COMPARISON OF ROOT CANAL CLEANING EFFICACY BETWEEN SELF ADJUSTING FILE AND A ROTARY SINGLE FILE SYSTEM ALONG WITH TWO DIFFERENT ROOT CANAL IRRIGANTS BY SEM EVALUATION-AN IN VITRO STUDY.

A Dissertation submitted

in partial fulfillment of the

requirements for the degree of

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BRANCH – IV

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2012– 2015

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"COMPARISON OF ROOT CANAL CLEANING EFFICACY BETWEEN SELF ADJUSTING FILE AND A ROTARY SINGLE FILE SYSTEM ALONG WITH TWO DIFFERENT ROOT CANAL IRRIGANTS BY SEM EVALUATION - AN IN VITRO STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr.K.Amudhalakshmi M.D.S**, **Associate Professor,** Department Of Conservative Dentistry and Endodontics, TamilNadu Government Dental College and Hospital, Chennai - 600003.

DR.B.BAKTHAVATCHALAM

CERTIFICATE BY GUIDE

This is to certify that **Dr. B.BAKTHAVATCHALAM**, Post Graduate student (2012-2015) in the Department Of Conservative Dentistry and Endodontics, TamilNadu Government Dental College and Hospital, Chennai - 600003 has done this dissertation titled **"COMPARISON OF ROOT CANAL CLEANING EFFICACY BETWEEN SELF ADJUSTING FILE AND A ROTARY SINGLE FILE SYSTEM ALONG WITH TWO DIFFERENT ROOT CANAL IRRIGANTS BY SEM EVALUATION-AN IN VITRO STUDY"** under my direct guidance and supervision in partial fulfillment of the regulations laid down by the TamilNadu Dr.M.G.R Medical University, Chennai - 600032, for M.D.S., Conservative Dentistry and Endodontics (Branch IV) Degree Examination .

DR.K.AMUDHALAKSHMI, M.D.S.

Associate Professor & Guide

Department of Conservative Dentistry and Endodontics.

TamilNadu Government Dental College and Hospital

Chennai – 600003.

ENDORSEMENT BY HEAD OF THE DEPARTMENT / HEAD OF THE INSTITUTION

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Dr.M.Kavitha M.D.S.,
Professor & H.O.D.,
Department of Conservative Dentistry & Endodontics .

Dr.S. Premkumar M.D.S.,
Principal I/C

TamilNadu Government Dental College and Hospital.
Chennai- 600003.

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DECLARATION

TITLE OF DISSERTATION	**"COMPARISON OF ROOT CANAL CLEANING EFFICACY BETWEEN SELF ADJUSTING FILE AND A ROTARY SINGLE FILE SYSTEM ALONG WITH TWO DIFFERENT ROOT CANAL IRRIGANTS BY SEM EVALUATION- AN IN VITRO STUDY"**
PLACE OF THE STUDY	**Tamil Nadu Government Dental college & Hospital, Chennai – 3.**
DURATION OF THE COURSE	**3 years**
NAME OF THE GUIDE	**Dr.K.Amudhalakshmi .**
HEAD OF THE DEPARTMENT	**DR. M. Kavitha.**

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This agreement herein after the "Agreement" is entered into on this day Dec 2014 between the Tamil Nadu Government Dental College and Hospital represented by its **Principal** having address at Tamil Nadu Government Dental College and Hospital, Chennai - 600 003, (hereafter referred to as, 'the college')

And

Mrs. Dr. K.Amudhalakshmi M.D.S aged 45 years working as **Associate Professor** in Department of Conservative Dentistry & Endodontics at the college, having residence address at AE 86-7th street,Tenth Main Road, Anna Nagar ,Chennai – 40 ('herein after referred to as the Principal Investigator')

And

Mr. Dr. B.Bakthavatchalam aged 37 years currently studying as **Post Graduate student** in Department of Conservtive Dentistry & Endodontics, Tamilnadu Government Dental College and Hospital, Chennai 3 ('herein after referred to as the PG student and co investigator').

Whereas the PG student as part of her curriculum undertakes to research on **" COMPARISON OF ROOT CANAL CLEANING EFFICACY BETWEEN SELF ADJUSTING FILE AND A ROTARY SINGLE FILE SYSTEM ALONG WITH TWO DIFFERENT ROOT CANAL IRRIGANTS BY SEM EVALUATION- AN IN VITRO STUDY "** for which purpose the Principal Investigator shall act as principal investigator and the college shall provide the requisite infrastructure based on availability and also provide facility to the PG student as to the extent possible as a Co-investigator.

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In witness where of the parties hereinabove mentioned have on this day, month and year herein above mentioned set their hands to this agreement in the presence of the following two witnesses.

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Witnesses **Student Guide**

1.

2.

ABSTRACT

Aim:

The aim of this study was to compare the root canal cleaning efficacy between Self Adjusting File and a Wave One File system along with two different root canal irrigants by SEM evaluation.

Materials and methods:

The study samples comprised of 50 recently extracted intact, non-carious, human mandibular premolars. Endodontic access cavity were prepared, working length was determined and assigned to five groups of ten specimens each (n=10). The root canals were prepared in each group as follows In Group 1 up to #30 size K file with saline, Group 2. SAF file with NaOCl . Group 3 SAF file used with QMix.Group 4 Primary Wave One file was used with NaOCl and Group 5 Primary Wave One file along with QMix . The crowns were decoronated with diamond disc at the cemento–enamel junction. Deep grooves were cut on the centre of each root both on the buccal and lingual surfaces. The roots were longitudinally split into two halves along the groove with chisel and mallet. One half of each tooth was selected and prepared for SEM examination.

Results:

Group 3(SAF with QMix) , followed by Group 5(Wave One with Q Mix) had statistically significant cleaned canal walls compared to other groups. The Group 5 differs from Group 3, which had statistically significant more amount of debris and homogeneously covered smear layer in the Apical third.In Group 2 and Group 4 more than 50% of the root canal walls were covered with debris and complete coverage of dentinal tubules by smear layer were evident at all the thirds.

Conclusion :

The SAF, operated with continuous flow of QMix resulted in root canals that were free of debris and almost completely free of the smear layer at coronal, middle and apical thirds. When operated with sodium hypochlorite ,SAF resulted in superficially debris free canals and has smear layer in all thirds. Wave One gives similar results with these irrigants as SAF in coronal and middle thirds but it has least cleaning efficacy at the apical third.

Key Words:

Self Adjusting Files, Wave One , QMix.

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ABBREVIATIONS

SAF	Self Adjusting File
Ni-Ti	Nickel Titanium
EDTA	Ethylene Diamine Tetra Acetic Acid
PCA	Para-Chloroaniline
MTAD	Mixture Of Tetracycline,Acid, and Detergent**.**
CHX	Chlorhexidine
SEM	Scanning Electron Microscope
CLSM	Confocal Laser Scanning Microscope
TOF-SIMS	Time-Of- Flight Secondary Ion Mass Spectrometry

CONTENTS

Introduction

INTRODUCTION

Endodontic therapy involves elimination of microbes in root canal system and avoid its recontamination which is done by proper cleaning , shaping ,and filling inert materials. This can be achieved by proper chemo-mechanical preparation. The endodontic files are used for cleaning and shaping the root canal.

Whenever dentine is cut using hand or rotary instruments, the mineralized tissues are not shredded or cleaved but shattered to produce considerable quantities of debris. Debris is defined as dentin chips and residual vital or necrotic pulp tissue attached to the root canal wall. Much of this, made up of very small particles of mineralized collagen matrix, is spread over the surface to form what is called the Smear Layer. It is a surface film approximately 1 to 2 μm of dentin particles, residual pulp tissue, and bacterial components that remain on the root canal wall after mechanical instrumentation.

Though rotary and hand files were used to prepare the root canals, a considerable amount of debris always remain in the canals. Complete debridement and removal of smear layer was still a challenging task. This was overcome by the recently introduced rotary Nickel-Titanium files, WaveOne and Self Adjusting Files (SAF) which are claimed to completely debride and clean the root canals.

Wave One files was first introduced in 2010 by Dentsply Maillefer . It is a prepackaged, pre-sterilized, single-use system indicated to shape the root canal[62]. They

were made of a special Nickel-Titanium (NiTi)alloy called M-Wire that is created by thermal-treatment process. The advantage of this M-Wire NiTi are increased flexibility of the instruments and improved resistance to cyclic fatigue[50]. These files are used in a reciprocal motion that requires special automated devices.

Different from the other NiTi rotary files, a new instrumentation and irrigation device, the SAF system, was introduced by ReDent-Nova[32]. This system uses a hollow files which allows for simultaneous irrigation throughout the mechanical preparation. When inserted into the root canal, it is capable of adapting itself to the canal shape three dimensionally. The instrument is used in a transline (in-and-out) motion and the abrasive surface of the lattice threads promotes a uniform removal of dentin .

It was impossible to create a sterile space in infected root canals with mechanical preparation alone because of the complexity of root canal systems [8]. Pulp tissue remnants and inorganic debris remain in well-shaped canals, especially in those areas where the instruments were not in contact. The amount of residual tissues was more in canals that were treated without irrigation than those in which root canal irrigants were used .Hence the irrigants were essential for successful debridement of the root canals after mechanical preparation[61].

A large number of substances have been used as root canal irrigants, including acids (Citric and Phosphoric), Chelating Agent (EDTA), Proteolytic Enzymes, Alkaline Solutions (Sodium Hypochlorite, Sodium Hydroxide, Urea, and Potassium Hydroxide), Oxidative Agents (Hydrogen Peroxide and Gly-Oxide), Local Anesthetic Solutions, and

Normal Saline[3]. All the irrigants have their own limitations and therefore the search for an ideal root canal irrigant continues with the development of newer materials.

Newer root canal irrigants in the horizon are MTAD, Tetraclean, Q Mix, Electrochemically Activated Solutions, Ozonated Water, Photon Activated Disinfection, and Herbal irrigants [58].

Among these, Q Mix (Dentsply Tulsa Dental Specialties) is a 2 in 1 endodontic irrigant for smear layer removal with added antimicrobial agents[11]. It contains EDTA, Chlorhexidine and a detergent. It is a clear solution, ready to use with no chair-side mixing. Sodium Hypochlorite (NaOCl) is used as a gold standard root canal irrigant for past 80 years in endodontics .Therefore we are using these irrigants in our study .

There are very limited studies available in literature on the cleaning efficacy of Wave One and Self Adjusting File System along with Q Mix as a irrigating solution .

Hence the purpose of this study is, to compare the cleaning efficacy between Self Adjusting File and Rotary Single File System (Wave One) along with two different root canal irrigants(QMix, NaOCl) by Scanning Electron Microscope (SEM).

Aim And Objectives

AIM AND OBJECTIVES

Aim

The aim of this study was to compare the root canal cleaning efficacy between Self Adjusting File and a Wave One File system along with two different root canal irrigants by SEM evaluation.

Objectives

The objectives of this study were

1. To evaluate the cleaning efficacy of Self Adjusting File System with Sodium Hypochlorite and Q mix as irrigants by SEM images.

2. To evaluate the cleaning efficacy of Wave One single file system with Sodium Hypochlorite and Q mix as irrigants by SEM images.

3. To compare the cleaning efficacy of Self Adjusting File system and Wave One file system using Sodium Hypochlorite and Q mix as irrigants by SEM images for presence of Debris and Smear Layer on Coronal, Middle and Apical third of the root canals at 200X and 1000X magnifications respectively by Hulsmann scores.

Review Of Literature

REVIEW OF LITERATURE

Mechanical Preparation of the root canal system is one of the most important step in root canal treatment . A vast array of instruments, both hand held and engine-driven, are available for root canal preparation. Edward Maynard has been credited with the development of the first endodontic hand instruments. In 1915 the K-files were introduced. The first description of the use of rotary devices seems to have been by Oltramare. Since the early 1990s, several rotary instrument systems manufactured from nickel-titanium (NiTi) have been introduced. The ProFile system (Dentsply Tulsa Dental) was introduced by Dr.Ben Johnson in 1994. The Greater Taper file was introduced by Dr. Steve Buchanan in 1994 . ProTaper Universal system designed by Dr. Cliff Ruddle, Dr.John West, and Dr. Pierre Machtou in 2003 . The RaCe file system has been manufactured since 1999 by FKG and Wastler. In 2008, Sybron Endo presented the first fluted NiTi file. In 2010 Dentsply and VDW companies introduced 2 new Ni-Ti systems, Wave-one & Reciproc. Different from the other NiTi rotary files, a new instrumentation and irrigation device, the SAF system was introduced by Re Dent Nova in 2010.

Wave One – File System

Burklein S et al (2012)[6] compared ability of shaping and cleaning of two reciprocating single-file systems with Mtwo and ProTaper rotary instruments in the preparation of curved canals in extracted teeth. Root Canals were prepared to the following apical sizes: Mtwo: # 35, using the single-length technique; ProTaper: F3 instruments were used in a modified crown-down method ; Reciproc and WaveOne upto

#25 size . With pre- and post-instrumentation radiographs, straightening of the root canal curvatures was evaluated with a computer image analysis program. They concluded that all instruments maintained the original root canal curvature well and the were safe to use. The Mtwo and Reciproc instruments resulted in better root canal cleanliness in the apical part of the canal compared with ProTaper and WaveOne.

Sebastian Beurklein, et al (2012) [47] assessed the amount of debris extruding apically using rotary and reciprocating Ni-Ti instrumentation systems.irrigant used was distilled water. The debris extruding apically was collected in pre weighted glass vials by using the Myers and Montgomery method. The mean weight of debris was evaluated with a microbalance .They concluded that apical debris was extruded apically in all systems but Full-sequence rotary instrumentation was associated with minimal amount of debris extruding out when compared with reciprocating single file systems.

Ghassan Yared et al (2013) [18] developed engine driven single file reciprocation for the preparation of curved root canals .An F 2 pro taper instrument was used with unequal clockwise and counter clock wise reciprocating movements.Dentsply (2010) introduced two single file rotational systems i)reciproc ii) wave one . The motor in both instruments have reciprocation movement. As the angles of rotation are un equal ,torsional stress would be reduced .the advantages of single file system includes(i) working time was short (ii) learning curve also was short. iii) less number of instruments were needed to obtain a desired shape (iv) very safe in concerning instrument fracture and procedural errors .

Paula Amaral et al [39] assessed that the smear layer was present after root canal instrumentation with two reciprocating rotary systems such as Reciproc and WaveOne with a continuous motion one . Thirty canals were shaped with Reciproc, WaveOne or Mtwo systems. Smear layer was assessed following a three value scale at coronal, middle and apical levels with a scanning electron microscopy. They concluded that the three root canal preparation techniques , Mtwo, WaveOne and Reciproc, are effective in removal of smear layer mainly in the middle and coronal thirds whereas smear layer present apically.

Self Adjusting File System

Metzger. Z et al (2010) [32] introduced a new concept, the self-adjusting file and its unique features and compared with rotary nickel-titanium file systems. The self adjusting file is hollow and it is designed as a thin cylindrical Ni- Ti lattice which adapts to the cross-section of the canal. A single rotary file is used throughout the procedure. It is inserted into a glide path initially which was prepared by a # 20 K-file , operated with trans-line vibratory motion . It resulted in circumferential pressure and allowed SAF file's abrasive surface to remove a thin uniform hard-tissue layer from the entire canal surface. This results in a root canal with a similar cross-section and larger dimensions. This is also applicable for root canals with an oval or flat cross-section. The straightening of curved root canals is also reduced because of the high pliability of the SAF file and the absence of a rigid core. Thus, the original shape of the canal is respected both longitudinally and in cross-section. The hollow file is operated with a continuous flow of irrigant that enters the full length of the root canal and was activated by the vibration and

was replaced continuously .This results in cleaning even at apical part of the root canal. The file has high mechanical endurance; SAF file separation does not occur. Thus they concluded that the self adjusting file represents a new step forward in endodontic file development.

Metzger.Z et al (2010)[33] evaluated the cleaning ability of the Self-Adjusting File system in terms of debris and smear layer removal. Sodium hypochlorite (3%) and EDTA (17%) were used as continuous irrigant solutions .The debris and a smear layer present coronally, middle and apically were examined through the analysis of the Scanning electron microscopy images using Hulsmann five-score evaluation system . They concluded that the operation of the self adjusting file system with continuous irrigation along with alternating sodium hypochlorite and EDTA resulted in a clean and mostly smear layer-free dentinal surface in all parts of the canal.

Hof .R. V. Perevalov et al (2010)[21] made a study on the mechanical properties of the self-adjusting file (SAF) and its application in the root canal using continuous irrigation. The compressibility of the SAF file and the resulting peripheral force were measured using specially designed systems. The abrasivity of the file was tested on dentin blocks representing a flat root canal. The durability of the SAF file was tested using a functional fatigue-to-failure assay. Degradation of the file was evaluated by using files that were previously used for 10, 20, and 30 minutes and comparing their efficacy with that of new, unused files. The potential of extruding irrigant beyond the apex was explored in roots with an open apical foramen. They concluded that the self adjusting file

is an elastically compressible file that removes dentin effectively and can mechanically endure use under its recommended operation with a minimal loss of efficacy.

Versiani M.A.et.al (2011)[59] evaluated the canal preparation in flat-oval root canals treated with either rotary or self-adjusting file by microtomography analysis and concluded that in the coronal third , mean increases of area and volume of the root canal as well as the percentage of prepared canal walls were significantly higher with self adjusting file than with rotary instrumentation. By using Self Adjusting Files , flat-oval canals were circumferentially prepared and was homogenous. The size of the self adjusting file preparation in the apical third of the root canal was equivalent to those prepared using #40 rotary file having 0.02 taper.

Solomonov .M (2011)[55] used SAF system to treat more than 50 cases over the prior eight months. Clinical cases prepared with the SAF system was first presented and described a clinical classification of root canals, according to their difficulty. They concluded that Clinical classification of root canal difficulty makes treatment sequences with the self adjusting file system relatively simple and predictable. All types of cases can be treated with the SAF system .

Metzger.Z (2011)[34] stated 3D cleaning, shaping and obturation of canals are the desired goal of root canal treatment . The introduction of NiTi files made a major change in endodontic practice .Over 16 years of intensive development, most of these instruments have drawbacks, the major being the inability to three-dimensionally prepare oval canals. The Self-Adjusting File System was designed to overcome drawbacks of

rotary file systems. The 3D scrubbing effect of the SAF file, combined with the fresh irrigant, result in clean canals which facilitate in turn better obturation.

Paqué F et.al (2011)[40] studied the shaping potential of a novel Ni-Ti instrument, the self-adjusting file, in long oval canals in distal roots of mandibular molars. Twenty mandibular molars with long oval distal root canals were selected and scanned preoperatively and postoperatively by using micro–computed tomography at an original resolution of 20 mm. Canals were shaped with the SAF, three-dimensionally reconstructed, and evaluated for volume, surface area, canal transportation, and prepared surface. Data were statistically contrasted by using paired t tests and regression analysis. The authors concluded that in vitro, preparation of long oval-shaped canals of mandibular molars with the self adjusting file was effective and safe. The shapes generated with the self adjusting file were more complete compared with other rotary canal preparation.

Adiguzel et.al (2011)[1] investigated the cleaning ability of a self-adjusting file system regarding debris and removal of smear layer using EDTA or MTAD and concluded that when using self adjusting file , the protocols used were effective for debridement for all regions of the canal even for the apical thirds.

Kaya.S et al (2011)[26] evaluated Self-Adjusting File in smear layer removal and impact on the dentin surface using sodium hypochlorite as an initial irrigant at three different concentrations combined with 1% EDTA. The erosive effect of this dual irrigation regime was evaluated.the author concluded that by using the self adjusting file with continuous irrigation and vibration, lower concentrations of sodium hypochlorite

and EDTA can be advised for efficient smear layer removal even in the apical thirds and avoid excessive erosion of dentin.

De-Deus.G et al (2011)[12] evaluated the debridement quality of the Self-Adjusting File system in oval canals and compared with the debridement achieved by NiTi rotary system which was commonly used. Oval-shaped root canals present a challenge for rotary nickel-titanium files because buccal or lingual recesses are left un-instrumented. They concluded that the self adjusting file system protocol was significantly more efficient for debridement of oval canals than the rotary ProTaper protocol.

Yigit-Ozer.S,et al (2011)[65] analysed the debridement potential of a novel system, self adjusting file system and its special irrigation device in curved canals. Debridement of the canal is mandatory and it is done by means of chemo-mechanical instrumentation and irrigation methods. 30 mesiobuccal root canals of maxillary molars were instrumented using SAF. Teeth were divided into three groups. In Group 1, 10 new SAF files were used for operation for 4 minutes. In Group 2, the 4-min previously used SAF files were operated in the same manner. In Group 3, the 8-min previously used SAF files were operated. During SAF operation 2.6 % NaOCl and 17 % EDTA were used alternately in all groups. Debris and smear layer removal were evaluated for the apical thirds under scanning electron microscope. Debris and removal of smear layer were examined for the apical thirds under SEM. They arrived to a conclusion that when self adjusting file is operated in curved canals with continuous flow of irrigation results in debris and smear-free canal walls in the critical apical thirds of the canal within 12 minutes.

Burroughs J.R et.al (2012)[7] made a study to determine the shaping ability of three nickel-titanium (NiTi) endodontic file systems by measuring root canal transportation .Seventy two S-shaped canals in resin blocks were randomly put into three groups. (i)the Self-Adjusting File group,(ii) the Typhoon group (iii)the Vortex group. The results showed the mean transportation was significantly higher for the Typhoon ($P < .001$) and Vortex ($P = .005$) groups compared with the SAF group.

Solomonov .M, F et. al (2012)[56] compared the efficacy of the SAF , in shaping C-shaped canals with that of the ProTaper rotary file system . Sixteen mandibular second molars and 4 maxillary second molars with C-shaped canals were obtained, originating from native Chinese population. They were divided into 2 equal groups of 10 teeth each, based on similar canal morphology as presented in preliminary micro–computed tomography–derived images. One group was shaped using the SAF, whereas the other was shaped using the ProTaper file system. Reconstructed micro–computed tomographic images before and after treatment were superimposed over each other and the percentage of the canal wall unaffected by the procedure was calculated. Comparison of the 2 groups for this parameter was performed using the Student t test. They concluded that the self adjusting file was more effective than the rotary ProTaper file system in shaping the walls of C-shaped canals.

Dietrich.M.A et. al (2012)[14] compared the effectiveness of debris removal between the Self-Adjusting File, Wave One, and K3 file systems in the mesial roots of mandibular molars. In addition, the self adjusting file was tested as an adjunct after instrumentation with other systems and concluded that there was no differences in root

canal cleanliness between the three file systems; however, the self adjusting files and K3 files performed better than the Wave One in isthmus cleaning . When used as a adjunct for final irrigation after instrumentation, the self adjusting file provided a significant improvement in a subset of the K3 group only**.**

Paqué .F, et. al (2012)[41] evaluated the accumulation of hard-tissue debris when using the Self-adjusting File system in mesial roots of mandibular molars containing isthmuses and comparing it with that occurring when the ProTaper file system was used along with sodium hypocholorite as irrigant .It was concluded that preparation with the Self adjusting file system resulted in minimal hard-tissue debris accumulation in isthmus-containing canal systems when compared with instrumentation with ProTaper files.

Metzger . Z, A. Kfir,et.al (2013) [35] demonstrated a new concept of minimally invasive endodontics by the new SAF technology.All the oldest and the newest systems use the principle of a rotating blade with flutes, provide adequate results in straight, narrow canals with round cross sections, but has limitations in oval or curved canals. This limitation is overcome by The Self-Adjusting File (SAF) system.

De Melo Ribeiro M.V et. al (2013)[13] evaluated the tissue debridement efficacy of the self-adjusting file protocol in the apical third of oval-shaped root canals of mandibular incisors in comparison with a Ni-Ti rotary system preparation and concluded that self adjusting file had significantly more contact to the root dentin walls and removed

more debris than other rotary instrumentation in the apical third of the mandibular incisors.

Ruckman et. al (2013) [46] compared the canal debridement ability of the self-adjusting file with ProFile rotary and hand filing instrumentation in long-oval–shaped root canals. Root Canals were filled with a radiopaque contrast material (Vitapex) and instrumented by using self-adjusting file, ProFile rotary and hand files with 20 ml of saline irrigation. Preoperative and postoperative radiographs were obtained and submitted to digital subtraction method and the percentage reduction of contrast medium was evaluated .It was concluded that all three techniques removed contrast medium equally well from the 0-to 5-mm segment of long oval–shaped root canals. The self adjusting file performed better than hand filing in the >5-to 10-mm root canal segment.

Sodium Hypochlorite

Bystrom et. al (1983)[9] investigated in vivo that the antibacterial effectiveness of 0.5% sodium hypochlorite on 15 single-rooted teeth. Each tooth was treated at 5 session and the presence of bacteria in the root canal was studied on each session . Antibacterial intracanal dressings were not used between the sessions. They concluded that when 0.5% NaOCl was used, no bacteria was seen from twelve of fifteen canals at the fifth session.

Siqueira et al (1997)[51] assessed the effectiveness of 4% NaOCl against Enterococcus faecalis in vitro and stated that it was significantly more effective than saline solution in disinfecting the root canal.

Siqueira et al (1998)[52] evaluated the antibacterial activity of 4% NaOCl; 2.5% NaOCl; 2% CHX; 0.2% CHX, EDTA, and citric acid; and 0.5% NaOCl irrigating solutions against 4 black-pigmented anaerobic bacteria and 4 facultative bacteria through Agar Diffusion Test . Their findings showed that the anti bacterial effect of 4% NaOCl and 2.5% NaOCl was relatively greater than other tested agents.

Gomes et al (2001)[19] demonstrated the effectiveness of 5 concentrations of NaOCl (0.5%, 1%, 2.5%, 4% and 5.25%) and 2 forms of chlorhexidine gluconate (gel and liquid) in 3 concentrations (0.2%, 1% and 2%) in the killing of E. faecalis. They found that all irriganting solutions were effective in eliminating E. faecalis, but at various times. Chlorhexidine in the liquid form was tested at all concentrations (0.2%, 1% and 2%) and NaOCI (5.25%) were the most effective irrigating solution.

Prabhu SG et al (2003)[43] compared the ability of maleic acid in different concentrations of sodium hypochlorite and EDTA in the smear layer removal formed along the root canal walls after chemo mechanical preparation. 60 freshly extracted maxillary incisors were divided into six groups and canals were prepared with step back technique, using different irrigating solutions namely, 5%, 7%, 10% and 15% maleic acid, 5.25% sodium hypochlorite and 17% EDTA. The teeth were then splitted and the root canal surfaces were viewed under SEM for smear layer removal. The results showed that sodium hypochlorite failed to remove the smear layer. Smear layer removing ability of maleic acid was better than EDTA.

Ercan et al. (2004)[16] examined the antibacterial efficacy of 2% chlorhexidine and 5.25% sodium hypochlorite as root canal irrigating solutions. Their findings concluded that both irrigants were significantly effective in eliminating the microorganisms from either necrotic pulp tissue or periapical lesions or both.

Vianna et al. (2006)[60] evaluated the degree of microbial elimination after chemo-mechanical preparation of root canals containing necrotic pulp, when using sodium hypochlorite solution or chlorhexidine gel with real-time quantitative-polymerase chain reaction and culture techniques. They concluded by using the identification techniques, the bacterial elimination in the sodium hypochlorite group was greater than in the chlorhexidine group.

Berber et al. (2006)[4] investigated the efficacy of 0.5%, 2.5% and 5.25% sodium hypochlorite as intracanal irrigating solution, associated with hand files and rotary instrumentation techniques. They are tested against *E.* faecalis within the canals and the dentinal tubules. They found that 5.25% concentration of NaOCl was the most effective irrigant followed by 2.5% concentration of NaOCl.

Oliveira et al (2007)[37] compared the efficacy of two different concentrations of sodium hypochlorite (5.25% and 1.5%) with 2% chlorhexidine gel against *E.*faecalis. They concluded that 5.25% of sodium hypochlorite and 2% chlorhexidine gel had a very good potential to keep CFU count of E. faecalis immediately and seven days after instrumentation, whereas 1.5% sodium hypochlorite reduced the *E.* faecalis *count* only after instrumentation.

Siqueira et al (2007)[54] studied the effectiveness of 2.5% sodium hypochlorite and 0.12% chlorhexidine as irrigating solutions in eliminating bacteria in infected root canals of teeth with apical periodontitis. Their study concluded that chemo-mechanical preparation using either irrigants substantially reduced bacterial population in the canals. There was no significant differences between the sodium hypochlorite and chlorhexidine groups in concern with number of cases producing negative cultures or quantitative bacterial elimination.

Zand V et al (2010) [67] studied the efficacy of gel and solution forms of sodium hypochlorite in smear layer removal from root canal walls. They concluded that the use of sodium hypochlorite gel can be as effective as sodium hypochlorite solution used with EDTA in removal of smear layer in the three parts of canal walls.

Flavio R.F. Alves et al (2011) [17] studied the time dependent ability of the self-adjusting file used with either of two sodium hypochlorite concentrations to reduce bacterial counts in long oval root canals. The study concluded that the Self Adjusting File promoted a marked reduction in bacterial counts even after only 2 minutes regardless of the sodium hypochlorite concentration. The most promising results were obtained after a 6-minute operation of SAF .

Luiz Fernando Machado Silveira et al (2013)[28] compared with scanning electron microscopy, the cleaning efficacy of a 2.5% sodium hypochlorite and a 17% EDTA solution with the 2 solutions either used alternately or mixed together for removal of smear layer after the use of each endodontic file in different root canal thirds. They

concluded that the alternate or mixed use of Ethylene Diamine Tetra-Acetic acid during instrumentation with 2.5% NaOCl was the most effective form of irrigation for smear layer removal on the cervical and middle thirds of the canal. No irrigant was sufficiently effective for the removal of the smear layer in the apical third.

QMix

Dai et al (2011)[11] examined the ability of 2 versions of QMix, an new anti microbial endodontic irrigant, on removal of root canal wall smear layers and debris using an open canal design.Cleaned and shaped single-rooted root canals were irrigated with sodium hypochlorite (NaOCl) as the initial irrigant and one of the following as the final irrigant: (1) QMix I (pH = 8), (2) QMix II (pH = 7.5), (3) Distilled water, (4) 17% EDTA, and (5) BioPure MTAD. Smear and debris scores were evaluated in scanning electron microscopy. They concluded within the limitations of an open-canal design, the 2 experimental QMix versions are as effective as 17% EDTA in removing root canal wall smear layers after the use of 5.25% Sodium Hypochlorite as the initial rinse.

Stojicic S et al (2012) [57] assessed in a laboratory experimental model that the efficacy of a root canal irrigant, QMix, against E. faecalis and mixed plaque bacteria in biofilms and planktonic phase, in addition, its ability to smear layer removal was examined. E faecalis and mixed plaque bacteria were exposed to QMix, 2% chlorhexidine , MTAD and 1% sodium hypochlorite (NaOCl) for 5 s, 30 s and 3 min. Following exposure, samples were taken, serially diluted and grown aerobically and anaerobically on tryptic soy agar (TSA) plates or on blood agar plates for 24 and 72 h,

respectively, to measure killing of bacteria. E. faecalis and plaque biofilms were grown for 3 weeks on collagen-coated hydroxyapatite or dentine discs and exposed for 1 and 3 min to QMix 2% CHX, MTAD, 1% and 2% NaOCl. The amount of killed bacteria in biofilms was analysed by confocal laser scanning microscopy using viability staining. Dentine blocks were exposed to QMix and 17% EDTA for 5 min. The effectiveness of smear layer removal by the solution was evaluated using scanning electron microscopy. For statistical analysis, one-way analysis of variance and comparison of two proportions were used.They concluded QMix and sodium hypochlorite were superior to chlorhexidine and MTAD in killing E. faecalis and plaque bacteria in biofilm culture. They concluded that the ability of smear layer removal by QMix was comparable to EDTA.

Wang et al (2013)[63] studied the effect of the presence of smear layer and the antibacterial effect of different disinfecting irrigating solutions in infected dentinal tubules. They concluded that the presence of smear layer reduces the effectiveness of disinfecting agents against Enterococcus faecalis in infected dentin. Solutions containing 6% sodium hypocholorite and/or QMix showed the highest antibacterial activity.

Eliot. c et al (2014)[15] evaluated the effectiveness over application time of different formulations of a new endodontic irrigant (QMix 2in1) consisting of a poly amino carboxylic acid chelating agent, a bisbiguanide which was an antimicrobial agent, surfactant and deionized water to remove the root canal smear layer and expose patent dentinal tubules QMix formulations were superior to EDTA in removal of smear layer and exposure of dentinal tubules in the canal system in single-rooted teeth.

Kamil P et al (2014)[25] analysed precipitate formation on the surface and in the tubules of dentin irrigated with Sodium Hypochlorite and a final rinse of Chlorhexidine or QMix. Dentin blocks were obtained from human maxillary molars, embedded in resin, and cross-sectioned to expose dentin. Specimens in group 1 were immersed in 2.5% NaOCl, followed by 17% EDTA, 2.5% NaOCl, and 2% CHx. Specimens in group 2 were immersed in 2.5% NaOCl, followed by saline and QMix. The dentin surfaces were subjected to TOF-SIMS spectra analysis. Longitudinal sections of dentin blocks were then exposed and subjected to Time-Of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) analysis. All samples and analysis were performed in triplicate for confirmation. They concluded para-chloroaniline (PCA)containing precipitate was formed on the surface and in the tubules of dentin irrigated with NaOCl followed by CHX. No precipitate or PCA was detected in the tubules of dentin irrigated with NaOCl followed by saline and QMix.

Materials And Methods

MATERIALS AND METHODS

Armamentarium For Specimen Preparation

- High speed airotor handpiece (NSK Japan)
- Round diamond bur (BR 31 ,Mani corporation,
- Endo access diamond bur (# 2 size , Densply Maillefer, Switzerland)
- Safe ended bur (EX 24 ,TC Endo Z bur, Densply Maillefer, Switzerland)
- Broaches (Mani Prime Dental Pvt .Ltd.)
- Reamers (Mani Prime Dental Pvt .Ltd.)
- K Files (Mani Prime Dental Pvt .Ltd.)
- Gates glidden drill (Densply Maillefer, Switzerland)
- Impression compound(Harvard Dental International,Germany).
- Self Adjusting File System (Redent Nova –Israel)
    i. RDT3 Head.
    ii. E type connector for NSK Micromotor contra angle Handpiece .
    iii. Contra Angle Handpiece (NSK Japan)
    iv. VATEA Irrigation System with Timer.
    v. Disposable Silicon tubes.
    vi. Self adjusting files #1.5 mm.

- Wave One (Dentsply Maillefer Ballaigues Switzerland)
    i. X Mart plus endo motor.
    ii. Wave One 6:1 reduction gear handpiece
    iii. Wave One Primary files (25/0.08)
- Q Mix 2 in 1 irrigating solution(Dentsply Tulsa Dental Specialties)
- 3% Sodium Hypochlorite (Prime dental products Pvt Ltd)
- Canal irrigating syringes with 27 gauge needles(Prime Dental Products pvt Ltd).
- Absorbent Paper Points (Densply Maillefer ,Switzerland)
- Wheel diamond bur with Mandrel.
- Chisel and Mallet.
- Adhesive tape.
- Micromotor (Marathon ,Korea)
- Straight Hand Piece (NSK Japan)

For Imaging Of Debris And Smear Layer

1. Ion sputter (Hitachi E 1010)
2. Scanning Electron Microscopy (HTAC -I S 3400 N)

METHODOLOGY

Fifty recently extracted, intact non carious mandibular premolar teeth were selected and stored in 10% buffered formalin(Fig-8) until the study was done. Each tooth was Radiovisuographed (RVG)(Fig-9) in buccolingual and mesiodistal projections to evaluate the shape of the root canal and to detect any obstruction. The root canal curvature was determined by Schneider's method. The tooth with straight root canal $<5^{o}$ angle were included in this study. Apical foramen of all selected teeth were sealed from outside using an Impression Compound .Endodontic access cavity was prepared using a high speed airotor hand piece with round Diamond Bur and Endo Access Bur. The pulp tissue was removed with Barbed Broaches and the root canals were negotiated with #10 Kfile. The working length was determined to be 1 mm short of the apical foramen. Then the teeth were randomly divided into 5 groups (Fig-10) of 10 teeth each (n=10).

Control group

Group 1

The root canals were prepared upto #30 size K file by Step Back method. Irrigation was done with saline using canal irrigating syringes during instrumentation.

Experimental group

Group 2

The coronal orifice of the root canals were enlarged with # 3 gates glidden drill. The glide path was established up to # 20 K-file according to manufacturer's instructions. It was checked by inserting SAF file # 1.5 manually to the established working length.

This file was used for cleaning and shaping the root canals. The RDT3 head for SAF file was fitted to the NSK contra angle handpiece with E type connector. This was connected to a micromotor working with a speed of 4000-5000 rpm. The flow rate of 4ml/min was set in the VATEA irrigation device which contains Sodium Hypochlorite solution and was connected to the file with Disposable Silicon tube. The file was gently inserted in the root canal and operated by in-and-out vibrations. Instrumentation was done for 4 minutes with 3% Sodium Hypochlorite as irrigant continuously during the procedure.

Group 3

The same procedure was followed as in group 2 except the irrigant. Here Q Mix was used as irrigating solution instead of Sodium Hypochlorite.

Group 4

A glide path was established by # 10 K-file according to manufacturer's guidelines .The X - Mart plus endomotor with 6:1 reduction gear hand piece was pre programmed in reciprocating mode for wave one files. Primary Wave One file (#0.25.08) was used for cleaning and shaping. The file was operated by inward pecking motion with short 2-3 mm amplitude strokes passively up to the determined working length. Irrigation was done with 3 % Sodium Hypochlorite using irrigating syringes.

Group 5

The procedure was followed similar to group 4 except the irrigating solution. Instead of Sodium Hypochlorite, Q Mix was used as an irrigant.

The 50 specimens were dried with absorbent paper points .A sterile paper point was kept inside each root canal. The crowns were decoronated with diamond disc at the cemento-enamel junction and their orifices were closed by a piece of adhesive tape[36]. Deep grooves were cut on the centre of each root both on the buccal and lingual surfaces, without perforating the root canal.The roots were longitudinally split into two halves (Fig-11) along the groove with chisel and mallet. One half of each tooth was selected and prepared for Scanning Electron Microscopy examination. After assembly on coded stubs, the specimens were placed in a vacuum chamber and sputter-coated with a 300 A° gold layer. (Hitachi E 1010). The specimens were then analyzed using a Scanning Electron Microscopy (HTAC I S 3400 N). The dentinal wall of the cervical, middle and apical thirds of each prepared specimens were observed at magnifications 200Xand 1000X for the presence of Debris and Smear Layer respectively.

Scoring Criteria

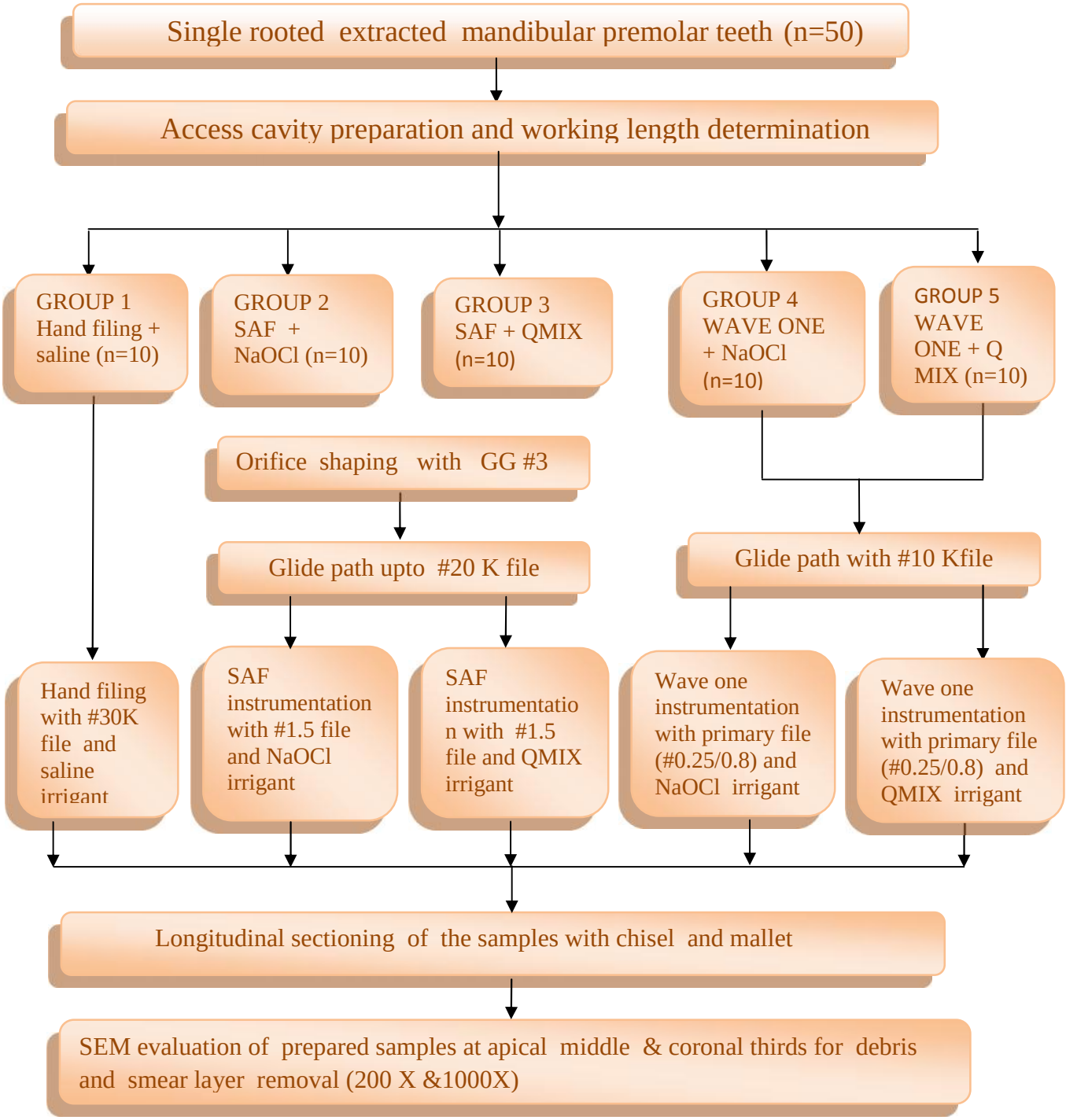
Presence of Debris was evaluated using **Hulsmann[22] s**cores as follows:

- Score 1: Clean root canal wall and only a few small Debris particles.
- Score 2: A few small agglomerations of Debris.
- Score 3: Many agglomerations of Debris covering less than 50% of the root canal wall.
- Score 4: More than 50% of the root canal walls were covered with Debris.
- Score 5: Complete or nearly complete root canal wall coverage with Debris.

The presence of Smear Layer was evaluated with **Hulsmann**[22] scores as follows:

- Score 1: No Smear Layer and all dentinal tubules were open.
- Score 2: A small amount of Smear Layer, and some dentinal tubules were open.
- Score 3: Homogenous Smear Layer covering the root canal wall, and only a few dentinal tubules open.
- Score 4: Complete root canal wall covered by a homogeneous Smear Layer, and no open dentinal tubules were observed.
- Score 5: Heavy, homogeneous Smear Layer covering the complete root canal wall.

PROCEDURAL FLOW CHART



(Fig-1) Armamentarium for access preparation .

(Fig-2) X Smart plus endomotor with 6:1 reduction gear handpiece.

(Fig -3) Wave one primary files.

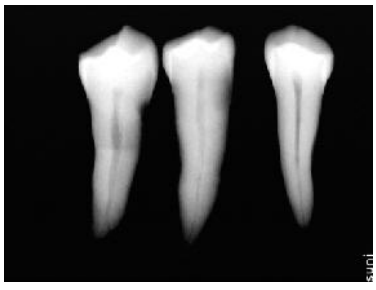
(Fig-4)Self adjusting file system with VATEA irrigation device.

(Fig-5) SAF-Files.

(Fig-6) Irrigants.

(Fig-7) Scanning Electron Microscope.

(Fig-8)Collection and storage of samples.



(Fig-9)Standardization of -RVG Samples

(Fig-10) Samples assigned into five groups.

(Fig-11) Longitudinaly sectioned samples.

Results

RESULTS

All the prepared samples are examined at the level of coronal, middle and apical third under Scanning Electron Microscopy using 200X and 1000 X magnification for presence of Debris and Smear Layer respectively. The scores are obtained and tabulated (Table 1 to5). The Mean and Standard Deviation values of Debris and Smear Layer Scores are showed in Table 6 and 7 respectively.

Debris and Smear Layer Scores

Table 1 (Group 1)

Specimen No.	Debris score			Smear Layer score		
	Coronal third	Middle third	Apical third	Coronal third	Middle third	Apical third
1	4	4	5	5	5	5
2	4	5	5	5	5	5
3	4	5	5	4	5	5
4	5	5	5	5	5	5
5	4	4	5	5	5	5
6	5	5	5	5	5	5
7	4	5	5	5	5	5
8	5	5	5	5	5	5
9	4	4	5	5	5	5
10	5	5	5	5	5	5

Table 2 (Group 2)

Specimen No.	Debris score			Smear Layer score		
	Coronal third	Middle third	Apical third	Coronal third	Middle third	Apical third
1	3	4	4	4	4	4
2	3	4	4	4	4	4
3	4	4	4	4	5	5
4	4	4	4	4	4	4
5	3	3	5	5	5	5
6	4	4	4	4	4	4
7	4	4	5	5	5	5
8	3	3	4	4	4	4
9	4	4	4	4	5	5
10	4	4	4	4	5	5

Table 3 (Group 3)

Specimen No.	Debris score			Smear Layer score		
	Coronal third	Middle third	Apical third	Coronal third	Middle third	Apical third
1	1	1	2	1	1	1
2	1	1	1	1	1	2
3	1	2	2	2	1	2
4	1	1	2	1	2	1
5	1	1	1	2	2	1
6	1	1	1	1	1	3
7	1	1	2	1	2	1
8	1	1	1	1	1	3
9	1	1	1	2	2	1
10	1	1	1	1	1	3

Table 4 (Group 4)

Specimen No.	Debris score			Smear Layer score		
	Coronal third	Middle third	Apical third	Coronal third	Middle third	Apical third
1	3	4	5	4	4	5
2	5	5	5	4	5	5
3	4	5	5	5	5	5
4	3	4	4	4	5	5
5	4	5	5	4	5	5
6	5	4	5	5	4	5
7	4	5	5	4	5	5
8	4	5	5	5	4	5
9	4	5	5	4	5	5
10	4	5	5	4	5	5

Table 5 (Group 5)

Specimen No.	Debris score			Smear Layer score		
	Coronal third	Middle third	Apical third	Coronal third	Middle third	Apical third
1	2	1	3	2	1	3
2	1	1	4	1	1	4
3	1	2	3	2	2	3
4	1	1	4	1	1	3
5	1	2	3	2	2	3
6	2	1	3	1	1	4
7	1	2	3	1	2	3
8	1	1	4	2	2	4
9	1	1	3	1	1	3
10	1	1	4	3	3	3

Table 6

Mean and Standard Deviation Values of Debris Scores.

Groups	Coronal third		Middle third		Apical third	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Group 1	4.4	0.52	4.7	0.48	5	0.00
Group 2	3.6	0.52	3.8	0.42	4.2	0.42
Group 3	1	0.00	1.1	0.32	1.2	0.52
Group 4	4	0.67	4.3	0.48	4.9	0.32
Group 5	1.2	0.42	1.5	0.48	1.9	0.52

Table 7

Mean and Standard Deviation Values of Smear Layer Scores.

Groups	Coronal third		Middle third		Apical third	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Group 1	4.9	0.32	5	0.00	5	0.00
Group 2	4.2	0.42	4.5	0.53	4.5	0.53
Group 3	1.3	0.48	1.4	0.52	1.5	0.92
Group 4	4.6	0.48	4.7	0.48	4.9	0.00
Group 5	1.6	0.7	1.8	0.7	2.2	0.48

STATISTICAL ANALYSIS

In analyzing the results of all samples, the following statistical analysis was employed after estimation of mean rank. The comparisons between the groups were performed by Kruskal-Wallis Test (Table 8 and 9) ,Mann-Whitney U test was used for paired comparisons (Table 10) and Intra Group comparisons at three levels by Wilcoxon Signed Rank Test (Table 11).All the statistical analysis was done with SPSS -16 Software. In all the above statistical tools the probability value < 0.05 is considered as significant level.

Table 8

Kruskal Wallis Test

Groups	Debris						Smear Layer					
	Coronal		Middle		Apical		Coronal		Middle		Apical	
	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank	N	Mean Rank
1	10	40.30	10	39.30	10	40.00	10	42.00	10	39.50	10	38.00
2	10	30.70	10	27.90	10	26.40	10	31.50	10	32.00	10	29.75
3	10	9.50	10	9.50	10	5.50	10	9.35	10	9.80	10	6.55
4	10	35.50	10	39.30	10	38.30	10	33.00	10	35.00	10	38.00
5	10	11.50	10	11.50	10	17.30	10	11.65	10	11.20	10	15.20
Total	**50**		**50**		**50**		**50**		**50**		**50**	

Table 9

Test Statistics - Kruskal Wallis Test

Levels		Chi-Square	Df	Asymp. Sig.(p)
Debris	Coronal	41.567	4	.000
	Middle	42.752	4	.000
	Apical	43.803	4	.000
Smear Layer	Coronal	41.389	4	.000
	Middle	40.924	4	.000
	Apical	43.433	4	.000

Table 10

Comparison Between Groups for Debris And Smear Layer Removal- Using Mann-Whitney U Test

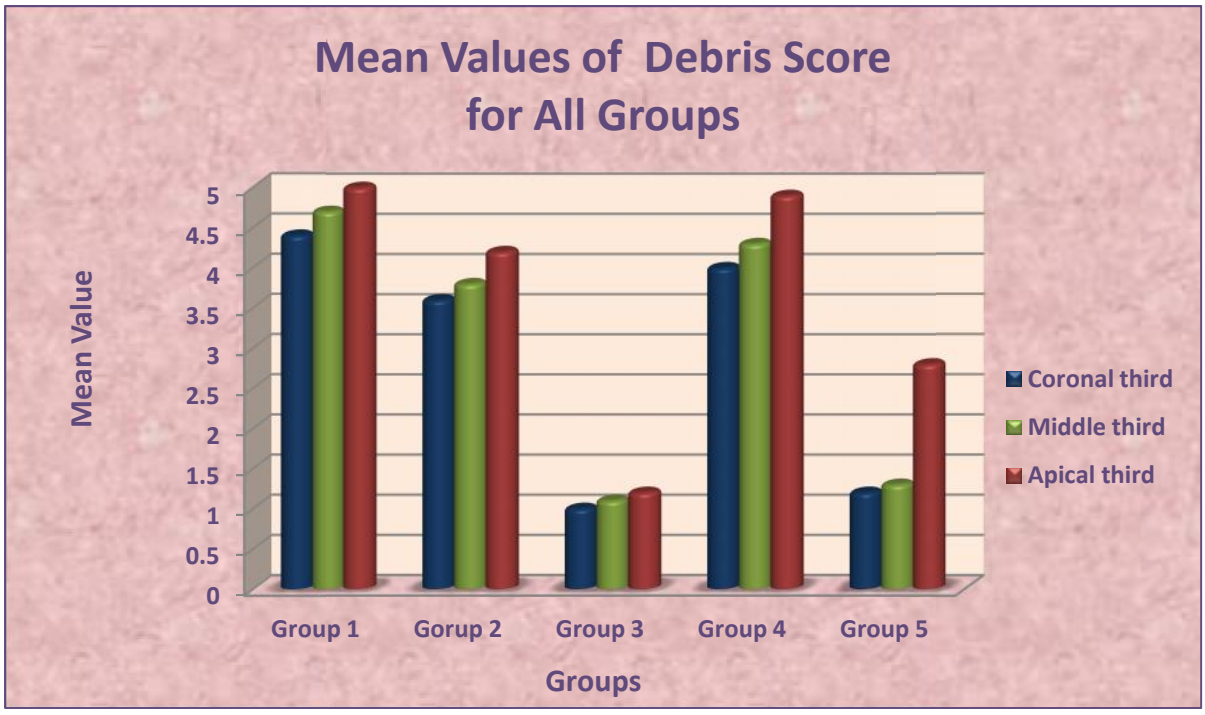
Groups	Multiple Comparison of Debris					Multiple Comparison of Smear Layer			
	Levels	Mann-Whitney U	Wilcoxon W	Z	p Value	Mann-Whitney U	Wilcoxon W	Z	p Value
1 Vs 2	Coronal	18.000	73.000	-2.757	.015[b]	15.000	70.000	-3.067	.007[b]
	Middle	12.000	67.000	-3.228	.003[b]	25.000	80.000	-2.517	.063[b]
	Apical	10.000	65.000	-3.559	.002[b]	25.000	80.000	-2.517	.063[b]
1 Vs 3	Coronal	0.000	55.000	-4.119	.000[b]	0.000	55.000	-4.065	.000[b]
	Middle	0.000	55.000	-4.065	.000[b]	0.000	55.000	-4.119	.000[b]
	Apical	0.000	55.000	-4.119	.000[b]	0.000	55.000	-4.082	.000[b]
1 Vs 4	Coronal	34.000	89.000	-1.389	.247[b]	20.000	75.000	-2.669	.023[b]
	Middle	50.000	105.000	0.000	1.000[b]	35.000	90.000	-1.831	.280[b]
	Apical	45.000	100.000	-1.000	.739[b]	50.000	105.000	0.000	1.000[b]
1 Vs 5	Coronal	0.000	55.000	-3.979	.000[b]	0.000	55.000	-4.013	.000[b]
	Middle	0.000	55.000	-3.963	.000[b]	0.000	55.000	-4.091	.000[b]
	Apical	0.000	55.000	-4.119	.000[b]	0.000	55.000	-4.147	.000[b]
-2 Vs 3	Coronal	0.000	55.000	-4.119	.000[b]	0.000	55.000	-4.004	.000[b]
	Middle	0.000	55.000	-4.110	.000[b]	0.000	55.000	-3.907	.000[b]
	Apical	0.000	55.000	-3.979	.000[b]	0.000	55.000	-3.876	.000[b]
2 Vs 4	Coronal	34.000	89.000	-1.389	.247[b]	45.000	100.000	-.503	.739[b]
	Middle	12.000	67.000	-3.228	.003[b]	40.000	95.000	-.890	.481[b]
	Apical	15.000	70.000	-3.067	.007[b]	25.000	80.000	-2.517	.063[b]
2 Vs 5	Coronal	0.000	55.000	-3.979	.000[b]	0.000	55.000	-3.954	.000[b]
	Middle	0.000	55.000	-4.004	.000[b]	0.000	55.000	-3.883	.000[b]
	Apical	16.000	71.000	-2.952	.009[b]	7.500	62.500	-3.425	.000[b]
3 Vs 4	Coronal	0.000	55.000	-4.104	.000[b]	0.000	55.000	-3.963	.000[b]
	Middle	0.000	55.000	-4.065	.000[b]	0.000	55.000	-3.938	.000[b]
	Apical	0.000	55.000	-4.038	.000[b]	0.000	55.000	-4.082	.000[b]
3 Vs 5	Coronal	40.000	95.000	-1.453	.481[b]	38.500	93.500	-1.009	.393[b]
	Middle	40.000	95.000	-1.090	.481[b]	43.000	98.000	-.602	.631[b]
	Apical	0.000	55.000	-3.914	.000[b]	10.500	65.500	-3.225	.002[b]
4 Vs 5	Coronal	0.000	55.000	-3.966	.000[b]	0.000	55.000	-3.914	.000[b]
	Middle	0.000	55.000	-3.963	.000[b]	0.000	55.000	-3.914	.000[b]
	Apical	2.000	57.000	-3.894	.000[b]	0.000	55.000	-4.147	.000[b]

Table 11

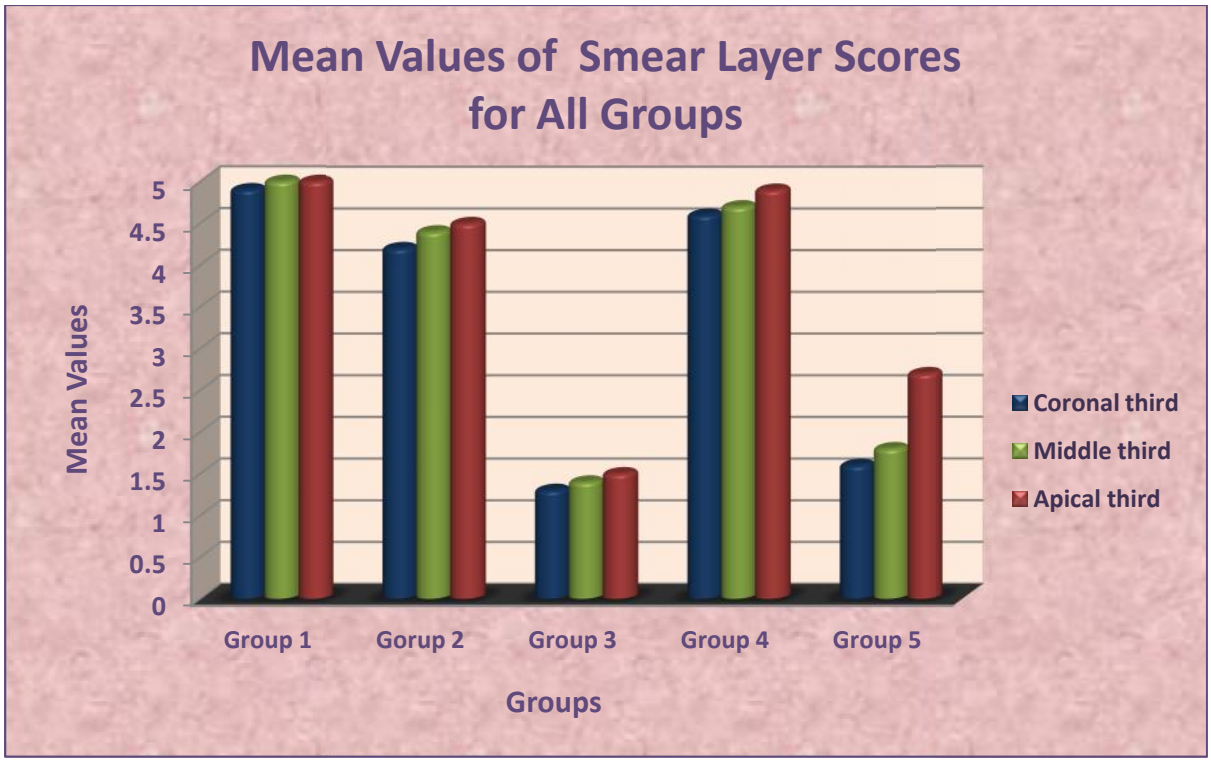
Intra Group Comparison of Debris and Smear Layer Scores at Three Levels Using Wilcoxon Signed Rank Test

Groups	Levels		Values	
			Z	p Value
Group 1	Debris	Middle – Coronal	-1.732[c]	.083
		Apical – Coronal	-2.449[c]	.014
		Apical – Middle	-1.732[c]	.083
	Smear Layer	Middle – Coronal	-1.000[c]	.317
		Apical – Coronal	-1.000[c]	.317
		Apical – Middle	.000[d]	1.000
Group 2	Debris	Middle – Coronal	-1.414[c]	.157
		Apical – Coronal	-2.121[c]	.034
		Apical – Middle	-1.633[c]	.102
	Smear Layer	Middle – Coronal	-1.732[c]	.083
		Apical – Coronal	-1.732[c]	.083
		Apical – Middle	.000[d]	1.000
Group 3	Debris	Middle – Coronal	-1.000[c]	.317
		Apical – Coronal	-2.000[c]	.046
		Apical – Middle	-1.732[c]	.083
	Smear Layer	Middle – Coronal	-.577[c]	.564
		Apical – Coronal	-1.394[c]	.163
		Apical – Middle	-1.043[c]	.297
Group 4	Debris	Middle – Coronal	-2.333[c]	.020
		Apical – Coronal	-2.714[c]	.007
		Apical – Middle	-1.414[c]	.157
	Smear Layer	Middle – Coronal	-1.414[c]	.157
		Apical – Coronal	-2.646[c]	.008
		Apical – Middle	-1.732[c]	.083
Group 5	Debris	Middle – Coronal	-.447[c]	.655
		Apical – Coronal	-2.842[c]	.004
		Apical – Middle	-2.836[c]	.005
	Smear Layer	Middle – Coronal	.000[d]	1.000
		Apical – Coronal	-2.701[c]	.007
		Apical – Middle	-2.701[c]	.007

Graph 1



Graph 2



INFERENCE

1. When analyzing the cleaning efficacy of all five groups, the results of this study at coronal, middle &apical thirds showed the amount of debris present in the following order.

Group 3< Group 5< Group 2<Group 4 <Group 1

2. Smear Layer analysis showed the presence of Smear Layer in the following order at all the thirds.

Group 3< Group 5< Group 2≤Group 4≤Group 1

The scores of all the groups are compared at coronal, middle and apical thirds for the presence of Debris and Smear Layer by **Kruskal Wallis Test**. The inter Group comparison results revealed that the mean rank of all the groups and levels are statistically significant ($p<0.05$).

Bivariate comparison of Groups for the presence of Debris:

Mann-Whitney U Test revealed that Group 3 (SAF with Q Mix) followed by Group 5 (Wave One with Q mix) has significantly ($p<0.05$) cleaned root canal walls when compared to Group 2(SAF with NaOCl) and Group 4(Wave One with NaOCl) in coronal, middle and apical thirds, but the apical third of Group 5(Wave One with Q Mix) has significantly more amount of Debris than Group 3.

Group 4(Wave One with NaOCl) has significantly ($p<0.05$) more amount of Debris than Group 2(SAF with NaOCl) at apical third. When comparing with Control Group, all

the Experimental Groups have significantly ($p<0.05$) less amount of Debris in all three levels.

Bivariate comparison of Groups for the presence of Smear Layer:

Group 3 (SAF with Q MIX) followed by Group 5 (Wave One with Q mix)has significantly, ($p<0.05$) cleaned canal walls when compared to coronal, middle and apical thirds of Group2(SAF with NaOCl) and Group 4 (Wave One with NaOCl) but the apical third of Group 5 has significantly($p<0.05$) heavy Smear Layer comparing to Group 3(SAF with QMix).

Group 2 (SAF with NaOCl) and Group 4 (Wave One with NaOCl) has Smear Layer throughout the root canal and were not statistically significant ($p>0.05$).

Control Group has significantly ($p<0.05$) heavy Smear Layer than Group 3 (SAF with Q Mix) and Group5 (Wave One with Q Mix) at coronal, middle and apical third but there is no significant ($p>0.05$) difference between Group 2(SAF with NaOCl) and Group 4(Wave One with NaOCl).

Intra Group Comparison For The Amount Of Debris Present At Three Levels:

Wilcoxon Signed Rank Test revealed in Apical Coronal comparison non significantly ($p>0.05$) cleaned root canal walls present in Coronal and Apical levels in Group 2(SAF with NaOCl) and Group 3(SAF with Q Mix). In all other Groups coronal third has significantly($p>0.05$) cleaned canal walls than Apical third.

Apical and Middle third comparison revealed non significant ($p>0.05$) difference in the amount of Debris in Group 2(SAF with NaOCl) and Group 3(SAF with Q Mix) at these levels .In all other Groups significantly ($p<0.05$) more amount of Debris present in Apical third than middle third.

In Middle and Coronal third comparison no significant ($p>0.05$) difference was found between these two levels for the presence of Debris in all Groups .

Intra Group Comparison for the Presence of Smear Layer at Three Levels

In Middle-Coronal, Apical-Coronal and Apical–Middle comparisons non significantly ($p>0.05$) heavy Smear Layer was present in Group 1(Control Group), followed by Group 2(SAF with NaOCl) and Group 4(Wave One with NaOCl) but in Group 3(SAF with Q Mix) no Smear Layer was present at all the levels which is insignificant ($p>0.05$)

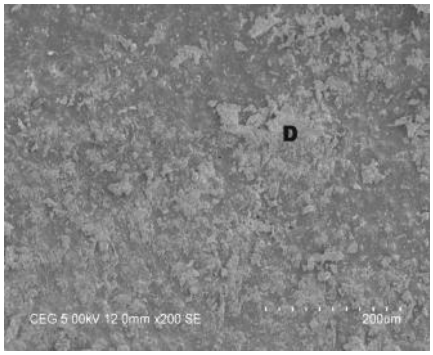
In Group 5(Wave One with Q Mix), statistically significant ($p<0.05$) heavy Smear Layer was found in Apical area in Apical-Coronal and Apical-Middle comparisons. In Middle-Coronal comparisons of Group 5 has non statistically ($p>0.05$) significant cleaned canal walls were present.

SEM-IMAGES

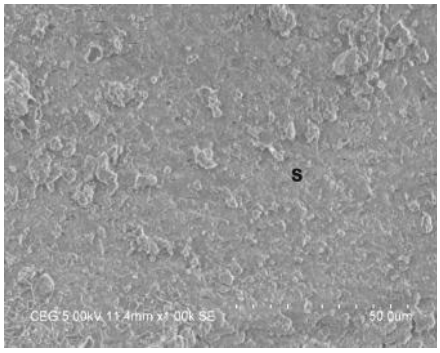
D-Debris**, S**-Smear Layer, **O**-Opened dentinal tubule, **C**-clean canal wall

Group-1

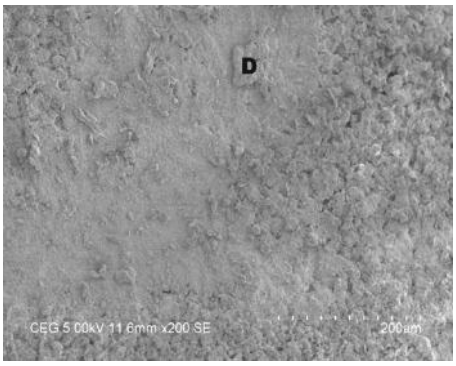
(Fig-12)Debris-Coronal third(200X)



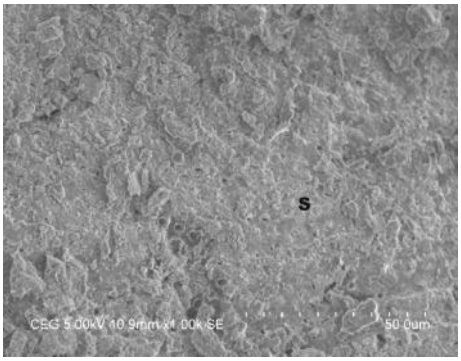
(Fig-13)Smear Layer–coronal third(1000X)



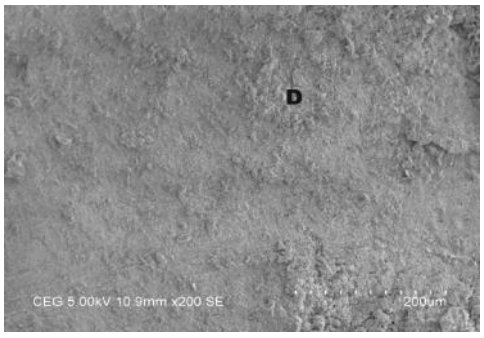
(Fig-14) Middle third (200X)



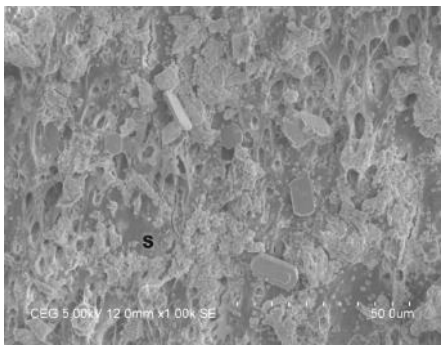
(Fig-15) Middle third (1000X)



(Fig-15)Apical third(200X)

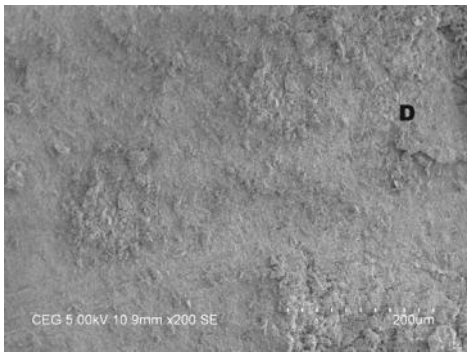


(Fig-16)Apical third(1000X)

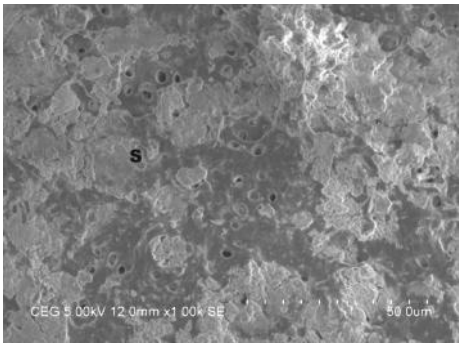


Group -2

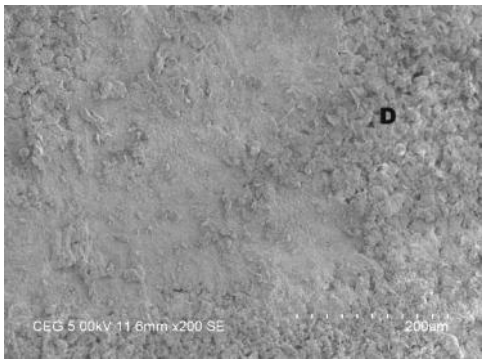
(Fig-17) Coronal third(200X)



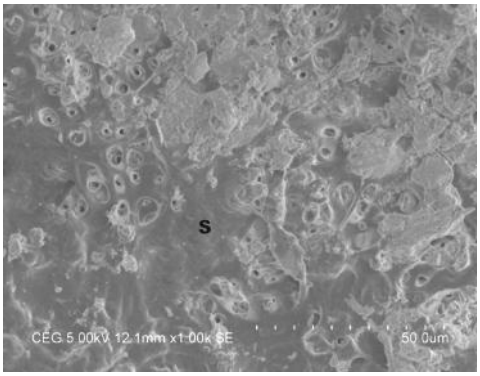
(Fig-18) Coronal third (1000X)



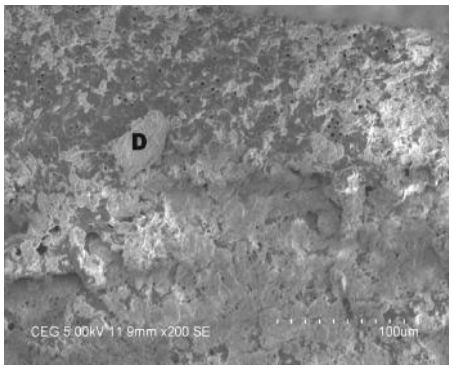
(Fig-19) Middle third (200X)



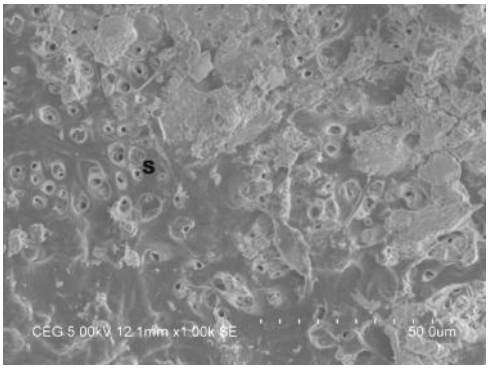
(Fig-20) Middle third (1000 X)



(Fig-21)Apical third (200X)

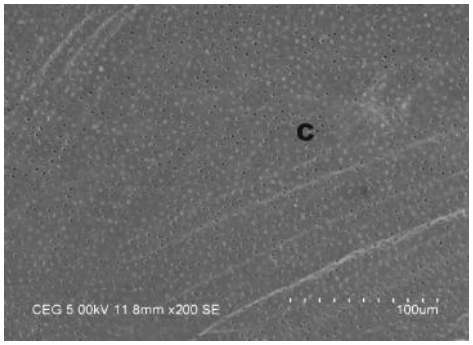


(Fig-22) Apical third (1000X)

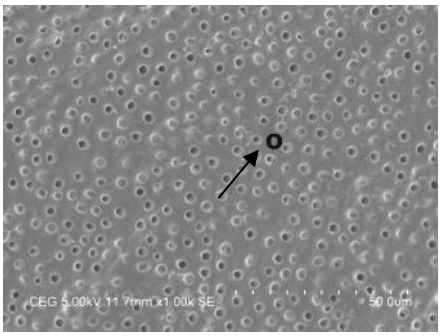


Group- 3

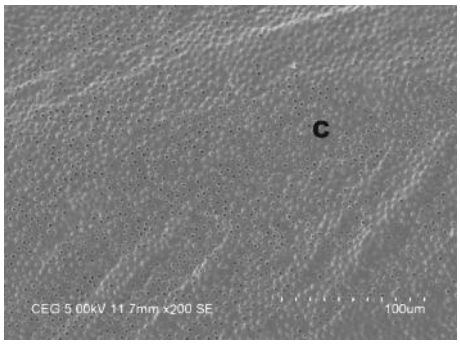
(Fig-23) Coronal third (200X)



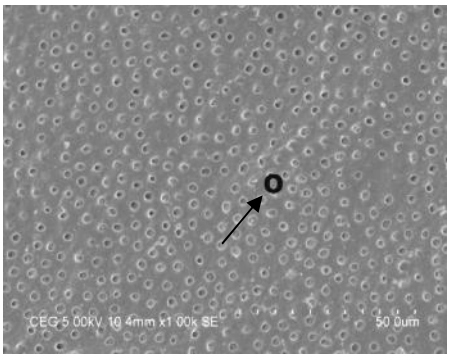
(Fig-24) Coronal third (1000X)



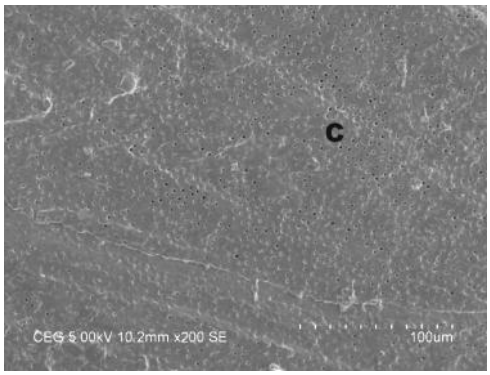
(Fig-25)Middle third 200X



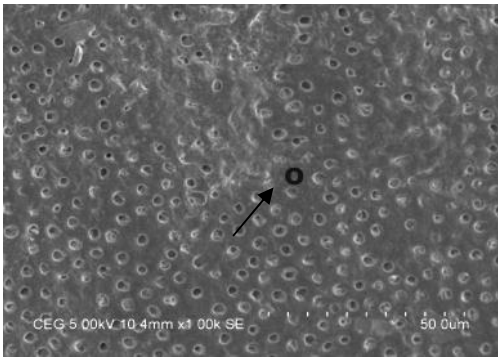
(Fig-26) Middle third (1000X)



(Fig-27) Apical third (200X)

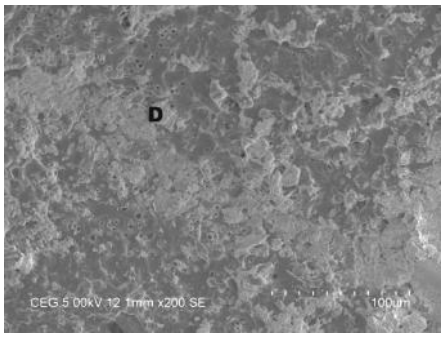


(Fig-28) Apical third (1000X)

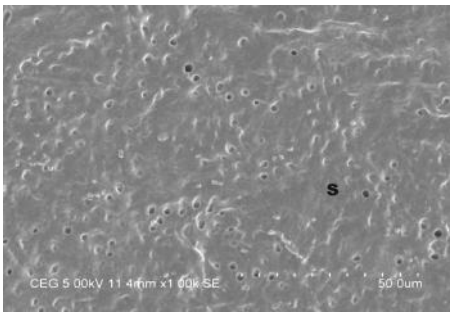


Group- 4

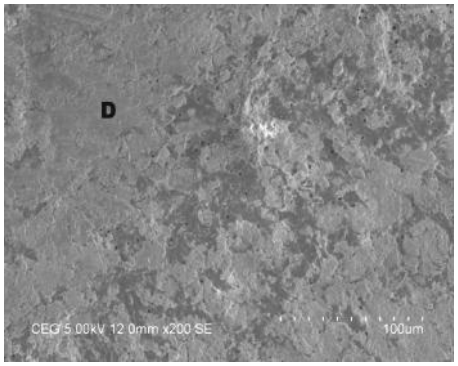
(Fig-29) Coronal third(200X)



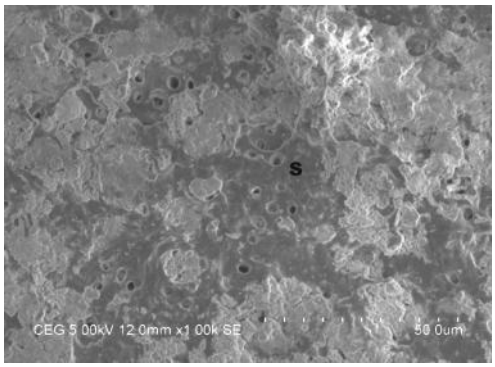
(Fig-30) Coronal third (1000X)



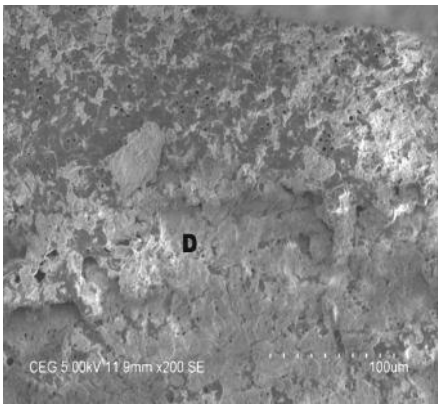
(Fig-31)Middle third (200X)



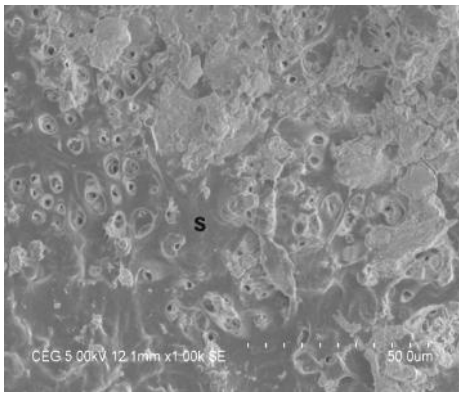
(Fig-32) Middle third (1000X)



(Fig-32) Apical third(200X)

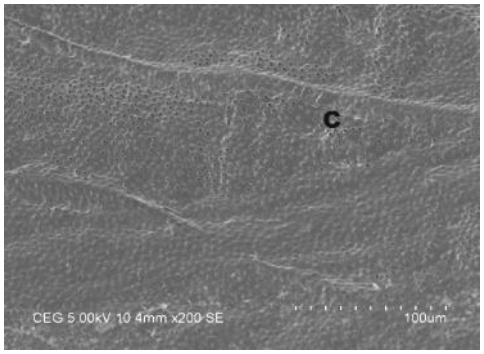


(Fig-33) Apical third (1000X)

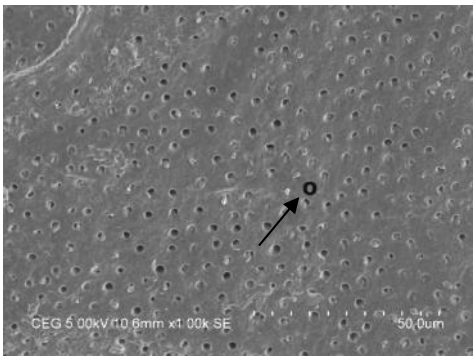


Group- 5

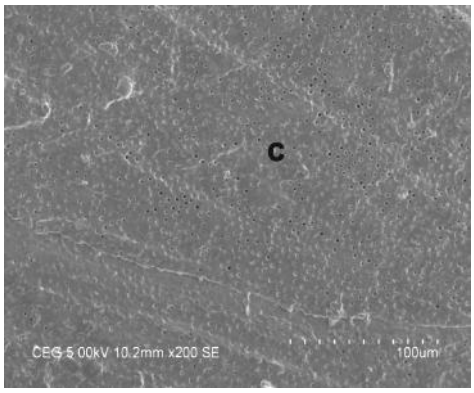
(Fig- 34)Coronal third (200X)



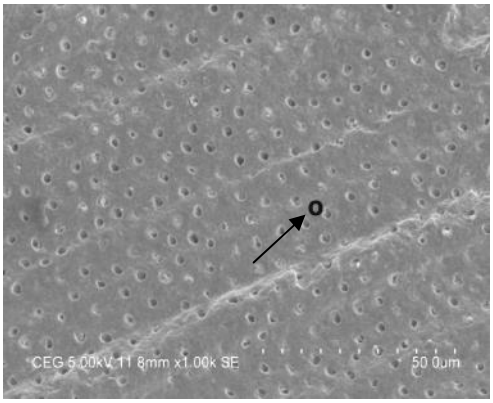
(Fig-35) Coronal third (1000X)



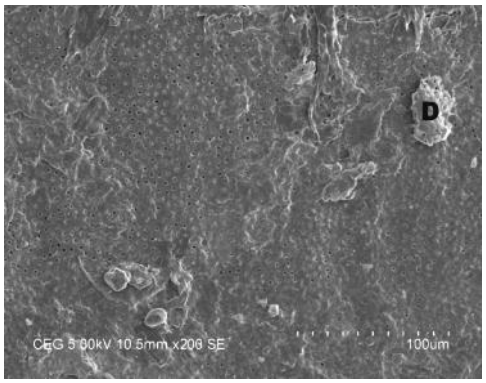
(Fig-36) Middle third(200X)



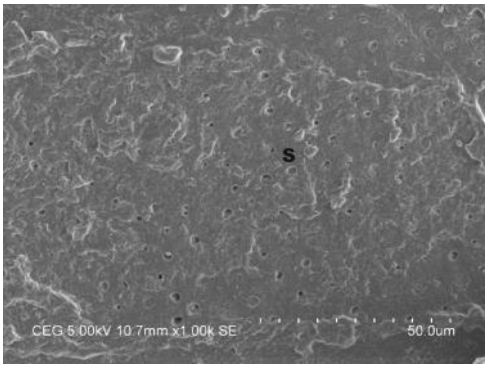
(Fig-37) Middle third (1000X)



(Fig-38)Apical third (200X)



(Fig-39) Apical third (1000X)



Discussion

DISCUSSION

Nickel –Titanium Rotary Instruments (NiTi) were introduced to achieve the mechanical objectives of canal preparation. They are flexible have increased cutting efficiency and less time consuming . Though these files possess shape memory effect and super elasticity characteristics separation still occurs in Rotary Instruments, as a result of rotational bending due to fatigue and shear fracture[64]. Therefore to improve the mechanical properties, these alloys were thermally treated and resultant alloy is M-Wire. The benefit of this M-Wire NiTi includes increased flexibility and improved resistance to cyclic fatigue while cleaning and shaping [24]. The currently available rotary Ni-Ti file systems are operated by continuous rotation, and this technique require multiple instruments for canal preparation. To overcome this drawback , an advancement in canal preparation procedures was achieved with reciprocation. It is a process with repetitive up-and-down or back and-forth motion. This technology was first introduced in late1950s by a French dentist. However in 2008, Yared tried single file with reciprocating hand piece for root canal preparation with F2 protaper rotary instrument which showed promising results[66]. Based on his study, a combination of reciprocation and M wire, the two single file systems were launched. They are Wave One and Reciproc.

Among these two systems **Wave One** was used for our study .The Wave One instrument can completely prepare a canal with single instrument by slow in and out pecking motion following minimal glide path preparation. The glide path was established using size #10 K file. In single file reciprocation, stresses on the instruments

are expected higher during the canal preparation. Hence these files are intended for single use. In this study we prepared glide path by # 10 Kfile.

There are 3 Wave One files for a wide range of use in everyday practice. They are *Small* (Yellow 21/06), *Primary* (Red 25/08) and *Large* (Black 40/08). The Small 21/06 file has a fixed taper of 6% over its active portion. These files are available in lengths of 21,25and 31mm . The Primary 25/08 and the large 40/08 Wave One files have fixed tapers of 8% from D1-D3, whereas from D4-D16, they have a unique progressively decreasing percentage in tapered design. This design serves to improve flexibility and conserve remaining dentin in the coronal two-thirds of the finished preparation [6].

Small Wave One file are used for preparation of the root canal resistant to size # 10 k file . It is mostly used in mandibular incisors,MB-2 canals in maxillary molars and canals with apical curvatures. If #10 K file goes to the working length easily the Primary Wave One file was used. This file was used to clean and shape the majority of all root canals .The Large Wave One file was used to clean the root canal if # 20 size K file easily goes to full length inside the canal.These files are used in a reciprocal motion that requires special automated devices. Hence in this study we selected Primary file which was operated with X Mart Plus endomotor in reciprocating mode to prepare the root canals. Another unique design feature of the Wave One files are they have a reverse helix and two distinct cross-sections along the length of their active portions. From D1-D8, the Wave One files have a modified convex triangular cross-section, whereas from D9-D16, these files have a convex triangular cross-section. The design is further

enhanced by a changing pitch and helical angle along their active portions. The Wave One files have a non cutting modified guiding tips, which enable these files to safely progress through any secured canal. These design features of Wave One enhances safety and efficiency in cleaning the root canals to have a confirmed, smooth, and reproducible glide path.

However the above systems removes considerable amount of dentin during root canal preparation and it will be effective only when the canals were simple, straight and narrow, with a round cross section. Also, in these file systems the irrigation was mostly done by syringe irrigation method so the irrigant was able to penetrate to a depth of only 1.5 -2.0 mm apical to the tip of the needle. Hence the three-dimensional (3D) cleaning and shaping of entire root canal system was still a challenging task. To overcome this, **Self Adjusting File (SAF) is the first rotary system that activates the irrigation solution throughout the entire cleaning procedure.** This file system is different from any other available file system in two major respects [32]. First, it is a hollow and flexible file that adapts itself three-dimensionally to the shape of the root canal, and second this may removes a uniform dentin layer from the root canal walls with continuous irrigation.

The SAF file is designed as a compressible, thin-walled pointed cylinder either 1.5 or 2.0 mm in diameter composed of 120-mm-thick nickel-titanium lattice. The 1.5-mm file may easily be compressed to the extent of being inserted into any root canal previously prepared or negotiated with a # 20 K-file. The 2.0-mm file will easily

compress into a canal that was prepared with a #30 K-file. The file will then attempt to regain its original dimensions, thus applying a constant delicate pressure on the root canal walls[21]. When they are inserted into a canal, it adapts itself to the canal's shape, both longitudinally and along the cross-section. In a round canal, it will attain a round cross-section, whereas in an oval or flat canal it will attain a flat or oval cross-section, providing a three-dimensional adaptation. In our study # 1.5 SAF file was used to prepare the canal and glide path was established by # 20 size K file .

The surface of the lattice threads in the file was lightly abrasive, which allows it to remove dentin with a back-and-forth grinding motion .The SAF is operated with transline (in and out) vibrating handpieces with 3,000 to 5,000 vibrations per minute and an amplitude of 0.4mm. Such a handpiece may be the KaVo Gentle power or equivalent combined with either a 3LDSY head (Kavo, Biberach Riss Germany) , MK-Dent head (MK-Dent, Bargteheide, Germany) or RDT3 head (ReDent-Nova, Raana, Israel). Among these RDT3 head has a dual mechanical function. It changes the rotation of the micromotor into a trans-line in-and-out vibration with an amplitude of 0.4 mm. It also contains a clutch mechanism that allows the SAF to rotate slowly when not engaged in the canal but completely stops the rotation once the file was engaged with the canal walls. The vibrating movement combined with intimate contact along the entire circumference and length of the canal removes a layer of dentin with a grinding motion. RDT3 heads are available in several configurations and were adapted to a large variety of endodontic motors/handpieces. In our study RDT3 head was connected to NSK contra

angle handpiece by E-type connector which was operated by Marathon micrometer at 4000-5000rpm.

A continuous irrigation was done throughout root canal cleaning and shaping using a special irrigation device named VATEA irrigation device. It was connected by a silicon tube to the irrigation hub on the SAF file and provides continuous flow of the irrigant of choice at a low pressure and at flow rates of 1 to 10 ml/min.The same irrigation device with timer at a flow rate of 4 ml/min was used in our study.

The SAF is inserted into the root canal while vibrating and is delicately pushed in until it reaches the predetermined working length. It is then operated with in-and-out manual motion and with continuous irrigation for 4 minutes per canal. This procedure will remove a uniform dentin layer 60- to 75-µm thick from the canal circumference[21]. In our study the same procedure was followed for root canal cleaning .

Preparation of root canals by any rotary systems will produce a smear layer when dentine surface is cut or drilled. The smear layer contains thin particles of inorganic material and organic elements such as pulp tissue debris, odontoblastic processes, bacteria and blood cells[48]. According to **Shaffer and Zapke (2000) [49]**, smear layer is found only on instrumented portion of canal walls, and absent in dentin walls that have not been instrumented. Bacteria might remain, multiply and grow up in smear layer and prevents penetration of root canal filling materials into dentinal tubules and might affect the microleakage. The organic content of the smear layer is relatively high in the early stages

of instrumentation due to the presence of viable pulp tissue in the root canal. The smear layer was not only found in the canal wall, but also packed into some dentinal tubules [44].

Mader et al. (1984)[30] described the formation of two kinds of smear layer: the first one consisted of a superficial layer loosely attached to the deninal walls and the second one of a smear material packed in the dentinal tubule openings. It contains bacteria and may prevent antimicrobial agents from having access to contaminated tubules.

There is no scientific consensus regarding the efficacy of smear layer removal in the root canal treatment[10]. However, currently, the focus is towards the smear layer removal in order to reduce the microflora and bacterial endotoxins[42].Then it was important that the root canal preparation in infected root canals not only clean and remove the smear layer but also have an antibacterial effect[20] . Because the mechanical preparation using current instrumentation techniques does not debride the total root canal system, due to the complexity of root canal anatomy, irrigation solutions are mandatory to improve root canal cleanliness.

A number of chemicals have been investigated as irrigants to remove the smear layer. According to **Kaufman & Greenberg (1986)[27]** an **irrigation solution** is the one which is essential to remove the debris and smear layer created by the instrumentation process. Irrigation plays a major role in endodontic treatment. During and after instrumentation, the irrigants facilitate removal of microorganisms, tissue remnants, and dentin chips from the root canal through a flushing mechanism. Irrigants can also help

prevent packing of the hard and soft tissue in the apical root canal and extrusion of infected material into the periapical area. Some irrigating solutions dissolve either organic or inorganic tissue in the root canal. In addition, some irrigating solutions have antimicrobial activity and actively kill bacteria and yeasts when introduced in direct contact with the microorganisms.

Sodium Hypochlorite (NaOCl) is the most popular and commonly used irrigating solution in concentrations between 0.5% and 6%. It also effectively dissolves pulpal remnants and collagen, the main organic components of dentin. Since sodium hypochlorite remains as Gold Standard irrigating solution till date, it was used in our study.

There has been much controversy over the concentration of hypochlorite solutions to be used in endodontics. Studies [53,51,19] showed that 5.25% sodium hypochlorite solution leading to tissue irritation ,decrease in flexural strength of dentin and the removal of microbiota was not significantly altered with this high concentration. The irrigation potential depends on the availability of fresh hypochlorite solution reached in the canal system, and thus concentration of the solution may not play a decisive role[4]. Unclean areas remained in the root canal systems were due to the inability of solutions to physically reach these areas rather than their concentration. In our study commonly available low concentration 3% sodium hypochlorite was used as an irrigant.

None of the available single irrigating solution can be regarded as optimal. Using combination of products in correct irrigation sequence contributes to a successful

treatment outcome. When mixing the irrigating solutions there was loss of activity and development of potentially toxic by-products. While mixing Chlorhexidine (CHX) and NaOCl, a brownish-orange precipitate is formed because they were not soluble in each other. According to **Rasimick et al (2008**)[45] White Precipitate was immediately produced when CHX mixed with EDTA. These precipitates prevent the clinical use of these mixtures. However many combination products are available on the market with some evidence of improved activity and function. **QMix** is an endodontic irrigant for smear layer removal with added antimicrobial agents. It contains EDTA, CHX and a Detergent. It is a clear solution, ready to use with no chair-side mixing.

In QMix, the formation of white precipitate while combining these two irrigants was avoided due to its chemical design. The presence of surface active agent in the QMix lowers the surface tension of solution, increase their wettability and better penetration of an irrigant. A unique advantage of adding CHX in this mixture was having substantivity, that is, ability to adsorb onto dentine and prevent microbial colonization on the dentine surface. Even though EDTA does not have an antibacterial effect when used alone, it can cause cell wall damage in gram-negative bacteria by chelating and removing divalent cat ions (Mg^{2+}andCa^{2+}) from bacterial cell membrane and increasing its permeability in the root canal[57].

In biofilm experiments**, Ma et al (2011)**[29] showed QMix to be as effective as 6% sodium hypochlorite against E. faecalis in dentinal tubules and it has mild or no carry-

over effect. **Dai et al (2011)**[11] reported that QMix was as effective as 17% EDTA in smear layer removal. Therefore in this study we used Q Mix as an another irrigant.

The success, reliability, and longevity of endodontic treatment was affected by endodontic files, rotary instrumentation, irrigants, and chelating agents. Nevertheless, certain controversy exists regarding their effectiveness. There are very limited studies available in literature on the cleaning efficacy of Wave One and SAF with QMix. Hence in our study we are comparing cleaning efficacy of these systems along with QMix and NaOCl as an irrigants.

In the clinical situation, the root was enclosed by the bone socket and the canal behaves as a closed-end channel. This results in gas entrapment because its closed end produces a vapor lock effect during irrigant delivery. This effect made difference between closed and open root canal systems in smear layer and debris removal, and the apical vapor lock had adverse effects on debridement efficacy. To simulate this effect in our study, a closed system was generated by closing the apical foramen with Impression compound.

In vitro root canal cleanliness was investigated histologically or under the SEM using longitudinal and horizontal section of extracted teeth[22]. In horizontal section loose debris inside the canal lumen might be lost during sectioning as well as contamination of the root canal system with dust from the saw blades might occur. The use of longitudinal sections allowed nearly complete inspection of both halves of the entire main root canal [23]. In making section, contamination was avoided by insertion of a paper point or a gutta-

percha cone inside the canal. Hence in this study we used longitudinal section for evaluation and during sectioning process paper points were placed inside the canals .

The root canal cleanliness was assessed with the presence of debris and smear layer on the prepared root canals. For this purpose Scanning Electron Microscopic (SEM) images were taken and analysed using various predefined scores. In this study we used five scoring system given by **Hulsmann et al (1997)[22].** The presence of debris was evaluated from images at 200X magnification and smear layer at 1,000 X magnification in coronal, middle and apical thirds.

Based on the results of this study **Group 3(SAF with QMix) , followed by Group 5(Wave One with Q Mix) had statistically significant cleaned canal walls** compared to other groups. The Group 5 differs from Group 3, which had statistically significant more amount of debris and homogeneously covered smear layer in the Apical third.

The Mechanical scrubbing action with in and out vibration movement of the SAF system removes uniform dentin layer so it forms less amount of debris during the preparation. The irrigation fluid enters the SAF file through a free-rotating hub and is continuously replaced throughout the procedure, thus providing a **fresh, fully active, supply of Q Mix** up to the working length resulted in highly effective cleaning of the root canal walls. These design features of SAF overcomes the drawbacks of all commonly used intermittent irrigation methods available till date.

According to **Dai et al. (2011)[11] reported that QMix was as effective as 17% EDTA in smear layer removal** so **Group 3** has an extremely cleaned root canal walls, they were **free from debris and no visible smear layer with complete opened dentinal tubules in all the thirds .**

These results are in accordance with **Ozkan Adigüzel et al (2011)[38]** who conducted a study on Effectiveness of EDTA and MTAD on debris and smear layer removal using a SAF. They concluded 17% EDTA and MTAD resulted in almost equally efficient debridement in all thirds of the root canal system using the SAF when continuous irrigation was performed. Debridement in the apical thirds was as successful as in the coronal and middle thirds for both irrigation solutions.

In Group 5(Wave One with Q Mix) coronal and middle third , has cleaned canal walls with few debris and all dentinal tubules were opened but in **apical third significantly more amount of debris** and completely covered canal walls by a **homogeneous smear layer and no opened dentinal tubules.** This was due to the irrigation done by canal irrigating syringes so the Q Mix not reaching till the apical third. The increased cutting ability of this file system associated with an increased cleaning efficacy may enhance **debris transportation towards the apex when used in combination with a reciprocal motion[47]**.

Matthew A et al (2012)[31] compared the effectiveness of debris removal between the SAF, WaveOne, and K3 file systems in the mesial roots of mandibular molars. They concluded that there was no difference in canal cleanliness between these three file

systems at all three levels. Our results are accordance with this study in coronal and middle third cleaning but differ in apical third cleanliness which was better in SAF system than Wave One .

In **Group 2(SAF with NaOCl) - Group 3(SAF with Q Mix)** and **Group 4(Wave One with NaOCl) - Group 5(Wave One with Q Mix),** the same instrument was used within these pairs for root canal preparation with different irrigants. Due to irrigation of EDTA in liquid form with chlorhexidine combination in the Q Mix gives better results comparing to sodium hypochlorite alone. Hence Group 3 and Group 5 has significantly cleaned root canal walls and no smear layer but in **Group 2 and Group 4 more than 50% of the root canal walls were covered with debris and complete coverage of dentinal tubules by smear layer at all the thirds.**

Complete cleaning of the root-canal system requires the use of irrigants that dissolve organic and inorganic material. Hypochlorite is active only against the organic material, but the debris originating from pulp tissue and microorganisms, are mostly inorganic component, so **hypochlorite was ineffective in complete removal of debris and smear layer**. In QMix, EDTA dissolves inorganic material, including hydroxyapatite and chlorhexidine has antibacterial activity. This proves that the irrigants plays a major role in the removal of debris and smear layer in combination with the rotary instruments.

Our results is in accordance with **Berg et al (1986)[5], Baumgartner & Mader (1987)[2],** they concluded that the use of NaOCl during or after instrumentation produces superficially clean canal walls with the presence of smear layer.

Control group has more amount of debris and heavy smear layer were present when comparing with other groups in all levels due to narrow canal space compared to rotary preparation and saline does not have any effect on organic and inorganic content of root canal.

Within the limitations of this in vitro study, the SAF, operated with the continuous flow of QMix resulted in root canals that were free of debris and almost completely free of the smear layer at coronal, middle and apical thirds. When operated with sodium hypochlorite ,SAF resulted in superficially debris free canals and has smear layer in all thirds. Wave One gives similar results with these irrigants as SAF in coronal and middle thirds but it has least cleaning efficacy at the apical third.

This study was done on extracted teeth having straight single root canal with no evidence of caries, but in clinical situations it differs as root canal treatment was performed mostly in carious teeth and in different root canal morphologies .

Therefore further investigations are necessary to predict the in vivo cleaning efficacy of Wave One and SAF files with NaOCl and QMix as irrigants.

Summary

SUMMARY

The purpose of this in vitro study was to evaluate ,the cleaning efficacy between Self Adjusting File and Wave One along with two different root canal irrigants (QMix, NaOCl) by Scanning Electron Microscope(SEM).

The study samples comprised of 50 recently extracted intact, non-carious, human mandibular premolars . Apical foramen of all selected teeth were sealed from outside using an Impression Compound. Endodontic access cavity were prepared, working length was determined and assigned to **five groups** of ten specimens each (n=10). The root canals were prepared in each group as follows

In Group 1 up to #30 size K file with saline.

Group 2. SAF file with NaOCl .

Group 3 SAF file used with QMix.

Group 4 Primary Wave One file was used with NaOCl and

Group 5 Primary Wave One file along with QMIX .

The 50 specimens were dried with absorbent paper points. The crowns were decoronated with diamond disc at the cemento–enamel junction and their orifices were closed by a piece of adhesive tape. Deep grooves were cut on the centre of each root both on the buccal and lingual surfaces. The roots were longitudinally split into two halves along the groove with chisel and mallet. One half of each tooth was selected and prepared for SEM examination.

The dentinal wall of the cervical, middle and apical thirds of each prepared specimens were observed at magnifications 200X and 1000X for the presence of Debris and Smear Layer respectively.

The root canal cleanliness was assessed by scoring system given by **Hulsmann et al**. When analyzing the cleaning efficacy of all five groups, the results of this Study at coronal, middle &apical thirds showed that the amount of Debris present in the following order

Group 3< Group 5< Group 2<Group 4 <Group 1 .

And the presence of Smear Layer in the following order

Group 3< Group 5< Group 2≤Group 4≤Group 1 .

Conclusion

CONCLUSION

Within the limitations of this in vitro study, the following conclusions were made.

- The SAF, operated with the continuous flow of QMix resulted in root canals that were almost completely free of debris and smear layer in all the thirds.
- When operated with NaOCl, SAF resulted in superficially debris free canals and has smear layer in all thirds
- Wave One with QMix and NaOCl gives similar results as SAF in coronal and middle thirds but it has least cleaning efficacy at the apical third.
- QMix effectively chelates debris and smear layer on the prepared root canal walls and gives better results.
- NaOCl was found to be lacking in capacity to remove debris and smear layer from instrumented root canal walls.

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