A New Solution for the Removal of the Smear Layer

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Various organic acids, ultrasonic instruments, and lasers have been used to remove the smear layer from the surface of instrumented root canals. The purpose of this study was to investigate the effect of a mixture of a tetracycline isomer, an acid, and a detergent (MTAD) as a final rinse on the surface of instrumented root canals. Forty-eight extracted maxillary and mandibular single-rooted human teeth were prepared by using a combination of passive step-back and rotary 0.04 taper nickel-titanium files. Sterile distilled water or 5.25% sodium hypochlorite was used as intracanal irrigant. The canals were then treated with 5 ml of one of the following solutions as a final rinse: sterile distilled water, 5.25% sodium hypochlorite, 17% EDTA, or a new solution, MTAD. The presence or absence of smear layer and the amount of erosion on the surface of the root canal walls at the coronal, middle, and apical portion of each canal were examined under a scanning electron microscope. The results show that MTAD is an effective solution for the removal of the smear layer and does not significantly change the structure of the dentinal tubules when canals are irrigated with sodium hypochlorite and followed with a final rinse of MTAD.

The main objectives of root canal therapy are cleaning and shaping and then obturating the root canal system in three dimensions to prevent reinfection. Many instrumentation techniques have been proposed to shape root canals to facilitate their complete obturation. Less attention has been directed toward the ability of these techniques to completely clean and disinfect the root canal system. Studies show that currently used methods of instrumentation, especially rotary instrumentation techniques, produce a smear layer that covers root canal walls and the openings to the dentinal tubules (2, 3). The smear layer consists of organic and inorganic substances, including fragments of odontoblastic processes, microorganisms, and necrotic materials. Presence of this smear layer prevents penetration of intracanal medication into the irregularities of the root canal system and the dentinal tubules and also prevents complete adaptation of obturation materials to the prepared root canal surfaces (4).

Various organic acids, ultrasonic instruments, and lasers have been used to remove the smear layer. Based on available evidence, it seems that these agents and methods do not provide complete disinfection of the root canal spaces in all cases when used in one-visit root canal therapy. Because of the ineffectiveness of these techniques, many practitioners rely on placement of Ca(OH)2 in the root canals to assist in canal disinfection (5, 6). As a result of this recommendation, root canal therapy has to be performed in more than one appointment.

In addition to acids, ultrasonic and lasers, tetracycline has been recommended as a chelating agent during periodontal and endodontic treatment. Doxycycline has been used during periodontal treatment because of its antibacterial and chelating ability as well as its substantiveness (7). Barkhordar et al. (8) and Haznedaroğlu and Ersev (9) recommended the use of tetracycline HCl to remove the smear layer from the surfaces of instrumented canals and root-end cavity preparations. However, these investigators did not examine the antibacterial effects of tetracycline when used as an intracanal irrigant. A search of the endodontic literature showed the absence of any reports regarding the ability of an irrigant capable of removing the smear layer and disinfecting the root canal system. The purpose of this study was to investigate the effect of a new irrigation solution (MTAD), containing a mixture of a tetracycline isomer, an acid, and a detergent on the surface of instrumented root canals. (A patent application has been filed covering the technology described in this article.)
The specimens were then coded based on the final irrigation solution. In a blind manner, two investigators scored the presence or absence of smear layer on the surface of the root canal or in the dentinal tubules at the coronal, middle, and apical portion of each canal according to the following criteria:

1 = No smear layer. No smear layer on the surface of the root canals; all tubules were clean and open.
2 = Moderate smear layer. No smear layer on the surface of root canal, but tubules contained debris.
3 = Heavy smear layer. Smear layer covered the root canal surface and the tubules.

In addition, the same investigators scored the degree of erosion of dentinal tubules as follows:

1 = No erosion. All tubules looked normal in appearance and size.
2 = Moderate erosion. The peritubular dentin was eroded.
3 = Severe erosion. The intertubular dentin was destroyed, and tubules were connected with each other.

The Cochran-Mantel-Haenszel method was used to analyze the data.

## Results

Removal of smear layer from the surfaces of root canals revealed the presence of more abundant and larger dentinal tubules in the coronal third of root canals compared with those seen in the middle and apical thirds of the root canal system. The dentinal tubules in the apical third of the canals were smaller and fewer than those observed in the rest of the root canals (Fig. 1). In addition, removal of the smear layer showed the presence of many lateral canals in the apical thirds of the root canal systems (Fig. 2).

Examination of the surface of root canal walls in group A (positive control) showed the presence of a heavy smear layer throughout the entire length of the root canals (Fig. 3). The surfaces of samples in group B were similarly covered with a heavy layer of debris in the coronal, middle, and apical portion of each canal (Fig. 4). Dentinal tubules were not visible in groups A and B.

The surfaces of root canals and the dentinal tubules in the coronal and middle thirds of samples in group C were free of debris. Severe erosion was noted on the root canal surfaces in this group (Fig. 5). The surfaces of root canals in the apical third of the samples in group C were also free of debris, but the dentinal tubules contained moderate amounts of debris (Fig. 6). The surfaces of root canals and the dentinal tubules in the coronal, middle, and apical thirds of samples in group D were free of debris (Fig. 7).

Comparison of the four treatment groups showed a statistically significant difference in the amount of debris remaining at all three levels of the canals ($p < 0.0001$). No significant difference was found between canals treated with distilled water (group A) and canals treated with NaOCl (group B) ($p = 1$). However, the canals in groups C and D were significantly cleaner than in groups A and B ($p < 0.0001$). Comparison of remaining debris in groups C and D in the coronal and middle thirds of the canals showed no significant differences between the effects of the final irrigants ($p$ values shown in Table 2). The dentinal tubules in the apical third of canals treated with MTAD were significantly cleaner than those treated with EDTA ($p < 0.0001$).

The amount of erosion was statistically analyzed only between groups C and D, because the smear layer was not removed in
groups A and B (Table 3). Although the coronal and middle sections were significantly more eroded in group C than in group D ($p = 0.0003$ and $p = 0.0005$, respectively), the amount of erosion in the apical section was not statistically different ($p = 0.1276$) in these two groups. Furthermore, EDTA caused significantly more erosion in the coronal portion of the canals compared with the middle third of the canals ($p = 0.0056$).

**DISCUSSION**

The main purpose of this investigation was to evaluate the effectiveness of an irrigant solution with ingredients capable of disinfecting the dentin, removing the smear layer, opening the dentinal tubules and allowing the antibacterial agents to penetrate the entire root canal system. Various antibiotics such as penicillin, bacitracin, and streptomycin have been used in the past to disinfect the root canals (11). However, because of the ineffectiveness of these antibiotics against the flora of infected root canals and their potential antigenicity, their use has been very limited. Tetracycline, including tetracycline-HCl, minocycline, and doxycycline, are
broad-spectrum antibiotics that are effective against a wide range of microorganisms. Tetracycline is bacteriostatic in nature. This property may be advantageous because in the absence of bacterial cell lysis, antigenic by-products (i.e. endotoxin) are not released. Tetracycline has many unique properties other than its antimicrobial effect. It has a low pH and thus can act as a calcium chelator and cause enamel and root surface demineralization (12). Its surface demineralization of dentin is comparable to that seen using citric acid (13). In addition, it has been shown that it is a substantive medication (becomes absorbed and gradually released from tooth structures such as dentin and cementum) (13, 14). Finally, studies have shown that tetracycline significantly enhances healing after surgical periodontal therapy (7).

The effects of the tetracycline family of antibiotics on the removal of smear layer from the surface of instrumented root canals and root-end cavity preparations have also been studied (8, 9). However, these studies did not examine the antibacterial effects of tested tetracyclines when used to remove the smear layer. In a pilot study we instrumented root canals, removed the smear layer, infected the dentinal tubules with whole saliva or Enterococcus faecalis for 2 weeks and then irrigated the root canals with 5 ml of different concentrations of doxycycline at various time intervals. Our results showed that placement of low concentrations of doxycycline in the root canals for 5 min was an effective antibacterial agent and prevented bacterial growth in 100% of our samples. Similar attempts with penicillin and erythromycin were ineffective.

Removal of the smear layer from the surface of instrumented root canals should allow the penetration of doxycycline into the root canal irregularities and the dentinal tubules. Various chemicals have been used to remove the smear layer. They include different formulations of EDTA, acetic acid, citric acid, polyacrylic acid, tannic acid, and Bis-dequalinium-acetate (4). The reagents that reacted with doxycycline in the test tubes were eliminated before their ability to remove the smear layer was tested. In several pilot studies we treated instrumented root canals with various volumes (1–10 ml) of different concentrations of the acetic acid, polyacrylic acid, and citric acid in combination with low concentrations of doxycycline as a final rinse for different time intervals (1–10 min). Our results showed that none of the above solutions were as effective as 5 ml of a mixture of doxycycline and citric acid for 1 to 5 min in removal of the smear layer. After identification of this mixture as our combination of choice, we mixed it with different concentrations of a number of detergents to lower the surface tension and increase the penetrating ability of the irrigating solution. Experimentation with various concentrations of these materials showed that a mixture of doxycycline, citric acid, and Tween-80 was capable of removing the smear layer from the surface of instrumented root canals better than a combination of only doxycycline and citric acid. After identification of our “ideal” combination, we set up this investigation to determine the effect of this solution as a final rinse on the surface of instrumented root canals compared with that of saline (positive control), NaOCl, and EDTA (negative control).
The teeth selected for this investigation ranged from 20 to 25 mm in length with intact clinical crowns. The entire canal length was utilized to test the efficacy of the solutions in all segments of the root including the apical third. In many previous studies the clinical crowns were removed and the effects of the test solutions at different levels of the root canals were not reported. The canals in this investigation were prepared with a combination of the passive step-back technique and rotary nickel-titanium instruments. This technique is an effective method to prepare root canals with rotary instruments (15). In addition, the use of the rotary files creates a significant amount of smear layer (3). The apical portion of each canal was enlarged to a size 30 file to allow adequate cleaning and penetration of the solution to the apical third of each root canal.

Scanning electron microscopy has been used to determine the effectiveness of various irrigants to remove the smear layer. Scanning electron microscopy allows an examination of morphologic details of the surfaces of prepared root canal. Based on the results of this investigation, it seems that there was no significant difference in the ability of distilled water and NaOCl to remove the smear layer from the surfaces of instrumented root canals, because both irrigants were ineffective. In a comparison of various mixtures of NaOCl, hydrogen peroxide, EDTA, and Glyoxide to saline, Baker et al. (16) found that none of the irrigants tested were significantly more effective than saline. Based on their findings and biocompatibility of saline, these investigators recommended the use of copious amounts of saline as a root canal irrigant.

The smear layer contains organic and inorganic components (4). To remove the smear layer, irrigating solutions should dissolve both components. When EDTA is alternately used with 5.25% NaOCl, the smear layer is completely removed in the middle and coronal thirds of canal preparations, but this combination is less effective in the apical third (17). This is probably because of inadequate volume and/or penetration of the solution into the

**TABLE 2. P values for smear layer removal among groups A to D**

<table>
<thead>
<tr>
<th>Canal Level</th>
<th>Group Comparison</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>No significant difference between groups A and B</td>
<td>p = 1</td>
</tr>
<tr>
<td>Coronal</td>
<td>Groups C and D were cleaner than groups A and B</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Coronal</td>
<td>No significant difference between groups C and D</td>
<td>p &lt; 0.2835</td>
</tr>
<tr>
<td>Middle</td>
<td>No significant difference between groups A and B</td>
<td>p = 1</td>
</tr>
<tr>
<td>Middle</td>
<td>Groups C and D were cleaner than groups A and B</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Middle</td>
<td>No significant difference between groups C and D</td>
<td>p = 0.5457</td>
</tr>
<tr>
<td>Apical</td>
<td>No significant difference between groups A and B</td>
<td>p = 1</td>
</tr>
<tr>
<td>Apical</td>
<td>Groups C and D were cleaner than groups A and B</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Apical</td>
<td>No significant difference between groups C and D</td>
<td>p = 0.2289</td>
</tr>
</tbody>
</table>

**TABLE 3. P values for the amount of erosion between groups C and D**

<table>
<thead>
<tr>
<th>Canal Level</th>
<th>Group Comparison</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>Group C had more erosion than group D</td>
<td>p = 0.0003</td>
</tr>
<tr>
<td>Middle</td>
<td>Group C had more erosion than group D</td>
<td>p = 0.0005</td>
</tr>
<tr>
<td>Apical</td>
<td>No significant difference between groups C and D</td>
<td>p = 0.1276</td>
</tr>
</tbody>
</table>
apical portion of the canal during irrigation. Our experiment corroborated these findings and showed that correct delivery of irrigating solutions is important. The placement of MTAD with a cotton-wrapped barbed broach allows intimate contact of the solution even in the apical region of the canals and improves debridement of the entire root canal wall. In a series of pilot projects, we tested foams and brushes in conjunction with MTAD solution to clean the surfaces of instrumented root canals. Our results showed that cotton-wrapped broaches were more effective and less abrasive than similar instruments covered with bristles or foams. Studies are in progress to determine the efficacy of other techniques to carry MTAD into the apical portion of the root canals systems.

Our results demonstrated that MTAD also is less destructive to the tooth structure compared with EDTA when used as a final irrigant. Close examination of the appearance of the dentinal tubules showed higher amounts of erosion with EDTA (Fig. 5). These findings corroborate the results of a recent investigation, which reported a correlation between the erosive property of EDTA and the length of time of dentin exposure to this material (18). EDTA is an effective etchant and can remove the smear layer in conjunction with NaOCl (17). The main disadvantages of the use of EDTA include its destructive effects on coronal and middle thirds of root dentin and its limited antibacterial effects. In contrast to the destructive effects of 5-min EDTA exposure, we observed no significant dentinal erosion in a pilot project when the surface of the root canals were in contact with MTAD for periods ranging from 1 to 20 min.

Based on the results of this investigation, it seems that MTAD is an effective solution for the removal of the smear layer when used as a final rinse. It does not significantly change the structure of the dentinal tubules when used in conjunction with NaOCl as a root canal irrigant. Studies are in progress to determine the efficacy of MTAD as a root canal irrigant with and without NaOCl for removing the smear layer and completely disinfecting the root canal system.

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References