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Bitter, N. C. (1989). "A 25% tannic acid solution as a root canal irrigant cleanser: a scanning electron microscope study." Oral Surg Oral Med Oral Pathol **67**(3): 333-7.

A scanning electron microscope was used to evaluate the cleansing properties of a 25% tannic acid solution on the dentinal surface in the pulp chamber of endodontically prepared teeth. This was compared with the amorphous smear layer of the canal with the use of hydrogen peroxide and sodium hypochlorite solution as an irrigant. The tannic acid solution removed the smear layer more effectively than the regular cleansing agent.

Ciucchi, B., M. Khettabi, et al. (1989). "The effectiveness of different endodontic irrigation procedures on the removal of the smear layer: a scanning electron microscopic study." Int Endod J **22**(1): 21-8.

To compare the effectiveness of different irrigation procedures on the removal of the smear layer, 40 curved canals were manually prepared in vitro under copious irrigation with 3 per cent NaOCl. Ten canals served as controls. The remaining 30 were equally distributed in three experimental groups and subsequently irrigated with the following: ultrasound with NaOCl; EDTA; ultrasound with EDTA. In the scanning electron microscope, the appearance of the smear layer was rated over the distribution of dentinal tubule openings for the coronal, middle and apical segments of the canals. Irrigation with NaOCl produced consistently smeared surfaces. Ultrasonic stirring of NaOCl removed the smear layer moderately, while EDTA produced almost smear-free surfaces. Ultrasound

in association with EDTA did not enhance the dissolving capability of this chelating agent. A definite decline in the efficiency of the irrigation procedures was also observed along the apical part of the canals.

Hulsmann, M. and G. Meyer (1989). "[Root canal preparation with Canal-Finder system. Scanning electron microscopy and clinical studies]." Zwr **98**(2): 114-8.
Root canal preparation was performed with the new Canal-Finder-System in extracted teeth and in simulated root canals in resin blocks. The results of SEM- and stereomicroscopic investigation showed severe alterations of root canal morphology in the apical part of the canal in many cases. Excellently cleaned and shaped canal walls were found as well as parts, which were not instrumented at all or covered with smear layer and debris. The Canal-Finder-System was found to be a good and suitable device for the initial instrumentation of narrow and severely curved canals, but cannot replace hand instrumentation as the standard method of root canal preparation.

Liesenhoff, T., H. Lenz, et al. (1989). "[Root canal preparation using Excimer laser beams]." Zwr **98**(12): 1034, 1037-9.
An in vitro investigation of root canal preparation on extracted human teeth by 308 nm Excimer Laser radiation was performed. It could be demonstrated that a secure and effective root canal preparation is possible by Excimer Laser radiation. SEM investigations on axially splitted roots showed root canal walls free of smear layer or any other soiling. The dentin-tubuli were open and free of clogging. There was no case of *via falsa* or overinstrumentation.

Bruno, E., A. Di Gianvittorio, et al. (1990). "[Canal Finder System" verification in vitro and in vivo]." G Ital Endod **4**(3): 29-33.
Many Authors investigated about the way of cleaning the root canal, using chemo-mechanical instruments. "Canal Finder System" too have been reported, both in in vitro and in vivo experiments, to be a proper method in endodontic treatments. We studied, in our past experiments, the real capacity of cleaning from dentinal debris the root canal and the wear of the instruments we use with CFS. At last we used CFS in patients and we agree with the other that, in the preparation of the apex it can't be use without associating it with manual instruments.

Czonstkowsky, M., E. G. Wilson, et al. (1990). "The smear layer in endodontics." Dent Clin North Am **34**(1): 13-25.
With the cascade of new restorative products being unveiled almost monthly, dentists incorporating endodontics into their practices must be able to evaluate the potential of these products for successful integration into their procedures. This evaluation should be based on a knowledge of how the new products relate to the smear layer formed along the root canal walls. Rather than relying on information supplied by the dental

manufacturers, the aware dentist should regularly resort to the most current research reports available in journal or abstract form. With the use of certain products in some clinical situations, other branches of restorative dentistry may suggest retention of the smear layer. Although pulpally infected teeth have been successfully treated for generations in the presence of the smear layer, it has become accepted practice now in endodontics to remove the smear layer. Different quantities and qualities of smear layer can be produced by various techniques of instrumentation. However, they all present a barrier to intimate contact between obturating materials and the canal wall. Various types of solvents will produce different results in smear layer removal. One ideal endodontic irrigant follows the use of the antimicrobial 5.25 per cent sodium hypochlorite solution with the equally antimicrobial 6 per cent citric acid solution or 17 per cent EDTA. Chelating agents are effective in that they remove the smear layer, open the dentinal tubules, and produce a clean surface for closer obturation. Removal of the smear layer encourages the creation of a good apical plug to prevent over filling, post-filling sensitivity, and possible microleakage. The use of glass ionomer cements and unfilled resin as a cementing medium following smear layer removal shows promising results in both strength of cementation and the possibility of reducing post lengths. Controversies will always arise in dentistry with the advent of new information and the discovery of new clinical techniques. But a total awareness of both sides of a controversy will enable the practitioner to find a way through the confusion.

Fogel, H. M. and D. H. Pashley (1990). "Dentin permeability: effects of endodontic procedures on root slabs." J Endod **16**(9): 442-5.

The permeability of human radicular dentin was measured as a hydraulic conductance before and after treatment with K files and before and after subsequent treatment of the endodontic smear layer with NaOCl, 50% citric acid, or 3% monopotassium-monohydrogen oxalate. Filing reduced dentin permeability 25 to 49%, respectively, depending upon whether outer or inner root dentin was filed. The permeability of these smear layers was unaffected by 5% NaOCl but increased many times after treatment with 50% citric acid for 2 min. Oxalate treatment lowered root dentin permeability to levels below that produced by creation of smear layers due to the production of a crystalline precipitate.

Gutierrez, J. H., V. R. Herrera, et al. (1990). "The risk of intentional dissolution of the smear layer after mechanical preparation of root canals." Oral Surg Oral Med Oral Pathol **70**(1): 96-108.

The root canals of 27 caries-free human cuspids were divided into 3 groups of 9 teeth each. Group I was mechanically prepared with reamers and files. Alternate irrigation with 5.25% NaOCl and 3% hydrogen peroxide was used between each instrument. The group II root canals were prepared with the use of alternate irrigation with the same

concentrations of NaOCl and hydrogen peroxide and finally flushed with 17% EDTA and NaOCl solution. Group III was prepared mechanically with the use of sterile distilled water as an irrigant followed by a final flush with 17% EDTA solution. The root canals of all specimens were obturated with gutta-percha points and Tubliseal by means of the lateral condensation technique. After the root canals were obturated, samples of each of the three groups were immersed in separate flasks containing *Streptococcus mutans*, *Staphylococcus epidermidis*, and *Corynebacterium hofmannii*. All the microorganisms tested invaded the coronal dentin--where the access cavity had been sealed with Fynal--and/or the main foramen.

Kim, D. Y. and G. W. Choi (1990). "[A scanning electron microscope study comparing the cleansing effect of the irrigating solutions and irrigating systems]." Taehan Chikkwa Uisa Hyophoe Chi **28**(2): 181-92.

The purpose of this study was to compare the effect of various irrigating solutions and irrigating debris and the smear layer from the walls of instrumented root canals. 20 single-rooted teeth were biomechanically instrumented to size 40 K-file using sterile saline. And then the teeth were divided into 4 groups and 5 teeth in each group. Groups were irrigated as follows: Group 1: Teeth were irrigated with 20 ml of sterile saline. Group 2: Teeth were irrigated with 10 ml of 3% H₂O₂ and 10 ml of 2.5% NaOCl using the syringe. Group 3: Teeth were irrigated with 10 ml of 3% H₂O₂ and 10 ml of 2.5% NaOCl using the ENAC. Group 4: Teeth were irrigated with 10 ml of 17% EDTA and 10 ml of 2.5% NaOCl using the Endo-mate. All specimens were viewed at the cervical, middle, and apical thirds of the root canals for evaluation of the cleaning effect with the scanning electron microscope. The results were as follows: 1. The Endo-mate with EDTA and NaOCl solutions was the most efficient in cleaning the cervical and middle thirds of the root canal. 2. There was no difference between the irrigating solutions and irrigating systems in the cleaning effect at the apical third of the root canal.

Klimm, W., G. Buchmann, et al. (1990). "[Scanning electron microscopic studies on the efficacy of irrigated, hand root canal preparation]." Zahn Mund Kieferheilkd Zentralbl **78**(3): 231-4.

The effectiveness of hand preparation and irrigation of 48 root canals of upper anterior teeth was evaluated by scanning electron microscopy. Independently of instrument (K reamer or combination K reamer and H file), irrigating solution (sodium chloride) and root canal dressing a similar degree of preparing and cleaning effectiveness of root canals was detected. In all groups a homogeneous or inhomogeneous smear layer of different thickness and extent dominated. A scale of preparing and cleaning effectiveness is recommended.

Mandel, E., P. Machtou, et al. (1990). "Scanning electron microscope observation of canal cleanliness." J Endod **16**(6): 279-83.

The aim of this study was to evaluate the cleansing efficiency of three root canal preparation techniques. The distal root canals of mandibular molars, divided into three groups of four teeth each, were prepared according to the following techniques: manual (serial), ultrasonic (Cavi-Endo), and automated (Canal Finder). The canal wall surfaces were examined under a scanning electron microscope at three levels. No preparation technique was found to result in any characteristic microscopic features that distinguished it from the other techniques. The lack of such differences makes it impossible to establish objective criteria for comparing these techniques in terms of root canal cleanliness. It was established that even canals that appeared to be clean included areas coated with smear layer and having uninstrumented areas and even pulpal tissue debris.

Mondragon Espinoza, J. D. and J. A. Camacho Mondragon (1990). "[Comparative efficiency of 2 products for cleaning the instrumented dentin wall]." Pract Odontol **11**(10): 31-2, 34-6.

Two dental cleansing products, Rc-Prep and Largal Ultra, were subjected to a comparative study, evaluating their efficacy in vitro on 15 recently-extracted dentary units, through optic microscopy applied on the dentine wall of the instrumented root canal. Both materials were applied on separate hemisections of the canal during 15 minutes intervals, with two applications on each canal. Rc-Prep was observed to have a slight, not significant advantage over Largal- Ultra in its cleansing effect over the dentine smear, although the compact, granular and amorphous layer of dentine smear over the root canal wall, blocking the entry to dentine channels, persisted after use of both products. In view of conditions observed in the dentine walls, the authors assume that adhesion and adaptation of obturating materials over these structures is exceedingly difficult. Although variability was not considered as is usual in clinical studies, in vitro evaluation as observed in this study allows a more accurate comparative analysis, since it was performed on one individual tooth, with analogous instrumentation and on dentary tissue with similar characteristics.

Orstavik, D. and M. Haapasalo (1990). "Disinfection by endodontic irrigants and dressings of experimentally infected dentinal tubules." Endod Dent Traumatol **6**(4): 142-9.

The effect of endodontic irrigants and dressings was tested on bacteria in bovine dentin specimens experimentally infected with *Enterococcus faecalis*, *Streptococcus sanguis*, *Escherichia coli*, or *Pseudomonas aeruginosa*. Standardized, cylindrical dentin test pieces were prepared and cleaned by ultrasonic treatment with EDTA and sodium hypochlorite. The specimens were infected with the test organism for periods up to 14 days, and the degree of infection into the tubules was monitored using Brown & Brenn stain, scanning electron microscopy, and culturing of dentin dust from sequential bur samples starting from the pulpal side. E.

faecalis rapidly infected the whole length of the tubules; *S. sanguis* required up to 2 weeks for complete infection; *E. coli* only penetrated to some 600 microns, even after prolonged incubation periods. *P. aeruginosa* infected dentin quickly, but apparently in very low numbers. *E. faecalis* persisted for at least 10 d after withdrawal of nutrient support, whereas the other 3 organisms died within 4 to 48 h. Endodontic medicaments were applied to infected specimen for comparison of antibacterial potency. Camphorated p-monochlorophenol was generally more efficient than Calasept, and of the irrigants tested, iodine potassium iodide appeared more potent than sodium hypochlorite or chlorhexidine. The presence of a smear layer delayed, but did not eliminate, the effect of the medicaments.

Rengo, S., A. Carano, et al. (1990). "[Ultrasound in endodontics: S.E.M. verification]." G Ital Endonzia 4(4): 29-35.

After giving a brief illustration of the complex morphology of the root canal system, the Authors discuss the use of ultrasound in Endodontics. Following a critical evaluation of the literature and of the mechanisms of ultrasonic instruments, they illustrate their experience through a wide selection of S.E.M. photographs of teeth treated in vitro with sodium hypochlorite at various concentrations and for different lengths of time. They demonstrate the synergistic action between ultrasound and irrigation solutions, and conclude that the best results are with 2.5% hypochlorite for 1 minute.

Schadle, C. W., P. Velvart, et al. (1990). "[The cleaning effect of different root canal instruments. A semiquantitative comparative study]." Schweiz Monatsschr Zahnmed 100(3): 274-85.

The efficacy of various root canal cleaning instruments was evaluated in this in vitro study. 60 freshly extracted teeth were divided into 6 groups of 10 teeth each. The root canals of the teeth were cleaned with hand-instruments, sonic instruments (Sonic Air 3000 and Endostar 5), mechanical instruments (Canalfinder System), and ultrasonic instruments (Cavi-Endo with or without integrated rinsing) according to the manufacturer's instructions. The canals were then examined in a SEM at 60 selected points to assess the presence or absence of smear layer, dentin chips, and cellular remnants. The smoothness of the canal walls was also evaluated. Similar amounts of tissue remnants were scored by the SEM method. None of the instruments tested were able to produce debris-free specimens. The Cavi-Endo, Endostar 5, Sonic Air 3000, and the hand-instruments yielded similar scores. However, the Endostar 5 cleaned the canals quicker and with fewer problems than the other instruments. The efficacy of the integrated rinsing in the Cavi-Endo must be questioned. The smear layer was somewhat reduced by the Cavi-Endo, using a syringe and needle, but without the integrated spray. The Canalfinder System produced poorer cleaning scores but they were not

significantly different from the other instruments' scores.

Tanboga, I. and T. Kuraner (1990). "A scanning electron microscope (SEM) study of the smear layer in root canals." J Marmara Univ Dent Fac **1**(1): 7-11.

A Scanning Electron Microscope was used to study the so-called "smear layer" produced in biomechanically prepared root canals. Fine, freshly-extracted incisors were used and the canals instrumented with K-type files and irrigated with 5% NaOCl and 3% H₂O₂. The structure of the "smear layer" produced was investigated.

Gutknecht, N. and V. G. Behrens (1991). "[Instrumentation of root canal walls with Nd-YAG laser]." Zwr **100**(10): 748-50, 752, 755.

An in vitro study showed that it is possible to alter the surface morphology of root canals with a Nd-YAG Laser. S.E.M. and dye penetration photographs showed these changes in the canal surface morphology. In our opinion when an energy level of 15 IPS/1,5 W is used, the resulting changes are useful and of benefit in root canal treatment.

Martin, H. (1991). "Cleanliness, disinfection, and sterilization of the root canal." Curr Opin Dent **1**(6): 734-6.

Disinfection is a key aspect in the preparation of root canals prior to obturation. Irrigation and intracanal medicaments are the chemical means of debridement. The bacterial role is significant, and intracanal medicaments must be cidal in their effect on bacteria and the dentinal tubules. Topical application of medicaments seem to be as effective or more effective than antibiotic applications. Glutaraldehyde and calcium hydroxide are two of the more recently studied medicaments. Calcium hydroxide shows promise as an effective microbicide. The importance of removal of bacteria and necrotic debris from the canal by chemomechanical means--mechanical preparation, cidal irrigation, antimicrobial medicaments--will enhance the successful outcome of endodontic therapy.

Petschelt, A. and J. Dobler (1991). "[High volume vs. activated root canal irrigation]." Dtsch Zahnarztl Z **46**(4): 285-7.

Irrigation of the root canal is carried out to remove the smear layer and the overlying pulp tissue remnants and dentin chips left by preparation. Our results show that even high volume irrigation is less effective in the apical section than towards cervical. A positive effect of activated continuous irrigation was demonstrated above all in the apical third of the root canal. Almost complete removal of both the smear layer and the overlying debris was achieved. Since high volume, continuous activated irrigation is superior to any other form of irrigation, particularly in the apical section, the results of our studies suggest that further efforts to develop such a root canal irrigation system to the state in which it can be clinically used are necessary.

Tao, L., R. W. Anderson, et al. (1991). "Effect of endodontic procedures on root dentin permeability." J Endod **17**(12): 583-8.

The purpose of this study was to quantitate the sequential effects of endodontic procedures on the permeability of human root dentin in vitro. Forty single-rooted teeth were used. Both the crown and the apical 2 mm of the root were removed. The hydraulic conductance of the root before and after various endodontic procedures was measured using a fluid filtration method. Measurements were also made of dentin thickness, intracanal diameter changes, and changes in intracanal surface area. The results showed that instrumentation by K files alone or in combination with Gates Glidden drills did not alter radicular dentin permeability when the cementum remained intact. After removing the cementum, the creation of a smear layer and smear plugs on the canal surface tended to offset the expected increase in dentin permeability created by increasing the intracanal surface area and decreasing root dentin thickness. EDTA treatment inside the instrumented canal to remove the smear layer did not increase permeability significantly. The use of K files followed by Gates Glidden drills tended to remove more cervical dentin, increased the intracanal surface area, and increased the hydraulic conductance of root dentin more than the use of K files alone.

Bakland, L. K. (1992). "Pulp biology research--is the frog still deaf? [editorial]." J Dent Res **71**(10): 1752-3.

[No Abstract Available]

Franchi, M., F. Eppinger, et al. (1992). "NaOCl and EDTA irrigating solutions for endodontics: SEM findings." Bull Group Int Rech Sci Stomatol Odontol **35**(3-4): 93-7.

Premolars roots of humans were manually instrumented with K-type files and irrigated with different solutions to evaluate the rate of cleaning of endodontic surface. Root canals irrigated with 0.9% saline solution or H₂O₂ (10 volumes) showed the presence of predentin and amorphous smear layer. Thick smear layer was always present on endodontic walls rinsed with 5% solution of NaOCl. Specimens treated with 0.2% solution of EDTA showed partially clean dentinal tubules orifices and remnants of a thin smear layer. Occasional uninstrumented areas of the same roots presented smear layer remnants and predentin with calcified bacteria. The root canals irrigated with NaOCl and EDTA solutions alternated after each instrument showed at the dentin surface thick smear layer: only few dentinal tubules orifices were visible. Endodontic surface of root canals irrigated with NaOCl during instrumentation and finally rinsed with EDTA solutions showed the most homogeneous ultrastructural pictures: partially clean dentinal orifices were detectable in the whole canals.

Lumley, P. J., A. D. Walmsley, et al. (1992). "Effect of precurving endosonic files

on the amount of debris and smear layer remaining in curved root canals." J Endod **18**(12): 616-9.

Endosonic files are prone to constraint; this reduces their efficiency, particularly in the apical third and in curved root canals. Precurving the file may reduce constraint, thereby improving the file's ability to debride. This investigation was undertaken to compare both straight and precurved endosonic files as to debris and smear layer removal. Thirty-six curved root canals were randomly allocated into six groups. Each group was prepared using a step-down technique, then instrumented with either a straight or precurved endosonic file of size 15, 20, or 25. The tooth roots were split and examined under the scanning electron microscope. Blind examinations were made for debris and smear layer removal and evaluation scores were analyzed using a log linear approach. The root canals instrumented with the precurved files had a significantly lower debris score than those prepared with straight files. Precurving did not affect smear layer removal. In conclusion, precurving of files decreased the amount of debris but did not affect smear layer removal.

Sornkul, E. and J. G. Stannard (1992). "Strength of roots before and after endodontic treatment and restoration." J Endod **18**(9): 440-3.

The resistance to fracture of mandibular premolar roots before and after endodontic and restorative procedures was tested. Seven treatment groups were evaluated. A Universal testing machine was used to apply vertical and lateral (45-degree) forces. Overall, the untreated roots showed the highest resistance to fracture. Factors of importance to prevent fracture were found to be (a) the amount of remaining tooth structure; (b) strength of post and core; and (c) bonding between core material and dentin. These factors suggest that a composite core following the use of EDTA to remove the smear layer may be a successful treatment when sufficient tooth structure remains.

Standlee, J. P. and A. A. Caputo (1992). "Endodontic dowel retention with resinous cements." J Prosthet Dent **68**(6): 913-7.

This study compared the capability of three composite resin cements to sustain a standard endodontic dowel. All of the systems incorporated some form of smear layer removal on the dentin of the endodontic channel. One system that used a methyl ethyl ketone drying agent provided inadequate clinical resistance to dislodgment of 5.4 DaN. A second cementing system that used only smear layer removal resisted loads at 54.7 DaN. The third cementing regimen that included a surface-initiated dentinal adhesive and smear layer removal recorded retention of 77.4 DaN. This study supported the concept that passively cemented dowels with composite resin can be as effective as actively seated dowels.

Bartha, K. and J. P. Rocca (1993). "[Cleansing effect of two micromotor-driven endodontic handpieces.II. Effect of various rinsing solutions on the cleansing

effect of the handpieces]." Fogorv Sz **86**(12): 401-6.

The cleansing effectivity of citric acid solution was significantly better than that of Neomagnol both with respect to the removal of the Smear Layer (SL) and to the number of visible dentinal tubular orifices, however a complete elimination of the SL could not be obtained. Neomagnol seemed to be more effective in the removal of superficial debris and tissue-remnants.

Bartha, K. and J. P. Rocca (1993). "[Comparison of the cleansing effect of two micromotor-driven endodontic hand pieces. I. Comparison of the cleansing effect of the two handpieces]." Fogorv Sz **86**(11): 365-72.

The aim of the study was to assess the cleansing-effect of two endodontic handpieces (Excalibur, W & H; MM 1400 Micro Mega) in root canals that were previously manually prepared, and treated with chlor- (Neomagnol) and citric acid containing solutions. The analyses were performed by scanning electron microscope (SEM). The elimination of the Smear Layer (SL) with Neomagnol was not successful with either of the two handpieces. The cleansing of the Superficial Debris (SD) with Neomagnol activated by MM 1400 was significantly more effective in the apical ($p < 0.05$) and in the middle ($p < 0.01$) third of the root- canal, than by Excalibur. In contrast, SL was better eliminated by Excalibur using citric acid, significant differences--when compared with MM 1400--could be seen in the middle third ($p < 0.05$) of the root-canal. The handpieces seem to have their own specific characteristics: thus MM 1400 was better in eliminating the SD (used with Neomagnol), while Excalibur was superior in eliminating the SL (used with citric acid).

Cheung, G. S. and C. J. Stock (1993). "In vitro cleaning ability of root canal irrigants with and without endosonics." Int Endod J **26**(6): 334-43.

A variety of methods have been used to evaluate the cleanliness of root canals after endodontic preparation and irrigation. Few irrigation agents other than sodium hypochlorite (NaOCl) have been tested in conjunction with endosonics. The purpose of this study was to examine the cleaning ability of water, NaOCl, Hibiscrub and a biological washing liquid when used as intracanal irrigants, with and without endosonics. Two methods of evaluation were employed to assess the root canal cleanliness after endodontic preparation. A total of 56 teeth, divided into eight groups, were prepared manually using the step-down technique. Each irrigating agent was used in two experimental groups, with and without endosonics. Two additional teeth which received neither instrumentation nor irrigation served as the controls. The teeth were split longitudinally and the state of cleanliness of the root canal was assessed by scoring the amount of stained organic debris and smear layer. It was demonstrated that the results of debris and smear layer scoring were significantly influenced by the type of irrigant and whether endosonics had been used. All agents exhibited similar cleaning ability when introduced manually. With

endosonics, NaOCl yielded significantly less stainable debris ($P < 0.05$) than the other groups which showed no significant difference. The ability to remove the smear layer was enhanced, but at some distance short of the working length, by endosonics for all irrigants tested. None of the solutions tested was able to produce a canal wall that was free of smear layer.

Goodis, H. E., J. M. White, et al. (1993). "Scanning electron microscopic examination of intracanal wall dentin: hand versus laser treatment." Scanning Microsc **7**(3): 979-87.

Conventional cleaning and shaping of root canal spaces involves the use of hand and rotary instruments with irrigation. The procedure results in the formation of a smear layer consisting of dentin shavings, organic tissue remnants and microorganisms. The laser has been suggested as an aid in root canal preparation. In this study, pulsed and continuous wave 1.06 microns wavelength Nd:YAG lasers were used to compare their abilities to clean and shape root canal spaces to conventional methods. After preparation, the test teeth were sectioned longitudinally and examined by scanning electron microscopy. The results demonstrated that the laser was capable of removing the smear layer in its entirety and could occasionally alter dentin walls.

Lumley, P. J., A. D. Walmsley, et al. (1993). "Cleaning of oval canals using ultrasonic or sonic instrumentation." J Endod **19**(9): 453-7.

This study investigated the effect of direction of file oscillation on the amount of debris and smear remaining within oval canals. Sixty-five lower premolars were allocated to six experimental groups ($n = 10$) and one control group ($n = 5$). Canals were prepared using Gates Glidden burs and hand instruments. Preparations were completed using either an ultrasonic size 15 K file or a sonic size 15 shaper file. Three preparation techniques were used: (a) file oscillation toward oval recesses within the canal, (b) file oscillation at right angles to the recesses, and (c) rotational movement of handpiece. Canals were examined under the scanning electron microscope and blindly scored for debris and smear layer. Log linear analysis revealed no significant difference ($p > 0.05$) between sonic or ultrasonic instrumentation as to debris or smear layer remaining. File oscillation directed toward oval recesses left the least amount of debris ($p < 0.05$). Smear layer remained unaffected by all techniques.

Shah, N. (1993). "Comparative study of cutting efficiency of hand, gyromatic and path-finder root canal instruments. A scanning electron microscope study." Indian J Dent Res **4**(1): 1-5.

The cutting efficiency of path finder system was evaluated and compared with gyromatic and hand instrumentation. Mesio-buccal root-canal of maxillary first permanent molar was chosen for the study. Each experimental group comprised of eight teeth each and a control group,

where no instrumentation of root-canal was done, comprised of 2 teeth. After preparation, the roots were split vertically, and prepared for SEM study. Debris and smear layer on canal walls were given a score of 0 to 3 where 0 denoted nil and 3 denoted heavy coatings. Statistical analysis of the result showed that there was no significant difference between the various experimental groups. The new path finder system compared favourably with Gyromatic and hand instruments in cleaning the canal walls.

Calas, P., F. Perez, et al. (1994). "[Incidence and elimination of parietal smear layer in endodontics]." Rev Belge Med Dent **49**(3): 42-56.

During canal preparation, the repeated passage of instruments provokes the formation of smear on the surface of the dentin. It is advisable to eliminate that, so as to increase antiseptics and filling impermeability. This is obtained by means of an irrigation, using a chelate compound of 6% citric acid for 60 seconds, at the end of the preparation.

Dautel-Morazin, A., J. M. Vulcain, et al. (1994). "An ultrastructural study of the smear layer: comparative aspects using secondary electron image and backscattered electron image." J Endod **20**(11): 531-4.

The aim of this investigation was to study the influence of three irrigation procedures on the composition, structure, and aspect of the smear layer within root canals. Three homogeneous groups were prepared without irrigation, with physiological serum, or with Dakin (dilute, neutral solution of sodium hypochlorite). Root canals were instrumented with Rispi Reamers mounted on a counterangle Gyromatic. The irrigating solution was delivered with an endodontic irrigation needle. Modifications were observed by scanning electron microscope using secondary electron imaging and backscattered electron imaging. Instrumentation without irrigation produced a very thick smear layer that appeared in backscattered electron imaging as a compact assembly of organic and inorganic components. Instrumentation using Dakin produced canal walls that were less smeared, and the pockets of debris remaining were smaller in size than when using physiological serum. When the root canals were irrigated, the smear layer appeared as a double layer, one superficial and the other deep. The layers were predominantly inorganic with Dakin.

Prati, C., M. Selighini, et al. (1994). "Scanning electron microscopic evaluation of different endodontic procedures on dentin morphology of human teeth." J Endod **20**(4): 174-9.

Four manual endodontic instruments, an ultrasonic and an endosonic system were studied with a view to evaluating the morphology of the smear layer and the amount of debris and pulpal residues in the apical third of human extracted straight teeth from 55- to 75-yr-old patients. The manual instruments were K files, Ergoflex files used with the step-back technique, Canal Master with its own technique, and Flex-R with the

Roane technique. The ultrasonic system was Suprasson Piezo and the endosonic was Excalibur. Human extracted teeth with straight canals were used and examined under a scanning electron microscope. All manual instrumentations showed a homogeneous compact smear layer and no pulp residues. No statistical differences were observed among the four manual techniques. Ultrasonic technique showed the complete removal of the smear layer, leaving small amounts of pulp debris at the apical third, while the Excalibur showed an almost complete elimination of the smear layer, leaving a homogeneous layer of pulpal residues along the canal.

Cameron, J. A. (1995). "The choice of irrigant during hand instrumentation and ultrasonic irrigation of the root canal: a scanning electron microscope study." Aust Dent J **40**(2): 85-90.

The purpose of this study was to investigate the use of 4 per cent sodium hypochlorite and 15 per cent EDTAC, either alone or in conjunction, as irrigants during hand instrumentation and ultrasonic irrigation of the root canal. Thirty-six extracted human teeth, each with a single, straight root 21-25 mm long were hand-instrumented through a clinical access cavity to file size 40. One millilitre of the test irrigant was used after each instrument size. Canal debridement was completed with an intermittent flush irrigation technique with one or both of the test irrigants activated by ultrasound at a medium effective power output. The specimens were sectioned longitudinally, viewed in a scanning electron microscope and scored for the presence or absence of debris and smear layer at levels less than 1 mm, 5 mm, and 10 mm from the apical seat. Under the conditions of this experiment the most effective regime was irrigation with 1 mL EDTAC after each instrument size, followed by two 30 second exposures to ultrasound+EDTAC then four 30 second exposures to ultrasound + 4 per cent sodium hypochlorite. The specimens in this group were free from retained pulp tissue and superficial smear layer, had the lowest debris scores at the < 1 mm and 5 mm levels, and the lowest total debris score. All of the techniques tested produced smear-free canals at the 10 mm level.

Cameron, J. A. (1995). "Factors affecting the clinical efficiency of ultrasonic endodontics: a scanning electron microscopy study." Int Endod J **28**(1): 47-53.

The purpose of this pilot study was to investigate some of the clinical variables in ultrasonic endodontics. forty extracted human teeth with a single, straight root 21-25 mm in length were prepared using combinations of the following variables: hand or ultrasonic instrumentation; apical seat prepared to file sizes 35, 40, 45 or 50; 1 ml of water, 4% sodium hypochlorite or EDTAC as irrigant between each instrument size; three brands of ultrasound generator and inserts; a 'low', 'medium' or 'high' effective power output; a tuned or untuned circuit; post-instrumentation ultrasonic irrigation with either 4% sodium hypochlorite, EDTAC, or the two used in sequence. The specimens were viewed in a scanning electron

microscope and scored for the presence or absence of a smear layer at levels < 1 mm, 5 mm and 10 mm from the apical seat. The most effective combination, as tested, was hand instrumentation to file size 40 with 1 ml EDTAC irrigation between each instrument size, supplemented by intermittent flush irrigation with EDTAC with ultrasound then 4% sodium hypochlorite with ultrasound. This technique left a minimum smear layer restricted to the apical seat. Other combinations of instrumentation and irrigation were not consistent in their effectiveness.

Machida, T., P. Wilder-Smith, et al. (1995). "Root canal preparation using the second harmonic KTP:YAG laser: a thermographic and scanning electron microscopic study." J Endod **21**(2): 88-91.

Thermal and microstructural events resulting from KTP laser use during root canal preparation were investigated in 30 extracted single-rooted human teeth. In the first section of this study, thermal events occurring on the root surfaces of 18 teeth during and after exposure of the root canal were measured using thermography. A variety of parameters were used to determine settings that would be effective without causing thermal damage to the periodontal ligament. In the second section of the study, root canals of 12 teeth exposed to KTP laser irradiation at parameters derived from section 1 were evaluated using Scanning electron microscopy. KTP laser application at a power setting of 3 W, an exposure time of 2 s, and a frequency of 5 Hz, applied five times, removed smear layer and debris from the root canal surface at temperatures below the thermal injury threshold for periodontal tissue.

Mohammed, A. N., R. E. Seif, et al. (1995). "An in-vitro comparative study of the retention of grooved and flat endodontic posts in treated root canals using two different types of cements." Egypt Dent J **41**(4): 1463-8.

This study evaluated and compared the retentive capability of performed cast posts in endodontically treated premolar teeth using the following: 1--smooth versus grooved post design 2--surface treatment of the root canals with either 17% EDTA followed by 2.25% Naocl or using Naocl only. 3--cementation of the posts with either polycarboxylate cement or C & B Metabond. Cast metal posts were made, cemented in root canals and divided into groups representing combinations of variables. The force required for post removal were recorded and statistically analysed. The results indicated that cementation of the grooved cast metal post with polycarboxylate cement after removal of the smear layer was the most retentive system. More over C & B Metabond resin cement with any post design in presence or absence of smear layer gave high retentive values.

Panighi, M. M. and B. Jacquot (1995). "Scanning electron microscopic evaluation of ultrasonic debridement comparing sodium hypochlorite and Bardac-22." J Endod **21**(5): 272-8.

This study compared in vitro the debridement ability of a 3% sodium

hypochlorite with a new quaternary ammonium derivative, a 0.5% Bardac-22 solution, in the apical third of freshly extracted teeth with straight root canals. Root canals were instrumented sequentially from size 10 to size 35 using alternatively hand and ultrasonic files. When the hand file was loose in the canal, the ultrasonic instrument of the same size was operated at working length for 30 s, delivering 15 ml of the selected solution. Both solutions were able to flush out pulpal debris from the canal space. At the apical end of the preparation, sodium hypochlorite left a thicker smear layer than Bardac-22 did. The quaternary ammonium derivative easily dissolved the inorganic portion of the smear layer, but did not dissolve proteins as well as sodium hypochlorite.

Sen, B. H., P. R. Wesselink, et al. (1995). "The smear layer: a phenomenon in root canal therapy." Int Endod J **28**(3): 141-8.

When the root canals are instrumented during endodontic therapy, a layer of material composed of dentine, remnants of pulp tissue and odontoblastic processes, and sometimes bacteria, is always formed on the canal walls. This layer has been called the smear layer. It has an amorphous, irregular and granular appearance under the 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. It has been shown that this layer is not a complete barrier to bacteria and it delays but does not abolish the action of endodontic disinfectants. Endodontic smear layer also acts as a physical barrier interfering with adhesion and penetration of sealers into dentinal tubules. In turn, it may affect the sealing efficiency of root canal obturation. When it is not removed, the durability of the apical and coronal seal should be evaluated over a long period. If smear layer is to be removed, EDTA and NaOCl solutions have been shown to be effective, among various irrigation solutions and techniques, including ultrasonics, that have been tested. Once this layer is removed, it should be borne in mind that there is a risk of re-infecting dentinal tubules if the seal fails. Further studies are needed to establish the clinical importance of the absence or presence of smear layer.

Meredith, N. and K. Gulabivala (1997). "Electrical impedance measurements of root canal length." Endod Dent Traumatol **13**(3): 126-31.

Electronic methods are now widely used during endodontic treatment for the assessment of root canal length. These commonly measure the electrical resistance or impedance between the root canal and the buccal mucosa. A number of studies have been undertaken to determine the accuracy of commercially available instruments. The aims of this investigation were to determine the electrical impedance characteristics of the root canal and periapical tissues in vivo, measure the changes relative to the distance of an endodontic instrument from the apical constriction and propose an equivalent circuit modelling the periapical tissues. The

length of the root canals of 20 previously untreated teeth were determined using radiographic and electronic methods. Minimal canal preparation was carried out and measurements were made with a size 10 K-Flex file. A microprocessor-controlled LCR analyser was used to measure the electrical impedance characteristics of each root canal. The instrument measured the series and parallel resistive (RS, RP) and capacitance (CS, CP) component of the tissues at two test frequencies, 100 Hz and 1 kHz. Measurements were made for each root canal when the diagnostic file was placed at the apical constriction and repeated when the file was withdrawn to -0.5, -1.0, -1.5, -2.0 and -5.0 mm from the foramen. Readings were taken for each canal after the canal had been dried with paper points, and flooded first with deionised water and then with sodium hypochlorite. The root canals were then prepared, cleaned and obturated using standard endodontic procedures. The LCR analyser selected the series resistance component as the major measurement parameter. There was a clear increase in series resistance (RS) with increasing distance from the radiographic apex for dry canals and those containing deionised water and sodium hypochlorite. The mean resistance for dry canals was markedly higher than for those containing fluid, ranging from 22.19 k ω to 92.07 k ω in comparison with 9.32 k ω to 12.10 k ω for deionised water and from 7.46 k ω to 8.92 k ω for canals containing sodium hypochlorite. There was a marked change in the series and parallel resistive component with distance from the apex, suggesting a complex relationship between the impedance of the smear layer and bulk dentine. The impedance characteristics of a root canal were a complex electrical network comprising resistive and capacitive series and parallel elements.

Saunders, W. P. and E. M. Saunders (1997). "The root filling and restoration continuum--prevention of long-term endodontic failures." Alpha Omegan **90**(4): 40-6.

[No Abstract Available]

Koton, D. (1999). "The prevention of endodontic failures." Sadj **54**(2): 109-13.

[No Abstract Available]

Johnson, M. E., G. P. Stewart, et al. (2000). "Evaluation of root reinforcement of endodontically treated teeth." Oral Surg Oral Med Oral Pathol Oral Radiol Endod **90**(3): 360-4.

OBJECTIVES: The purpose of this study was to test the root reinforcing capabilities of a glass ionomer sealer and to test whether pretreatment of the instrumented canal to alter or remove the smear layer might enhance the reinforcement. **STUDY DESIGN:** Ninety single-canaled roots of standardized dimensions were instrumented to International Standards Organization size 45 and were analyzed for resistance to vertical fracture. Six groups were tested (n = 15). **RESULTS:** No significant difference in

fracture resistance was observed between any of the groups.

CONCLUSIONS: Under the conditions of this study, reinforcement of endodontically treated mature teeth by placement of adhesive materials in the root was not demonstrated.

von Fraunhofer, J. A., D. K. Fagundes, et al. (2000). "The effect of root canal preparation on microleakage within endodontically treated teeth: an in vitro study." Int Endod J **33**(4): 355-60.

AIM: The purpose of this study was to evaluate the effects of smear layer and canal instrumentation on leakage in root-filled teeth.

METHODOLOGY: Six groups (n = 12) of freshly extracted human canines and premolars with closed apices and single roots were used. Groups A, B, C, and D were instrumented with engine-driven rotary nickel- titanium MXXIM files and Groups E and F were instrumented with conventional stainless steel hand files. Groups A, C, and E were flushed with 3.0 mL of 17.0% REDTA to remove the smear layer prior to obturation. All teeth were flushed with 5.25% NaOCl, then obturated with AH-26 sealer and either the lateral condensation (Groups C-E) or thermomechanical compaction technique (Groups A and B). Copper wire was placed coronally in contact with the gutta-percha in each tooth and, after immersion in 0.9% NaCl solution, a 10 volt dc voltage was connected between each tooth and a stainless steel electrode. The current flow in the circuit was observed for 45 days. One way ANOVA and Duncan's Multiple Range Test were used to compare Groups A-F at time intervals of 10, 20, 30 and 45 days and identify statistically significant differences. **RESULTS:** Significantly less microleakage occurred when the smear layer was removed and when the canals were obturated with thermoplasticized gutta-percha. Canals instrumented with engine-driven NiTi files exhibited less leakage than hand- instrumented canals irrespective of obturation method. **CONCLUSIONS:** Smear layer removal is beneficial to root canal sealing. Obturation with thermoplasticized gutta-percha provides a superior seal whilst canal instrumentation with engine-driven NiTi files reduces the extent of microleakage in root canals.

Wauters, T. and J. Wauters (2000). "[Should the dentin smear layer be preserved or eliminated? (Review of the literature)]." Rev Belge Med Dent **55**(2): 93-103.

The smear layer is a direct consequence of instrumentation of the root canal wall. Hand instrumentation as well as ultrasonic instrumentation produce a smear layer on the canal wall. This smear layer is composed of dentine, remnants of pulp tissue and odontoblastic processes and bacteria in an infected canal. Removal of the smear layer is accomplished by the irrigation of root canals with EDTA (17%) followed by NaOCl (5.25%). Permeability of the dentine is increased by the removal of smear layer. In this way the bacteria within the infected tubuli can be more easily destroyed by an intracanal dressing. Whether the removal of smear layer decreases the apical leakage is uncertain. To establish the clinical

consequences from removal or preservation of the smear layer, further research is needed.

Moss, H. D., J. D. Allemang, et al. (2001). "Philosophies and practices regarding the management of the endodontic smear layer: results from two surveys." J Endod **27**(8): 537-9.

The purpose of this investigation was to ascertain the prevailing attitudes within the endodontic community regarding smear layer removal. The first survey asked the philosophies and techniques currently being taught to predoctoral dental students and postdoctoral endodontic residents in the United States, whereas the second surveyed some of the members of the American Association of Endodontists currently practicing in the United States. Findings from these surveys revealed that more than three-fourths of the dental students and nearly two-thirds of the endodontic residents are not being taught routine smear layer removal. Slightly more than one-half of endodontists responded they practice smear layer removal. These surveys indicate that there is no clear consensus in the endodontic community, either academically or clinically, as to whether the smear layer should be removed or be allowed to remain before obturation of the root canal space.

Schafer, E. and K. Bossmann (2001). "Antimicrobial efficacy of chloroxylenol and chlorhexidine in the treatment of infected root canals." Am J Dent **14**(4): 233-7.

PURPOSE: To investigate the antimicrobial efficacy of a chlorhexidine gluconate (2.0%) and of an ethanolic chloroxylenol solution (10%) as a temporary root canal dressing against selected test microorganisms (Staphylococcus aureus, Streptococcus faecium, Escherichia coli, Candida albicans). **MATERIALS AND METHODS:** Extracted single-rooted human teeth were instrumented up to size 40. After removal of the smear layer suspensions of the test microorganisms were inserted into the root canals. After incubation for 48 hrs each suspension of the test organisms was removed and the root canals were filled with one of the two different disinfectants. The teeth were then incubated for 48 hrs. Twelve teeth and three controls were used for each of the four test organisms and each of the two regimens. After incubation, each root canal was instrumented and the removed canal wall dentin was examined microbiologically. **RESULTS:** With a contact time of 48 hrs between the two disinfectants and the four bacterial suspensions the medications led to a total killing of microorganisms in 82% of a total of 96 contaminated teeth. In the dentin layer situated 50 microm from the root canal, both medications achieved bacterial killing in a range from 99.9% to 99.99%, depending on the test organism. There were no significant differences ($P > 0.1$) between the relative antimicrobial activity of the two root canal dressings.