Dentinal Tubule Penetration of a Calcium Silicate–based Root Canal Sealer with Different Obturation Methods

Ji Wook Jeong, DMD, Anna DeGraft-Johnson, DDS, Samuel O. Dorn, DDS, and Peter M. Di Fiore, DDS, MS

Abstract

Introduction: The purpose of this study was to investigate the depths of penetration of a calcium silicate–based sealer in dentinal tubules by using 3 different obturation methods. **Methods:** One hundred extracted human permanent anterior teeth were endodontically prepared and divided equally into 3 experimental groups and 1 control group as follows: CPoint single cone (CPSC), gutta-percha single cone (GPSC), gutta-percha vertical condensation (GPVC), all with a calcium silicate–based sealer and calcium indicator Fluo-3, and CPoint single cone with a calcium indicator Fluo-3 (CPF3) without sealer as the control. The roots of the teeth in each group were axially cross-sectioned, and the surfaces were examined under confocal laser scanning microscopy at ×10 and ×20 magnifications. The sealer penetration depths were measured at their maximum depths and at 4 circumferential depths (12, 3, 6, and 9 o'clock) by using fluorescence. **Results:** Statistical analyses by using one-way analysis of variance and repeated measures analysis with linear mixed models showed no statistically significant difference among the mean maximum depth measurements (CPSC, 283.83 μm; GPSC, 318.66 μm; and GPVC, 313.03 μm; P = .7553) and among the average depths across all points (CPSC, 111.24 μm; GPSC, 135.38 μm; and GPVC, 126.62 μm; P = .5304) for the 3 experimental groups. **Conclusions:** The pressure derived from hygroscopic expansion of CPoint or warm vertical condensation did not enhance penetration depths of the calcium silicate–based sealer. Sealer penetration into the dentinal tubules occurred independent of the obturation technique. *(J Endod 2017;■:1–5)*

Key Words

Calcium silicate-based sealer, dentinal tubules, penetration

Significance

The choice of the obturation technique used with a calcium silicate–based sealer may not necessarily influence sealer penetration in the apical portion of the root canal.

Root canal obturation as the final phase of endodontic treatment has the objective of providing a fluid-tight seal within prepared root canals for preventing reinfection by microleakage (1). It has been suggested that inadequately filled root canals can be a factor in treatment failures (2). Three-dimensional filling of root canals is a concept that emphasized the complete filling of all irregularities within the entire root canal system (3). Various methods have been used to approach a three-dimensional root canal filling and include lateral condensation, warm vertical condensation, and single-cone obturation techniques, all of which use gutta-percha as the core material and a flowable cement-like material as the sealer (4, 5). These methods play an important role in filling the morphologic irregularities within the root canal system and providing some degree of dentinal tubule sealer penetration for enhancing the obturation seal and preventing or minimizing microleakage (6).

CPoint (EndoTechnologies, Shrewsbury, MA) is a new root canal obturation system with a 2-component design consisting of an inner solid central core of polymerized nylon fibers and an outer semi-solid hydrophilic polymer coating. When the CPoint is inserted into the root canal with a compatible hydrophilic bioceramic calcium silicate sealer Smartpastebio (Smartseal, Stamford, UK), the outer copolymer coating is hydrated by moisture in the dentinal tubules and laterally expands, with the potential of forcing sealer into the dentinal tubules (7). A recent study estimated the expansion of the polymer coating was up to 14.4% (8). This led to the hypothesis that the CPoint obturation method might enhance the obturation seal and reduce the potential of reinfection by microleakage (7). Moreover, calcium silicate–based sealers are reported to have a sealing ability comparable to resin-based sealers such as AH Plus (9). In addition, calcium silicate–based sealers show low cytotoxicity and high biocompatibility, with the potential to promote an osteogenic response (10). Because of the high hydraulic conductance of calcium silicate–based sealers to obstruct dentinal tubules (11), an assessment of the dentinal tubule penetration of calcium silicate–based sealers by using different obturation methods would be useful in determining their potential sealing effect in obturated root canals. Also, because it has been suggested that an adequate root canal obturation seal can be obtained with the single-cone technique by using a calcium silicate–based sealer (12), the elimination of excessive intracanal compaction forces during condensation procedures could reduce the potential for root fracture, especially in thin or weakened roots.

From the Department of Endodontics, University of Texas, School of Dentistry, Houston, Texas.
Address requests for reprints to Dr Ji Wook Jeong, Department of Endodontics, University of Texas, School of Dentistry, Houston, TX 77054 E-mail address: ji.wook.jeong@uth.tmc.edu
0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2016.11.023

Different indicators to trace the penetration depths of root canal sealers in dentinal tubules have been used in the past (4, 5, 13, 14). However, no decisive method to measure the penetration depths of calcium silicate–based sealers in dentinal tubules has emerged. Fluo-3 is a fluorescent indicator that traces calcium ion; therefore, it was selected as a suitable marker to trace the penetration of calcium silicate–based sealers in dental tubules.

The purpose of this study was to investigate the penetration depths of a calcium silicate–based sealer into dentinal tubules by using 3 different obturation methods under confocal laser scanning microscopy (CLSM) with Fluo-3 as the sealer marker. The null hypothesis tested was that there were no significant differences in sealer penetration depths among the 3 experimental groups.

Materials and Methods

Selection of Teeth

One hundred fully developed human extracted permanent canines and maxillary incisors (47 canines and 53 incisors) were sterilized according to the protocol of the University School of Dentistry and stored at 37°C and 100% humidity for 2 weeks before use. The distribution of extracted teeth for the 4 groups is shown in Table 1.

Root Canal Treatment

A standard access preparation was made for each tooth according to type. A #10 K-file (Dentsply Maillefer, Johnson City, TN) was inserted into each root canal until it was visible at the apical foramen, and its length was measured in millimeters from the incisal edge reference point. The working length was established by reducing that length by 0.5 mm. The root canals were instrumented to size #15 K-file (Dentsply Maillefer), followed by ProFile (Dentsply Maillefer) rotary instruments using a crown-down technique to a master apical file #40/06. During instrumentation, the root canals were copiously irrigated with 10 mL 5.25% NaOCl. After instrumentation, the canals were irrigated with 10 mL 17% EDTA, followed by 3 mL 5.25% NaOCl each for 3 minutes and then followed by a final flush with 10 mL deionized water. All root canals were irrigated by using 30-gauge irrigation needles (Max-I-Probe; Dentsply Maillefer) and dried with 2 paper points for 3 seconds each. The teeth were then randomly divided into 4 groups as shown in Table 1.

Root Canal Obturations

In CPoint single-cone group (CPSC), the root canals were obturated by using a single 40/06 CPoint according to the manufacturer's recommendations. In gutta-percha single-cone group (GPSC), the root canals were obturated with a single 40/06 gutta-percha cone. In gutta-percha vertical condensation group (GPVC), the root canals were obturated with a 40/06 gutta-percha cone by using the B&L Alpha and Beta (B&L Biotech, Fairfax, VA) vertical condensation continuous wave system. In control group CPF3, the root canals were obturated with a single 40/06 CPoint. For CPSC, GPSC, and CPVC groups, 2 mg Smartpastebio calcium silicate–based sealer mixed with 1 mg Fluo-3 pentaamonium salt (Life Technologies, Carlsbad, CA) indicator was used as the sealer. For control group CPF3, 3 mL deionized water mixed with 0.5 mg Fluo-3 pentaamonium salt was used without sealer. After the completion of the root canal obturations, the access cavities in the teeth of all groups were filled with Cavit (3M ESPE, St Paul, MN), and the teeth were stored at 37°C and 100% humidity for 2 weeks.

Sectioning of Roots and Preparation of Root Surfaces

The roots of the teeth in each of the 4 groups were cross-sectioned perpendicular to their long axis by using diamond disks with a slow speed (25,000 rpm) handpiece at the level of 4 and 7 mm from the root apex. The apical portions and coronal portions of the sectioned roots were discarded, and the middle portions were retained. The apical surfaces of the middle portions were polished sequentially from 320 to 1500 grit size of Carbimet (Buehler, Lake Bluff, IL) and Wetordry 414Q (3M, St Paul, MN), mounted on glass slides, and examined by fluorescence under ×10 and ×20 magnification by using CLSM (Leica TCS SP5, Wetzlar, Germany). The acquired images were analyzed with LAS AF Software (Leica). The sealer penetration depths in the dentinal tubules were measured at their maximum depth and at 4 circumferential points (12, 3, 6, and 9 o'clock) buccolingually and mesiodistally for each specimen (Fig. 1*C*)

Statistical Analysis

One-way analysis of variance was used to determine whether there was a significant difference among the maximum depths of the 3 experimental groups ($P < .05$). Repeated measures analysis with linear mixed models was used for comparison between 3 averaged depths across all points ($P < .05$).

Results

Of the 100 cross-sectioned disks, 1 specimen in each of the GPSC group and the CPF3 control group broke during sectioning and were discarded, leaving 29 specimens in the GPSC group and 9 specimens in the CPF3 control group for data analysis. No specimens in the CPSC and GPVC groups SC were lost, allowing 30 specimens for each of these groups for data analysis. Representative cross-sectional images for each group are shown (Fig. 1*A–C*). The results for all groups are shown in Table 2, where the *P* value for all of the experimental groups indicated that there was no statistically significant difference among the mean maximum depth measurements (CPSC SC, 283.83 μm; GPSC SG, 318.66 μm; and GPVC CG, 313.03 μm; $P = .7553$). Furthermore, the average depths across all 4 circumferential points did not show a statistically significant difference between the 3 groups ($P = .5304$). By contrast, in the CPF3 control group, there was no intensity of fluorescence, indicating that the Fluo-3 does not generate fluorescence in the absence of the calcium silicate–based sealer (Fig. 1*D*).

Discussion

Our results demonstrated that the Fluo-3 was an appropriate fluorescent dye to trace the calcium silicate–based sealer because this dye is able to selectively be fluorescent in the presence of calcium silicate–based sealer but not in the absence of the sealer (Fig. 1).

TABLE 1. Distribution of Extracted Teeth for 4 Groups

Extracted teeth	Group CPSC Single-cone CPoint	Group GPSC Single-cone gutta-percha	Group GPVC Warm vertical compaction	Group CPF3 Control
Incisors (upper)	16	16	16	5
Canines (upper and lower)	14	14	14	5
Total (n = 100)	30	30	30	10