Cleaning efficacy of different root canal preparation systems and irrigation regimens

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Abstract

Purpose: To compare the cleaning efficacy of root canal walls after using two Nickel—Titanium (Ni—Ti) rotary files (Flexmaster and Mtwo) and one hand Ni—Ti file (Ni—Ti flex-K) when associated with different final irrigation regimens (SmearClear, 17% ethylene diamine tetra acetic acid (EDTA) and sodium hypochlorite).

Materials and methods: Ninety extracted human premolars with similar range of canal curvature (21—39°) were selected. After crown removal and working length determination, roots were divided into three equal groups according to root canal instrumentation: Group I and Group II were prepared using Flexmaster, Mtwo Ni—Ti rotary systems respectively where Group III was prepared using hand NiTi flex-K files. Each group was further subdivided into three equal subgroups according to root canal final irrigation; subgroup A: SmearClear, subgroup B: 17% EDTA and subgroup C: NaOCl. Roots were then splitted longitudinally and processed for scanning electron microscopic (SEM) examination to evaluate and score the root canal cleanliness.

Results: Final root canal irrigation using either SmearClear or 17% EDTA had significantly better cleaning efficiency than that of NaOCl in all tested groups. Ni—Ti hand files had significantly less cleaning efficacy than that of rotary systems except in subgroup C using NaOCl.

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Keywords: Cleaning efficacy; Flexmaster; Mtwo; SmearClear

1. Introduction

The goals of root canal therapy are to remove infected and necrotic pulpal tissue remnants, shape the root canal system to facilitate irrigation and medication and adequate sealing using obturation materials [1].

Proper biomechanical cleaning and shaping of root canals require the use of stainless steel hand files with the increase of stiffness in larger instrument sizes that may cause several mishaps, such as ledges, zips, perforation and root canal transportation [2]. This was replaced by hand Ni—Ti instruments which possessed...
advantageous bending and torsional properties attributed to their low modulus of elasticity.

Further research led to handpiece-driven rotary Ni—Ti systems [3], which vary widely regarding their design features [4] that may significantly affect the clinical performance of the instruments [5]. Flexmaster and Mtwo are Ni—Ti rotary systems with many improvements in configuration and design.

The type of instruments and materials used affected the formation of smear layer which varies in thickness, roughness, density and degree of attachment to the underlying tooth structure [6].

Sodium hypochlorite is a chemical solution which has an excellent antimicrobial activity and capacity of dissolving organic material [7]. However, it has to be associated with EDTA to efficiently remove the smear layer [8]. Thus, a product containing 17% EDTA solution along with cetrimide and additional proprietary surfactants has been launched under the brand name SmearClear. The manufacturer claimed that SmearClear is specifically designed for smear layer removal and root canal cleansing [9].

To investigate the influence of different endodontic instruments or irrigants on the cleanliness of dentin surfaces, SEM analysis was recommended [10]. Therefore, the purpose of this study is to compare using SEM the cleaning efficacy of root canal walls after using two Ni—Ti rotary files and one hand Ni—Ti file when associated with different final irrigation regimens.

2. Materials and methods

Ninety freshly extracted, fully developed human premolars with single root canals were collected. The teeth were extracted for orthodontic or periodontal reasons according to the ethical committee, Faculty of Dentistry, Tanta University. All patients knew the reason for extraction and agreed to have their extracted teeth involved in the research. Teeth were thoroughly cleaned, polished, rinsed under running water and stored in sterile saline solution at 4°C until use [11].

All selected teeth had similar range of canal curvature (21–39°), which was recorded according to Schneider's method [12]. All teeth were decoronated using water cooled low speed diamond disc leaving 13 mm long roots. Canal diameter was standardized by selecting roots fitting initial apical file #15. Canals wider or smaller than this diameter were discarded. Working length of each canal was determined by measuring the length of K-type file size #10 at the apical foramen minus 1 mm [13].

The apical foramen of each root was then sealed with casting wax [14], numbered, labeled and randomly divided into three equal groups, (30 roots each) according to the type of instrument used in root canal cleaning and shaping.

**Group I (Flexmaster):** Thirty roots were prepared with Flexmaster Ni—Ti rotary system up to 35/0.02 master apical file in a crown down manner at 250–350 rpm with 20:1 gear reduction handpiece powered with a torque limited electric motor. Each instrument was coated with a conditioner (Glyde file prep) according to the manufacturer's instructions. The preparation sequence was performed according to Schafer and Lohmann [15].

**Group II (Mtwo):** Thirty roots were prepared with Mtwo Ni—Ti rotary system up to 35/0.04 master apical file. The preparation based on the single length technique, whereby each instrument was used to the full working length using Glyde file prep. The instrumentation sequence was performed according to Schafer et al. [16].

**Group III (NiTi flex K-files):** Thirty roots were prepared with NiTi flex-K hand files using crown down technique up to master apical file 35/0.02 according to the manufacturer's instructions.

For all groups, each instrument was used only for the preparation of four root canals. Irrigation was performed using 2 ml of 5.25% NaOCl solution after using each file and before proceeding to the next and as a final irrigation using a plastic syringe with a 30-gauge closed-end needle.

After instrumentation, each main group was further subdivided into three equal subgroups (10 roots each) according to the final irrigation protocol:

2.1. **Subgroup A (SmearClear)**

According to the manufacturer's instructions, 1 ml of SmearClear solution was delivered to fill the entire root canal using a side-vented needle that was inserted 2–3 mm into each canal. Irrigant was left for 1 min inside the root canal and a final rinse with 3 ml of 5.25% NaOCl was performed.

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1 Komet, Brasseler, Lemgo, Germany.

2 Whip-mix, Louisville, Kentucky, U.S.A.

3 VDW, Munich, Germany.

4 Endo-mate DT, NSK, Tokyo, Japan.

5 Dentsply/Maillefer, Ballaigues, Switzerland.

6 Clorox Co., 10th of Ramadan, Egypt.

7 Sybron Endo, Orange, CA.
2.2. Subgroup B (17% EDTA)

Final irrigation using 1 ml of 17% EDTA solution was delivered into each canal with a plastic syringe with a 30-gauge closed-end needle. The tip of the irrigating needle was inserted leaving nearly 2 mm of the working length. Irrigant was left for 1 min inside the root canal [18] and a final rinse with 3 ml of 5.25% NaOCl was performed.

2.3. Subgroup C (NaOCl)

A plastic syringe with a 30-gauge closed-end needle was used to deliver 1 ml of 5.25% NaOCl to fill the entire root canal. It had been placed down the canal leaving nearly 2 mm of the working length and irrigant was left for 1 min.

2.4. SEM evaluation

Root canals of each tested group were dried with paper points, and the casting wax sealing the apical foramen of each root was removed. Roots were split longitudinally in a bucco-lingual direction to expose root interior by making two grooves on the buccal and lingual aspects of each root with a low speed diamond disk. The grooves were not deep enough to enter the canals and a plastic instrument was then used to section the root into two halves [19]. For each root, the half containing the most visible part of apex was conserved and coded. Roots showing evidence that the grooves had penetrated into the root canal or exhibiting an irregular cleavage were discarded and replaced by new specimens.

Coded samples were mounted on metallic stubs, sputter gold-coated to render the surface electrically conductive, and then examined under SEM at ×1000. The root canal cleanliness was evaluated according to Silva et al. [10] scoring system.

Kruskal–Wallis test was used to reveal statistically significant differences among tested groups or subgroups. Whenever statistically significant difference was recorded, Mann–Whitney pair-wise comparison test was performed to compare between each two tested groups or subgroups with significance level of \( p \leq 0.05 \).

### Table 1

<table>
<thead>
<tr>
<th>Groups</th>
<th>Scores</th>
<th>Subgroup A (SmearClear)</th>
<th>Subgroup B (17% EDTA)</th>
<th>Subgroup C (NaOCl)</th>
<th>Kruskal–Wallis test</th>
<th>Mann–Whitney test</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>( \chi^2 )</td>
<td>( p )-Value</td>
</tr>
<tr>
<td>Group I (Flexmaster NiTi rotary files)</td>
<td>0</td>
<td>56.67%</td>
<td>56.67%</td>
<td>0.00%</td>
<td>63.164</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>43.33%</td>
<td>43.33%</td>
<td>6.67%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.00%</td>
<td>0.00%</td>
<td>93.33%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group II (Mtwo NiTi rotary files)</td>
<td>0</td>
<td>73.33%</td>
<td>76.67%</td>
<td>0.00%</td>
<td>65.918</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>26.67%</td>
<td>23.33%</td>
<td>13.33%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.00%</td>
<td>0.00%</td>
<td>86.67%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III (Ni–Ti flex hand files)</td>
<td>1</td>
<td>33.33%</td>
<td>33.33%</td>
<td>0.00%</td>
<td>48.756</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>50.00%</td>
<td>56.67%</td>
<td>3.33%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant result at \( p \leq 0.05 \).

8 Pulpdent, Watertown, MA.
9 Diadent Group International, Burnaby, B.C. Canada.
10 Dentsply/Ash, York, USA.

3. Results

Table 1 represents the comparison of the three tested irrigation regimens (subgroups) on the cleaning efficacy in each group. When using Flexmaster Ni–Ti rotary system (Group I), a statistically significant difference was found among tested subgroups. Mann–Whitney test revealed statistically significant differences between subgroups A and C and between subgroups B and C while there was no statistically significant difference between subgroups A and B.

Regarding Mtwo Ni–Ti rotary system and Ni–Ti flex K-hand files (Groups II, III respectively), a statistically significant difference was recorded among different irrigation regimens and pair wise comparisons revealed similar findings to Group I. There was a significantly better cleaning efficacy using SmearClear compared to sodium hypochlorite. In addition, using of 17% EDTA produced significantly better cleaning...
efficacy than sodium hypochlorite. However, there was no statistically significant difference between subgroups A and B when using either Mtwo Ni—Ti rotary system or Ni—Ti flex K-hand files.

Comparison of the three tested instruments for each irrigation solution was performed and represented in Table 2. Concerning SmearClear and 17% EDTA final irrigations, statistical analysis revealed statistically significant differences among tested instruments. Mann—Whitney test demonstrated statistically significant differences between Group I vs Group III in addition to Group II vs Group III. While no statistically significant difference was recorded regarding Group I vs II.

Regarding NaOCl final irrigation regimen, no statistical significant difference among the examined instruments was recorded using the same previous test.

### 4. Discussion

However natural teeth examined currently showing large variations in dentine hardness and root canal morphology, their use seems to be the available way to evaluate the cleaning efficiency of a preparation technique [20]. Several attempts have been made to ensure standardization of the experimental groups in this study as teeth with similar apical diameters (size #15) and similar range of canal curvature (21—39°) were selected.

Root canal preparations were performed up to #35/0.02, #35/0.04 and #35/0.02 for Flexmaster, Mtwo and hand instrumentation groups respectively to obtain nearly similar apical preparation diameter, so that, cleanliness evaluation of root canals could be only attributed to the different root canal preparation techniques and irrigation regimens used.

NaOCl appears to be the simplest solely available canal irrigant with antibacterial and organic tissue dissolving properties [21]. However using antibacterial irrigants in combination with chelating agents remove debris as well as the inorganic/organic smear layer [22], thus the experimented irrigants grouping were selected. This explained also the current results which showed that: root canals finally irrigated with either SmearClear or 17% EDTA were significantly cleaner than that of NaOCl regardless the instrumentation system used.

Cleaner canals after irrigation with NaOCl followed by EDTA might be explained as EDTA facilitates decalcification of the inorganic component and NaOCl promotes dissolution of the organic matrix which was

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**Table 2**

<table>
<thead>
<tr>
<th>Sub groups</th>
<th>Group I (Flexmaster NiTi rotary files)</th>
<th>Group II (Mtwo NiTi rotary files)</th>
<th>Group III (Ni—Ti flex hand files)</th>
<th>Kruskal—Wallis test</th>
<th>Mann—Whitney test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 56.67%</td>
<td>73.33%</td>
<td>33.33%</td>
<td>12.198</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>1 43.33%</td>
<td>26.67%</td>
<td>50.00%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 0.00%</td>
<td>0.00%</td>
<td>16.67%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0 56.67%</td>
<td>76.67%</td>
<td>33.33%</td>
<td>12.701</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>1 43.33%</td>
<td>23.33%</td>
<td>56.67%</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2 0.00%</td>
<td>0.00%</td>
<td>10.00%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0 0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>2.145</td>
<td>0.342</td>
</tr>
<tr>
<td></td>
<td>1 6.67%</td>
<td>13.33%</td>
<td>3.33%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 93.33%</td>
<td>86.67%</td>
<td>96.67%</td>
<td></td>
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</tr>
</tbody>
</table>

*Significant result at \( p \leq 0.05 \).
obviously shown in Fig. 1. These results also confirmed a number of previous findings [23,24,11,18].

However, SmearClear (17% EDTA solutions with two additional surfactants) did not improve the efficacy in smear layer removal compared to 17% EDTA in the current study (Fig. 2). This was explained by others [9,17] as they revealed that application of 1 ml of SmearClear, 17% EDTA was not sufficient to remove the smear layer, especially in the apical third.

On the other hand, some authors obtained different results. Wu et al., 2012 [8] found that the smear layer removal effect of 17% EDTA was better than SmearClear explaining that the surfactants of SmearClear had a negative impact on the chelation ability of EDTA.

Regarding the examination of different instruments, it was obvious that they varied in their debris removal efficiency. Mtwo and Flexmaster rotary prepared root canals were significantly cleaner than those prepared with NiTi flex-K hand files. This may be explained that rotary Ni–Ti preparation creates a uniformly wide rounded canal shape than hand preparation which facilitates the efficiency of smear layer removal compared to narrow canals created by hand preparation [26,27]. These results confirmed the findings of previous studies that proved unfavorable performance of hand instrumentation [28,19].

Another explanation is the flute design of files which is a key factor for the cleaning efficiency of these instruments [16], both hand and rotary canal preparation systems with different design features (cross-section, rake angle, helical angle and pitch) were used in this study.

The slight superior cleaning ability of Mtwo rotary system vs Flexmaster rotary system might confirm the second explanation since Mtwo rotary files have positive rake angles compared to negative rake angles in Flexmaster instruments which scrape inside of the root canal [29,30]. In addition, Mtwo files are characterized by two sharp cutting edges and a relatively small core diameter. The smaller the core diameter, the greater the space between the cutting edges and the canal wall. This file design together with increasing pitch length from the tip to the shaft may enhance the debris removal capacity of the Mtwo files [16]. In addition, Flexmaster files have three sharp K-type cutting edges and a convex triangular cross-section, so that, their chip spaces are smaller than that of Mtwo files [31].

This was not the case in root canals finally irrigated with NaOCl (Fig. 3), since no significant differences among the tested instruments were found. Finding out that the irrigant plays a major role in cleanliness of canals. Confirming this finding in the current research even when a chelator paste was used at each file of both rotary systems, the cleanliness was poor. However this might be also attributed to the fact that serial rotary instrumentation may recreate the smear layer in the root canal and the distribution of the chelator paste over the curved root-canal walls may also be more difficult to control compared to the straight canals [29].
5. Conclusions

Different instruments vary in their debris removal efficiency. However, final irrigation regimens play a key role in smear layer removal.

References