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ORIGINAl RESEARCH

Effect of manual dynamic activation on smear layer removal efficacy of ethylenediaminetetraacetic acid and SmearClear: An in vitro scanning electron microscopic study

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Abstract
The purpose of the present study was to evaluate the effect of manual dynamic activation (MDA) with a master gutta-percha point on the smear layer removal efficacy of 17% ethylenediaminetetraacetic acid (EDTA) and SmearClear. Fifty freshly extracted human single-rooted teeth were prepared using ProTaper rotary system up to F3 size. The prepared teeth were divided into five groups on the basis of final irrigation received. Group A: 3% NaOCl solution (negative control group). Group B: 5 mL of 17% EDTA. Group C: 1 mL of 17% EDTA + MDA for 2 min + 4 mL of 17% EDTA rinse. Group D: 5 mL of SmearClear. Group E: 1 mL of SmearClear + MDA for 2 min + 4 mL of SmearClear rinse. Prepared samples were decoronated and then longitudinally split into two halves and evaluated under scanning electron microscope. Representative images at coronal, middle and apical third level were taken and scored for the amount of smear layer present, using a three-score system. The data were analysed through Kruskal–Wallis and Mann–Whitney U-test. The root canal surfaces of samples of group C and group E (where MDA was done) were significantly cleaner in apical third regions than those of group B and group D (P < 0.05).

Introduction
The generation of a smear layer is almost inevitable during root canal instrumentation. Smear layer is a mixture of inorganic and organic substances that include dentinal shavings, tissue debris, odontoblastic processes, coagulated proteins and microbial elements (1–3). Smear layer prevents penetration of intracanal medicaments into the irregularities of the canal and dentinal tubules and also prevents complete adaptation of obturation materials to the prepared root canal surfaces (4–6). Smear layer, being a loosely adherent structure, should be completely removed from the surface of the root canal wall because it can harbour bacteria and provide an avenue for leakage (7–10).

So far, the most commonly used method of smear layer removal has been the alternating irrigation with a combination of ethylenediaminetetraacetic acid (EDTA) and NaOCl. This combination removes the smear layer completely in the coronal and middle thirds but is less effective in the apical third owing to the inability of the irrigating solutions to reach the apical third of the root canals (11,12).

In order to be effective, the solutions must come into contact with the entire surface of the root canal walls. But owing to the complex anatomy and the vapour lock effect in the apical third, conventional static irrigation will not be able to wet the entire surface of the root canal walls (13).

Conventional syringe irrigation has been found to reach not 1.5–2.0 mm beyond the tip of the needle, which in most of the cases is within coronal to middle third area (14). Therefore, intracanal agitation/activation of the irrigants is a necessary adjunct to mechanical instrumentation to remove debris and bacteria from the root canals (15,16). Several systems for intracanal...
agitation of the irrigants have been proposed, which might be categorised as manual agitation devices including the use of hand files, gutta-percha points, and canal brushes, and machine-assisted agitation devices like sonic and ultrasonic devices, rotary brushes and pressure alternation devices (17–22).

Studies have shown that gentle up and down movement of a well-fitting gutta-percha master cone in short 2- to 3-mm strokes (manual dynamic activation (MDA)) within an instrumented canal can produce an effective hydrodynamic effect and significantly improve the displacement and exchange of any given reagent (17,23). This will result in better contact of the irrigating solution with the root canal walls, and thus enhance debridement. Studies evaluating the effect of MDA on the smear layer removal efficacy of irrigating solutions are lacking, and therefore the present study was taken.

The aim of this study was to compare the smear layer removal efficacy of 17% EDTA (Canalarge; Ammundt, Chandigarh, India) and SmearClear (Sybron Endo, Orange, CA, USA) with and without manual dynamic agitation (MDA).

Materials and methods

The present study was done in the Department of Conservative Dentistry and Endodontics, Dr. Z.A. Dental College, Aligarh Muslim University, Aligarh, India.

Sample selection

Fifty freshly extracted human single-rooted maxillary and mandibular teeth consisting of incisors, canines and premolars were collected from the Department of Oral and Maxillofacial Surgery, Dr. Z.A. Dental College, Aligarh Muslim University, Aligarh. All the collected teeth were cleared of blood and saliva and stored in buffered isotonic saline solution. All teeth were radiographed to verify the presence of mature apex, absence of resorption or endodontic obturation. All teeth were stored in 10% formalin solution at 4°C until used. All specimen teeth were utilised for this study within 1 month of extraction.

Experimental procedures

Access preparations were made by round diamond burs and patency established by passing a #15 k-file (Dentsply Maillefer, Ballaigues, Switzerland) beyond the apex of all canals. Working lengths were determined by subtracting 1 mm from the length at which the tip of the file was visible at the apical foramen. Canals were prepared by ProTaper rotary system. Each canal was prepared up to an apical preparation of F3 size. Sodium hypochlorite 3% (NaOCl; Dentpro Ltd, Chandigarh, India) was used as an intracanal irrigant in between each file size. All prepared teeth were then randomly divided into five groups, four experimental groups and one control group. Each group consisted of 10 teeth. To determine the effect of final rinse on the surface of root canals after instrumentation, the canals in each group were treated with 5 mL of one of the irrigating solutions as follows:

- **Group A**: 3% NaOCl solution used as the sole irrigant.
  - (negative control group)
- **Group B**: 5 mL of 17% EDTA as a continuous rinse for 3 min
- **Group C**: 1 mL of 17% EDTA manually activated with F3 Protaper GP point for 2 min (=100 push-pull strokes per minute or 1.6 Hz) followed by 4 mL of 17% EDTA rinse for 1 min.
- **Group D**: 5 mL of SmearClear as a continuous rinse for 3 min.
- **Group E**: 1 mL of SmearClear manually activated with a F3 Protaper GP for 2 min (=100 push-pull strokes per minute or 1.6 Hz) followed by 4 mL of SmearClear rinse for 1 min.

The frequency of the push and pull activation movements with GP point was kept approximately 100 times per minute (=1.6 Hz). On completion of the final rinse for each group the canals were then dried with paper points. The crowns of all teeth were sectioned at the level of cemento-enamel junction (CEJ) using slow speed diamond disc with water coolant system and a chisel. In the process of decoronation, first a non-penetrating groove was prepared around the CEJ of each tooth and then split with a chisel. The decoronated teeth were then prepared for sectioning. Two longitudinal grooves were prepared on the buccal and lingual root surfaces of the prepared teeth without penetrating into the canal, and teeth were finally divided into two halves with the help of a chisel. The half containing the most part of the apex was selected as the representative sample and coded. Coded samples were then scheduled for scanning electron microscopic (SEM) evaluation.

Coded samples were dehydrated with ascending concentrations of ethyl alcohol (30%–100%), and placed in a desiccator for at least 24 h, mounted on metallic stubs, gold sputtered and viewed under scanning electron microscope (Inca-x 50; Oxford Instruments, England, UK, 2.0 nm @ 30 kV 5× to 500000×).

SEM evaluation

The entire length of the sample was divided equally into cervical, middle and apical thirds in order to be evaluated separately. After a general survey scan of each third of the canal wall at a magnification of 250×, representative
images of each third were taken with 500×, 1000× and 2000×. The images of 1000× were then analyzed for the amount of smear layer present by two independent observers without knowing which group they were analyzing. Evaluation was repeated twice for the first 10 specimens to ensure intra-examiner consistency.

The amount of smear layer remained on the surface of the root canal and dentinal tubules were scored according to the following criteria used by Torabinejad et al.:  
Score 1 = no smear layer: no smear layer was detected on the surface of root canal and all tubules were open (Fig. 1a)  
Score 2 = moderate smear layer: no smear layer on root canal walls but tubules contained debris (Fig. 1b)  
Score 3 = heavy smear layer: smear layer covered the root canal wall surface and the tubules (Fig. 1c)

The data were analyzed through Kruskal–Wallis and Mann–Whitney U-test and comparisons were made as follows:  
1. Pairwise comparison of all groups with the control group at coronal, middle and apical third level using Mann–Whitney U-test.  
2. Pairwise intergroup comparison of all experimental groups with each other at coronal, middle and apical third level using Mann–Whitney U-test.  
3. Intra-group comparison of each group within coronal, middle and apical third level using Kruskal–Wallis test.

Results

The examination of the surface of root canal walls in group A (control group) showed the presence of a heavy smear layer throughout the entire length of the root canals (Fig. 2). The mean scores of the samples for all experimental groups at each third of the canal were less than those of the control group (Table 1).

The comparison of all the five groups at coronal and middle thirds showed that the canal walls in the group B (Fig. 3), group C (Fig. 4), group D (Fig. 5) and group E (Fig. 6) were significantly cleaner than in group A (control group) ($P < 0.01$).

Intergroup comparison of groups B, C, D and E showed no statistically significant difference at coronal and middle levels. Comparison of the apical third scores of all the experimental groups showed that the root canal surfaces were comparatively cleaner in apical thirds of groups C and E where manual activation was done than in groups B and D where no manual activation of the irrigating solution was done ($P < 0.05$).

On intra-group comparison of three one-thirds of the canals in each group (using Kruskal–Wallis test), there was no statistically significant difference seen ($P > 0.05$) in group C (EDTA with manual activation) and group E (SmearClear with manual activation). But in the groups B and D (where no manual activation was done), the
The efficacy of the agent was significantly less in the apical third of the samples compared with the coronal and middle thirds \((P < 0.05)\) (Table 1).

**Discussion**

MDA involves repeated up and down motion of a well-tapered gutta-percha master cone in short gentle strokes to hydrodynamically displace and agitate a solution by producing eddy currents. This results in displacement of the apical air bubble which is responsible for the ‘vapor lock effect’. The up and down motion of a well-fitting gutta-percha point in the canal generates higher intracanal pressure changes leading to more effective delivery of irrigant to the ‘untouched’ canal surfaces and also results in better mixing of the fresh unreacted solution with the spent, reacted irrigant \((23,24)\).

MDA of the solution showed significantly cleaner root canal surfaces than those where no activation was done. This can be attributed to the fact that the vertical stroke pumping motion of a tapered gutta-percha cone produces an effective hydrodynamic activation of the solution and constant renewal of the spent irrigant. Whenever the gutta-percha tip moves towards working length, the

<table>
<thead>
<tr>
<th>Group</th>
<th>Coronal third scores</th>
<th>Middle third scores</th>
<th>Apical third scores</th>
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<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
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<tr>
<td></td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
</tr>
<tr>
<td>Group A (negative control</td>
<td>0 0 10</td>
<td>0 0 10</td>
<td>0 0 10</td>
</tr>
<tr>
<td>Group B (17% EDTA</td>
<td>8 2 0</td>
<td>1.2 ± 0.42</td>
<td>7 3 0</td>
</tr>
<tr>
<td>continuous rinse)</td>
<td></td>
<td></td>
<td>1.3 ± 0.48</td>
</tr>
<tr>
<td>Group C (17% EDTA with MDA)</td>
<td>9 1 0</td>
<td>1.1 ± 0.31</td>
<td>8 2 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.2 ± 0.42</td>
</tr>
<tr>
<td>Group D (SmearClear</td>
<td>8 2 0</td>
<td>1.2 ± 0.42</td>
<td>7 2 1</td>
</tr>
<tr>
<td>continuous rinse)</td>
<td></td>
<td></td>
<td>1.4 ± 0.69</td>
</tr>
<tr>
<td>Group E (SmearClear with MDA)</td>
<td>8 2 0</td>
<td>1.2 ± 0.42</td>
<td>8 2 0</td>
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<tr>
<td></td>
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<td>1.2 ± 0.42</td>
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EDTA, ethylenediaminetetraacetic acid; MDA, manual dynamic activation; SD, standard deviation.

**Figure 3** Scanning electron microscopic images of group B (ethylenediaminetetraacetic acid): (a) coronal third image, (b) middle third image, (c) apical third image.

**Figure 4** Scanning electron microscopic images of group C (ethylenediaminetetraacetic acid with manual dynamic activation): (a) coronal third image, (b) middle third image, (c) apical third image.
reagent is displaced, and whenever the tip is partially withdrawn, there is an effective exchange of solution into the apical one-third of the canal. This hydrodynamic circuit produces better reach of the solution into the apical third area and also neutralises the vapour lock effect resulting in enhanced smear layer removal and cleaner root canal surfaces. Manual activation with gutta-percha points can be more effective because they are non-cutting and there is no risk of generation of a new smear layer on their contact with the canal walls. Furthermore, there will be no risks of generation of an internal ledge or external transportation of the foramen.

The laborious nature of the MDA can be seen as a major disadvantage of this technique. This may become a limiting factor for some clinicians to adopt this technique in routine endodontic practice. However, its cost-effectiveness, simplicity and efficacy to enhance root canal irrigation can outweigh the amount of labour involved in this technique. Furthermore, other contemporary machine-assisted irrigant activation systems are technique sensitive and require a specific equipment, and also there is no clinical study available to date supporting the supremacy of these devices over MDA in terms of improvements in treatment outcomes.

**Conclusion**

Within the experimental protocol of the present study, MDA of both EDTA and SmearClear improves their smear layer removing efficacy especially in the apical third area of the root canals. Thus, it can be used as an adjunct to routine chemo-mechanical debridement. Further studies evaluating its effectiveness in clinical conditions are needed.

**References**