

# Smear layer: a brief review of general concepts. Part II. The most common agents to remove endodontic smear layer

*Smear layer, uma breve revisão de conceitos gerais. Parte II. Agentes mais comuns para remoção da smear layer endodontônica*

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## Abstract

Root canal instrumentation produces a smear layer that covers prepared canal walls surface. The influence of this layer on endodontic treatment success rate has not been determined yet. It is currently considered important to promote techniques and products that may eliminate this layer. The aim of this study was to briefly review the most common agents to remove endodontic smear layer. Different irrigation solutions have been used to remove the smear layer, with very variable results. Investigations suggest association of agents to simultaneous removal of organic and inorganic constituents of smear layer.

Key words: *Smear layer, EDTA, laser, ultrasonic, NaOCl.*

## Introduction

Smear layer is formed during root canal preparation. It consists of dentin, organic material and microorganisms that adhere to root canal walls<sup>1</sup>. In agreement with some authors<sup>2-4</sup>, removal of this layer is important for endodontic treatment success. Its removal is obtained using chemical solutions during root canal preparation such as Ethylene Diamine Tetra acetic acid (EDTA) preparations<sup>1,4</sup>, combination of EDTA and NaOCl solutions<sup>1,5-6</sup>, ultrasound<sup>7-8</sup>, organic acids<sup>9-10</sup> and, more recently, laser use<sup>11-12</sup>.

The aim of this study was to briefly review the most common agents for endodontic smear layer removal.

## Agents able to remove the smear layer

Mechanical instrumentation alone will not completely eliminate bacteria from a root canal system. In order to predictably eliminate bacteria from the root canal system, it is necessary to use the supporting action of disinfecting agents such as irrigants<sup>13-14</sup>.

A number of studies using scanning electron microscopy indicate that irrigation with NaOCl is effective on removing debris and cleaning organic matter from root canals<sup>3,5</sup>. Sodium hypochlorite is commonly used in concentrations ranging from 0.5% to 5.25%. This chemical

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Recebido: 27.01.2005 Aceito: 16.09.2005

oxidant exhibits powerful antimicrobial activity and is an excellent necrotic tissue solvent<sup>13-14</sup>. However, sodium hypochlorite is not effective to remove smear layer<sup>15</sup>. It has very little effect on this layer, removing only organic matter. In order to remove inorganic components of the smear layer it is necessary the use of auxiliary irrigating solutions<sup>3-4,16</sup>.

The smear layer may be removed by the chelating agent ethylene diaminetetra-acetic acid (EDTA) and solutions containing EDTA, which have been recommended for irrigation<sup>2,4,6</sup>.

This chelator reacts with calcium ions in the hydroxyapatite crystals of dentine producing a metallic chelate<sup>17</sup>. The pH of EDTA solutions affects their efficacy and calcium ion availability in several ways. As the pH increases, the availability of calcium ions from hydroxyapatite for chelation decreases. Conversely, at lower pHs calcium ions become more available for chelation, but the efficacy of EDTA decreases. The optimal pH for EDTA solutions seems to be between 6-10<sup>18</sup>. Neutral EDTA solutions reduce mineral and noncollagenous proteins, leading to surface softening but not the erosion of surface dentine layer<sup>19</sup>. The use of solutions in higher concentrations might lead to increased demineralization properties<sup>20</sup>, aiding the smear layer removal<sup>3,18</sup>.

Although the efficacy of EDTA on smear layer removal was proven, different mixtures, methods of application, concentrations and volumes of irrigation are often used<sup>18</sup>. The time of permanency of EDTA in the root canal influenced the cleaning<sup>3-4,21-23</sup>. Goldeberg and Spielberg<sup>24</sup> (1982) demonstrated a better effect with EDTA when applied for 15 min. In contrast<sup>16</sup> established a working time of 2-3 min necessary to obtain the complete removal of smear layer and plugs for each irrigant, which prolongs the endodontic procedure. Çalt and Serper<sup>22</sup> (2002) suggested that the application of EDTA should not be prolonged to more than 1 minute during endodontic treatment. Several studies confirmed that mineral loss, changes in dentine hardness and cleanliness of root

canal walls depend on the working time<sup>3,10,23</sup>. Nevertheless, currently, no definite recommendation may be given on the optimal amount of working time for chelating agents under clinical conditions<sup>4</sup>. Studies have demonstrated the necessity of mechanical shaking of EDTA during the endodontic work<sup>21</sup>.

EDTA can be used as a liquid or a paste preparation combined to other compounds in order to accentuate their effect. Initially, chelators were used as liquids for irrigation during mechanical instrumentation of root canal. Liquid irrigations more commonly used are EDTAC (a combination of EDTA and cetavalon), EDTAT (EDTA-Tergentol), REDTA (obtained by adding a quaternary ammonium bromide to EDTA solutions), Largal Ultra<sup>TM</sup> (a 15% EDTA solution as a disodium salt, 0.75%-Cetyl-Tri-methylammonium bromide Cetrimide), Tubulicid plus<sup>TM</sup> (EDTA dihydrate and 50% citric acid), EGTA.

Smear layer may be largely removed by chelating action of ethylenediamine tetra-acetic combined with cetrimide (EDTAC)<sup>16,25</sup>. Cetrimide reduces surface tension and viscosity enabling the chelating solution to flow or be more easily carried to the full depth of the canal<sup>8,14</sup>. Adding Tergentol to EDTA (EDTAT) caused a significant decrease in surface tension, creating more favorable conditions for the chelating agent EDTA<sup>26</sup>. EDTAT has a good effect on the permeability of dentin in the apical third<sup>27</sup>. REDTA produced a very clean canal. Instrumented areas showed open dentinal tubules and no smear layer<sup>28-29</sup>. Both Tubulicid plus<sup>TM</sup> and Largal Ultra<sup>TM</sup> removed the smear layer resulting in a surface with open dentinal tubules<sup>30</sup>.

EGTA – ethylene Glycolbis (beta-aminoethylether)-N,N,N',N'-tetracetic acid has been suggested for smear layer removal<sup>22,31</sup>. This agent is able to remove the layer causing less tubulus erosion than EDTA<sup>22</sup>. Another chelating irrigant is Salvizol, a chemotherapeutic agent, which consists of amino-quinaldinium-diacetate in propylene glycol with a pH value of 7.4. This material is less tissue toxic than EDTAC, capable of removing or-

ganic material from dentin, thus exposing dentinal tubules<sup>32</sup>.

More recently a new intra-canal irrigant – MDTA was proposed as a final attempt to remove the smear layer. MDTA is made up of a mixture of a tetracycline isomer, an acid, and a detergent. It is an effective smear layer removing solution<sup>33-36</sup>. Similar results were obtained when organic and inorganic matter dissolving capabilities of MDTA and 17% EDTA were compared<sup>34,36</sup>. The better effects of MDTA were enhanced when lower concentrations of NaOCl were used as irrigant before the use of MDTA<sup>35</sup>. This solution does not significantly change dentinal tubule structure<sup>33-35</sup>.

Paste-type chelators have been regaining popularity due most manufacturers of NI-TI instruments recommend their use as a lubricant during rotary root canal preparation<sup>4</sup>. The best-known paste chelators include the following substances: Calcinase slide<sup>TM</sup> (contains 15% sodium EDTA and water), Rc-Prep<sup>TM</sup> (an EDTA- urea peroxide-carbowax compound), Glyde File Prep<sup>TM</sup>.

Rc-Prep<sup>TM</sup> is probably the best known paste-type chelating agent. It contains glycol in an aqueous ointment base that serves as a lubricant for instruments. According to Verdellis et al.<sup>19</sup> (1999), Rc-Prep<sup>TM</sup> decalcified and removed especially the loosely attached part of superficial smear layer, but was not able to modify the subsurface dentine. It has been used to float dentinal debris from the root canal<sup>4</sup>. However, it is speculated that some residue material may be retained in the canal even after using Rc-Prep<sup>TM</sup> followed by reinstrumentation and irrigation<sup>32</sup>. A comparasion of EDTA, Rc-Prep<sup>TM</sup>, and Salvizol<sup>TM</sup> showed that EDTA was the most effective solution to remove the smear layer<sup>37</sup>. In agreement, Verdellis et al.<sup>19</sup> (1999), showed that EDTA had a better performance than Rc-Prep<sup>TM</sup>.

Glyde file Prep<sup>TM</sup> is designed to be used in conjunction with root canal instrumentation and NaOCl<sup>38</sup>. This root canal conditioner consists of EDTA and carbamide peroxide in water soluble base<sup>4</sup>. A non-sig-

nificant difference was found when the effectiveness of 17% EDTA and Glyde file Prep™ was compared<sup>15</sup>. An intimate tissue contact between Glyde File Prep™ and the dentinal walls might be expected, in theory, to improve canal cleaning<sup>38</sup>. However the canal appearance was the same for both products<sup>15</sup>. A comparative in vitro evaluation of Glyde file prep™ and two other chelator pastes (Calcinase Slide™ and Rc Prep™) showed only slight differences in the cleanliness of root canal walls<sup>3</sup>. An increase in the contact time between these chelating agents and dentin increases the loss of hardness of the root dentin. These three chelating agents may be useful in enhancing the cleanliness of the middle and coronal thirds<sup>3</sup>.

Decalcifying solutions such as polyacrylic, latic, phosphoric and citric acid have also been reported as able to remove smear layer<sup>16,25,39</sup>. Citric acid is probably the most used organic acid for smear layer removal<sup>9-10</sup>. It shows a marked demineralizing effect on dentinal walls and tubules<sup>40</sup>.

Scelza et al.<sup>10</sup> (2003) conducted a study to determine the efficacy of EDTA-T, 10% Citric acid, and 17% EDTA in the extraction of calcium. EDTA-T extracted the least amount of Ca from dentin. The results showed that 10% citric acid and 17% EDTA were statistically similar with respect to efficacy. Scelza et al.<sup>26</sup> (2000) confirmed that both citric acid and EDTA-T were equally efficient in opening dentinal tubules at 4 minutes.

Lilios et al.<sup>30</sup> (1997), evaluated and compared the efficacy of Largal Ultra™, Tubulicid Plus™ and 50% citric acid after hand and mechanical instrumentation. Largal Ultra™ and Tubulicid Plus™ removed considerable amounts of the smear layer regardless the method of instrumentation. Citric acid only partially removed the smear layer. Lower concentrations of citric acid were as effective as higher ones in the superficial smear layer removal<sup>10</sup>.

One of the main problems associated to citric acid use is its very low pH, while an EDTA solution is almost neutral<sup>16</sup>. However,

the analysis of cytotoxic effects of 10% Citric acid and EDTA-T showed that citric acid was more biocompatible than EDTA-T. EDTA exerted more cytotoxic effects than citric acid<sup>41</sup>.

## Association NaOCl and EDTA

The combined use of NaOCl in conjunction with other irrigating agents was investigated for their ability to achieve simultaneous removal of organic soft tissue remnants as well as most of the inorganic constituents of the smear layer<sup>1</sup>. Hypochlorite irrigating solutions may not be ideal when used alone<sup>16,42</sup>. A review of literature revealed an expressive agreement on the alternate use of two different irrigation substances: sodium hypochlorite and EDTA<sup>5,43</sup>. A more efficient action was demonstrated when the hypochlorite was used sequentially with EDTA<sup>44</sup>. This combination of solutions was an effective means of removing both organic and inorganic matter from the root canal lumen<sup>5-6</sup>. Cengiz et al.<sup>45</sup> (1990) showed that 1% NaOCl irrigation during instrumentation and a final flush with 17% EDTA was significantly more effective in removing debris and smear layer than NaOCl alone. According to Abbot et al.<sup>8</sup> (1991), the most effective irrigation regimen for removing the smear layer and other debris was EDTAC/NaOCl/EDTAC.

The use of an organic solvent and a chelating agent was proved to be indispensable, as already reported by many investigators<sup>2,4</sup>. This association either combined in one product<sup>5,27</sup> or used in an alternating manner<sup>5,8,26</sup> promotes better root canal wall cleaning.

## Ultrasonic removal

Ultrasound in endodontic procedures have been alleged as being capable of cleaning root canals and removing the smear layer more effectively than conventional methods<sup>25</sup>. Ultrasonics has become popular in endodontics as an aid to irrigation and disinfection of root canal systems<sup>46</sup>. The association

of ultrasonics to NaOCl irrigation has had various reported effects on smear layer removal, ranging from a small<sup>7</sup> to a moderate<sup>42</sup>, and to a quite marked effect<sup>8</sup>.

Huque et al.<sup>46</sup> (1998) reported that ultrasound increased the bacterial action of 12% sodium hypochlorite, eliminating bacteria even in deep layers of root dentine. However, Ciucchi et al.<sup>42</sup> (1989), reported that ultrasound in association with 3% sodium hypochlorite did not remove all the smear layer and did not enhance the chelating capability of EDTA. Although ultrasound has been reported to improve the efficiency of NaOCl in smear layer removal<sup>2</sup>, no such improvement occurred when EDTA was used as the irrigant<sup>8,42</sup>.

Guerisoli et al.<sup>14</sup> (2002) evaluated smear layer removal with different irrigating solutions under ultrasonic agitation. The authors concluded that under ultrasonic agitation sodium hypochlorite associated with EDTAC removed the smear layer, whereas irrigation with distilled water or 1.0% sodium hypochlorite alone did not remove it. Ultrasonically activated irrigants did not reduce debris or smear layer scores in instrumented root walls<sup>47</sup>.

## Lasers and smear layer

Laser techniques have been used to remove smear layer on root canal walls<sup>2</sup>. The effects of laser irradiation in endodontics have also been investigated. Argon laser showed an efficient cleaning activity on the instrumented root canal surfaces<sup>48</sup>. The Nd:YAG laser was able to produce clean root canals when combined with hand filling and showed a general absence of smear layer and tissue remnants on the root canal wall<sup>49</sup>. The CO<sub>2</sub> laser has been used to remove organic tissue from root canal and to open dentinal tubules<sup>50</sup>. It was observed that after Er:YAG laser irradiation most debris and smear layer on the root canal wall were removed, and dentinal tubules were patent<sup>11</sup>. Er YAG laser irradiation has an efficient cleaning

effect on the prepared root canal walls<sup>11</sup>. Pécora et al.<sup>12</sup> (2000) evaluated dentin root permeability after instrumentation and Er YAG laser application. The authors concluded that using water after instrumentation and Er YAG laser irradiation was effective for increasing dentin permeability. Lan et al.<sup>51</sup> (2000), compared morphological changes after ND-YAG and CO<sub>2</sub> laser irradiation on dentin surfaces with or without smear layer. The two types of laser had a significant influence bringing about morphological changes on irradiated dentin surfaces. ND-YAG laser caused craters and melting of dentin surface, specially in areas with smear. CO<sub>2</sub> laser produced extensive cracking lines on dentin surfaces with smear layer. On the other hand, Barbakow et al.<sup>52</sup> (1999), using the Nd: YAG laser on root canal walls, concluded that it did not reduce the amounts of debris and smear layer compared to a nonirradiated group. Takeda et al.<sup>53</sup> (1999), compared 6% phosphoric acid, 6% citric acid, CO<sub>2</sub> laser irradiation, and Er: YAG laser irradiation on removing the smear layer from prepared root canal walls. Specimens treated with phosphoric and citric acid had similar results with enlarged tubule openings. The two types of laser (CO<sub>2</sub> and Er:YAG) showed ability to remove the smear layer, and the surfaces presented specific characteristics in each of the laser types. When Argon, Nd:YAG and Er: YAG lasers were compared regarding to their ability to remove the endodontic smear layer, the results showed that Argon laser and Nd:YAG laser were useful to remove the smear layer, being the Er: YAG laser the most effective one<sup>54</sup>. If lasers are irradiated for a long time, a thermal damage to the periapical tissue may occur<sup>53</sup>. It was been demonstrated that Er:YAG laser causes less thermal damage than CO<sub>2</sub> or Nd:YAG lasers<sup>55</sup>.

## Final considerations

The influence of the smear layer on endodontic therapy remains to be ascertained. Literature is full of numerous reports using various methods to remove this

layer. Despite the great number of commercially available smear layer removing agents and the several methods to use them, clinicians seem confused. More studies are required in order to clarify the role of the smear layer, its removal need and what is the best method and substance to do it.

## Resumo

A *smear layer* é produzida na superfície dos canais radiculares instrumentados. A influência dessa camada no sucesso dos tratamentos endodônticos ainda não foi determinada, embora existam vários métodos e agentes propostos para sua remoção. O objetivo deste estudo foi realizar uma breve revisão sobre os principais agentes de remoção da *smear layer* endodôntica. Diferentes métodos e soluções irrigadoras têm sido utilizados na remoção da *smear layer*, apresentando resultados variáveis. As investigações sugerem que é necessária a associação de agentes para remoção dos componentes orgânicos e inorgânicos da *smear layer*.

*Palavras-chave:* *Smear layer, EDTA, laser, ultrassom, NaOCL.*

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