AN EVALUATION OF THE EFFICIENCY OF DIFFERENT IRRIGATION SYSTEMS ON THE SMEAR LAYER

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Abstract

The aim of this study is to investigate the effect of three different irrigation technics on smear layer occured during root canal preparation of maxillary incisors that has endodontic treatment indications.

Freshly extracted 60 maxillary incisors because of periodontal problems were used in this study. In preferring teeth such criterias as; nearly similar root lengths, no inclination of roorts and the same pulpal width were used. Debridement on roots were removed with a cretuar after extraction. Root surfaces were cleaned with brushes. Teeth were protected at room temperature in distilled water until usage day in study. Teeth were sectioned vertically to long axis 2 mm over enamel cement junction (cervical line). Teeth were randomly divided into three groups of each 20. Coronal access of teeth were extended by the help of Gates Glidden bur No V. Root canal preparation was started by using endodontic device (Vdw. Gold, Munich, Germany) and Protaper (Dentsply, Maillefer, Ballaigues, Switzerland) rotary instruments. Firstly root canal lengths were measured by K type root canal insturment (Dentsply, Maillefer, Ballaigues, Switzerland) and working lengths were determined as 1 mm shorter than foramen apicale. Extending operation was first started with SX (Dentsply, Maillefer, Ballaigues, Switzerland) among rotary instruments and then continued respectively as S1,S2,F1,F2 and resulted with F3. Different irrigation technics were used for each group. In group 1 irrigation was done with ultrasonic device (Nsk Various 970, Japan). Irrigation was done at a regulated frequency for endodontic operation and by using specially prepared E4 and E11 instruments. First tank was filled with 5.25% NaOCl and second tank was filled with 17% EDTA as irrigation solution. When between each instrument changes 5.25% NaOCl was used,17% EDTA was used for final irrigation. In second group irrigation was done with classical method. After using SX instrument, irrigation was done by 27-gauge plastic syringe (Hayat Medical Instruments, İstanbul ,Turkey) with 5.25% NaOCl. Irrigation was repeated after every instrument and finally was done with 17% EDTA. In third group irrigation was done by Endo-Vac (Discus Dental, Culver City, California) device. After every rotary instrument irrigation was done by MDT and macro canula with 5.25% NaOCl. And final irrigation was done by micro canula with 17% EDTA. After irrigations root canals were dried with paper points (Meta Dental Co, Ltd, Korea). After preparation teeth were bucco-lingually and longitudinally sectioned by opening thin tunnels (hollows) burs by aerator device. Coronal, middle and apical parts of roots were analyzed under SEM (EVO 40-LEO, Germany). Obtained data was assessed with one way Kruskal-Wallis variance analysis ($p<0.05$).

Among Group 1 (Ultrasonic), Group 2 (Classic) and Group 3 (Endo-Vac) in terms of capacity of cleaning root surfaces statistically a significance was determined. That means presence of smear layer in three groups and in terms of whether dentine tubules are open and not; on coronal, middle and apical regions af root surface variability was determined.

When capacity of cleaning of root canal surfaces of teeth were investigated; in coronal region irrigation by ultrasonic system, in middle region irrigation by classical syringe method and in apical region irrigation by Endo-Vac device determined successful.

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Introduction

The aim of preventative dentistry is to keep live teeth in the mouth and to prevent the development of pulp and peridontal diseases. Endodontic treatment is necessary when tooth decay is at an advanced stage, when diseases have occurred because of trauma or pulp and peridontal causes or in cases where conservative treatment is not sufficient.

The aim of endodontic treatment is to eliminate microorganisms by removing the crown and root pulp and mechanically cleaning and shaping the root canals. Microorganisms which are not eliminated may cause infection.[1, 2,3]

During the preparation of root canals it is necessary to clean the smear layer of the canal surfaces. This smear layer of the root canal surfaces may negatively affect the success of endodontic treatment. During the chemomechanical processes, the smear layer which is formed on the dentine and canal walls may negatively affect the adaptation of the canal filling material.[4,5]

Several methods are applied to eliminate the smear layer from the root canals. These can be classified as chemical and

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mechanical methods. As chemical methods, sodium hypochloride, chelation agents, acids and tetracyclines are used. As mechanical methods, ultrasonic devices, sonic systems, Endo-Vac device and the traditional method of using washing solutions are used.[6]

The structure of the smear layer is formed of organic and inorganic matter. The organic structure contains blood cells, necrotic pulp residue, live pulp residue, microorganisms, proteins and odontoblasts. Whereas in the inorganic structure, dentine particles are seen which occur during the shaping process of the root canals in endodontic treatment.[7, 8]

The smear layer was first determined in a study by Boyde and Knight in 1970.[9]

In a study by McComb and Smith in 1975, the smear layer was shown on scanning electron microscopy (SEM) after cleaning and shaping the root canals and it was determined that this layer was similar to the smear layer on the tooth crown.[10]

Gilboe et al reported that the thickness of the smear layer is affected by factors such as the manner of filing used in shaping the root canal, the filing technique, the direction of force, the amount and type of irrigation agent and whether dentine is cut dry or wet.[11]

A study made with SEM defended the view that the presence of a smear layer in the dentinal tubules prevented the penetration of the root canal filling to the dentine.[12]

Torabinejad et al reported that the smear layer could be eliminated in 3 different ways by chemical methods, mechanical methods and by laser.[6]

1) Chemical Methods
   a- Sodium Hypochloride (NaOCl)
   b- Chelation agents
   c- Chlorhexidine Gluconate
   d- Tetracyclines
   e- Acids
   f- Other
2) Mechanical Methods
   a- Ultrasonic and Sonic systems
   b- EndoVac
3) Lasers

Sodium hypochloride, which is used in the removal of pulp residue, has been reported to be highly effective in removing organic and necrotic residue which is lightly attached to the surface.[10]

Hand et al reported that low concentrations of sodium hypochloride had lower properties of disconnecting tissues. In their study, it was determined that 0.5%-1% of sodium hypochloride had no effect, whereas 5.25% NaOCl was 3 times more effective than 2.5%.[13]

A 17% ethylene-diamine-tetraacetic acid (EDTA) solution is recommended as an effective irrigation in root canal cleaning and shaping in endodontic treatment. Whereas a low concentration is less effective, high concentrations have been reported to cause decalcification where there is a thick film layer on the root canal walls.[14]

Ultrasonic system devices are instruments which work on a frequency above that of human hearing. They are used in the root canal preparation and cleaning processes in endodontic treatment. Ultrasonic energy is obtained by the transformation of electromagnetic or piezoelectric energy to oscillation movements in the ultrasonic tips. These ultrasonic tips reach the root canals with irrigation agents and an effective cleaning process is made with oscillation movements. With the use of sonic instruments, pressurised air is useful to achieve the oscillation actions of filing.[15,16]

The use of ultrasonic systems together with 4% NaOCl has been reported to result in he removal of the smear level of the root canals in a short time such as to minutes.[5] In another study, to have better cleaning of the smear layer, 15% EDTA solution together with NaOCl and different irrigation agents such as distilled water were used with ultrasonic devices in root canal irrigation systems.[17]

Endo-Vac irrigation technique is a system which uses negative pressure. One of the main reasons for the development of the Endo-Vac irrigation technique was to prevent the irrigation agents moving from the apex to the periapical tissues. Nonetheless, with a negative pressure system, in the cleaning of the smear canal from the area of the entire root canal, that is starting from the apical third as far as the foramen apical, residue can be more easily cleaned from very narrow canals and irrigation can be made of areas of apical narrowing. In the Endo-Vac system, with the help of apical negative pressure there is a high degree of absorption and washing can be performed easily with intensive irrigation agents.[18]

A greater amount of irrigation agents are used in Endo-Vac irrigation technique compared to the amount used in classic methods, that is irrigation techniques using endodontic needles.[18]

This study aimed to compare the effectiveness of different irrrigation techniques in eliminating the smear layer during root canal shaping and widening processes in endodontic treatment.

Materials and Methods

Sixty newly-extracted upper middle incisor teeth were used in this study. Teeth with peridontal problems and without decay were preferred. In the selection of the teeth, attention was paid to the dimensions of the root being similar to each other, and that there had been no restorative treatment or endodontic treatment. In particular, teeth with straight roots with an inclination of less than 5º were preferred. Whether calcification could form or not along the root canal was determined by taking radiographs of the teeth and teeth with approximately the same width of pulp were preferred. After extraction, the tissues which had formed on the root surfaces were removed using a peridontal curette and the teeth were cleaned with a brush. Until the sttudy, all the teeth were stored in distilled water at room temperature. Using a diamond-tipped separator (Horico, Diamond Instruments, Germany) and handpiece (Ultimate 500K, NSK, Japan), the crown section of the tooth was removed by cutting 2mm above the enamel-cement nerve.

At the study stage, the root canal preparation and shaping processes were carried out by a single operator. Firstly, pulpal residue in the root canals was removed using a tirnerf (Dentalwerke Gmbh, Kg, Germany). For the widening of the canal mouth and coronal section a number 5 Gates Glidden drill was used (Gates Drills 32, Mani, Japan).

Prior to starting the preparation processes, the teeth had been randomly allocated to one of 3 groups of 20. The different irrigation techniques were applied to the groups as follows:

Group 1: Ultrasonic irrigation technique
Group 2: Classic irrigation technique
Group 3: Endo-Vac irrigation technique

Group 1: After widening the coronal openings of the teeth with a No 5 Gates Glidden drill, the preparation procedure was started with a multi-function drill (Vdw Gold, Munich, Germany) using a Protaper (Dentsply, Maillefer, Ballaigues, Switzerland) rotating attachment. To measure the length of the root canals, a No 15 K-type ni-ti canal file (Dentsply, Maillefer, Ballaigues, Switzerland) was used. This file widens approximately a two-thirds section of the root and provides a straight entrance. After the SX file, irrigation was made after each filing using S1, S2, F1, F2 and F3 and the canal widening process was finished. The irrigation after each filing was made using a multi-function ultrasonic irrigation device (Nsk Various 970, Japan). The irrigation procedure was made at the recorded frequency for endodontic irrigation recommended by the manufacturer and using E4 and E11 tips specially designed for endodontic irrigation. In one chamber, 5.25% NaOCl was added and in the other, 17% EDTA solution. In the move to the rotating instruments, the 5.25% NaOCl in the first chamber and the 17% EDTA solution in the second chamber were used in combination. At the final irrigation the irrigation procedure was finished using distilled water. Finally the canals were dried with the placement of sterile paper (Absorbent Paper Points, Germany).

Group 2: After widening the coronal openings of the teeth with a No 5 Gates Glidden drill, the preparation procedure was started with an endodontic drill using a Protaper rotating attachment. Firstly a No 15 K-type ni-ti canal file was used to measure the length of the root canals. The working length of the root canals was defined as the foramen 1mm short of the apical. An SX file was used firstly on the rotating device. This file widens approximately a two-thirds section of the root and provides a straight entrance. After using the SX file, irrigation was started with a 5.25% NaOCl solution from a 27-gauge plastic syringe (Hayat Tibbi Aletler, Istanbul, Turkey) and was then continued with a 17% EDTA solution. After the SX file, irrigation was made after each filing using S1, S2, F1, F2 and F3 and the canal widening process was finished. The final irrigation was made with distilled water. The canals were dried with paper pointers.

Group 3: After widening the coronal openings of the teeth with a No 5 Gates Glidden drill, the preparation procedure was started with an endodontic drill using a Protaper rotating attachment. Firstly a No 15 K-type ni-ti canal file was used to measure the length of the root canals. The working length of the root canals was defined as the foramen 1mm short of the apical. An SX file was used firstly on the rotating device. This file widens approximately a two-thirds section of the root and provides a straight entrance. After the SX file, irrigation was made after each filing using S1, S2, F1, F2 and F3 and the canal widening process was finished. During the preparation of the teeth in this group, irrigation was made using the Endo-Vac system (Discus Dental, Culver City, California). With each change of file, irrigation was made to the root canals using a master delivery tip and macro cannula with 5.25% NaOCl and then 17% EDTA solution. After the macro cannula, by irrigating with a micro cannula using firstly 17% EDTA solution then 5.25% NaOCl solution, the small smear residue was removed. The final irrigation was made with distilled water and the irrigation procedure was finished. The canals were dried with sterile paper.

The preparation and irrigation procedures were finished and in the teeth of each group buccolingual and longitudinal narrow grooves were opened. All the teeth were sepaated into two from the grooves using a narrow flame tip attachd to an aerator.

Before the SEM (EO 40-LEO, Germany) stage, the teeth were dried and each sample was covered with a 10-15mm thickness gold-palladium coating using a coating device.

The degree of cleaning and removal of the smear layer from the root canal surfaces of the teeth coated with gold-palladium were examined with a SEM device (EVO 40-LEO, Germany) at 20,000 kV.

Images at 2000 magnification of the apical, mid and coronal sections of the root canal surfaces of the total 60 teeth were taken with a SEM device.

The obtained images were evaluated in respect of the presence of a smear layer and whether or not the dentinal tubules were open. To obtain statistical data, scoring was made as to whether or not a smear layer was present on these images (Figure 1).

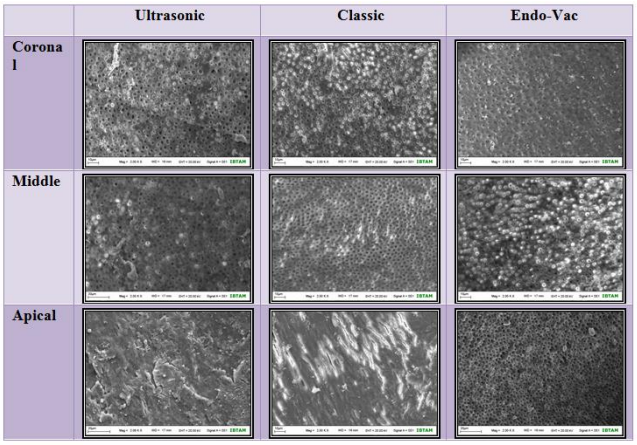

Figure 1. Images at 2000 magnification of the apical, middle and coronal sections of the root canal surfaces with a SEM device.

Score 0: Dentinal tubules open and no smear layer.
Score 1: Dentinal tubules open and regional smear layer.
Score 2: Dentinal tubules seem to be present and smear layer is present in the form of a thin line.
Score 3: Dentinal canals cannot be seen and a very ntense smear layer is present.[19]

Results

To evaluate whether or not there was any statistically significant relationship between the groups, the Kruskal Wallis One-Way Variance analysis test was applied ($p<0.05$).

The results obtained from the evaluation by the Kruskal Wallis One-Way Variance Analysis of the scores of the dentine coronal, mid and apical areas of the root canal surfaces of the ultrasonic, classic and Endo-Vac groups are shown (Table 1).

A statistically significant difference was determined between Group 1 (ultrasonic), Group 2 (classic) and Group 3 (Endo-Vac) in respect of the capacity to clean the root canal surfaces ($p<0.05$).

In the evaluation of the coronal region of the root canals, the most succcessful result of the three groups was in Group 1(ultrasonic). In the evaluation of the mid third region of the root canals, the most succcessful result was determined to be in Group 2 (classic). In the evaluation of the apical region of the root canals, the most succcessful result was in Group 3 (Endo-Vac) ($p<0.05$).

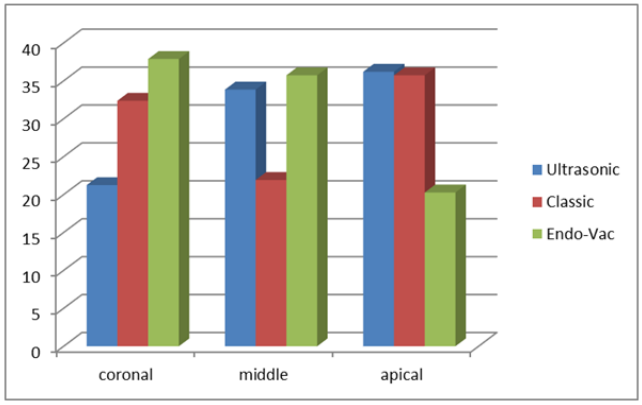

Table 1. Analysis of the scores of the dentine coronal, middle and apical areas of the root canal surfaces of the Ultrasonic, Classic and Endo-Vac groups are shown

Discussion

One of the most important aims of endodontic treatment is to completely remove toxic substances caused by microorganisms in the root canals, which are the reason for infections and periapical lesions.

The smear layer is formed of organic and inorganic structures. While microrganisms, live and necrotic pulp residue, proteins and odontoblasts are seen in the organic part, dentine fragments, which occur as a result of endodontic treatment, are encountered in the inorganic part. When there is a thick smear layer, the efficacy of irrigation solution is reduced thus allowing bacteria to easily proliferate and to easily pass to the dentinal tubules.[8, 10]

To be able to thoroughly clean the residue which has formed in the root canals, just as researchers have used different techniques, so have they used different irrigation solutions. Different agents have been used as irrigation solutions in endodontic treatment. From the past to the present day, materials such as water, saline, oxidants, acids, chelation agents, proteolytic enzymes and alkaline solutions have been used at different concentrations.[20]

It has been said that irrigation agents alone are not sufficient to clean the smear layer which forms on the root canal surfaces and it has been reported that it is necessary for the irrigation agents used to clear both the organic and inorganic structures of the dentine. Therefore, while EDTA solution is recommended as an irrigation solution to demineralise the inorganic structure of the dentine, the use of NaOCl solution is suggested to resolve the organic structure of the dentine. The use of NaOCl alone results in an accumulation of inorganic matter residue being seen on the root canal surfaces and the use of EDTA alone has been determined to result in the root canal dentine not being resolved.[21,22]

While Niu et al recommend the use of NaOCl solution to resolve the organic matrix of the root canal dentine, they recommend EDTA irrigation solution for the demineralisation of the contents of the inorganic structure.[22]

In a study by Yamada et al, irrigation procedures were made with 17% EDTA solution and 10ml 5.25% NaOCl solution and the results of very good cleaning of the dentinal tubules were observed on SEM.[23]

In the current study, sodium hypochloride (NaOCl) was used as an irrigation solution as it has the property of being able to dissolve necrotic tissues in the organic structure of the dentine, has an antibacterial effect and is able to effectively clean the smear layer of the root canal walls. A concentration of 5.25% was preferred as tthat has been found to be the most effective concentration.

EDTA solution was used in this study as the adjunct irrigation solution as it demineralises the inorganic structure of the dentine, facilitates the cleaning of narrow canals and by showing a chelation effect with the calcium ions of the dentine, increases the effect of NaOCl.

The aim of irrigation techniques developed by present-day researchers is to increase the success rates of endodontic treatment by providing an effective irrigation of the root canal surfaces and thoroughly cleaning microorganisms on the surface, toxic substances, smear and debris residue.[24-26]

Therefore, by comparing the currently produced and developed irrigation techniques with the efficacy of irrigation agents in removing the smear layer of the root canals, an attempt is made to determine which is the ideal technique.

Three different irrigation techniques were used in the current study. These were the Ultrasonic Irrigation Technique, the Classic Irrigation Technique and the Endo-Vac Irrigation Technique. In addition to the classic irrigation technique which has been used since endodontic treatment started, the ultrasonic sysem and Endo-Vac systems were selected as they have

yielded very good results anda re stil being developed. With these techniques, smear and debris residue on the root canal surfaces are cleaned and the rates of surface cleaning have been determined. Thus the smear layer is removed from the surfaces which are able to be cleaned and the success of endodontic treatment is increased by a significant rate.

In a study by Xin-Hua Gu et al, it was reported that the teeth were cut 2mm above the enamel-cement border of the anatomic crown.[27] In the light of this information, the crown sections of all the teeth in the current study were cut with the long axis vertical, 2mm above the enamel – cement border with a diamond cutter and handpiece under water cooling. The lengths of the roots of the teeth were corrected to be approximately the same length. Thus, in this study, it was attempted to reduce any possible effect of variables associated with the size of the tooth.

In a study by Myers and Montgomery, the inside of the canal was washed with 2ml of solution before the shaping process of the root canals.[28] In the current study, after cleaning pulp residue in the canals with tirnerf, the canal entrance was opened witha Gates Glidden drill. For more effective use of the instruments for canal shaping, the root canals were wet with 2ml saline.

In the current study, only a Protaper was used as a rotating instrument in the canal shaping procedure. Thus, variations were avoided in the root canal widening and shaping procedures.

In a study by Nielsen et al, in which the newly-developed Endo-Vac irrigation system was used, the micro cannula was applied as far as 0.2mm of the apical foramen.[18] In the current study, to be able to clean the apical region effectively, the use of negative pressure in that region meant that there was no possibility of any irrigation agent passing from the apical so the tip of the micro cannula of the Endo-Vac device was used within 0.2mm of the apical.

Baumgartner et al researched the efficacy of 4 different irrigation agents on the smear layer using the normal classic irrigation technique. Examination on SEM determined that the irrigation agents gave effective results particularly on the mid and coronal sections of the teeth.[21]

In the current study, the intensity of the smear layer was examined in 3 different areas of the root canals. Using the classic irrigation technique with 17% EDTA and 5.25% NaOCl, less smear layer was observed particularly in the mid-section of the root canals. In other words, it was revealed that the irrigation technique with a normal dental injector cleaned particularly the mid-third of the tooth in a more efffective way.

Nielsen et al conducted a study using the recently-developed Endo-Vac irrigation technique. This new system which works with an apical negatie pressure system was reported to effectively clean the smear layer in the apical region of the root canals.[18]

In a study by Pranav and Van evaluating the reliability of different irrigation techniques, the Endo-Vac device was determined to be more reliable.[29]

Walker et al conducted irrigation procedures with ultrasonic devices and hand instruments on teeth with inclined canals. In that study, the ultrasonic device was determined to be most effective in the cleaning of the smear layer in the root canals.[30]

In a study by Mayer et al, an evaluation was made of the efficacy of the removal of smear and debris residue in the root canals with passive ultrasonic irrigation and syringe irrigation. No significant difference was determined between the two irrigation techniques.[1]

In the current study, the irrigation procedure made with the ultrasonic technique was found to be more successful in the coronal section of the canals. It was determined that smear residue in that area was more effectively cleaned.

Conclusion

When the results of this study are examined, the irrigation procedure made with the ultrasonic irrigation device was determined to be successful in the coronal third of the root canals. Less smear layer was observed in the mid-third section of the root canals after irrigation made with the traditional syringe technique.

In the irrigation made with Endo-Vac using the apical negative pressure system, successful results were obtained in the apical region of the root canals and it was determined to be more effective in the washing of the apical regions.

Declaration of Interest

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References

1. Mayer BE, Peters OA, Barbakow F: Effects of rotary instruments and ultrasonic irrigation on debris and smear layer scores: a scanning electron microscopic study. International Endodontic Journal, 2002; 35: 582–589.
2. Schilder H: Cleaning and shaping the root canal, Dent Clin Nort Am 1974: 269-296.
3. Bayırlı G: Kök kanallarının temizlenmesi ve şekillendirilmesi, İ.Ü. Basımevi ve Film Merkezi, İstanbul
4. Bayırlı G.: Pulpa patolojisi ve tedavileri, İ.Ü. Basımevi ve Film Merkezi, İstanbul 1991.
5. Stosk CJR, Gulabivala K, Walker R, Goodman JR: Color atlas and text of endodontics, 2 th Ed. Mosby C, 1995 :14-18.
6. Torabinejad, M., Handysides, R., Khademi, A.A., Bakland, L.K. Clinical implications of the smear layer in endodontics: a review. Oral Surgery Oral Medicine and Oral Pathology Oral Radiology and Endodontology, 2002; 94; 658- 666.
7. Jodaikin, A., Austin, J.C.: The effects of cavity smear layer removal on experimental marginal leakage around amalgam restorations. Journal of Dental Research, 1981; 60: 1861- 1866.
8. Mader, C.L., Baumgartner, J.C., Peters, D.D.: Scanning electron microscopic investigation of the smeared layer on root canal walls. Journal of Endodontics, 1984; 10: 477- 483.
9. Boyde, A., Knight, P.J.: Scanning electron microscope studies of the preparation of the embrasure walls of class II cavities. British Dental Journal, 1970; 129 : 557- 564.
10. McComb D., Smıth D.C.: A preliminary scanning electron microscope study of root canals after endodontic procedures, Journal of Endodontics, 1975; 1:238-242.
11. Gilboe, D.B., Svare, C.W., Thayer, K.E., Drennon, D.G.: Dentinal smearing: an investigation of the phenomenon. Journal of Prosthetic Dentistry, 1980; 44: 310- 316.
12. White, R.R., Goldman, M., Lin, P.S.: The influence of the smeared layer upon dentinal tubule penetration by endodontic filling materials. Part II. Journal of Endodontics, 1987; 13; 369-374.
13. Hand RE, Smıth ML, Harrıson JW: Analysis of the effect of dilution on the necrotic tissue dissolution property of sodium hypochlorite. J. Endod. 1978; 4: 60-64.
14. Weller, R.N., Brady, J.M., Bernier, W.E.: Efficacy of ultrasonic cleaning. Journal of Endodontics, 1980; 6: 740- 743.
15. Jensen SA, et al.: Comparison of the cleaning efficacy of passive sonic activation and passive ultrasonic.J Endod., 1979; 5: 735-738.
16. Cunningham WT, et al.: Evaluation of root canal debridement by the endosonic ultrasonic synergistic system. Oral Surg Oral Med Oral Pathol., 1982; 53: 401-404.
17. Guerisoli DMZ, et al.: Evaluatin of smear layer removel by EDTAC and sodium hypochlorite with ultrasonic agitation. Int Endod J., 2002; 35: 418-421.
18. Nielsen BA. Craig Baumgarther J,: Comparision of the Endo-Vac system to neddle irrigation of root canals. J Endod., 2007; 33: 611-615.
19. Takeda FH, et al.: Efficicacy of Er:YAG laser irradiation in removing debrs and smear layer on root canal walls. J Endod. 1998; 24: 548-551.
20. Harrison WJ: Irrigation of root canal system. Dent. Clin. Nort Am., 1984; 28: 797-808.
21. Baumgartner, J.C., Mader, C.L.: A scanning electron microscopic evaluation of four root canal irrigation regimens. Journal of Endodontics, 1987, 13: 147- 157.
22. Niu, W., Yoshioka, T., Kobayashi, C., Suda, H.: A scanning electron microscopic study of dentinal erosion by final irrigation with EDTA and NaOCl solutions. International Endodontic Journal, 2002; 35: 934- 939.
23. Yamada, R.S., Armas, A., Goldman, M., Lin, P.S.: A scanning electron microscopic comparison of a high volume final flush with several irrigating solutions: Part 3. Journal of Endodontics, 1983; 9: 137- 142.
24. L. W. M. van der Sluis, M.-K. Wu & P. R.: Wesselink A comparison between a smooth wire and a K-file in removing artificially placed dentine debris from root canals in resin blocks during ultrasonic irrigation International Endodontic Journal, 2005; 38: 593–596.
25. Michael Hfilsmann, Dr med dent, Claudia R~immelin, DDS, and Frank Schifers, Dr med dent.: Root Canal Cleanliness After Preparation with Different Endodontic Handpieces and Hand Instruments: A Comparative SEM Investigation J Endod., 1997; 23: 301-306
26. Ove A. Peters, Dr. Med Dent, and Fred Barbakow: Effects of Irrigation on Debris and Smear Layer on Canal Walls Prepared by Two Rotary Techniques: A Scanning Electron Microscopic Study J Endod., 2000; 25: 583-586
27. Xin-Hua Gu, Cai-Yun Mao, and Matthias Kern.: Effect of Different Irrigation on Smear Layer Removal after Post Space Preparation J Endod., 2009; 35: 6-10.
28. Myers GL, Montgomery S.: A comparision of weights of debris extruded apically by conventional filling and Canal Master techniques. J Endod., 1991; 17: 275-279.
29. Pranav D, Van H.: Comparative safety of various intracanal irrigation systems. J Endod., 2009; 35: 545-549.
30. Walker TL, del Rio CE.: Histological evaluatin of ultrasonic and sonic instrumentation of curved root canals. J Endod., 1989; 15: 49-59.