SMEAR LAYER IN ENDODONTICS - A REVIEW

Rakesh Mittal, Dr Ashima Garg, Dr Meenu.G.Singla, Dr Anshu Gupta

ABSTRACT:
When root canals are instrumented during endodontic therapy, a layer of material composed of dentine, remnants of pulp tissue and odontoblastic processes and bacteria is alwaysformed on the canal walls. This layer has been called the smear layer. It has an amorphous, irregular and granular appearance under scanning electron microscope. The advantages and disadvantages of the presence of smear layer, and whether it should be removed or not from the instrumented root canals, are still controversial. Once this layer is removed, it should be borne in mind that there is a risk of reinfecting dentinal tubules if the seal fails. Further studies are needed to establish the clinical importance of the absence or presence of smear layer. This article provides anoverview of the smear layer, focusing on its relevanceto endodontics. Conflictstill remains regarding the removal of thesmear layer before filling root canals, with investigationsrequired to determine the role of the smear layerin the outcomes of root canal treatment.

INTRODUCTION

The term 'smear layer' applies to any debris produced iatrogenically by cuttingof dentine of root canal wall. Whenever dentine is cut using hand or rotary instruments mineralized tissues are not shredded or cleaved but shattered to produce considerable quantities of debris 1.

It was not until the advent of scanning electron microscopy that the grinding debris was first referred to as 'smear layer' by Boyde, Switsur and Stewart2 and further defined by Eick and others3 who referred to it as 'smeared layer'.Eick et al reported that smear layer was made of particles ranging in size from less than 0.5-15µm.Scanning electron microscopic studies by Bra¨nnstro¨m & Johnson 4 estimated it to be 2-5µm thick extending a few micrometers into the dentinal tubules.The question of keeping or removing smear layer is controversial as some authors suggest that maintaining the smear layer may block the dentinal tubules and may limit bacterial or toxin penetration by altering dentinal permeability. Others believe that smear layer being a loosely adherent structure should be completely removed as it can harbour bacteria and provide an avenue for leakage. It may also limit the disinfection of dentinal tubules by preventing sodium hypochlorite, calcium hydroxide or any intracanal medicament from penetrating the dentinal tubules; it may act as a substrate for bacteria allowing their deeper penetration in the dentinal tubules. It may also act as barrier between filling material and root canal wall and thus compromise the formation of a satisfactory seal5.

MORPHOLOGY OF SMEAR LAYER

Cameron6 and Mader et al. 7 discussed the smear material in two parts: first,superficiallayer and second, adeep layer in which the material is packed into the dentinal tubules. Packing of smear debris was present in the tubules to a depth of 40 µm. From a chemical point of view smear layer has two components, organic and inorganic. Organic part of smear layer contains dentine collagen fibers and glycosaminoglycane, originating from extracellular matrix. This part presents a base for the dominant inorganic component consisting of calcified tissue.

Bra¨nnstro¨m & Johnson4 and Mader et al.concluded that packing of debris in the dentinal tubules isdue to the action of instruments. Components of the smear layer can be forced into dentinal tubules to varying distances to form smear plugs. In early stages of instrumentation, smear layer on walls of canals have a relatively high organic content because of necrotic and or viable pulp tissue in root canal. 8

However, it was proposed that penetration of smear material into dentinal tubules could also be caused by capillary actionas explained by the packing phenomenon observed by Aktener et al.9, who showed that penetration could increase up to 110 µm when using surface-active reagents in canal during endodontic instrumentation.

It has been observed that neither manual nor mechanical instrumentation techniques achieve total debridement of the root canal. Manual instrumentation is more effective than mechanical instrumentation when creating a well shaped root, although contradictory results have also been reported.Ahlquist et al concluded that manually filled canals had less debris than those cut with rotary techniques10.While comparing various rotary systems,Shariar shahi et al11 concluded that RaCe instruments leave smear layer with lower grades in comparison to FlexMaster and ProFile instruments.Dhanyakumar et al12concluded that there was no significant difference in smear layer production with K3, endowave and protaper rotary instrumentation.Foschi et al13 also compared and concluded that there was no significant difference between Mtwo and protaper rotary NiTi instruments for smear layer production.

A number of investigations have shown that pulpal and periradicular pathosis do not develop without presence of bacteria. Perez et al14 found a mean penetration depth of 479 µm for Streptococcus sanguis after 28 days of incubation, with a maximum penetration of 737 µm. Peters et al15 reported presence of bacteria in more than half of their samples close to cementum. Drake et al 16 showed that removal of smear layer opened the tubules, allowing bacteria to colonize in tubules to a much higher degree (10-fold) compared with roots with an intact smear layer.

MICROLEAKAGE OF ROOT CANAL FILLINGS WITH AND WITHOUT A SMEAR LAYER

Smear layer act as a reservoir or substrate for microorganisms, but it can also obstruct the extension of sealer tags into dentinal tubules and thereby decreasing adhesion by micromechanical forces. 5

Studies have shown a significant increase in adhesive strength and resistance to microleakage of AH26 sealer when smear layer was removed17. Ayce Unverdi Eldeniz et al (2005)18 concluded that AH Plus sealer showed highest bond strength in smear layer removed surfaces.

Other investigators have reported that removal of smear layer did not have any significant effect on microleakage of root canals when various sealers and obturation techniques were used19. In contrast to these findings, Timpawat et al (2001)20 have reported that removal of smear layer has adverse effects on microleakage of filled root canals.

These conflicting results might be attributable to differences in types of sealer and obturation techniques, means of producing a smear layer, and the diversity of bacteria.

A meta-analysis by Shahravan et al21, 41.5% reported a significant difference in favour of removing smear layer and 4.7% found a significant difference in favour of keeping smear layer. Several authors support the idea of removing smear layer as it has an unpredictable diameter and volume, because a great portion of it consists of water22. It contains bacteria and necrotic tissue23. It may act as a substrate for the bacteria, letting them penetrate deeper into dentinal-tubules24. It may also limit optimum penetration of disinfecting agents, medicaments, and root canal filling materials into dentinal tubules25.On the other hand, some authors believe in keeping smear layer during canal preparation, because it can block the dentinal tubules, preventing inward and outward movement of bacteria and other irritants26. However, Williams and Goldman27 reported that smear layer is not a complete barrier and can only delay bacterial penetration.

INFLUENCE OF SMEAR LAYER ON THE APICAL SEALING ABILITY OF MTA

MTA is currently used as a root-end filling material or to obturate teeth with open apices. The smear layer might act as a "coupling agent" enhancing the bond between the MTA and root canal dentine. MTA is a type of hydraulic cement that can set in the presence of water. The reaction results in the formation of hydrated compounds whose strength increases with time. The smear layer is a more or less moist layer. The moist environment caused by the smear layer might have a positive effect on the adaptation of MTA to the root canal wall. Thus,Tahsin Yildirim et al28 concluded that, whenleft intact, smearlayer decreases the microleakage of MTA when used as an orthograde root canal filling material.

EFFECT OF SMEAR LAYER ON ENDODONTIC SURGICAL TECHNIQUES

Root end resection results in a smear layer on exposed dentine surface. Traditionally a 30- to 45-degree oblique angle was prepared at root end to facilitate visibility and placement of root-end filling materials. Recently, application of surgical operating microscopes and ultrasonic instrumentation systems allow for a more conservative root-end preparation, resulting in a 0-degree bevel angle at root end. As root end bevel angle increases, dentine permeability increases. Removal of smear layer has been demonstrated to enhance cementogenesis and dentoalveolar healing as it produces a varied surface topography by exposing dentinal tubules at different angles corresponding to the angles of root.29

Zhu et al30 reported that there was no difference with or without a smear layer for growth of osteoblasts on the dentine surface.

SMEAR LAYER REMOVAL

To date, no single irrigant has been demonstrated to be capable of dissolving organic pulpal material and predentin as well as demineralisingorganic calcified portion of canal wall. Thuscombinations of various irrigants have been recommended to accomplish these goals.

SODIUM HYPOCHLORITE (NaOCl)

Sodium hypochlorite is considered as an irrigant of choice in contemporary endodontic therapy. It is available in concentrations of 0.5-5.25%.It cannot completely remove smear layer (other than superficial layer), and therefore it is used in combination with chelate solutions (Ethylene diamine tetracetic acid and citric acid) 31.

CHELATING AGENTS

It has been reported that EDTA decalcified dentine to a depth of 20–30 μm in 5 minutes. 32However, Fraser33 stated that chelating effect was almost negligible in the apical third of root canals. Different formulations of EDTA have been used as root canalirrigants.O'Connell et al 34compared ability of various salts of EDTA to remove smear layer. They showed that all salts of EDTA were capable of removing smear layer from coronal two thirds of root canals. Sidney ricardo dotto *et al* 35 stated that there was no statistical significant difference between EDTA solution and gel for smear layer removal. A quaternary ammonium bromide (cetrimide) has been added to EDTA solutions to reduce surface tension and increase penetrability of the solution32.McComb & Smith 36reported that when this combination (REDTA) wasused during instrumentation, there was no smear layer remaining except in apical part of canal.

Calt & Serper37compared the effects of ethylene glycol-bis (ß-amino ethyl ether)-N,N,N', N'-tetraacetic acid (EGTA) with EDTA.The smear layer was completely removed by EDTA, but it caused erosion of the peritubular and intertubular dentine.

Tetracyclines are antibiotics effective against a wide range of microorganisms. Barkhordar et al. 38 reported that doxycycline hydrochloride was effective in removing the smear layer from the surface of instrumented canals and root-end cavity preparations.

Torabinejad et al. 39developed a new irrigating solution containing a mixture of atetracycline isomer, an acid, and a detergent (MTAD). Their work concluded MTAD to be an effective solution for the removal of the smear layer. It does not significantly change the structure of the dentinal tubules when the canals are irrigated with sodium hypochlorite and followed with a final rinse of MTAD40.

Chlorhexidine has also been studied as a material which helps in removal of smear layer. It was observed that Chlorhexidine was not effective in smear layer removal, infactYamashita et al (2003) concluded that worst cleaning was seen with Chlorhexidine when compared to sodium hypochlorite and EDTA41.

ORGANIC ACIDS

The effectiveness of citric acidas a root canal irrigant has been confirmed to be more effective than NaOCl alone in removing smear layer. Citric acid removed smear layer better than polyacrylic acid, lactic acid and phosphoric acid42. Yamada et al (1983)43 observed that 25% citric acid–NaOCl was not as effective as a 17% EDTA–NaOCl combination. To its detriment, citric acid left precipitated crystals in root canal which might be disadvantageous to root canal filling.

Canal walls irrigated with 25% tannic acid solution removed smear layer. Sabbak & Hassanin44 refuted these findings and explained that tannic acid increased the cross-linking of exposed collagen with smear layer and within the matrix of the underlying dentine, therefore increasing organic cohesion to the tubules.

SODIUM HYPOCHLORITE AND EDTA

Numerous authors have agreed that the removal of smear layer as well as soft tissue and debris can be achieved by alternate use of EDTA and NaOCl. Goldman et al28examined effect of various combinations of EDTA and NaOCl, and the most effective final rinse was 10 ml of 17% EDTA followed by 10 ml of 5.25% NaOCl. Used in combination with EDTA, NaOCl is inactivated with EDTA remaining functional for several minutes.

The effect of application time is very essential on smear layer removal.C.S.Teixeira et al 45 concluded that canal irrigated with EDTA and NaOCl for 1, 3 and 5 minutes were equally effective in removing smear layer although they were more effective in removing smear layer in cervical and middle thirds than apical third. Another factor essential in removal of smear layer is 'volume' of irrigant. Larger volumes of NaOCl and

EDTA yielded cleaner canals than smaller volumes (Yamada 1993) 43

ULTRASONIC SMEAR LAYER REMOVAL

Ultrasonic devices were first introduced in endodontics by Richman in 1957.A continuous flow of NaOCl activated by an ultrasonic delivery system was used for preparation and irrigation of canals. Smear-free canal surfaces were observed using this method. While concentrations of 2–4% sodium hypochlorite in combination with ultrasonic energy were able to remove smear layer, lower concentrations of the solutions were unsatisfactory46.

Cameron7 also compared the effect of different ultrasonic irrigation periods on removing smear layer and found that a 3-minute and 5-minute irrigation produced smear-free canal walls, whereas an 1-minute irrigation was ineffective. Whereas, Hong-Guan Kuah et al 47concluded that 1minute use of EDTA with ultrasonics is efficient in removal of smear layer and debris removal in the apical region of root canal. In contrast to these results, other investigators found ultrasonic preparation unable to remove smear layer48.

LASERS

Lasers can be used to vaporize tissues in the main canal, remove the smear layer and eliminate residual tissue in apical portion of root canals. The effectiveness of lasers depends on many factors, including the power level, the duration of exposure, the absorption of light in the tissues, the geometry of the root canal and the tip-to-target distance 49.

Tewfik *et al.* 50 used variants of neodymium–yttrium-aluminium-garnet (Nd: YAG) laser and reported a range of findings from no change or disruption of smear layer to actual melting and recrystallization of dentine.

Takeda et al5 1using erbium yttrium- aluminium-garnet (Er: YAG) laser, demonstrated optimal removal of smear layer without melting, charring or recrystallization associated with other laser types.Kimura et al. 52also demonstrated the removal of the smear layer with an Er: YAG laser. Although they showed removal of smear layer, photomicrographs showed destruction of peritubular dentine.

OXIDATIVE POTENTIAL WATER

Oxidative potential water (OPW) has bactericidal activity.According to Becking et al ,the scientific basis for the development of OPW is that microorganisms cannot survive in an aqueous environment with both low pH (less than 3) and high oxidation-reduction potential (greater than 0.9 V) 53.

Hataet al54 showed that OPW effectively removed smear layer from instrumented canal walls when used as an irrigant. They concluded that ultrasonic irrigation with OPW was less effective in removing smear layer than syringe irrigation.

CONCLUSION

Root canal instrumentation produce a layer of organic and inorganic material called the smear layer that may also contain bacteria and their by-products. The question of keeping or removing smear layer is controversial. Although most authors suggestthat removalof smearlayer can result in a more thorough disinfection of root canal system and the dentinal tubules, whichwould ensure a better adaptation between obturationmaterials and root canal walls .Some debate also exists on how to best remove the smear layer. Current methods of smear layer removal include chemical, ultrasonic and laser techniques etc but the method of choice seems to be the alternate use of EDTA and sodium hypochlorite solutions.Further,clinical investigations are needed to determine the role of smear layer in the outcome of root canal therapy.

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DR RAKESH MITTAL,
HEAD OF THE DEPARTMENT

DR HEMANSHI KUMAR, *SENIOR LECTURER; DEVIKA DHAWAN (POST GRADUATE STUDENT)*

DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS, SUDHA RUSTAGI DENTAL COLLEGE, FARIDABAD.