Type ZSS, Phytron, Gröbenzell, Germany) were mounted on a stable metal platform, which moved along a low-friction guide rail. A linear precision potentiometer (Lp-100, Midori, Osaka, Japan) was attached to the sliding platform to record linear movements. The movements of the instruments relative to the discs were executed by a linear drive (P01-2380, LinMot, Zürich, Switzerland), which was controlled by a computer program called Endotest running on a Macintosh PowerPC computer (Apple Inc., Cupertino, CA).

Data for torque, force, and insertion depth were acquired from the sensors by three analogue channels at a sampling rate of 100 Hz using a 12-bit interface (PCI-MIO-16CE, National Instruments, Austin, TX) using the Endotest software package, which was specifically written for that purpose. Variables recorded during each measurement were registered as "Ncm," "N," and "mm," respectively, for torque, force, and distance of instrument insertion and were stored in a proprietary format for subsequent off-line analyses.

Lubricants

For evaluation of the effect of different aqueous lubricants on torque values the following substances were used for the first set of tests: 1% (w/v) NaOCl, 18% etidronic acid (also known as 1-hydroxyethylidene-1, 1-bisphosphonate or HEBP, Zschimmer & Schwarz, Burgstädt, Germany), deionized water, and no lubricant (control, Table 1). To determine the influence of exposure time and galenic form the tested substances were: no lubricant (control), water, HEBP in aqueous solution, and gel-type HEBP. The latter contained 2% alginate (D2998, Red Carnation Gums Ltd., Basildon, UK), 3% aerosil, 10% Tween 80, and 18% HEBP and was prepared as previously described (10). Twenty discs were immediately subjected to torque testing and 20 discs after 10-min exposure to test and control lubricants.

To determine equal amounts of lubricants, the volume for the SSRCs was calculated under the assumption that the canals were cylinders of 0.59 mm^3. On this basis, it was decided to use 0.5 μL of the tested solutions and water. NaOCl, HEBP, and water were placed into the SSRC using a pipette with disposable tip. The gel-type HEBP was filled into the SSRC using a 26-gauge irrigating needle (Sterican; B. Braun Medical AG, Emmenbrücke, Switzerland).

Each disc per group was subjected to all four regimens. To control for differences in dentin structure and positioning of the discs, and to exclude any bias caused by possible carryover of medicaments, a rolling sequence for the tested media was determined at the beginning of the experiments. This sequence was changed with each subsequent disc, so that each tested medium and control substance was five times in the first, five times in the second, five times in the third, and five times in the fourth SSRC. To minimize carryover of lubricants from one SSRC to the others, discs were mounted so that the canal under investigation faced downward. The appropriate medium was loaded into the SSRC, the tip of the instrument was positioned at the center of the pilot hole, and Endotest was activated. Between the four individual tests per disc, these were washed in deionized water. Instruments were cleaned for 1 minute using an ultrasonic bath with 100 mL deionized water. Subsequently, the dentin discs were dried using compressed air (GEPE "Air Duster"; Image Trade, Safenwil, Switzerland) and again mounted into the holder.

Used nickel–titanium (NiTi) rotary instruments were replaced with new ones after preparation of 16 SSRCs. Preliminary tests showed that using a file for 16 SSRCs did not affect the parameters under investigation.

Data Analysis

Maximum values for torque and force were calculated off-line; the full torsional load over time (in Ncm · seconds) was calculated by integrating the area under the torque curve as described (7). One-way analyses of variance (ANOVAs) with Newman–Keuls tests were used to compare means among various lubricants. To assess the impact of exposure time and galenic form of the chelator on outcome variables, comparisons were made by two-way ANOVA followed by Newman–Keuls test. For all tests, the alpha-type error was set at <0.05.

Results

With no lubrication and air-dried dentin, a mean maximum torque score ($\pm$ SD) of 2.65 $\pm$ 0.25 Ncm was recorded. Torque scores were significantly reduced by all of the applied media. Maximum torque scores of 2.45 $\pm$ 0.26 and 2.49 $\pm$ 0.20 Ncm were measured with water and 1% NaOCl in the SSRC, respectively. Aqueous HEBP showed a further significant ($p < 0.05$) reduction in maximum torque to 2.27 $\pm$ 0.20 Ncm (Fig. 1, *A*). Similarly, full torsional loads over time and maximum apically directed force values were significantly lower if SSRCs were filled with any of the three media. Again the chelator caused a significant ($p < 0.05$) reduction compared to both other lubricants (Fig. 1, *B* and *C*).

The time the chelator was left in the root canal did not influence the dependent variables ($p > 0.05$). The galenic form of the chelating agent, on the other hand, significantly influenced maximum torque and full torsional load values ($p < 0.001$), whereas the maximum apically directed force was not altered ($p > 0.05$). In this set of experiments, maximum torque scores were 2.09 $\pm$ 0.24 Ncm with HEBP in liquid and 2.34 $\pm$ 0.23 Ncm with HEBP in gel form immediately after lubrication. The corresponding full torsional load values were 3.92 $\pm$ 1.16 Ncm · s with liquid HEBP compared to 4.69 $\pm$ 0.95 Ncm · s with HEBP gel ($p < 0.05$).

Discussion

Under the conditions of the current study, the galenic form of a lubricant was the main factor to influence mechanical stress on ProFile instruments in simulated root canals in human dentin. Aqueous solutions were superior to a gel-type preparation. Furthermore, the addition of a chelating agent caused some further decrease in torque, torsional load, and force values. This effect occurred immediately and did not increase with time.

The current study was an attempt at simulating mechanical conditions encountered during root canal preparation in a standardized en-

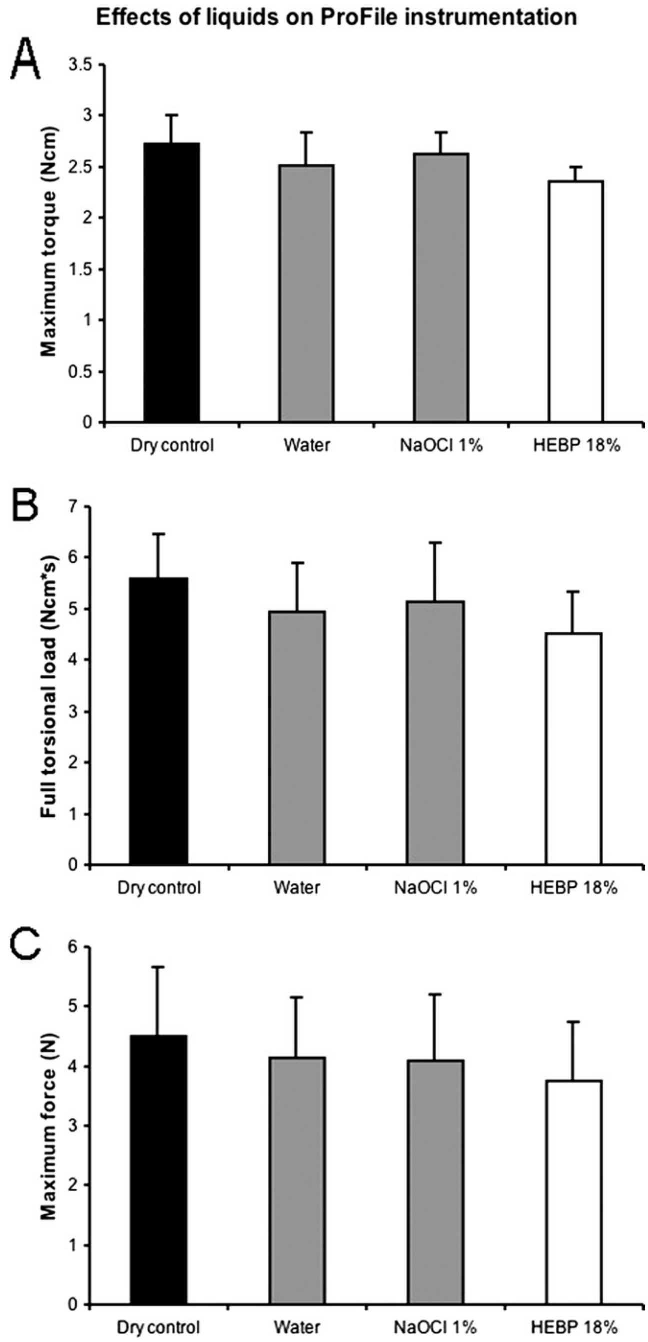

Figure 1. Impact of liquid media on maximum torque (*A*), full torsional load (*B*), and maximum force values (*C*) of size 30 ProFile .06 instruments used in milled artificial canals in human dentin. Columns indicate means and error, bars indicate standard deviations. Columns of the same shade represent data sets that did not differ from each other for a specific parameter ($p > 0.05$, one-way ANOVA, Newman–Keuls tests).

vironment. The idea of presenting a model was derived from an older study, in which the researchers used bovine bone disks to simulate root canals (11). In the clinic, however, canal curvatures, instrument sequences, and multiple other factors may affect mechanical stress on rotary instruments. Nevertheless, the current model allowed us to study chemical interactions of active lubricant moieties with dentin, a phenomenon that has received relatively little attention thus far, given that the great majority of researchers used plastic blocks to study root canal instruments (12). Plastic blocks were again used recently to assess simulated stress in root canal walls in contact with saline and a gel-based lubricant (13). In that study, the gel-based lubricant was superior to saline; the likely reason for this apparent variance from the current results may be a different interaction of lubricants with dentin compared to plastic material.

Despite the standardized conditions of the current model, relatively high variations in outcome variables were observed. This finding may be explained by the inherent variations in dentin structure (14). The predominant effect of galenic lubricant properties on mechanical instrumentation may be explained by the observation that fluids such as water flush hard tissue debris away from the instrument (15). Collection of debris in cutting flutes is a frequent phenomenon (16) and has been implicated in dulling of burs and dentinal cracking after pin placement (17). Based on that and the current findings, it appears relatively obvious that aqueous irrigants are more advantageous than gel-type preparations in conjunction with ProFile instrumentation (7). The addition of a chelator had a further beneficial effect under the current conditions, a phenomenon that was not previously observed, when EDTA was used instead of HEBP (7). Both, HEBP and EDTA have a similar affinity to calcium (18). In the earlier experiment (7), aqueous EDTA did show a propensity to reduce mechanical stress on ProFile instruments compared to deionized water, but that reduction was not statistically significant. The number of specimens, however, was higher in the current study, and statistical power therefore greater. Based on this report and the published material, it may be concluded that chelators exert only a relatively minor effect on ProFile instrumentation. Furthermore, it should be realized that using an aqueous chelator solution during instrumentation, preparation errors such as straightening of curved canals could occur (19).

The addition of NaOCl to an aqueous irrigant did not have an impact under the current conditions. However, a solution of relatively low concentration was used in this study. It cannot be excluded based on the current data that an NaOCl solution of higher concentration may have lowered torque and force values on the ProFile instruments. Previous work showed that concentrated solutions of >3% profoundly affect mechanical dentin properties within the time frame of an endodontic treatment (20), whereas lower concentrations did not.

It may be concluded that, based on the current observations, it appears advisable to keep the root canal system filled with an aqueous irrigant during instrumentation.

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