COMPARATIVE CBCT EVALUATION OF DENTINAL CRACK FORMATION, CANAL CENTERING ABILITY & APICAL TRANSPORTATION OF HYFLEX-EDM, ONESHAPE, WAVE-ONE GOLD AND RECIPROC FILES - AN IN VITRO STUDY

A Dissertation submitted in
partial fulfillment of the requirements
for the degree of

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BRANCH – IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

THE TAMILNADU DR. MGR MEDICAL UNIVERSITY

CHENNAI – 600 032

2015 – 2018

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **“COMPARATIVE CBCT EVALUATION OF DENTINAL CRACK FORMATION, CANAL CENTERING ABILITY & APICAL TRANSPORTATION OF HYFLEX-EDM, ONESHAPE, WAVE-ONE GOLD AND RECIPROC FILES–AN IN VITRO STUDY”** is a bonafide and genuine research work carried out by me under the guidance of **Dr.B.Ramaprabha MDS, Professor,** Department of Conservative Dentistry and Endodontics, Tamil Nadu Government Dental College and Hospital, Chennai-600003.

DR ANBARASU. S

CERTIFICATE BY GUIDE

This is to certify that **Dr.ANBARASU. S,** Post Graduate student (2015-2018) in the Department of Conservative Dentistry and Endodontics, TamilNadu Government Dental College and Hospital, Chennai- 600003 has done this dissertation titled **"COMPARATIVE CBCT EVALUATION OF DENTINAL CRACK FORMATION, CANAL CENTERING ABILITY & APICAL TRANSPORTATION OF HYFLEX-EDM, ONE SHAPE, WAVE-ONE GOLD AND RECIPROC FILES–AN IN VITRO STUDY"** under my direct guidance and supervision in partial fulfillment of the regulations laid down by the Tamil Nadu Dr.M.G.R Medical University Chennai -600032, for M.D.S., Conservative Dentistry and Endodontics (Branch IV) Degree Examination .

DR. B. RAMAPRABHA, M.D.S.
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ENDORSEMENT BY HEAD OF THE DEPARTMENT / HEAD OF THE INSTITUTION

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Above all I pray and thank THE ALMIGHTY GOD for His continuous grace and blessings in my every endeavour.

In His time He makes all things beautiful!

DECLARATION

TITLE OF DISSERTATION	COMPARATIVE CBCT EVALUATION OF DENTINAL CRACK FORMATION, CANAL CENTERING ABILITY & APICAL TRANSPORTATION OF HYFLEX-EDM, ONESHAPE, WAVE-ONE GOLD AND RECIPROC FILES–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. B.RAMA PRABHA
HEAD OF THE DEPARTMENT	DR. M. KAVITHA

I hereby declare that no part of dissertation will be utilized for gaining financial assistance or any promotion without obtaining prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai – 3. In addition I declare that no part of this work will be published either in print or in electronic media without the guide who has been actively involved in dissertation. The author has the right to preserve for publish of the work solely with the prior permission of Principal, Tamil Nadu Government Dental College & Hospital, Chennai – 3.

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And

MRS. DR. B. RAMAPRABHA aged 48 years working as **Professor** in Department of Conservative Dentistry & Endodontics at the college, having residence address at 191/5, Green Fields Apts. R-30A, Ambattur, Thirumangalam High Road, Mugappair, Chennai-3 (herein after referred to as the Principal Investigator’)

And

DR. ANBARASU S, aged 37 years currently studying as **Post Graduate student** in Department of Conservative Dentistry & Endodontics, Tamil Nadu Government Dental College and Hospital, Chennai 3 (herein after referred to as the PG student and coinvestigator).

Whereas the PG student as part of his curriculum undertakes to research on **COMPARATIVE CBCT EVALUATION OF DENTINAL CRACK FORMATION, CANAL CENTERING ABILITY& APICAL TRANSPORTATION OF HYFLEX-EDM, ONE SHAPE, WAVE-ONE GOLD AND RECIPROC FILES–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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10. If any dispute arises as to the matters related or connected to this agreement herein, it shall be referred to arbitration in accordance with the provisions of the Arbitration and Conciliation Act 1996.

In witness where of the parties herein above 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.

College represented by its **Principal** **PG Student**

Witnesses **Student Guide**

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CERTIFICATE – II

This is to certify that this dissertation work titled "**Comparative CBCT evaluation of Dentinal crack formation, Canal centering ability & Apical transportation of Hyflex-EDM, One shape, Wave-one gold & Reciproc files - an in vitro study"** of the candidate **Dr. S. Anbarasu** with registration Number **24151 7001** for the award of **M.D.S - Conservative Dentistry and Endodontics** in the branch of **IV**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows 4 % percentage of plagiarism in the dissertation.

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ABSTRACT

AIM: Recently single file systems have come to replace conventional rotary instruments. In this in vitro study four single file systems- two rotary and two reciprocating instruments were selected to evaluate and compare the Canal centering ability, Apical transportation, Dentinal crack formation in the mesio-buccal root of maxillary first molar at coronal, middle and apical third using **CBCT** and **SEM.**

MATERIALS AND METHODS: One hundred and twenty freshly extracted human maxillary first molars with curvature 10-20 degrees were analyzed by Schneider's method as per inclusion criteria. Mesio buccal roots of 120 teeth were sectioned and root samples were divided into four experimental groups containing thirty teeth each,**Group I – Hyflex EDM, Group II- OneShape, Group III- WaveOne Gold, Group IV- Reciproc.** After cleaning and shaping as per standard irrigation protocol, the teeth were sectioned and scanned at coronal $1/3^{rd}$(4mm), middle $1/3^{rd}$(8mm), apical $1/3^{rd}$(12mm) of the canal in an axial slice thickness of 1mm. The images were recorded in the computer. The values were tabulated by pre and post instrumentation CBCT images. Canal centering ability and apical transportation were calculated using these CBCT values. Five mesio buccal root specimens from each group were taken for dentinal crack analysis; (5×3=15 samples for each group) 2mm from each section of the coronal middle apical 3^{rd} of the samples were observed under SEM for dentinal crack formation.

RESULTS:The canal centering ability was found to be better for OneShape at coronal $1/3^{rd}$ whereas WaveOne Gold was found to be superior to other three groups at the middle & apical $1/3^{rd}$. The canal transportation was found to be least for WaveOne Gold followed by Reciproc, whereas the two rotary files Hyflex-EDM and OneShape showed higher value for transportation towards the lateral wall. Using SEM analysis it was observed that OneShape causes more dentinal cracks than other files systems in coronal and middle thirds with cracks evident in all samples at the apical third. Hyflex-EDM and WaveOne Gold showed similar results in the coronal and middle third. But Hyflex-EDM was found to be better in the apical third.

CONCLUSION: Canal Centering Ability was not statistically significant for all four experimental groups. Least values for canal transportation was obtained for **WaveOne Gold** almost equivalent to **Reciproc** whereas both rotary files showed higher values for canal transportation. OneShape showed most dentinal crack in the coronal, middle and apical third. **Hyflex-EDM** and **WaveOne Gold** produced least dentinal cracks at all levels.

KEY WORDS: Maxillary first molar, Apical transportation, Canal centering ability, Dentinal crack formation, Cone Beam Computed Tomography(CBCT), Scanning Electron Microscope (SEM), **HYFLEX-EDM, ONESHAPE, WAVEONE GOLD, RECIPROC.**

CONTENTS

ABBREVIATIONS USED

CA	Canal Centering Ability
CAC	Canal Centering Ability-Coronal
CAM	Canal Centering Ability-Middle
CAA	Canal Centering Ability-Apical
CTC	Canal Transportation-Coronal
CTM	Canal Transportation-Middle
CTA	Canal Transportation-Apical
DC	Dentinal Crack
OS	OneShape
HFEM	HyFlex EDM
WOG	WaveOne Gold
R25	Reciporc 0.25mm
SS	Stainless Steel
NiTi	Nickel Titanium

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Introduction

INTRODUCTION

Preparation of the root canal system is recognized as being one of the most important stages in root canal treatment. It includes the removal of vital and necrotic tissues from the root canal system, along with infected root dentin. It aims to prepare the canal space to facilitate disinfection by irrigants and medicaments, thus it eliminates infection and prevention of reinfection which is then achieved through the provision of a fluid-tight root canal filling and a coronal restoration[69]. Effective cleaning and shaping of the root canal system is essential for achieving the biological and mechanical objectives of root canal treatment.

Mechanical debridement of root canal has evolved from hand instrumentation to rotary, from rotary to reciprocal instrumentation, each of which method has its proponents and opponent. Rotary stainless steel(SS) root canal instruments, such as Gates Glidden burs and Peeso reamers, can be safely used in the coronal and sometimes the middle third of relatively straight root canals, but their stiffness increases the risk of root perforation as the clinician approaches the middle third of the canal[65].

For this reason, a rotary movement that has equal angles in both directions was successfully introduced resembling the classic watch-winding movement used with manual SS files. Since the introduction of Niti files in 1988, and recent advanced techniques for the mechanical preparation of root canal systems are less procedural error due to their special shaping ability.

Rotary instruments fail via two mechanisms, flexural fatigue and torsional fatigue. The latter occurs when the instrument engages the canal wall and continues to rotate which is common in rotary files. To reduce or avoid torsional fatigue reciprocal files came in to play. Rotary files spin uni-directionally in a clockwise(CW) rotation while reciprocating files oscillate in the clockwise and counterclockwise(CCW) rotation in different direction; the values of the CW and CCW rotations are different[77]. When the instrument rotates in the cutting direction it will advance in the canal and engage dentine to cut it. When it rotates in the opposite direction (smaller rotation) the instrument will be immediately disengaged. Both the files are effective when flexed against canal wall.

New reciprocation files oscillate counterclockwise (150°), then clockwise (30°) resulting in one complete revolution for every three oscillation cycles (~600 rpm combined with 200 rpm). Recently the advances in endodontic root canal preparation focus on the idea that single-file shaping technique is cost effective, simplifying the instrumentation protocol while reducing the risk of instrument failure, reducing the time for preparation and cross contamination[20].

Root canal treatment done using single file rotary systems is approximately 4 times faster than a conventional treatment. Minimal fatigue along the length of the file virtually eliminates the risk of separation, the instrument will unwind to avoid separation and is characterized by different cross sectional designs over the entire length of the working part[27].

The single-file systems in use for the different concepts of continuous rotation and reciprocation are Hyflex-EDM, Hyflex-CM, Race, Self-Adjusting File, One Shape, WaveOne, WaveOne-GOLD, Reciproc, Twisted Adaptive, F360, NEOENDOFLEX, NEOLIX-ENDONITI, REVO-S. These single file systems have different instrument designs and metallurgy[16].

Among these, four newly introduced single file systems Hyflex-EDM and Oneshape, belong to continuous ROTATION FILES; WaveOne-GOLD and Reciproc being the two RECIPROCATING FILES choosen for this study.

These files were used in the mesio buccal root of maxillary first molar and analyzed for its curvature &apical foramen size by Cone –Beam Computed Tomography (CBCT).

Cone –Beam Computed Tomography (CBCT) can render cross-sectional (cut plane) and 3D images that are highly accurate and quantifiable[75]. Comparisons using CBCT have provided repeatable results and also have allowed non-invasive experimentation of various aspects of endodontic instrumentation. The ability to enlarge the canal without canal deviation, apical transportation or instrument separation is a primary objective in endodontics. So it is important to compare the efficacy of instruments to maintain original canal curvature, centering ability of instrument during canal preparation and its ability to preserve dentine thickness.

Apart from the prevention of apical transportation and canal centering ability of the rotary and reciprocating instruments, instrumentation of the root canal has been suggested as a contributing factor to the induction of dentinal defects such as crack formation which decrease the longevity of the root treated teeth that warrants special attention[7]

HYFLEX-EDM Files (COLTENE/WHALEDENT AG, Altstatten, Switzerland)can be used at 500 rpm and at a torque of up to 2.5 Ncm without the glide path files and with the glide path it can be used with 300 rpm and at a torque of up to 1.8 Ncm with slight apical pressure and pecking motion. Other Hyflex-EDM files available are HyFlex-EDM Finishing 40/.04 25mm, HyFlex-EDM Finishing

50/.03 25mm, HyFlex-EDM Finishing 60/.02 25mm, HyFlex-EDM GPF 10/.05 25mm, HyFlex-EDM One File 25/.08 25mm, HyFlex-EDM Orifice 25/.12 15mm. There are three different cross section designs in single file. The rectangular cross section at the tip provides more ‘core material’, which results in high resistance to breakage of these files[39,41]. Then the cross section becomes trapezoidal in the middle of the file and finally near the handle, the cross section changes to triangle which keeps the file more flexible there.

ONE SHAPE (MICROMEGA, Besancon, France) has a unique design that incorporates a variety of different cross sections along the active length of the file, which offers an optimal and improved cutting action in three zones of the root canal. Each instrument has been electro polished to enhance cutting efficiency[40]. The one shape system consists of only one instrument made of a conventional Austenite 55 NiTi alloy with the tip size of 25 and a constant taper of 0.06. At the apical part there are three symmetrical cutting edges, in the middle the number decrease to two cutting edges; this part is asymmetrical. In the coronal part there are two S shaped cutting edges with the rotational speed of 350-450 rpm and 4 Ncm with a slow passive pressure motion and an upward circumferential filing movement.

WAVEONE-GOLD In a single reciprocating file system made from an M-Wire nickel-titanium with gold treatment to increase the cyclic fatigue resistance, having non-cutting tip with a cross section of convex triangular shape, which has a tip size of 0.25 mm and a taper of 0.08 in apical 3 mm. Instrumentation was done as per manufacturer's instructions, 20/07, 25/07/, 35/06, 45/05[60,64].

RECIPROC instruments (VDW, Munich, Germany) are slimmer at the end of the working part than most conical NiTi instruments of comparable diameter, with no need to prepare glide path. It has non cutting tip. R40 prepares the root canal to a diameter of 0.40 mm with a taper of .06 over the first apical millimetres. R50 prepares the root canal to a diameter of 0.50 mm with a taper of .05 over the first apical millimetres. Reciproc files have a continuous taper over the first 3 mm of their working part followed by a decreasing taper until the shaft. The R25 has a diameter of 0.25 mm at the tip and an 8% (0.08 mm / mm) taper over the first 3 mm from the tip. The diameter at D16 is 1.05 mm. The R40 has a diameter of 0.40 mm at the tip and a 6% (0.06 mm / mm) taper over the first 3 mm at the tip and a 5% (0.05 mm / mm) taper over the first 3 mm from the tip[71]. The diameter at D16 is 1.17 mm.

Hence the purpose of this study is to compare and evaluate the canal centering ability, canal transportation, and dentine crack formation of continuous rotary and reciprocating file systems **HYFLEX-EDM** and **ONESHAPE** are used in full continuous rotation, whereas **WAVEONE GOLD** and **RECIPROC** are used in a reciprocal motion.

Aims and Objectives

AIM AND OBJECTIVES

AIM :

The aim of the study is to evaluate and compare the Canal centering ability, Apical transportation, Dentinal crack formation in the mesio-buccal root of maxillary first molar at coronal, middle and apical third using four different files. (Rotary files - **HYFLEX-EDM**, **ONESHAPE** and Reciprocation files – **WAVEONE-GOLD, RECIPROC**) using CBCT and SEM.

OBJECTIVES :

The objective of this study is to determine after careful evaluation which of the four different files has better canal centering ability, less apical transportation and minimal dentinal crack formation.

-To Compare and evaluate the Canal centering ability of HYFLEX-EDM, ONE SHAPE, WAVEONE-GOLD, RECIPROC files after standard mechanical preparation.

-To Compare and evaluate the Apical transportation of HYFLEX-EDM, ONE SHAPE, WAVEONE-GOLD, RECIPROC files after standard mechanical preparation.

-To compare and evaluate Dentinal crack formation of HYFLEX-EDM, ONE SHAPEWAVEONE-GOLD, RECIPROC files after standard mechanical preparation.

The Canal centering ability, Apical transportation are evaluated using Cone Beam Computed tomography (CBCT) whereas Dentinal crack formation is evaluated using Scanning Electron Microscope (SEM).

Review of Literature

CANAL CENTERING ABILITY AND APICAL TRANSPORTATION

Park H et al (2001)[55] did a study on a comparison of greater taper files, ProFiles, and stainless steel files to shape curved root canals. The study concluded that the canals prepared with GT files and Profiles were excellently tapered and maintained the original curvature of the canals in comparison with the ones prepared with stainless steel files.

Garip Y et al (2001)[31] conducted a study on the use of computed tomography when comparing nickel titanium and stainless steel files during preparation of simulated curved canals. They concluded that Ni-Ti instruments produced preparations with adequate enlargement, less transportation, and a better centering ratio.

Schafer AE et al (2003)[65] conducted a study on the Efficiency of rotary nickel-titanium K3 instruments in comparison with stainless steel hand K-Flexofile, shaping ability in simulated curved canals. They concluded that K3 instruments prepared curved canals rapidly and with minimal transportation towards the outer aspect of the curve. Fractures occurred significantly more often with K3.

Song YL et al (2004)[69] performed a study on a comparison of instrument-centering ability within the root canal for three contemporary instrumentation techniques. The result showed that SS K-files, GT hand files and NiTi flex files remain better centered and produce significantly less transportation in curved canals.

Gunday M et al (2005)[37] conducted a study by comparing three different root canal curvature measurement techniques measuring the canal access angle in curved canals. They concluded that using a multiple regression analysis, the CAA was significantly related with a positive correlation between the CAA and curvature height. The results indicated that the CAA is a more effective way of evaluating the root canal curvature.

Hartmann MS et al (2007)[40] investigated Canal transportation after root canal instrumentation using computed tomography and concluded that the manual technique produced same canal transportation compared with oscillatory and rotary techniques. All studied techniques produced canal transportation.

Yared G et al (2008)[76] examined Canal preparation using only one NiTi rotary instrument and concluded that a novel canal preparation technique is introduced using only one Ni-Ti rotary instrument in a reciprocating movement and its advantages include a reduced number of instruments, lower cost, a reduced instrument fatigue and the elimination of possible prior cross-contamination associated with the single use of endodontic instruments.

You SY et al (2011)[77] examined shaping ability of reciprocating motion in curved root canals using micro-computed tomography and reported that the application of reciprocating motion during instrumentation did not result in increased apical transportation when compared with continuous rotation motion, even in the apical part of curved canals. Reciprocating motion might be an attractive alternative method to prevent procedural errors during root canal shaping.

Elio Berutti et al(2012)[22] investigated root canal anatomy preservation using Waveone Reciprocation Files with or without Glide Path and showed that canal modifications seem to be significantly reduced when previous glide path is performed by using the new Waveone nickel-titanium single-file system.

Arias A et al (2012)[6] conducted a study on differences in cyclic fatigue resistance at apical and coronal levels of Reciproc and Waveone new files. They concluded that it was determined that all of the tested NiTi files caused various levels of resin removal. However, Waveone Gold and Hyflex EDM NiTi files were found to cause a lower level of resin removal than Reciproc NiTi files.

Burklein et al (2012)[22] evaluated shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals and concluded that single file systems (Reciproc and Waveone versus Mtwo and Protaper) maintained the original root canal curvature and had no impact on canal cleanliness.

Goldberg M et al (2012)[34] conducted a study on Centering Ability and Influence of experience when using Waveone single-File technique in Simulated canals. They concluded that the Waveone instrument had excellent centering ability with a low risk of fracture or blockage and a short shaping time, regardless of the operator's level of experience.

Schafer E et al (2012)[66] showed that Nickel-titanium (NiTi) root canal instruments have improved the technical quality of enlarging and shaping. These instruments have been shown to prepare even severely curved root canal with fewer procedural errors than traditional stainless steel hand instruments. Evidence from one clinical trial suggests that (i) better maintenance of the original canal curvature and shape results in increased success rates and (ii) that ledging of root canals results in reduced success rates. Evidence from two studies indicates that the use of NiTi-either hand or rotary-instruments significantly increases success rates of primary nonsurgical root canal treatment compared with the use of stainless steel hand instruments, while three investigations failed to show any significant differences.

Al-Sudani D et al (2014)[4]examinedthe influence of different angles and reciprocation on the shaping ability of two nickel-titanium rotary root canal instruments and concluded that the results of the present study demonstrated that differences among various reciprocating motions and angles could affect the shaping ability of a single-file Nickel-titanium (NiTi) instrument.

Dhingra et al (2014)[20] conducted a study to compare and evaluate reciprocating Waveone, Reciproc and rotary One shape single file instrumentation system on cervical dentin thickness, cross sectional area and canal transportation on first mandibular molar using Cone Beam Computed Tomography. They concluded that concluded that reciprocating motion is better than rotary motion in all the three parameters canal transportation, cross-sectional area and cervical dentinal thickness.

Karova E et al (2014)[45] investigatedthe influence of a glide path on the lifespan of Waveone reciprocating files. They concluded that NiTi rotary Path files appear to be suitable instruments for safe and easy creation of the glide path before use of Waveone reciprocating files. The initial enlargement of the canals increases significantly the average lifespan and the survival rate of Waveone files.

Saber SE et al (2014)[64]conducted a study to compare the shaping ability of Waveone, Reciproc and Oneshape single-file systems in severely curved root canals in extracted human molar teeth. They concluded that Reciproc and Waveone instruments respected the original canal curvature better than Oneshape files, the use of Oneshape instruments required less time to prepare the curved canals compared with Reciproc and Waveone.

Moghadam N K et al (2014)[52] examined canal transportation and centering ability of twisted file and Reciproc using cone-beam computed tomography and concluded that both file systems were able keep the original curvature of the canal and thus can be considered safe for clinical application.

Capar ID et al (2014)[16] evaluated different novel nickel-titanium rotary systems for root canal preparation in severely curved root canals and they concluded that the 6 different file systems straightened root canal curvature similarly and produced similar canal transportation in the preparation of mesial canals of mandibular molars. Reciproc instrumentation exhibited superior performance compared with the One Shape, Twisted File Adaptive, and ProTaper Universal systems with respect to volumetric change.

McRay B et al (2014)[49] using micro-computed tomography compared canal transportation and centering ability of ProTaper Universal rotary and Waveone reciprocating files and reported that this study does not support the use of one file system over the other (ProTaper or WaveOne) when comparing transportation and centering ability. Both file systems proved safe for endodontic instrumentation.

Barbieri N et al (2015)[8] conducted study on influence of cervical preflaring on apical transportation in curved root canals instrumented by reciprocating file systems. They concluded that cervical preflaring did not influence apical transportation in curved root canals instrumented using Reciproc R25 and the Waveone Primary files, based on the in vitro measurements of apical transportation, the reciprocating files may be used without preflaring in curved root canals.

Carvalho et al (2015)[17] examined apical transportation, centering ability, and cleaning effectiveness of reciprocating single-file system associated with different Glide Path techniques and they concluded that, the reciprocating single-file system, irrespective of the glide path technique used, promoted minimal apical transportation and remained relatively centralized within the root canal.

Dhingra A et al (2015)[21] compared single file systems Reciproc, Oneshape and Waveone using Cone Beam Computed Tomography and concluded that reciprocating motion is better than rotary motion in all the three parameters canal transportation, cross-sectional area, cervical dentinal thickness.

Saber SE et al (2015)[63] evaluated the shaping ability of Waveone, Reciproc and Oneshape single-file systems in severely curved root canals of extracted teeth and showed that Reciproc and Waveone instruments respected the original canal curvature better than Oneshape files. The use of Oneshape instruments required less time to prepare the curved canals compared with Reciproc and Waveone.

Uzunoglu E et al (2015)[75] conducted a study on comparison of canal transportation, centering ratio by Cone-Beam Computed Tomography after preparation with different file systems and the study was concluded that no significant difference was found between the file systems regarding apical transportation and centering ratio values. Transportation in the mesial direction was greater than the distal transportation for both file systems.

Aditi Jain et al (2016)[1] compared canal transportation, centering ability, and remaining dentin thickness of Waveone and ProTaper rotary by using cone beam computed tomography and showed that Waveone single reciprocation file system respected better canal anatomy better than ProTaper. Individually, centering ability of Waveone was better at 3 mm, 6 mm, and 9 mm levels. However, ProTaper individually was better centered at 3 mm (apical third) and 9 mm (coronal 3rd) levels than 6 mm level.

Hoppe CB et al (2016)[41] conducted study on comparison of curved root canals preparation using reciprocating, continuous and an association of motions and the study was concluded that the single-file reciprocating instrument was capable of providing faster root canal preparation with similar transporting, centralization and cleaning ability when compared with continuous and an association of motions in curved canals.

Simpsy GS et al (2016)[68] conducted a study on shaping ability of reciprocating motion of Waveone and Hyflex in moderate to severe curved canals: A comparative study with cone beam computed tomography and this present study concluded that all systems could be employed in routine endodontics whereas Hyflex and Waveone could be employed in severely curved canals.

Agarwal RS et al (2017)[3] conducted an invitro study on Comparative Analysis of Canal Centering Ability of Different Single File Systems Using Cone Beam Computed Tomography- and the study concluded that there was minor difference between the tested groups. Single file systems demonstrated average canal transportation and centering ability comparable to full sequence Protaper system in curved root canals.

Burklein S et al (2017)[13] conducted a study on apical transportation and canal straightening with different rotary file systems in severely curved root canals: they concluded that all rotary NiTi systems maintained root canal curvature and apical transportation was negligible.

Caroline Zanesco et al (2017)[15] conducted study on apical Transportation, centering ratio, and volume increase after manual, rotary, and reciprocating instrumentation in curved root canals, analyzing by micro-computed tomographic and digital subtraction radiography. They concluded that apical Transportation, centering ratio, and volume increase were similar for manual, rotary, and reciprocating instrumentation.

Maurizio DA et al (2017)[48] conducted a study on Canal shaping of different single-file systems in curved root canals. They concluded thatboth continuous rotary instrument and reciprocating systems did not have any influence on the presence of apical transportation or caused an alteration in angle of canal curvature.

Mittal A et al (2017)[50] conducted a study on Comparative Assessment of Canal Transportation and Centering Ability of Reciproc and One Shape File Systems Using CBCT-An In Vitro Study and they concluded that One shape and Reciproc performed similar in terms of canal transportation & centering ability.

Ozyurek T et al (2017)[53] conducted a study on Shaping Ability of Reciproc, Waveone GOLD, and Hyflex EDM Single-file Systems in Simulated S-shaped Canals. They concluded that, all of the tested NiTi files caused various levels of resin removal. However, the Waveone Gold and Hyflex-EDM NiTi files were found to cause a lower level of dentine removal than the Reciproc NiTi files.

Pier Matteo Venino et al (2017)[59] conducted a study on the Shaping Ability of Two Nickel-Titanium Instruments, Hyflex EDM and ProTaper Next, they concluded that between the middle and coronal thirds, Hyflex EDM files performed better in terms of buccolingual canal transportation and centering ratio. Overall, HFEDM and PTN systems were similarly effective, and both safely prepared the root canals, respecting their original anatomies.

DENTINAL CRACK FORMATION

Marco A et al (2005)[46] conducted a study on micro cracks in endodontic, methodological issues, contemporary concepts, and future perspectives. They concluded that these micro cracks start in the radicular dentin, and laboratory studies have linked crack formation to some routine endodontic procedures, namely root canal preparation, obturation, and retreatment. Most of these studies were performed using destructive methods, such as the sectioning technique, previously developed for the study of the internal anatomy of teeth.

Rui Liu et al (2013)[62] conducted a study on the incidence of root micro cracks caused by 3 different Single-file Systems versus the ProTaper System. They concluded that the Reciproc and SAF file systems caused less root cracks than the ProTaper and Oneshape files.

Ashwinkumar V et al (2014)[7] conducted a study on effect of reciprocating file motion on micro crack formation in root canals: a SEM study and they concluded that ProTaper rotary files produced the most micro cracks when compared to Wave one reciprocating file.

Rohit Kansal et al (2014)[60] conducted a study on assessment of dentinal crack during canal preparation using reciprocating and rotary files. They concluded that motion kinematics has some significant bearing on the dentinal damage during biomechanical preparation.

Tulasi Priya N et al (2014)[73] conducted a study on the incidence of dentinal micro cracks after instrumentation with various types of NiTi files in rotary and reciprocating motion and they concluded that least defects were seen in canals with hand instrumentation, than the rotation and reciprocating motion.

Gergi1 MR et al (2015)[32] conducted a study on dentinal crack formation during root canal preparations by the twisted file adaptive, Reciproc and Waveone instruments. They concluded that the TFA system caused less cracks than the full reciprocating system (Reciproc and Waveone). Single-file reciprocating files produced significantly more incomplete dentinal cracks than full-sequence adaptive rotary motion.

Karatas E et al (2015)[44] conducted a study on dentinal crack formation during root canal preparations by the Twisted File Adaptive, ProTaper Next, ProTaper Universal, and Waveone Instruments, They concluded that all file systems produce dentinal cracks irrespective of the motion.

Jamleh A et al (2015)[42] conducted a study on root surface strain during canal shaping and its influence on apical micro cracks development. They concluded that canal shaping appears to cause apical micro cracks regardless of the type of rotary instrument motion. Contrast-enhanced micro-CT was able to identify micro cracks in root.

Saber et al (2016)[63] conducted a study on incidence of dentinal defects after preparation of severely curved root canals using the Reciproc single-file system with and without prior creation of a glide path. They concluded that root canal preparation with Reciproc resulted in dentinal defects. Prior preparation of a glide path had no positive impact on the incidence of dentinal defects when using Reciproc files.

Topçuoglu HS et al (2016)[72] conducted a study on effect of glide path and apical preparation size on the incidence of apical crack during the canal preparation using Reciproc, Waveone, and ProTaper Next systems in curved root canals using stereomicroscope. The study concluded that canal preparation using size 40 files did not cause propagation of existing cracks. Performing a glide path prior to canal preparation did not change the incidence of apical crack during preparation. Additionally, increasing apical preparation size may increase the incidence of apical crack during canal preparation.

De-Deus et al (2017)[19] conducted a study on dentinal micro cracks development after Canal Preparation with Micro–computed Tomography. They concluded that root canal preparation of maxillary premolars with Reciproc and ProTaper Universal systems did not induce the formation of dentinal micro cracks as observed by micro-CT imaging.

Damla Kirici et al (2017)[18] conducted a study on comparison of the effect of different glide path Ni-Ti rotary systems on the formation of dentinal crack on curved root canals. They concluded that the glide path preparation can prevent instrument fracture and shaping aberrations and it can reduce the risk of taper lock and frictional forces to the canal particularly in teeth with constricted or severely curved canals

Oliveira BP et al (2017)[53] conducted study on micro–Computed Tomographic analysis of apical micro cracks before and after root canal preparation by hand, rotary, and reciprocating instruments at different working lengths. They concluded that Root canal shaping with ProTaper Universal for hand use, Hyflex CM, and Reciproc systems, regardless of the working length, did not produce apical micro cracks.

Pedull E et al (2017)[57] conducted a study on effects of single-file systems on dentinal crack formation. They concluded that multiple factors cause dentinal cracks, but the flexibility of NiTi instruments because of heat treatment seems to influence the incidence of micro cracks more than other factors. In particular, HYFLEX EDM caused less micro cracks than other instruments.

Materials and Methods

MATERIALS

- 3% sodium hypochlorite solution (Septodont)
- 17% EDTA solution (Endoprep-Rc, Anabond Stedman)
- Normal Saline solution(0.9%)- Otsuka
- Clear acrylic resin(DPI)
- 0.3% thymol solution (Micro Fine Chemicals)
- Disposable syringe (2.5ml,27 gauge, (Dispovan)

ARMAMENTARIUM:

- Diamond disc and mandrel (Dimond disc) #109-1302 double-sided 7/8” dia 0.15mm thick.
- Aluminium mold (3cm length,1cm width,1cmheight)
- Air rotor hand piece (NSK, japan)
- Micro motor hand piece (NSK)
- K files (flex files, SybronEndo)
- Stainless steel hand K- file #10,#15, #20 (Dentsply-Maillefer, Switzerland)
- X smart plus motor with hand piece (Dentsply-Maillefer, Switzerland)
- HYFLEX-EDM files (coltene,)
- ONESHAPE files (micromega)
- WAVEONE GOLD files (Dentsply)
- RECIPROC files (VDW, Munich, Germany)
- Endoblock (Dentsply-Maillefer, Switzerland)

EQUIPMENT USED:

Cone Beam Computed Tomography (CBCT) – (CARESTREAM:CS9300C). Scanning electron microscope(SEM)-JSM-7610F-Schottky Field Emission Scanning Electron Microscope.

METHODS :

Selection of teeth:

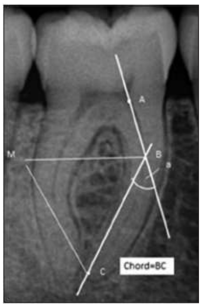
One hundred and twenty (120) freshly extracted maxillary first molars were collected from the Department of Oral and Maxillofacial Surgery, Tamilnadu Government Dental College and Hospital, Chennai.

Criteria for selection of teeth were:

Inclusion criteria:

- Free of caries.
- Free of cracks
- Free of restorations.
- Completely formed root apices.
- Curved root canal of mesiobuccal root of the maxillary first molar with angle of curvature of 10-20 degree selected by schneider’s method.
- **Schneider's method**: Using this method, a mid-point is marked on the file at the level of the canal orifice. A straight line is drawn parallel to the image and that point is labeled as point A. Another second point is marked where the

flare starts to deviate that is labeled point B. A third point is marked at the apical foramen and is termed point C and the angle formed by the intersection of these lines is measured. If the angle is less than 5°, the canal is straight; if the angle is 5-20°, the canal is moderately curved; and if the angle is greater than 20°, the canal is classified as a severely curved canal.



Exclusion criteria:

- Calcified canals.
- Root canals with double or more curvatures
- Curvature more than 20degrees.

PREPARATION OF SPECIMENS:

The study samples comprised of one hundred and twenty freshly extracted human maxillary first molars and were selected based on the inclusion criteria. The teeth were cleaned free of debris and calculus and then were stored in 0.3% thymol solution in order to maintain the physiological characteristics of the teeth.

All the teeth were de-coronated at the level of CEJ using a diamond disc Palatal and distobuccal roots were separated from the tooth and the mesio-buccal root was taken for instrumentation. The root length of the specimens were standardized to a length of about 14-16mm. A patency 10 size stainless steel K- file was passively introduced into the canal until it became visible at the apical foramen and the working length (WL) was established 0.5mm short of this length. All the specimens were taken and embedded into clear acrylic resin, which was placed in aluminium mold measuring 3cm length, 1cm width, 1cm height. The one hundred and twenty specimens were randomly divided into four experimental groups containing 30 teeth each.

All the 120 meiso buccal roots of the maxillary first molar were scanned using a cone beam computed tomography (84Kvp, 5.0mA, 90mm Voxel, Exposure time-20 sec, 1-mm-thickaxial sections, 32 cm display field). Effective dose-598 (μSv) to determine mesio-distal thickness of canal and dentinal crack of the root canal before instrumentation. The teeth were scanned at 4mm, 8mm and 12mm from the apex of the canal in an axial slice thickness of 0.1mm. The values were recorded in the computer.

GROUP 1 : HYFLEX-EDM(n=30):

GROUP 2 : ONE SHAPE(n=30):

GROUP 3 : WAVEONE-GOLD: (n=30)

GROUP 4 : RECIPROC(n=30)

After initial scanning, one twenty specimen canals were negotiated and enlarged upto 20 stainless steel K file. Throughout the instrumentation, all the specimens were irrigated alternatively with 10 ml 3% Naocl and 17% EDTA with duration of 2 minutes using 27 gauge needle. After each instrumentation, irrigation was done, allowing for adequate back flow. Endoprep RC was used throughout the procedure.

Group 1 (Hyflex-EDM)

In group1 canals were instrumented using **Hyflex-EDM** (coltene), with torque control endodontic hand piece (X smart plus with rotational speed of 250r.p.m.). Thirty specimens were prepared according to the manufacturer's recommendation. The canals were finished with apical diameter of 0.25mm with taper of 8%.

Post instrumentation teeth were scanned under the same conditions as the initial scans using CBCT. Data were stored on a magnetic optical disc.

Group II (one shape)

In Group 2 canals were prepared with one shape (MICROMEGA, Besancon, France). using torque control endodontic hand piece (X smart plus rotational speed 250r.p.m.). Thirty specimens were prepared according to the manufacturer's recommendation. The canals were finished with apical diameter of 0.25mm with 6% taper. Post instrumentation teeth were then scanned under the same conditions as the initial scans using CBCT. Data were stored on a magnetic optical disc.

Group III (Wave one-GOLD)

- In group 3 canals were prepared with Wave One Gold primary using torque control endodontic hand piece (X smart plus with reciprocation mode). The single Wave one Gold primary file system has a tip size of 0.25 mm and a taper of 0.07 in apical 3 mm. instrumentation was done as per manufacturer's instructions. Post instrumentation teeth were then scanned under the same conditions as the initial scans using CBCT. Data were stored on a magnetic optical disc.

Group IV (Reciproc)

In group 4 canals were prepared with Reciproc using torque control endodontic hand piece (X smart plus with reciprocation mode), RECIPROC instruments are marked with the ISO colour of the instrument tip size for easy identification.

Thirty specimens were prepared with single Reciproc file with a tip size of 0.25mm and a taper of 0.08 as per manufacturer's instructions. Post instrumentation teeth were then scanned under the same conditions as the initial scans using CBCT. Data were stored on a magnetic optical disc.

All the values (Preinstrumentation and Postinstrumentation) were noted in excel spreadsheet (TABLE 1,2,3&4) and the statistical analysis were done using Statistical Package for the Social Sciences (SPSS) 20 software.

Scanning and imaging:

Sectioning was started at 2 mm from the apex up to coronal orifice (Level 1). The images were stored in the computer's hard disk for further comparison between pre instrumentation and post instrumentation data by CBCT (CARESTREAM: CS9300C).

All the groups were scanned using cone beam CT(Siemens Emotion 6sliceCT scanner) before instrumentation. The CBCT scans were done using the inner ear protocol supplied by the CT scanner, at 84Kvp, 5.0mA, 90mm Voxel, Exposure time-20 sec, 1-mm-thickaxial sections, 32 cm display field of view, and beam incidence at the central portion on the device used to fix the specimens. 3 levels (4mm, 8mm, 12mm) were chosen for evaluation in the CBCT.

Evaluation of canal transportation:

The amount of Canal Transportation was determined by measuring the shortest distance from the edge of uninstrumented canal to the periphery of the root (mesial and distal) and then comparing this with the same measurements obtained from the instrumented images. All values were measured by two evaluators and a mean value was taken.

The following formula was used for the calculation of transportation:

(M1-M2) - (D1-D2)

M1=is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal.

M2= is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal.

D1= is the shortest distance from distal edge of the root to the distal edge of the uninstrumented canal.

D2= is the shortest distance from distal edge of the root to the distal edge of the instrumented canal.

According to this formula, a result other than 0 indicates that transportation has occurred in the canal.

Evaluation of centering ability:

The mean centering ratio indicates the ability of the instrument to stay centered in the canal. It was calculated for each section by using the following ratio:

(M1-M2)/(D1-D2)or(D1-D2)/(M1-M2)

If these numbers are not equal, the lower figure calculated is considered as the numerator of the ratio. According to this formula, a result value of 1 indicates perfect centering. For all groups, shortest distance from the canal outline to the closest adjacent root Surface was measured at each level.

Evaluation of microcracks

Five mesio buccal roots from each group were horizontally sectioned at 4, 8, and 12 mm from the apex with a low-speed dimond disc and mandrel under water cooling resulting in fifteen (5×3) samples for each experimental group. 2mm section from each sample were taken SEM study.

All Sixty specimen were analyzed using Scanning Electron Microscopy CEG 500 KV 690 mm x 100 SE 500 µm slice thickness. Samples were coated with gold-palladium sputtering to make them conductive and samples analyzed in SEM. Post instrumentation pictures were taken with a camera to examine the sections for dentin cracks. Statistical Analysis of cracked root was determined when a crack was found. The results were expressed as the number of cracked roots in each group.

PROCEDURAL FLOWCHART

PREPARATION OF SAMPLES

120 Freshly extracted human maxillary first molars collected.
Plaque and calculus removed
Stored in 0.3% thymol solution

↓

Decoronation done at the CEJ level.

Using diamond disk with .5mm

↓

Mesio buccal root sample sectioned.

Palatal and distobuccal root removed

↓

Root canal curvature assessed by Schneiders method
Canals 10-20 degree were selected.
Standardization of root length for about 14mm

↓

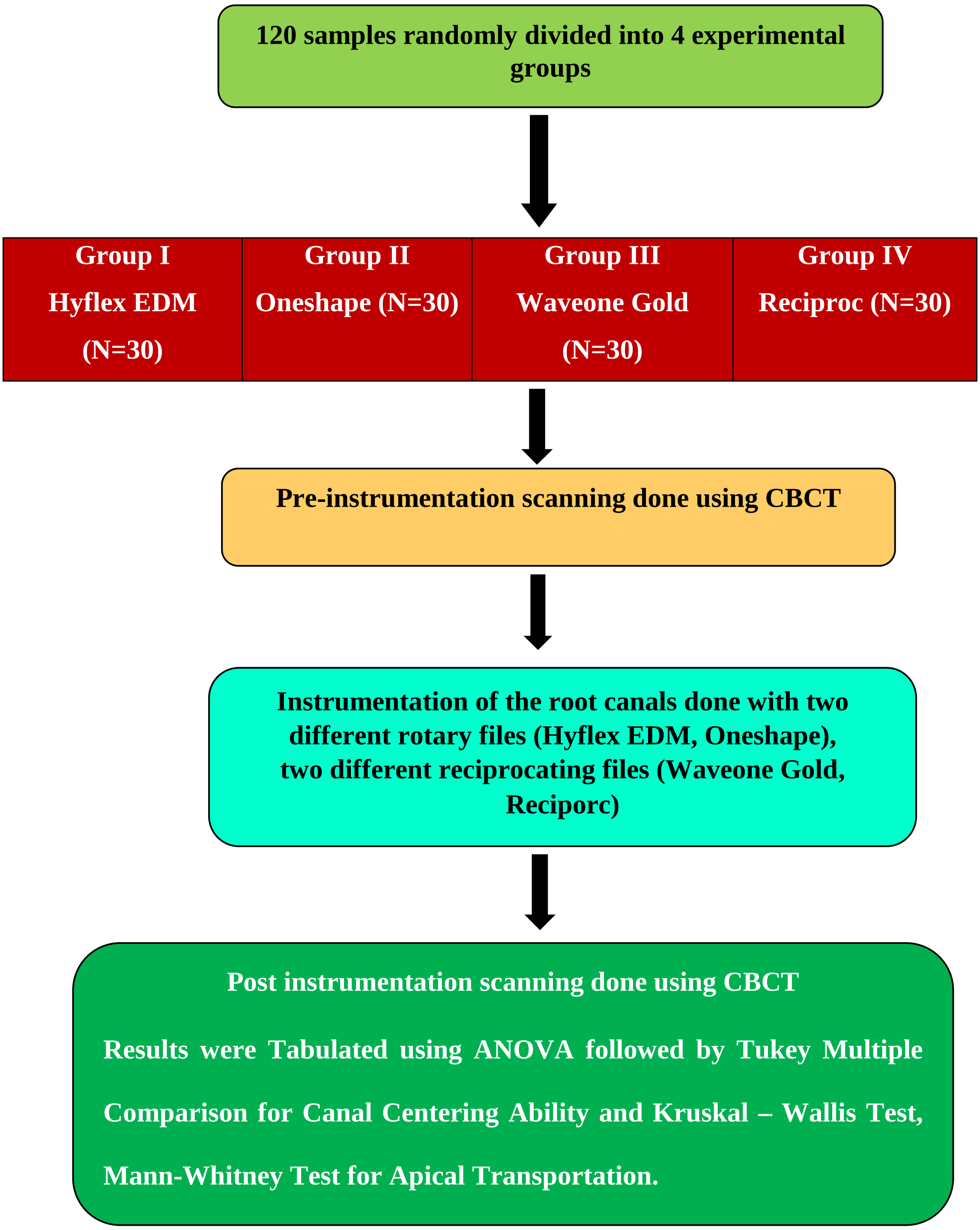
Patency done using 10 size k file.

Working length established 0.5mm of the length

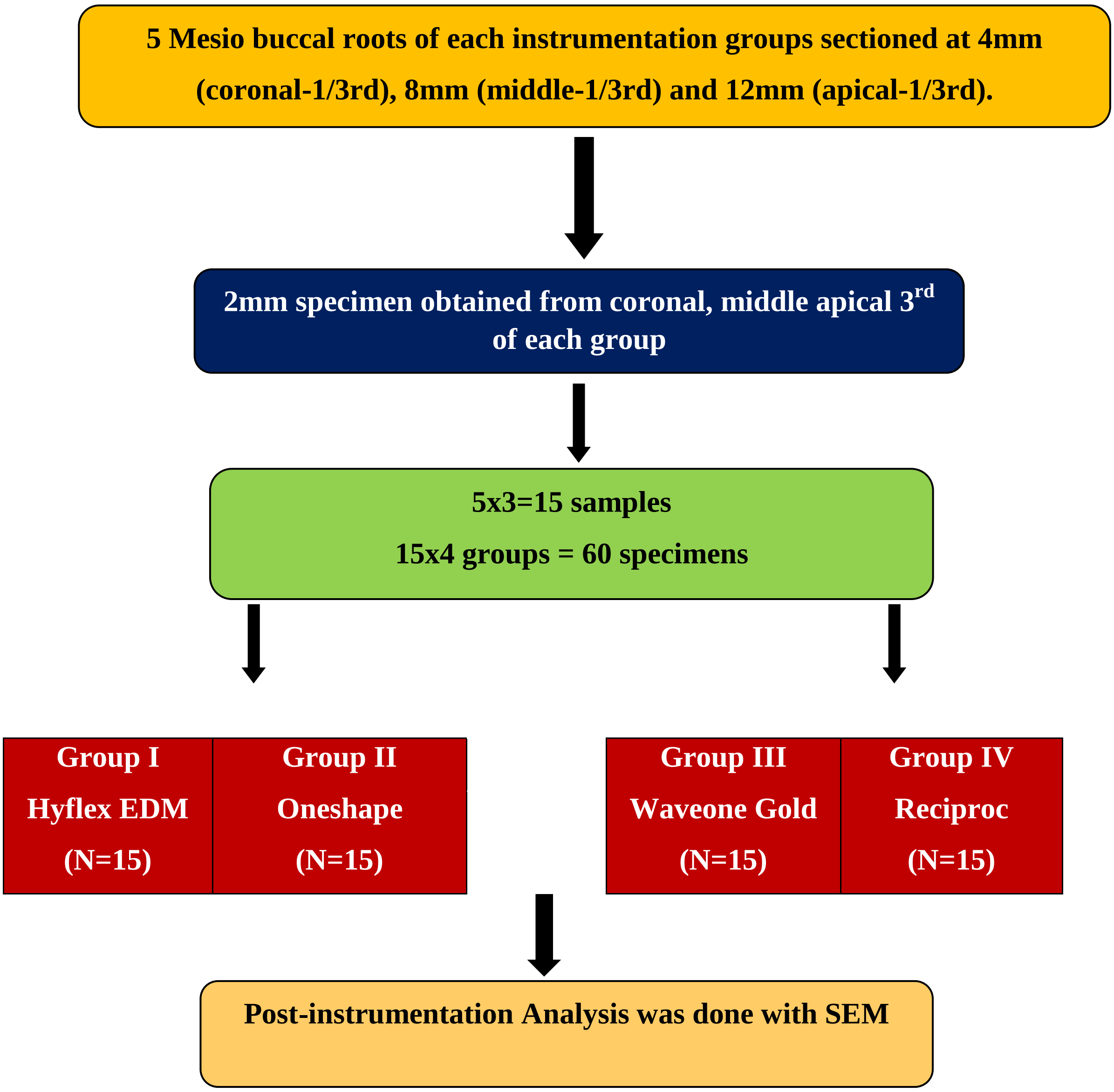
↓

Specimen mounted in an acrylic model.

PROCEDURAL FLOWCHART FOR CBCT SCANNING



PROCEDURAL FLOWCHART FOR SEM ANALYSIS



ARMAMENTARIUM

FIG.1. TEETH SAMPLES

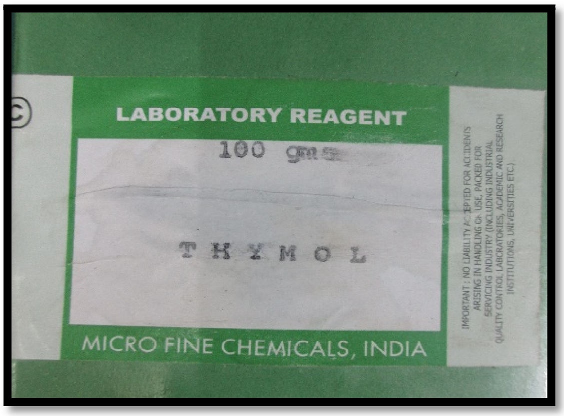


FIG.2. THYMOL REAGENT

FIG.3. NORMAL SALINE, 3% NOCL ENDOPREP-RC

FIG.4. K FILE, DIMOND DISC & MANDREL, ENDO BLOCK

FIG.5. HYFLEX EDM (GROUP –I)

FIG.6. ONE SHAPE (GROUP-II)

FIG.7. XMART PLUS MOTOR

FIG.8. WAVEONE GOLD (GROUP –III)

FIG.9. RECIPROC (GROUP-IV)

FIG.10. SECTIONING OF TOOTH

FIG.11. SECTIONED ROOT

FIG.12. SPECIMEN MOUNTED IN ACRYLIC MODEL FOR CBCT ASSESSMENT

FIG.13. BIOMECHANICAL PREPARATION OF EACH SAMPLE

FIG.14-CONE BEAM COPUTERAISED TOMOGRAPHY

FIG.15 CBCT IMAGING OF THE SPECIMEN

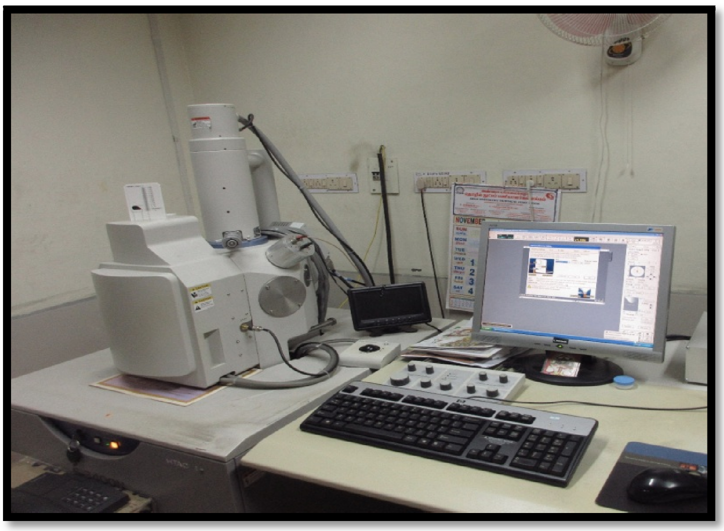
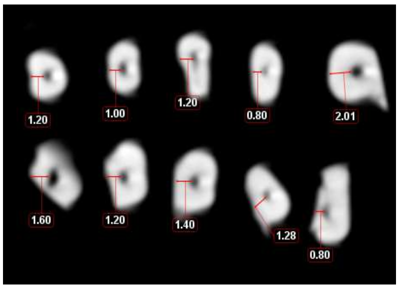


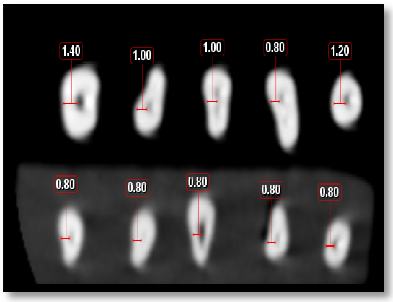
FIG.16 SCANNAING ELECTRON MICROSCOPE

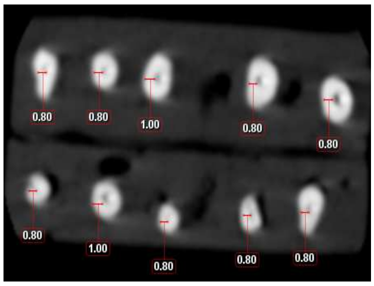
FIG.17. PRE INSTRUMENTATISON CBCT IMAGE

MESIAL SIDE

CORONAL 1/3RD | **MIDDLE 3RD** | **APICAL 3RD**

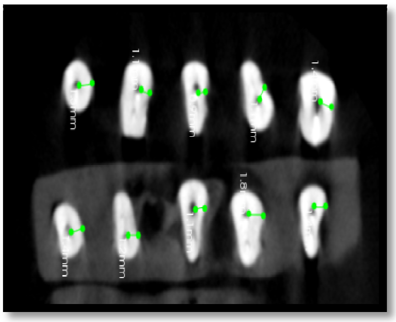


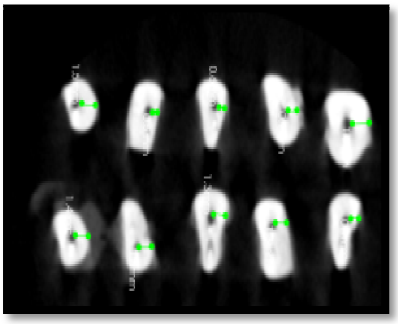


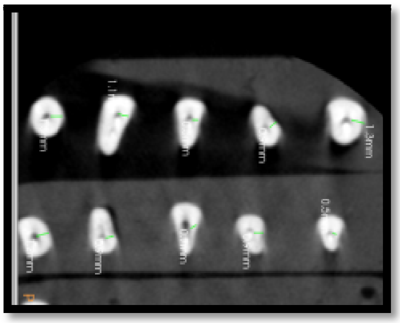


DISTAL SIDE

CORONAL 1/3RD | **MIDDLE 3RD** | **APICAL 3RD**







Results

THIS TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED AND ANALYSED BY CBCT

TABLE -1: CANAL CENTERING ABILITY AND APICAL TRANSPORATION OF GROUP-I HYFLEX EDM FILES

THE TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED USING THE FORMULA 1 AND 2

Sample	Groups	m1c	m2c	m1- m2a	d1c	d2c	d1c-d2c	Coronal Transportation	CAC	m1m	m2m	m1m-m2m	d1m	d2m	d1m-d2m	Middle Transportation	CAM	M1a	m2a	m1a-m2a	d1a	d2a	d1a-d2a	Apical Transportation	CAA
1	Group-I Hy Flex EDM	0.5	0.2	0.3	0.1	0	0.1	0.2	0.333333	1.8	1.2	0.6	1.7	1.4	0.3	0.3	0.5	2	1.8	0.2	1.8	1.3	0.5	-0.3	0.4
2		0.5	0.3	0.2	0.2	0	0.2	0	1	1.7	1.2	0.5	1.2	0.7	0.5	0	1	1.2	1.2	0	1.4	1	0.4	-0.4	0
3		0.6	0.2	0.4	0.3	0.1	0.2	0.2	0.5	1.2	0.5	0.7	1.5	0.9	0.6	0.1	0.85714	1.4	1	0.4	1.2	0.8	0.4	0	1
4		0.5	0.3	0.2	0.3	0	0.3	-0.1	0.666667	1	0.5	0.5	1.2	0.9	0.3	0.2	0.6	1.2	1	0.2	1.8	1.2	0.6	-0.4	0.33333
5		0.4	0.2	0.2	0.2	0	0.2	0	1	1.2	0.8	0.4	1.2	0.8	0.4	0	1	1.6	1.4	0.2	1.2	0.8	0.4	-0.2	0.5
6		0.3	0.1	0.2	0.2	0	0.2	0	1	1.6	1.1	0.5	2	1.6	0.4	0.1	0.8	2	1.5	0.5	1.8	1.5	0.3	0.2	0.6
7		0.3	0.1	0.2	0.1	0	0.1	0.1	0.5	1.2	0.6	0.6	1.8	1.3	0.5	0.1	0.83333	1.7	1.4	0.3	2	1.6	0.4	-0.1	0.75
8		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.4	1.1	0.3	1.2	0.8	0.4	-0.1	0.75	1.8	1.5	0.3	1.4	1.1	0.3	0	1
9		0.4	0.1	0.3	0.4	0.1	0.3	0	1	1.2	0.6	0.6	0.8	0.3	0.5	0.1	0.83333	1.6	1.4	0.2	1.2	0.8	0.4	-0.2	0.5
10		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	0.8	0.3	0.5	1.7	1.3	0.4	0.1	0.8	2	1.6	0.4	1.2	0.7	0.5	-0.1	0.8
11		0.3	0.1	0.2	0.2	0	0.2	0	1	1.2	0.6	0.6	1.9	1.5	0.4	0.2	0.66667	1.3	1	0.3	1.6	1.2	0.4	-0.1	0.75
12		0.5	0.3	0.2	0.2	0	0.2	0	1	1.4	0.9	0.5	1.8	1.5	0.3	0.2	0.6	1.4	1	0.4	1.4	1	0.4	0	1
13		0.6	0.3	0.3	0.3	0	0.3	0	1	1.1	0.6	0.5	1.8	1.7	0.1	0.4	0.2	1	0.6	0.4	1.4	1.1	0.3	0.1	0.75
14		0.4	0.2	0.2	0.4	0.2	0.2	0	1	1.4	1	0.4	1.9	1.5	0.4	0	1	1.8	1.4	0.4	1.5	1.1	0.4	0	1
15		0.4	0.2	0.2	0.3	0.1	0.2	0	1	1.4	0.9	0.5	1.7	1.3	0.4	0.1	0.8	1.6	1.2	0.4	1.2	0.8	0.4	0	1
16		0.4	0.2	0.2	0.3	0	0.3	-0.1	0.666667	1.5	0.8	0.7	1.9	1.5	0.4	0.3	0.57143	1.4	1.1	0.3	1.1	0.9	0.2	0.1	0.66667
17		0.5	0.2	0.3	0.1	0	0.1	0.2	0.333333	1.6	1.2	0.4	1.8	1.4	0.4	0	1	1.2	1	0.2	1.6	1.2	0.4	-0.2	0.5
18		0.7	0.3	0.4	0.1	0	0.1	0.3	0.25	1.4	0.9	0.5	1.8	1.5	0.3	0.2	0.6	1.5	1.3	0.2	1.2	0.7	0.5	-0.3	0.4
19		0.8	0.4	0.4	0.2	0	0.2	0.2	0.5	1.6	1.2	0.4	2	1.7	0.3	0.1	0.75	1.7	1.4	0.3	1.1	0.8	0.3	0	1
20		0.8	0.4	0.4	0.2	0	0.2	0.2	0.5	1.4	1.1	0.3	1.5	1.3	0.2	0.1	0.66667	1.6	1.3	0.3	1.4	1.1	0.3	0	1
21		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.6	0.9	0.7	1.8	1.3	0.5	0.2	0.71429	1.4	1.1	0.3	1.2	0.8	0.4	-0.1	0.75
22		0.6	0.3	0.3	0.3	0.1	0.2	0.1	0.666667	1.4	1.1	0.3	2	1.8	0.2	0.1	0.66667	1.8	1.4	0.4	1.4	0.9	0.5	-0.1	0.8
23		0.4	0.2	0.2	0.2	0	0.2	0	1	1.3	0.8	0.5	1.8	1.5	0.3	0.2	0.6	1.4	1.1	0.3	1.4	0.9	0.5	-0.2	0.6
24		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	1.1	0.7	0.4	1.8	1.4	0.4	0	1	1.3	1	0.3	1.1	0.7	0.4	-0.1	0.75
25		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.5	1.1	0.4	1.9	1.5	0.4	0	1	1.2	1	0.2	1.1	0.8	0.3	-0.1	0.66667
26		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.4	1.1	0.3	1.6	1.3	0.3	0	1	1.4	1.1	0.3	1.4	1.1	0.3	0	1
27		0.3	0.2	0.1	0.2	0.1	0.1	0	1	1.2	1.1	0.1	1.9	1.8	0.1	0	1	1.4	1	0.4	1.6	1.2	0.4	0	1
28		0.4	0.2	0.2	0.1	0	0.1	0.1	0.5	1.2	1.1	0.1	1.9	1.6	0.3	-0.2	0.33333	1.5	1.1	0.4	1.4	1	0.4	0	1
29		0.4	0.2	0.2	0.3	0.1	0.2	0	1	1.4	1.1	0.3	1.8	1.5	0.3	0	1	1.7	1.2	0.5	1.7	1.3	0.4	0.1	0.8
30		0.4	0.3	0.1	0.2	0.1	0.1	0	1	1.1	0.5	0.6	1.8	1.5	0.3	0.3	0.5	1.8	1.2	0.6	1.7	1.3	0.4	0.2	0.66667

THIS TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED AND ANALYSED BY CBCT

TABLE -2: CANAL CENTERING ABILITY AND APICAL TRANSPORATION OF GROUP-II ONE SHAPE FILES

THE TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED USING THE FORMULA 1 AND 2

Sample	Groups	m1c	m2c	m1- m2a	d1c	d2c	d1c-d2c	Coronal Transportation	CAC	m1m	m2m	m1m-m2m	d1m	d2m	d1m-d2m	Middle Transportation	CAM	M1a	m2a	m1a-m2a	d1a	d2a	d1a-d2a	Apical Transportation	CAA
1	Group-II: One Shape Files	0.5	0	0.5	0.6	0.2	0.4	0.1	0.8	0.8	0.4	0.4	1.9	1.6	0.3	0.1	0.75	1.5	1.1	0.4	1.5	1.1	0.4	0	1
2		0.6	0.2	0.4	0.4	0.1	0.3	0.1	0.75	1.2	0.8	0.4	1.9	1.5	0.4	0	1	1.7	1.4	0.3	1.4	1	0.4	-0.1	0.75
3		0.4	0.1	0.3	0.4	0.2	0.2	0.1	0.666667	1.4	0.9	0.5	1.7	1.3	0.4	0.1	0.8	1.6	1.2	0.4	1.6	1.2	0.4	0	1
4		0.5	0.1	0.4	0.5	0.2	0.3	0.1	0.75	1.2	0.9	0.3	1.9	1.6	0.3	0	1	1.8	1.4	0.4	1.4	1.1	0.3	0.1	0.75
5		0.3	0	0.3	0.3	0.1	0.2	0.1	0.666667	1.4	1	0.4	1.7	1.3	0.4	0	1	1.4	1.1	0.3	1.6	1.2	0.4	-0.1	0.75
6		0.3	0	0.3	0.3	0.1	0.2	0.1	0.666667	1.2	0.7	0.5	1.7	1.2	0.5	0	1	1.6	1.4	0.2	1.3	1	0.3	-0.1	0.66667
7		0.4	0.1	0.3	0.4	0.1	0.3	0	1	1.4	0.9	0.5	1.9	1.5	0.4	0.1	0.8	1.6	1.2	0.4	1.5	1.2	0.3	0.1	0.75
8		0.8	0.5	0.3	0.2	0	0.2	0.1	0.666667	1.2	0.8	0.4	1.9	1.6	0.3	0.1	0.75	1.4	1.2	0.2	1.4	1.1	0.3	-0.1	0.66667
9		1	0.6	0.4	0.4	0.1	0.3	0.1	0.75	1.2	0.6	0.6	1.7	1.2	0.5	0.1	0.83333	1.7	1.4	0.3	1.4	1	0.4	-0.1	0.75
10		1	0.5	0.5	0.3	0	0.3	0.2	0.6	1.3	0.8	0.5	1.8	1.3	0.5	0	1	1.4	1.1	0.3	1.5	1.2	0.3	0	1
11		0.5	0	0.5	0.2	0	0.2	0.3	0.4	1.6	1.2	0.4	1.9	1.6	0.3	0.1	0.75	1.6	1.1	0.5	1.7	1.3	0.4	0.1	0.8
12		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.5	0.9	0.6	1.7	1.4	0.3	0.3	0.5	1.8	1.4	0.4	1.8	1.4	0.4	0	1
13		0.6	0.1	0.5	0.1	0	0.1	0.4	0.2	1.4	1.1	0.3	1.9	1.6	0.3	0	1	1.6	1.2	0.4	1.6	1.2	0.4	0	1
14		0.4	0.1	0.3	0.1	0	0.1	0.2	0.333333	1.4	0.9	0.5	1.9	1.5	0.4	0.1	0.8	1.4	1.2	0.2	1.5	1.2	0.3	-0.1	0.66667
15		0.7	0.2	0.5	0.3	0.1	0.2	0.3	0.4	1.4	0.8	0.6	1.5	1.1	0.4	0.2	0.66667	1.7	1.4	0.3	1.5	1.1	0.4	-0.1	0.75
16		0.4	0	0.4	0.4	0.1	0.3	0.1	0.75	1.2	0.8	0.4	1.1	0.7	0.4	0	1	1.6	1.3	0.3	1.5	1.1	0.4	-0.1	0.75
17		0.6	0.2	0.4	0.3	0.1	0.2	0.2	0.5	1.2	0.9	0.3	1.1	0.8	0.3	0	1	1.8	1.5	0.3	1.1	0.7	0.4	-0.1	0.75
18		0.5	0.1	0.4	0.4	0.1	0.3	0.1	0.75	1.2	0.5	0.7	1.2	0.7	0.5	0.2	0.71429	1.4	1.1	0.3	1.2	0.8	0.4	-0.1	0.75
19		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.5	1.1	0.4	1.1	0.7	0.4	0	1	1.6	1.2	0.4	1.4	1	0.4	0	1
20		0.7	0.3	0.4	0.2	0.1	0.1	0.3	0.25	1.3	1.1	0.2	1.1	0.7	0.4	-0.2	0.5	1.5	1.1	0.4	1.4	1.1	0.3	0.1	0.75
21		0.5	0.1	0.4	0.2	0	0.2	0.2	0.5	1.5	0.7	0.8	1.1	0.6	0.5	0.3	0.625	1.6	1.2	0.4	1.2	0.8	0.4	0	1
22		0.8	0.3	0.5	0.3	0.1	0.2	0.3	0.4	1.2	0.8	0.4	0.9	0.4	0.5	-0.1	0.8	1.8	1.4	0.4	1.4	1.1	0.3	0.1	0.75
23		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.1	0.5	0.6	1.2	0.7	0.5	0.1	0.83333	1.4	1	0.4	1.5	1.2	0.3	0.1	0.75
24		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.4	1.1	0.3	1.1	0.8	0.3	0	1	1.8	1.2	0.6	1.4	1.1	0.3	0.3	0.5
25		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.2	0.9	0.3	1.2	0.9	0.3	0	1	1.7	1.2	0.5	1.1	0.8	0.3	0.2	0.6
26		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.3	0.9	0.4	1.3	1	0.3	0.1	0.75	1.6	1.1	0.5	1.4	1.1	0.3	0.2	0.6
27		0.5	0.3	0.2	0.2	0	0.2	0	1	1.4	1.1	0.3	1.3	0.9	0.4	-0.1	0.75	1.8	1.4	0.4	1.2	1	0.2	0.2	0.5
28		0.6	0.2	0.4	0.2	0	0.2	0.2	0.5	1.6	1.1	0.5	1.3	0.9	0.4	0.1	0.8	1.3	1	0.3	1.4	1.1	0.3	0	1
29		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.1	0.9	0.2	1.3	0.9	0.4	-0.2	0.5	1.2	1	0.2	1.1	0.8	0.3	-0.1	0.66667
30		0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.5	1.3	1	0.3	1.1	0.6	0.5	-0.2	0.6	1.6	1.2	0.4	1.4	1.1	0.3	0.1	0.75

THIS TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED AND ANALYSED BY CBCT

TABLE -3: CANAL CENTERING ABILITY AND APICAL TRANSPORATION OF GROUP-III WAVEONE GOLD FILES

THE TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED USING THE FORMULA 1 AND 2

Sample	Groups	m1c	m2c	m1- m2a	d1c	d2c	d1c-d2c	Coronal Transportation	CAC	m1m	m2m	m1m-m2m	d1m	d2m	d1m-d2m	Middle Transportation	CAM	M1a	m2a	m1a-m2a	d1a	d2a	d1a-d2a	Apical Transportation	CAA
1	Group-III: Waveone Gold Files	0.3	0.1	0.2	0.2	0	0.2	0	1	1.5	1.1	0.4	0.9	0.5	0.4	0	1	1.5	1.1	0.4	1.1	0.8	0.3	0.1	0.75
2		0.3	0	0.3	0.2	0	0.2	0.1	0.666667	1.3	1	0.3	0.9	0.7	0.2	0.1	0.66667	1.8	1.3	0.5	1.4	1	0.4	0.1	1.25
3		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	1.7	1.4	0.3	0.9	0.6	0.3	0	1	1.7	1.4	0.3	1.1	0.7	0.4	-0.1	0.75
4		0.5	0.1	0.4	0.1	0	0.1	0.3	0.25	0.9	0.8	0.1	0.8	0.6	0.2	-0.1	0.5	1.8	1.6	0.2	1.1	0.7	0.4	-0.2	0.5
5		0.5	0.1	0.4	0.3	0.1	0.2	0.2	0.5	0.9	0.6	0.3	0.9	0.5	0.4	-0.1	0.75	1.2	0.7	0.5	1.4	1.1	0.3	0.2	0.6
6		0.4	0.1	0.3	0.4	0.1	0.3	0	1	1.1	1.1	0	1.1	0.7	0.4	-0.4	0	1.3	1	0.3	1.3	0.8	0.5	-0.2	0.6
7		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.2	1	0.2	1.1	0.7	0.4	-0.2	0.5	1.4	1.1	0.3	1.1	0.7	0.4	-0.1	0.75
8		0.4	0.1	0.3	0.2	0	0.2	0.1	0.666667	1.2	0.8	0.4	0.8	0.7	0.1	0.3	0.25	1.4	1	0.4	1.3	0.9	0.4	0	1
9		0.5	0.2	0.3	0.4	0.1	0.3	0	1	1.1	1	0.1	1.1	0.8	0.3	-0.2	0.33333	1.6	1.2	0.4	1.1	0.7	0.4	0	1
10		0.5	0.2	0.3	0.4	0.2	0.2	0.1	0.666667	1.3	0.8	0.5	1.1	0.8	0.3	0.2	0.6	1.4	1	0.4	1.3	0.9	0.4	0	1
11		0.5	0.1	0.4	0.3	0.1	0.2	0.2	0.5	1.4	0.9	0.5	0.8	0.6	0.2	0.3	0.4	1.8	1.4	0.4	1.4	1.1	0.3	0.1	0.75
12		0.4	0.1	0.3	0.4	0.1	0.3	0	1	1.2	0.7	0.5	0.7	0.7	0	0.5	0	1.2	1	0.2	1.2	0.9	0.3	-0.1	0.66667
13		0.5	0.2	0.3	0.4	0.1	0.3	0	1	0.8	0.6	0.2	0.9	0.7	0.2	0	1	1.4	1	0.4	1.2	0.9	0.3	0.1	0.75
14		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	0.7	0.5	0.2	0.8	0.6	0.2	0	1	1.5	1.1	0.4	1.3	0.9	0.4	0	1
15		0.5	0.1	0.4	0.3	0.1	0.2	0.2	0.5	0.8	0.6	0.2	0.9	0.7	0.2	0	1	1.2	1	0.2	1.2	0.9	0.3	-0.1	0.66667
16		0.6	0.2	0.4	0.4	0.1	0.3	0.1	1.333333	1.4	1.1	0.3	1.1	0.7	0.4	-0.1	0.75	1.6	1.3	0.3	1.1	0.6	0.5	-0.2	0.6
17		0.4	0.2	0.2	0.4	0.1	0.3	-0.1	0.666667	1.4	0.9	0.5	1.2	0.7	0.5	0	1	1.8	1.4	0.4	1.4	1.1	0.3	0.1	0.75
18		0.4	0.2	0.2	0.4	0.1	0.3	-0.1	0.666667	1.4	0.8	0.6	1.1	0.8	0.3	0.3	2	1.7	1.4	0.3	1.3	1	0.3	0	1
19		0.5	0.2	0.3	0.4	0.4	0	0.3	0	1.2	0.8	0.4	1.1	0.8	0.3	0.1	0.75	1.7	1.5	0.2	1.3	1	0.3	-0.1	0.66667
20		0.5	0.2	0.3	0.3	0	0.3	0	1	1.4	1.1	0.3	1.1	1	0.1	0.2	3	1.9	1.4	0.5	1.4	1	0.4	0.1	0.8
21		0.4	0.1	0.3	0.4	0.1	0.3	0	1	1.4	1	0.4	1.2	1	0.2	0.2	2	1.5	1.4	0.1	1.1	0.6	0.5	-0.4	0.2
22		0.4	0.1	0.3	0.4	0	0.4	-0.1	0.75	1.4	0.9	0.5	1.2	0.8	0.4	0.1	0.8	2	1.5	0.5	1.1	0.8	0.3	0.2	0.6
23		0.5	0.2	0.3	0.1	0	0.1	0.2	0.333333	1.1	0.7	0.4	1.2	0.7	0.5	-0.1	0.8	1.9	1.5	0.4	1.2	0.8	0.4	0	1
24		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	1.3	0.7	0.6	1.1	0.6	0.5	0.1	0.83333	1.8	1.4	0.4	1.3	1	0.3	0.1	0.75
25		0.4	0.2	0.2	0.2	0	0.2	0	1	1.2	0.7	0.5	0.9	0.6	0.3	0.2	0.6	1.9	1.4	0.5	1.4	1.1	0.3	0.2	0.6
26		0.3	0.1	0.2	0.1	0	0.1	0.1	0.5	1.1	0.7	0.4	0.8	0.6	0.2	0.2	0.5	1.8	1.5	0.3	1.3	0.9	0.4	-0.1	0.75
27		0.3	0.1	0.2	0.2	0	0.2	0	1	1.3	0.9	0.4	0.8	0.6	0.2	0.2	0.5	1.8	1.5	0.3	1.3	1	0.3	0	1
28		0.4	0.1	0.3	0.1	0	0.1	0.2	0.333333	1.4	0.9	0.5	0.9	0.6	0.3	0.2	0.6	1.8	1.5	0.3	1.1	0.8	0.3	0	1
29		0.2	0	0.2	0.2	0	0.2	0	1	1.2	0.7	0.5	0.8	0.7	0.1	0.4	0.2	1.9	1.5	0.4	1.3	1	0.3	0.1	0.75

THIS TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED AND ANALYSED BY CBCT

TABLE -4: CANAL CENTERING ABILITY AND APICAL TRANSPORATION OF GROUP-IV RECIPROC FILES

THE TABLE SHOWS THE VALUES OF CANAL CENTERING ABILITY AND APICAL TRANSPORATION WERE CALCULATED USING THE FORMULA 1 AND 2

Sample	Groups	m1c	m2c	m1- m2a	d1c	d2c	d1c-d2c	Coronal Transportation	CAC	m1m	m2m	m1m-m2m	d1m	d2m	d1m-d2m	Middle Transportation	CAM	M1a	m2a	m1a-m2a	d1a	d2a	d1a-d2a	Apical Transportation	CAA
1	Group-IV: Reciproc Files	0.6	0.3	0.3	0.3	0.1	0.2	0.1	0.666667	1.2	0.7	0.5	1.1	0.7	0.4	0.1	0.8	2.1	1.6	0.5	1.1	0.8	0.3	0.2	0.6
2		0.5	0.3	0.2	0.3	0	0.3	-0.1	0.666667	1.1	0.6	0.5	1.1	0.7	0.4	0.1	0.8	2	1.6	0.4	1.3	0.4	0.9	-0.5	0.44444
3		0.6	0.4	0.2	0.2	0	0.2	0	1	1.3	0.9	0.4	0.8	0.5	0.3	0.1	0.75	2.1	1.7	0.4	1.1	0.6	0.5	-0.1	0.8
4		0.4	0.2	0.2	0.2	0	0.2	0	1	1.2	0.9	0.3	0.7	0.5	0.2	0.1	0.66667	2	1.6	0.4	1.1	0.6	0.5	-0.1	0.8
5		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	1.2	0.9	0.3	0.9	0.6	0.3	0	1	1.9	1.5	0.4	1.3	1	0.3	0.1	0.75
6		0.6	0.3	0.3	0.2	0	0.2	0.1	0.666667	1.2	1	0.2	1.1	0.7	0.4	-0.2	0.5	1.8	1.4	0.4	1.1	0.6	0.5	-0.1	0.8
7		0.5	0.2	0.3	0.3	0.1	0.2	0.1	0.666667	1.3	1	0.3	1	0.7	0.3	0	1	1.7	1.5	0.2	1.3	1	0.3	-0.1	0.66667
8		0.6	0.3	0.3	0.2	0	0.2	0.1	0.666667	1.4	1	0.4	1	0.7	0.3	0.1	0.75	1.8	1.6	0.2	1.3	1	0.3	-0.1	0.66667
9		0.5	0.3	0.2	0.2	0	0.2	0	1	1.2	0.8	0.4	0.9	0.6	0.3	0.1	0.75	1.9	1.5	0.4	1.1	0.7	0.4	0	1
10		0.8	0.5	0.3	0.3	0.1	0.2	0.1	0.666667	1.2	0.9	0.3	0.9	0.5	0.4	-0.1	0.75	1.9	1.5	0.4	1.3	1	0.3	0.1	0.75
11		0.4	0.2	0.2	0.4	0.2	0.2	0	1	1.2	0.9	0.3	1.1	0.7	0.4	-0.1	0.75	1.8	1.4	0.4	1.1	0.7	0.4	0	1
12		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	0.8	0.5	0.3	0.9	0.6	0.3	0	1	1.9	1.6	0.3	1.4	0.8	0.6	-0.3	0.5
13		0.7	0.3	0.4	0.2	0	0.2	0.2	0.5	1.1	0.5	0.6	1.1	0.9	0.2	0.4	0.33333	2	1.6	0.4	1.3	1	0.3	0.1	0.75
14		0.5	0.1	0.4	0.2	0	0.2	0.2	0.5	1.2	0.9	0.3	1.1	0.7	0.4	-0.1	0.75	2.1	1.7	0.4	1.3	1	0.3	0.1	0.75
15		0.5	0.2	0.3	0.2	0	0.2	0.1	0.666667	1.1	0.7	0.4	1.1	0.8	0.3	0.1	0.75	1.9	1.5	0.4	1.2	0.6	0.6	-0.2	0.66667
16		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.1	0.9	0.2	1.1	0.7	0.4	-0.2	0.5	1.8	1.4	0.4	1.4	1.1	0.3	0.1	0.75
17		0.3	0	0.3	0.2	0	0.2	0.1	0.666667	1.2	0.8	0.4	1.1	0.7	0.4	0	1	1.9	1.4	0.5	1.2	0.8	0.4	0.1	0.8
18		0.9	0.3	0.6	0.2	0	0.2	0.4	0.333333	1.1	0.7	0.4	0.8	0.5	0.3	0.1	0.75	1.8	1.5	0.3	1.3	0.9	0.4	-0.1	0.75
19		0.6	0.3	0.3	0.3	0.1	0.2	0.1	0.666667	1.3	0.6	0.7	0.9	0.7	0.2	0.5	0.28571	1.3	1	0.3	1.1	0.8	0.3	0	1
20		0.6	0.3	0.3	0.3	0.1	0.2	0.1	0.666667	1.2	0.7	0.5	1.2	0.9	0.3	0.2	0.6	1.6	1.4	0.2	1.3	1	0.3	-0.1	0.66667
21		0.5	0.2	0.3	0.4	0.2	0.2	0.1	0.666667	1.1	0.9	0.2	0.9	0.7	0.2	0	1	1.8	1.5	0.3	1.4	1.1	0.3	0	1
22		0.5	0.3	0.2	0.4	0.2	0.2	0	1	1.1	0.6	0.5	0.8	0.5	0.3	0.2	0.6	1.7	1.4	0.3	1.3	0.8	0.5	-0.2	0.6
23		0.6	0.2	0.4	0.4	0.2	0.2	0.2	0.5	1.2	0.9	0.3	0.9	0.6	0.3	0	1	2.1	1.8	0.3	1.1	0.8	0.3	0	1
24		0.4	0.1	0.3	0.3	0.1	0.2	0.1	0.666667	1.4	1	0.4	0.9	0.6	0.3	0.1	0.75	1.9	1.5	0.4	1.4	1.1	0.3	0.1	0.75
25		0.6	0.2	0.4	0.2	0	0.2	0.2	0.5	1.2	0.6	0.6	0.8	0.6	0.2	0.4	0.33333	1.8	1.6	0.2	1.1	0.8	0.3	-0.1	1.5
26		0.4	0.1	0.3	0.3	0	0.3	0	1	1.2	0.9	0.3	0.8	0.6	0.2	0.1	0.66667	2	1.7	0.3	1.3	0.9	0.4	-0.1	0.75
27		0.7	0.2	0.5	0.2	0	0.2	0.3	0.4	1.2	0.8	0.4	0.9	0.6	0.3	0.1	0.75	2	1.7	0.3	1.4	1.1	0.3	0	1
28		0.5	0.3	0.2	0.2	0	0.2	0	1	1.1	0.7	0.4	0.9	0.6	0.3	0.1	0.75	1.9	1.5	0.4	1.1	0.8	0.3	0.1	0.75
29		0.4	0.2	0.2	0.2	0	0.2	0	1	1.2	0.6	0.6	0.9	0.6	0.3	0.3	0.5	1.7	1.2	0.5	1.3	1	0.3	0.2	0.6
30		0.4	0.2	0.2	0.2	0	0.2	0	1	1.2	0.9	0.3	1.1	0.7	0.4	-0.1	0.75	1.9	1.6	0.3	1.1	0.8	0.3	0	1

TABLE 5 Shows Descriptive statistics of CCA in coronal 1/3rd, middle 1/3rdapical 1/3rd and ANOVA followed by Tukey multiple comparison test as represented in Table 7A and Table 7B. This table is used to analyze the canal centering ability of Group-I, Group-II, Group-III and Group-IV file at coronal, middle, apical 1/3rd and shows no statistical significance among all the Rotary and Reciprocatary files at the 3 different region (p>0.05).

TABLE 5 Shows that Descriptive statistics of CCA in coronal 1/3, Middle 1/3, apical 1/3
TABLE 5 - CANAL CENTERING ABILITY
Descriptive

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
CAC	Hyflex EDM	30	.7156	.24806	.04529	.6546	.8398	.25	1.00
	One shape	30	.7369	.18825	.03437	.5453	.6859	.20	1.00
	Wave one Gold	30	.7251	.28895	.05276	.6143	.8301	.00	1.33
	Reciproc	30	.7244	.20284	.03703	.6487	.8002	.33	1.00
	Total	120	.7024	.23798	.02172	.6593	.7454	.00	1.33
CAM	Hy flex EDM	30	.7548	.21494	.03924	.6745	.8350	.20	1.00
	One shape	30	.7351	.16727	.03054	.7550	.8799	.50	1.00
	Wave one Gold	30	.7978	.61101	.11155	.5696	1.0259	.00	3.00
	Reciproc	30	.7195	.20011	.03654	.6448	.7942	.29	1.00
	Total	120	.7724	.34680	.03166	.7097	.8351	.00	3.00
CAA	Hiyflex EDM	30	.7451	.20337	.03713	.7194	.8713	.44	1.50
	One shape	30	.7521	.15226	.02780	.7237	.8374	.50	1.00
	Wave one Gold	30	.7833	.21009	.03836	.7049	.8618	.20	1.25
	Reciproc	30	.7643	.25312	.04621	.6383	.8273	.00	1.00
	Total	120	.7730	.20658	.01886	.7357	.8103	.00	1.50

TABLE 5A Showed ONEWAY ANOVA
TABLE 5A – ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CAC	Between Groups	.313	3	.104	1.883	**.136**
	Within Groups	6.427	116	.055		
	Total	6.740	119			
CAM	Between Groups	.173	3	.058	.474	**.701**
	Within Groups	14.139	116	.122		
	Total	14.312	119			
CAA	Between Groups	.068	3	.023	.528	**.664**
	Within Groups	5.010	116	.043		
	Total	5.078	119			

TALBLE 5B Showing Tukey Multiple Comparison Test

TABLE 5B - MULTIPLE COMPARISONS

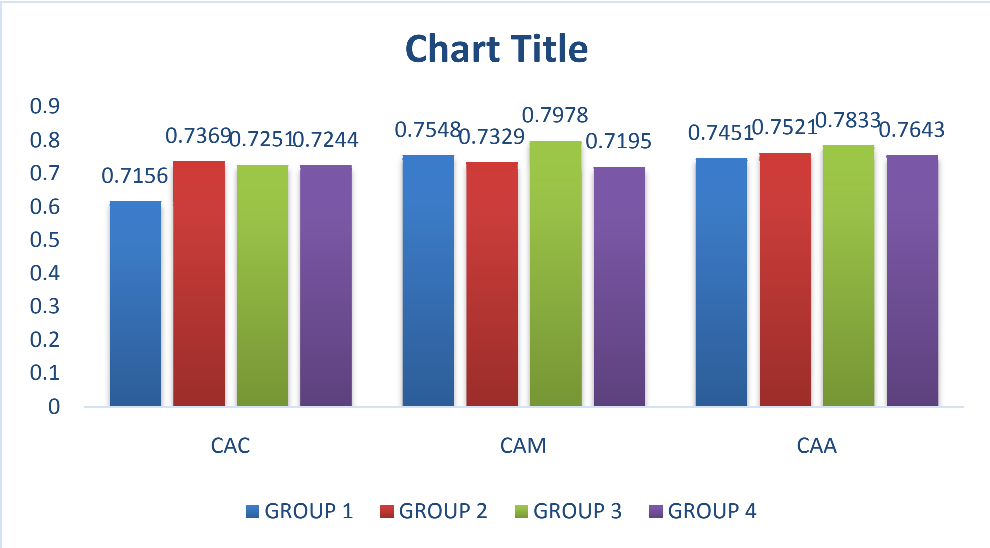
Tukey HSD

Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
CAC	Hy flex EDM	One shape	.13167	.06077	.139	-.0268	.2901
		Wave one Gold	.02500	.06077	.976	-.1334	.1834
		Reciproc	.02278	.06077	.982	-.1356	.1812
	One shape	Hy flex EDM	-.13167	.06077	.139	-.2901	.0268
		Wave one Gold	-.10667	.06077	.300	-.2651	.0518
		Reciproc	-.10889	.06077	.283	-.2673	.0495
	Wave one Gold	Hy flex EDM	-.02500	.06077	.976	-.1834	.1334
		One shape	.10667	.06077	.300	-.0518	.2651
		Reciproc	-.00222	.06077	1.000	-.1606	.1562
	Reciproc	Hy flex EDM	-.02278	.06077	.982	-.1812	.1356
		One shape	.10889	.06077	.283	-.0495	.2673
		Wave one Gold	.00222	.06077	1.000	-.1562	.1606
CAM	Hy flex EDM	One shape	-.06266	.09014	.899	-.2976	.1723
		Wave one Gold	-.04302	.09014	.964	-.2780	.1920
		Reciproc	.03524	.09014	.980	-.1997	.2702
	One shape	Hyflex EDM	.06266	.09014	.899	-.1723	.2976
		Wave one Gold	.01964	.09014	.996	-.2153	.2546
		Reciproc	.09790	.09014	.699	-.1371	.3329
	Wave one Gold	Hy flex EDM	.04302	.09014	.964	-.1920	.2780
		One shape	-.01964	.09014	.996	-.2546	.2153
		Reciproc	.07825	.09014	.821	-.1567	.3132
	Reciproc	Hy flex EDM	-.03524	.09014	.980	-.2702	.1997
		One shape	-.09790	.09014	.699	-.3329	.1371
		Wave one Gold	-.07825	.09014	.821	-.3132	.1567
CAA	Hy flex EDM	One shape	-.04778	.05366	.810	-.1876	.0921
		Wave one Gold	-.05056	.05366	.782	-.1904	.0893
		Reciproc	-.06259	.05366	.649	-.2025	.0773
	One shape	Hyflex EDM	.04778	.05366	.810	-.0921	.1876
		Wave one Gold	-.00278	.05366	1.000	-.1426	.1371
		Reciproc	-.01481	.05366	.993	-.1547	.1251
	Wave one Gold	Hy flex EDM	.05056	.05366	.782	-.0893	.1904
		One shape	.00278	.05366	1.000	-.1371	.1426
		Reciproc	-.01204	.05366	.996	-.1519	.1278
	Reciproc	Hy flex EDM	.06259	.05366	.649	-.0773	.2025
		One shape	.01481	.05366	.993	-.1251	.1547
		Wave one Gold	.01204	.05366	.996	-.1278	.1519

CANAL CENTERING ABILITY (CA)

Graph-1 showing Canal Centering Ability of Group-I, Group-II, Group-III and Group-IV at Coronal, Middle and Apical Level.

Graph-1



At coronal third, ratio for waveone Gold is 0.73 which is little more than others and close to 1 compared to other files, revealing that it maintained the canal centering ability better than other file systems.

At middle third, waveone gold appears to be better than other systems (0.79)

At apical third, waveone gold (0.78) maintained the canal centering ability better than other file systems.

GRAPH-1 showing that apical 1/3 of **WAVEONE-GOLD** file has higher canal centering ability and **HYFLEX-EDM** shows lower canal centering ability but there is no statistically significant difference among the four groups.

TABLE 6 CANAL TRANSPORTATION

Table 6 shows the Descriptive statistics of Canal Transportation.

Report

Groups		Coronal Transportation	Middle Transportation	Apical Transportation
Hy flex EDM	Mean	.0667	.0733	.0472
	N	30	30	30
	Std. Deviation	.15298	.12994	.09589
	Median	-.0500	.1000	.0500
One shape	Mean	.0996	.0780	.0167
	N	30	30	30
	Std. Deviation	.11472	.12484	.09371
	Median	.0000	.0000	.1000
Wave one Gold	Mean	0.0700	.0733	-0.0067
	N	30	30	30
	Std. Deviation	.13629	.19989	.11188
	Median	.0000	.1000	.1000
Reciproc	Mean	0.0933	.0800	-0.0300
	N	30	30	30
	Std. Deviation	.14890	.16484	.10148
	Median	.0000	.1000	.1000
Total	Mean	0.0933	.0742	-0.0300
	N	120	120	120
	Std. Deviation	.14126	.15745	.10476
	Median	.0000	.1000	.1000

Table 6A Kruskal-Wallis Test

Table 6A shows Kruskal-Wallis Test revealing that **HYFLEX-EDM** Causes more than Apical Transportation then other files.

Ranks

	Groups	N	Mean Rank
Coronal Transportation	Hy flex EDM	30	61.48
	One shape	30	57.62
	Wave one Gold	30	53.12
	Reciproc	30	59.78
	Total	120	
Middle Transportation	Hy flex EDM	30	67.57
	One shape	30	52.88
	Wave one Gold	30	61.23
	Reciproc	30	60.32
	Total	120	
Apical Transportation	Hyflex EDM	30	48.35
	One shape	30	57.80
	Wave one Gold	30	55.03
	Reciproc	30	59.82
	Total	120	

Test Statistics[a,b]

	Coronal Transportation	Middle Transportation	Apical Transportation
Chi-Square	11.820	2.827	5.210
Df	3	3	3
Asymp. Sig.	**.157**	**.219**	**.004**

a. Kruskal Wallis Test

TABLE 7 GROUP 1 VS 2

ONLY TAKE THE HIGHLIGHTED P VALUES-Mann-Whitney Test

Table 7 shows Mann-Whitney Test between Group 1 & 2 and

HYFLEX-EDM causes more apical transportation than **ONE SHAPE**

This results shows there is no statistically significant difference. (P>0.05)

Ranks

	Groups	N	Mean Rank	Sum of Ranks	P Value
Coronal Transportation	Hy flex EDM	30	37.12	1113.50	.027
	One shape	30	33.88	1042.50	
	Total	60			
Middle Transportation	Hy flex EDM	30	26.57	797.00	.070
	One shape	30	34.43	71033.00	
	Total	60			
Apical Transportation	Hyflex EDM	30	35.13	1054.000	.034
	One shape	30	25.13	776.00	
	Total	60			

TABLE 8 GROUP 1 VS 3

Mann-Whitney Test

Table 8 shows that Mann-Whitney Test between Group 1 & 3 and hyflex-EDM causes more apical transportation than wave one gold. It is statistically significant. (p<0.05)

Ranks

	Groups	N	Mean Rank	Sum of Ranks	P Value
Coronal Transportation	Hyflex EDM	30	30.30	909.00	
	Wave one Gold	30	20.70	821.00	.926
	Total	60			
Middle Transportation	Hyflex EDM	30	31.78	953.50	.562
	Wave one Gold	30	19.22	776.50	
	Total	60			
Apical Transportation	Hy flex EDM	30	26.60	798.00	.003
	Wave one Gold	30	14.40	732.00	
	Total	60			

TABLE 9 GROUP 1 VS 4

Mann-Whitney Test

Table 9 shows Mann-Whitney Test between Group 1 and 4 providing the result **Hyflex EDM** Causes more apical transportation than RECIPROC. It is statistically significant. ($p<0.05$).

Ranks

	Groups	N	Mean Rank	Sum of Ranks	P Value
Coronal Transportation	Hyflex EDM	30	28.30	849.00	
	Reciproc	30	12.70	781.00	.301
	Total	60			
Middle Transportation	Hyflex EDM	30	32.35	970.50	
	Reciproc	30	18.65	759.50	.397
	Total	60			
Apical Transportation	Hyflex EDM	30	27.88	836.50	
	Reciproc	30	13.12	793.50	
	Total	60			0.004

TABLE 10 GROUP 2 VS 3

Mann-Whitney Test

Table 10 shows Mann-Whitney Test between Group 2 and 3 providing the results **One Shape** file more apical transportation than Wave One Gold file. But it is not statistically significant. ($p>0.05$).

Ranks

	Groups	N	Mean Rank	Sum of Ranks	P Value
Coronal Transportation	One shape	30	36.32	1089.50	
	Wave one Gold	30	24.68	740.50	.766
	Total	60			
Middle Transportation	One shape	30	28.72	861.50	
	Wave one Gold	30	32.28	968.50	.419
	Total	60			
Apical Transportation	One shape	30	31.15	934.50	
	Wave one Gold	30	29.85	895.50	.016
	Total	60			

TABLE 11 Mann-Whitney Test

Table 11 shows Mann-Whitney Test between Group 2 and 4 providing the result **ONE SHAPE** file causes more apical transportation than **RECIPROC** file. The result there is no statistically significant. (p>0.05).

Ranks

	Groups	N	Mean Rank	Sum of Ranks	P Value
Coronal Transportation	One shape	30	35.18	1055.50	
	Reciproc	30	25.82	774.50	.354
	Total	60			
Middle Transportation	One shape	30	28.60	858.00	
	Reciproc	30	32.40	972.00	.381
	Total	60			
Apical Transportation	One shape	30	32.52	975.50	
	Reciproc	30	28.48	854.50	.223
	Total	60			

Table 12 Mann-Whitney Test

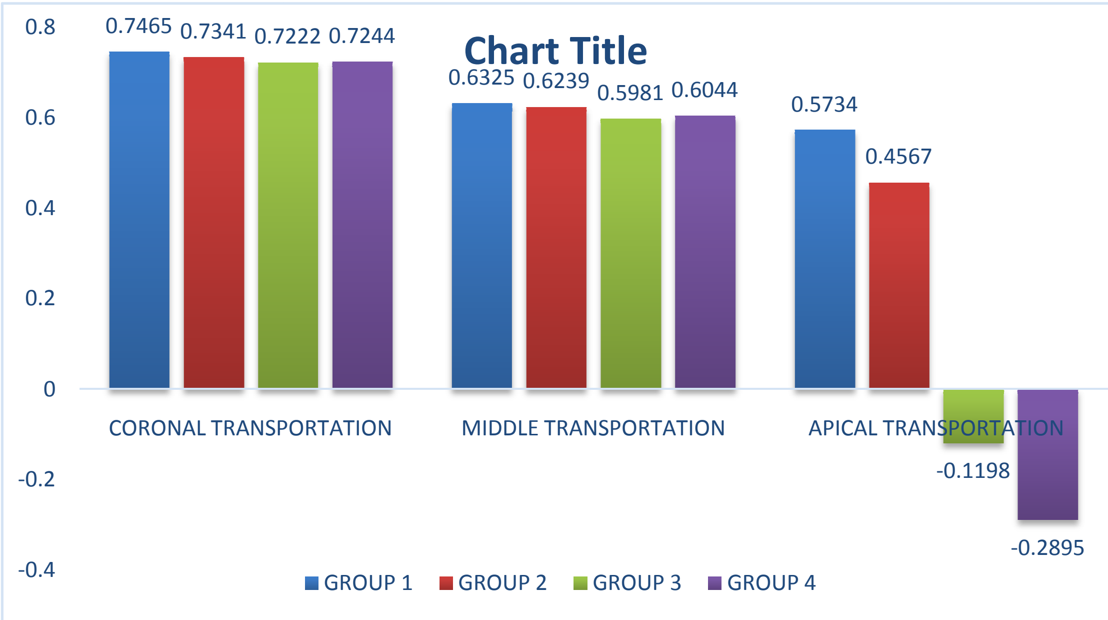
Table 12 shows Mann-Whitney Test between Group 3 and 4 providing the result that that Reciproc causes more apical transportation than wave one gold file. The result is not statistically significant. (p>0.05).

Ranks

	Groups	N	Mean Rank	Sum of Ranks	P Value
Coronal Transportation	Wave one Gold	30	28.73	862.00	
	Reciproc	30	32.27	968.00	.411
	Total	60			
Middle Transportation	Wave one Gold	30	30.73	922.00	
	Reciproc	30	30.27	908.00	.916
	Total	60			
Apical Transportation	Wave one Gold	30	31.78	953.50	
	Reciproc	30	29.22	876.50	.558
	Total	60			

GRAPH-2

Graph-2 showing Transportation of Group-I, Group-II, Group-III and Group-IV at Coronal, Middle and Apical Level.



At coronal third, ratio for **Hyflex-EDM** is 0.74 which is little more than others and away from 0 is revealed that the Apical transportation is more compared to other files. But it is not statistically significant. In coronal $1/3^{rd}$ all files causes canal transportation towards lateral wall of the canal.

At middle third, ratio for **Hyflex-EDM** is 0.63 which is little more than others and away from 0 is revealed that the Apical transportation is more compared to other files. But it is not statistically significant difference. In middle third all files causes canal transportation towards lateral wall of the canal.

At Apical third, ratio for **Hyflex-EDM** is 0.57 which is little more than others and away from 0 is revealed that the Apical transportation is more compared to other files it is statistically significant. (P<0.004)

In Apical 1/3 **Reciproc, Waveone-Gold files** causes canal transportation towards furcation wall of the canal and **Hyflex-EDM, One shape** files causes canal transportation towards lateral the wall of the canal.

Table 13 Numerical Calculation value for Dentinal Crack Formation

Table 13 shows the presence (1) or absence (0) of dentin crack created by all four files at 3 diff regions.

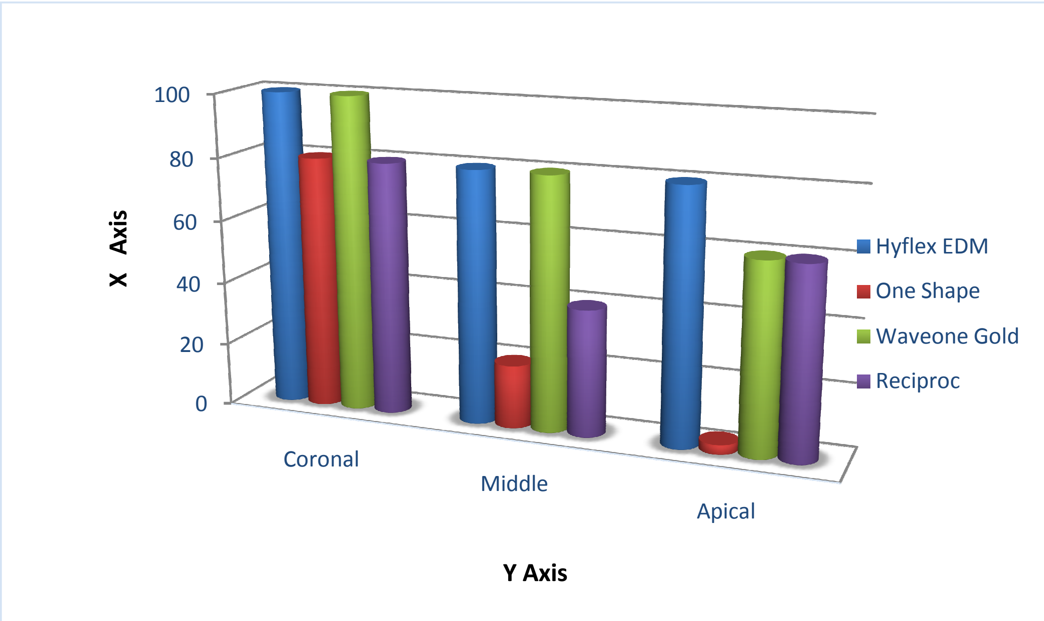
Type of Rotary	Cor	Mid	Apical
HYFLEX	0	0	0
	0	0	0
	0	0	1
	0	0	0
	0	1	0
ONE SHAPE	0	0	1
	0	1	1
	1	1	1
	0	1	1
	0	1	1
WAVE ONE GOLD	0	1	0
	0	0	1
	0	0	0
	0	0	1
	0	0	0
RECIPROC	0	1	0
	1	0	0
	0	1	0
	0	1	1
	0	0	1
‘P’ Value	0.528	0.141	0.016

Table 14

COMPARISION OF DENTINAL CRACK ABSENCE AMONG VARIOUS TYPES OF FILES AT THE VARIOUS LEVEL OF ROOT

Position	Hyflex EDM		One Shape		Waveone Gold		Reciproc		P.Value
	Absent Count	%	Absent Count	%	Absent Count	%	Absent Count	%	
Coronal	5	100	4	80	5	100	4	80	0.528
Middle	4	80	1	20	4	80	2	40	0.141
Apical	4	80	0	0	4	60	3	60	0.016

Graph-3 Dentinal Crack Formation Bar Diagram



Y: Axis – Dentinal Cracks of Group-I, Group-II, Group-III and Group-IV Files

X: Axis – Percentage Value

INFERENCE

It was observed that there were no differences in the magnitude of transportation between the rotary instruments and reciprocating instruments. ($p>0.05$) at both coronal level as well as middle level from the apex.

At Coronal 1/3rd level, Group IHYFLEX-EDM showed significantly higher mean canal transportation and lower centering ability, as compared to Group II one shape, Group III wave one gold, Group IV Reciproc.

At middle 1/3rd level, Group III Wave One Gold showed significantly higher centering ability, lower mean canal transportation and as compared to Hyflex-EDM, Group II one shape, Group IV Reciproc.

At apical level, Group I Hyflex-EDM showed significantly higher mean canal transportation and lower centering ability, as compared to Group II one shape, Group III wave one gold, Group IV Reciproc.

Order of canal centering ability

Order of canal Centering Ability in the Coronal third of the canal were as follows

Hyflexedm ≤ Waveone gold ≤ Reciproc ≤ One shape

Order of canal Centering Ability in the Middle third of the canal were as follows

Hyflexedm ≤ Reciproc ≤ One shape ≤ Waveonegold

Order of canal Centering Ability in the Apical third of the canal were as follows

Hyflexedm ≤ One shape ≤ Reciproc ≤ Waveone gold

OneShape files shows better canal centering ability in the coronal third of the canal when compared to other files. But not statistically significant.

Wave one-Gold files shows better canal centering ability in the middle third, apical third of the canal when compared to other files. But not statistically significant.

Order of Canal Transportation

Order of Canal Transportation in the Coronal third of the canal were follows

Wave One Gold ≤ **Reciproc = One shape** ≤ **Hyflex-EDM.**

Order of Canal Transportation in the middle third of the canal were follows

Wave One Gold ≤ Reciproc = One shape ≤ Hyflex-EDM.

Order of Apical Transportation in the apical third of the canal were follows

Wave One Gold ≤ Reciproc ≤ One shape ≤ Hyflex-EDM

Wave one gold maintains the originalcanal anatomy at apical 1/3rd when compared to other file. Hyflex-EDM is least in maintaining the original canal anatomy in the apical 1/3rd when compared to other files, and it is statistically significant only between Hyflex EDM and Wave One Gold.

Order of Dentinal Crack

Order of dentinal cracks in coronal third of the canal was as follows

One shape = Reciproc > Hyflex-EDM = WaveoneGold

Order of dentinal cracks in middle third of the canal was as follows

One shape > Reciproc > Hyflex-EDM = WaveoneGold.

Order of dentinal cracks in apical third of the canal was as follows

One shape > Reciproc > Hyflex-EDM = WaveoneGold.

One shape files shows more Dentinal cracks at all the slevels of the canal when compared to other files.

Hyflex-EDM Comparable to Wave one gold in the coronal and middle 1/3rd and performed better at apical 1/3rd which is not statistically significant.

Table 15 Percentage value of Canal Centering Ability and Apical Transportation of Group I, II, III, IV, V

Groups		**Percentage Value**
Group I	A	5.67%
	B	94.33%
Group II	A	8.45 %
	B	91.55%
Group III	A	3.33%
	B	96.67%
Group IV	A	6.33%
	B	93.67%

A- Negative

B- Positive

INTERGROUPS COMPARISON

Table No.15 shows 5.67% of Group-I (Hyflex-EDM) has negative value and 94.33% has positive value. So the negative value states that 5.67% of the Group-I files causes canal transportation towards the furcation of the canal and 94.33% of the files causes canal transportation towards lateral surface to the canal.

It shows 8.45% of Group-II (One shape) has negative value and 91.55% has positive value. So the negative value states that 8.45% of the Group-II files causes canal transportation towards the furcation of the canal and 91.55% of the files causes canal transportation towards lateral surface to the canal.

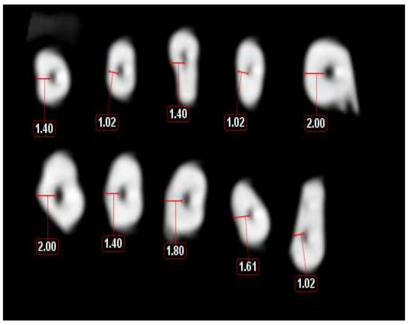
It shows 3.33% of Group-III (Wave One Gold) has negative value and 96.67% has positive value. So the negative value states that 3.33% of the Group-III files causes canal transportation towards the furcation of the canal and 96.67% of the files causes canal transportation towards lateral surface to the canal.

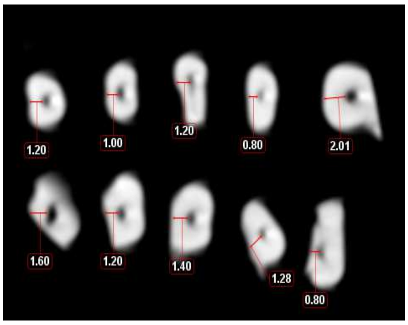
It shows 6.33% of Group-IV (Reciproc) has negative value and 93.67% has positive value. So the negative value states that 3.33% of the Group IV files causes canal transportation towards to the furcation of the canal and 96.67% of the files causes canal transportation towards lateral surface to the canal.

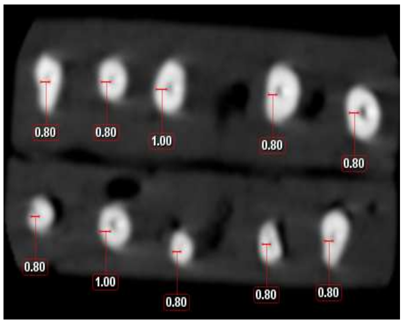
FIG.18. POST INSTRUMENTATISON CBCT IMAGES FOR GROUP-I HYFLEX-EDM

MESIAL SIDE

CORONAL 1/3RD | **MIDDLE 3RD** | **APICAL 3RD**

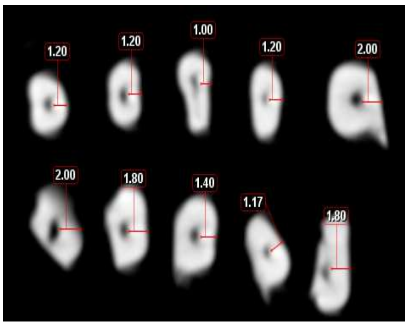


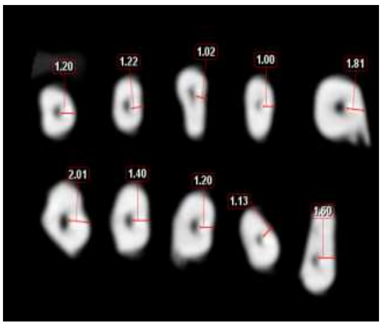




DISTAL SIDE

CORONAL 1/3RD | **MIDDLE 3RD** | **APICAL 3RD**





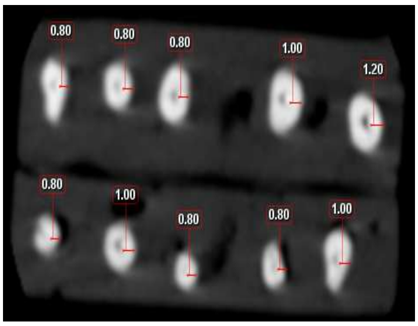
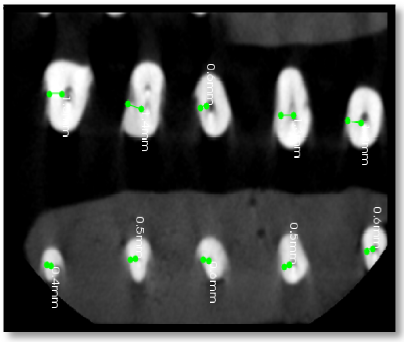


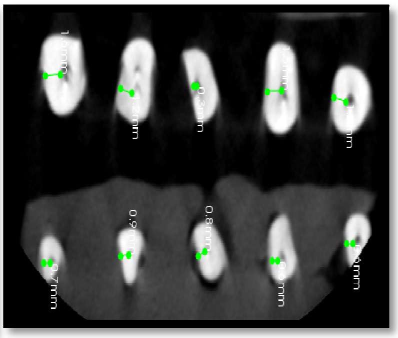
FIG.19. POST INSTRUMENTATISON CBCT IMAGES FOR GROUP-II ONESHAPE

MESIAL SIDE

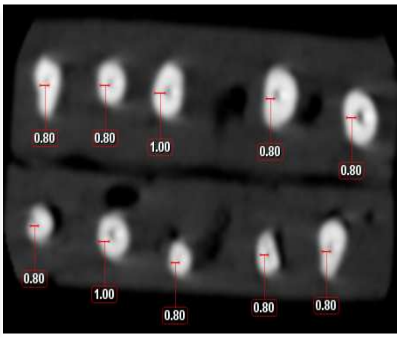
CORONAL 1/3RD



MIDDLE 3RD

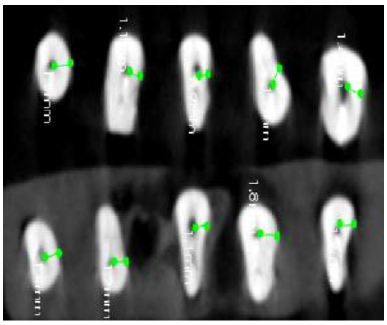


APICAL 3RD

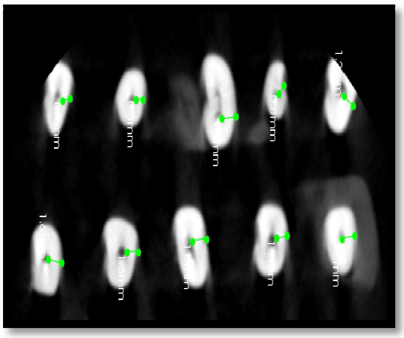


DISTAL SIDE

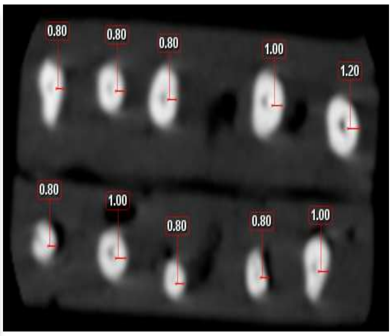
CORONAL 1/3RD



MIDDLE 3RD



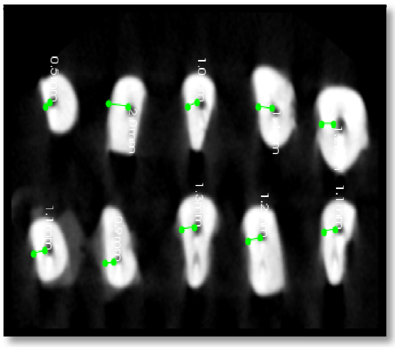
APICAL 3RD

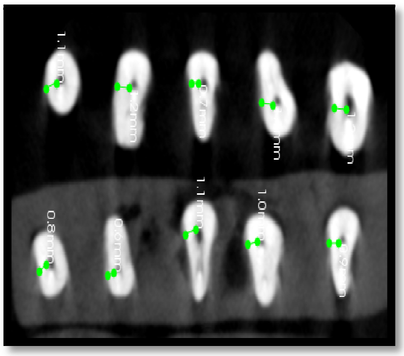


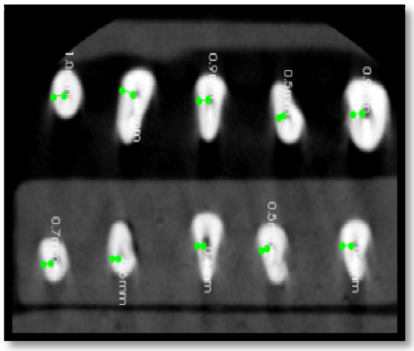
PIG.20. POST INSTRUMENTATISON CBCT IMAGES FOR GROUP-III WAVEONE GOLD

MESIAL SIDE

CORONAL 1/3RD | **MIDDLE 3RD** | **APICAL 3RD**

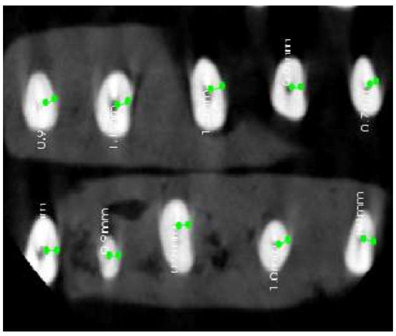


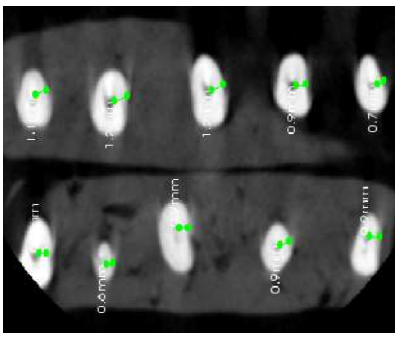




DISTAL SIDE

CORONAL 1/3RD | **MIDDLE 3RD** | **APICAL 3RD**





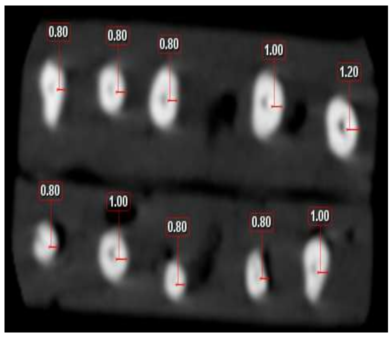
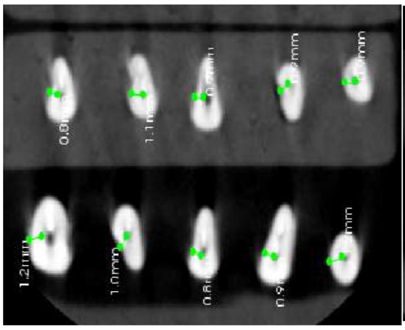
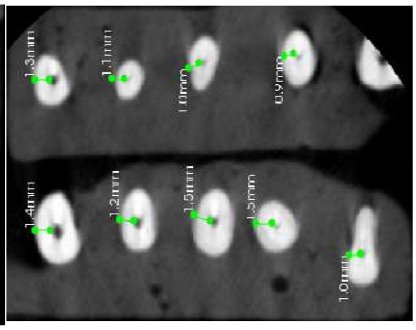
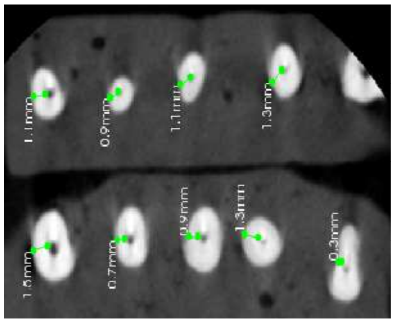


FIG.21. POST INSTRUMENTATISON CBCT IMAGES FOR GROUP-IV RECIPROC

MESIAL SIDE

CORONAL 1/3RD	MIDDLE 3RD	APICAL 3RD
		

DISTAL SIDE

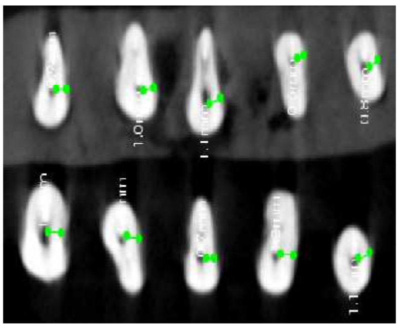
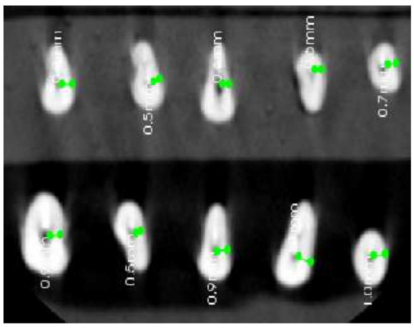
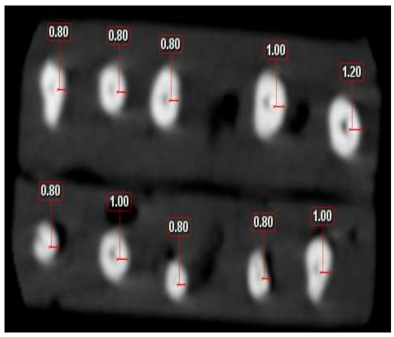
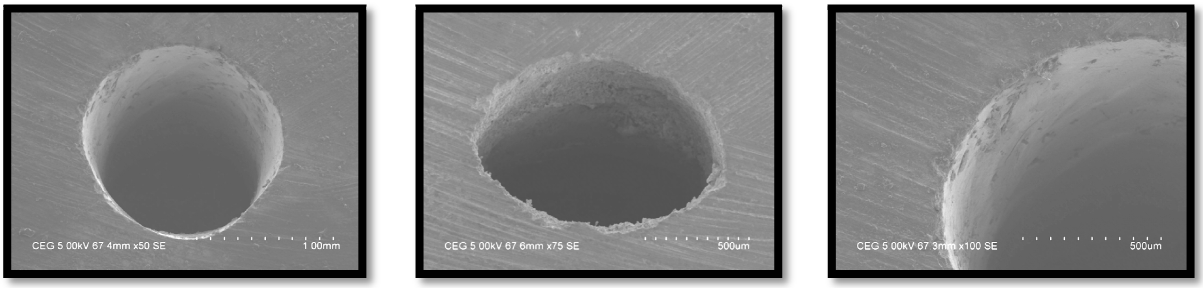
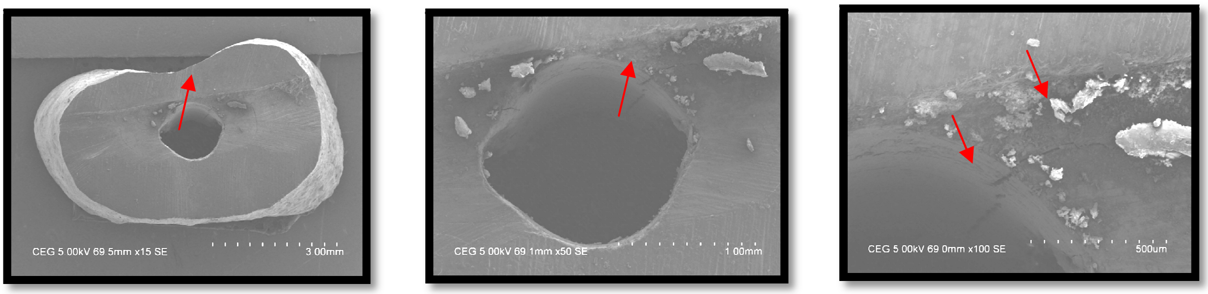
CORONAL 1/3RD	MIDDLE 3RD	APICAL 3RD
		

FIG.22. DENTINAL CRACK FORMATION - SEM ANALYSIS

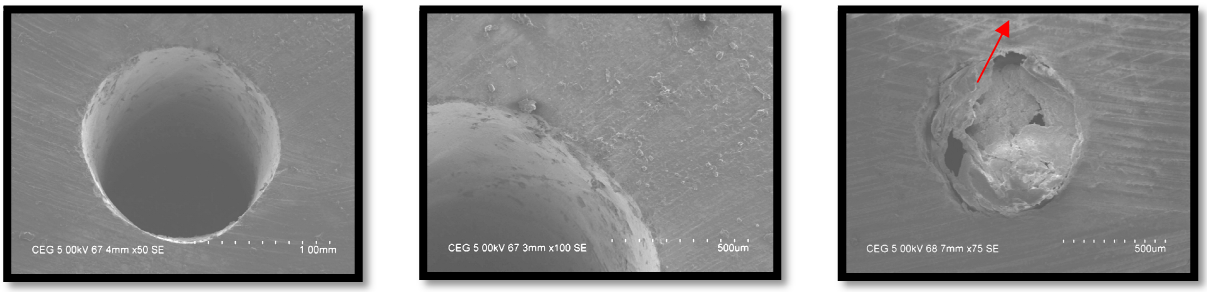
Dentinal Crack Formation in Hyflex-EDM File System in Coronal Middle Apical 1/3rd of The Root



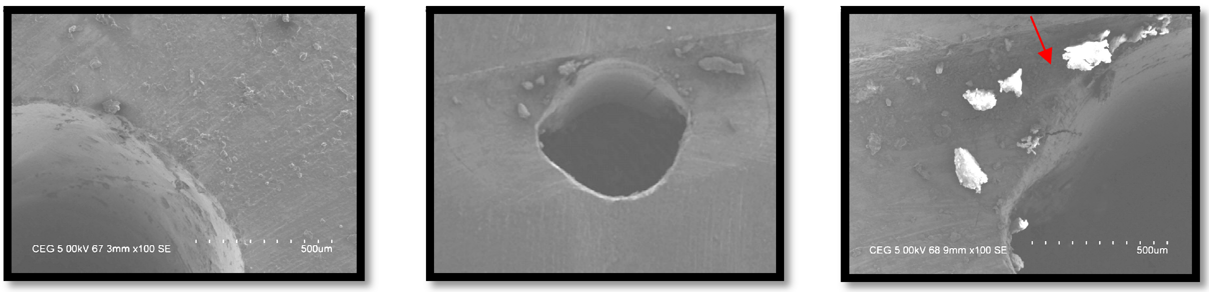
Dentinal Crack Formation in One Shape File System in Coronal Middle Apical 1/3rd of The Root



Dentinal Crack Formation in Waveone Gold File System in Coronal Middle Apical 1/3rd of The Root



Dentinal Crack Formation in Reciproc File System in Coronal Middle Apical 1/3rd of The Root



Discussion

DISCUSSION

Endodontic cleaning and shaping is a challenging procedure in the root canal treatment due to the variations in root canal anatomy. Root canal shaping influences the quality of the next steps of root canal irrigation and filling. Ideally, root canal shaping should create a continuous tapered preparation from crown to apex while maintaining the original path of the canal and keeping the foramen size as small as possible[31].

Endodontic treatment of root canals with accentuated curvature can result in accidents, such as ledge formation, perforations, canal transportation, zip formation; demanding longer clinical chair time, patience and operator skills[8]. These accidents make it difficult for clinicians to obtain a properly cleaned and filled root canal and might lead to endodontic treatment failure. Any new instrument has to fulfill the objectives proposed by Schilder. These objectives can be difficult to achieve by using stainless steel hand instruments especially in curved canals.

The introduction of the number of rotary and reciprocation systems used for the biomechanical preparation of root canals has been increasing by the day. These instruments present great flexibility, excellent cutting efficacy, and they maintain a constant, central position in the main canal, thus reducing the possibility of apical transportation. Thus, the introduction of rotary nickel titanium (NiTi) instrumentation was an important step in optimal root canal shaping.

Curved canals have been commonly used as specimens in research studies because these canals present with a greater challenge to instrumentation. Thus, evaluation of the performance of different instrument systems has been correlated to their ability for shaping curved canals and their ability to maintain the original anatomy of the canal to verify its curvatures.

Mesio buccal root of extracted human maxillary first molars were used in the present study because they usually present an accentuated curvature and mesio-distal flattening and on average, foramina with diameters ranging from 0.18–0.25 mm[41]; hence it was decided to enlarge using master apical files #25. As below 0.25 mm small apical preparation, is associated with reduced and incomplete preparation and reduced frequency of irrigation.

Since their introduction, in the early 1960's numerous NiTi rotary systems have been added to the arsenal of endodontic instruments. NiTi possess shape memory and super elasticity characteristics. Despite this separation occurs in rotary instruments, as a result of rotational bending due to fatigue and shear fracture. Therefore, to improve the mechanical properties, these alloys were thermally treated and the resultant alloy is M-Wire[64].

The benefit of this M-Wire NiTi includes increased flexibility and improved resistance to cyclic fatigue while cleaning and shaping. The currently available rotary NiTi 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. This M-wire alloy provides increased flexibility and improved resistance to cyclic fatigue of the instruments[5]. The reciprocating movement is claimed to relieve stress on the instrument by special counterclockwise (cutting action) and clockwise (release of the instrument) movements, and it is assumed that this movement reduces the risk of cyclic fatigue caused by tension and compression It might be speculated that when using only one instrument for complete preparation, more stress will be generated during mechanical instrumentation compared with canal instrumentation by using full-sequence systems[15]. Thus, it might be assumed that the incidence of dentinal defects might be increased when compared with preparations by using full-sequence rotary systems[3].

Single file (NiTi) rotary systems are gaining clinical acceptance as they reduce the time required for biomechanical preparation, as well as reduce the number of failures related to instrumentation[30, 31]. The single file systems can be used either in a continuous rotation (Hyflex-EDM, One Shape), (WaveOne-Gold, Reciproc) or in the reciprocating working motion which consists of an unequal counterclockwise and clockwise motion. The greater angle of the counterclockwise rotation ensures apical advancement of the file while the clockwise motion disengages the file[10, 49].

The reciprocating action acts to reduce the problem of taper lock by continually reversing the direction of rotation and minimizes torsional and flexural stresses on the instrument. This technology was first introduced in late1950s by a French dentist. However in 2008, Yared[76] tried single file with reciprocating hand piece for root canal preparation with F2 ProTaper rotary instrument which showed promising results. Based on his study, a combination of reciprocation and M wire, two single file systems were launched. They are WaveOne Gold and Reciproc. The WaveOne Gold and Reciproc instruments can completely prepare a canal with single instrument by slow in and out pecking motion following minimal glide path preparation. In single file reciprocation, stresses on the instruments are expected to be higher during the canal preparation. Hence these files are intended for single use. In this study glide path was done by size # 10 K file[28].

The assessment of canal instrumentation, methods such as scanning electron microscope, radiographic evaluation, photographic assessment, computer manipulation for comparative analysis have been used in the past, but accurate repositioning of pre- and post-instrumented specimens is difficult. Cone Beam Computed Tomography (CBCT), a non-destructive technology has been advocated for pre-and post-instrumentation evaluation of canal. It can render cross-sectional (cut plane) and 3D images that are highly accurate and quantifiable[2, 4].

In this study four file systems have been evaluated including two Rotary files (Hyflex-EDM, One Shape), two Reciprocating files (Wave One-Gold, Reciproc). **CBCT examination of the preoperative and postoperative images of the cross-section of root canal facilitates the evaluation of the significant parameters of root canal preparation, namely canal centering ability and canal transportation**. Comparisons using CBCT have provided repeatable results and also have allowed non-invasive experimentation of various aspects of endodontic instrumentation. At any level, the amount and direction of canal transportation can be viewed without loss of specimen[20, 25].

Hence in the present study we have used Cone Beam Computed Tomography(CBCT) to compare the Pre-operative and Post-operative images of curved root canal for canal centering and canal transportation ability, propagation of tiny cracks in tooth structure which occurs during root canal instrumentation techniques; Found to induce the formation of dentine cracks, resulting in vertical root fracture during sustained function.

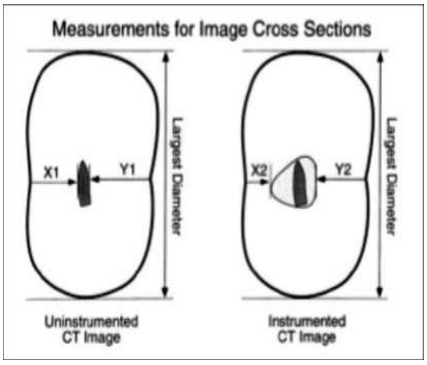
The incidence of root dentinal cracks has been noted in Biomechanical preparation and hence there is seeking for a safer instruments. Most studies on the incidence of dentinal cracks have been based on the root sectioning method in which, after root canal instrumentation, the specimens are sectioned at various levels from the cervical third to the apical third of the radicular dentine, and the resulting slices have been observed through various methods like stereomicroscope, Micro Computed Tomographic analysis and also through Scanning Electron Microscopic analysis. In this study SEM analysis[7] was chosen to evaluate dentinal crack formation after instrumentation with various files namely HYFLEX-EDM, ONE SHAPE, WaveOne GOLD, RECIPROC files systems as it has much greater magnification[31].

There are literature evidences on the reduction of fatigue and extended life span of the instrument but there is requirement of investigations regarding canal shaping ability of single file systems. These are necessary because fast approaches toward the apex with fewer instruments and sharp cutting edges produces aberrations.

CANAL APICAL TRANPORTATION, CANAL CENTERING ABILITY

The Glossary of Endodontic Terms of the American Association of Endodontists defines transportation as ‘The removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation’. You et al in 2011[77]., stated that apical transportation of more than 300 µm has the capability of negatively affecting the sealing of the obturation.

The **Degree of canal transportation** at each level i.e. 4 mm, 8 mm and 12mm from the apex was calculated according to the formula given by Gambill et al 1996 [29].



Instrumentation occurs most frequently in three different areas. The first of these areas is in the apical third, where the apical portion of the instrument enlarges the external wall of the canal; the second is located in the middle third, where the instrument tends to cut the internal wall of the canal, and the third is located at the opening facing the external wall of the tooth. (EL Batouty, Elmallah & Freire et al. 2011)[9]. In addition to the degree of curvature, factors such as location of the foramen, dentine hardness, flexibility and diameter of the endodontic instruments, as well as the type of movement used, may have a direct influence on the final results of preparation Berutti et al in 2012[10].

When comparing the canal transportation at the coronal third, middle third levels of cross-sectional images, all the four single-file systems (Group I-Hyflex-EDM, Group II-One Shape, Group-III-WaveOne gold, Group IV–Reciproc), maintain the original canal anatomy.

Among the groups, Group I (HYFLEX-EDM) files shows maximum canal transportation in original canal anatomy at the coronal and middle third level than the Group I, Group III, Group IV, which is statistically insignificant. (p value 0.74).

At apical level (12mm from CEJ) Group I shows maximum canal transportation when compared with Group II, III, and IV, which is statistically significant between Group IV WaveOne Gold (P= 0.04). Whereas Group III maintain the Original canal anatomy when compared to Group I, II, IV.

One-Shape instruments have different cross-sectional designs and variable pitch length along the working part. This design helps to eliminate threading and binding of the instrument in continuous rotation. The more transportation with One Shape could be due to its decreased flexibility, more tip stiffness[27, 32].

Burklein et al in 2012[14] studied, One Shape instruments that have a variable 3cutting-edge design at the tip region that progressively changes from 3 to 2 cutting edges in the middle part, whilst near the shaft, the instrument has 2 cutting edges. This design used in continuous rotation at a relatively higher speed allows the instruments to rapidly progress into the curved root canals. This could create some stress that might have resulted in the observed canal straightening and apical transportation and canal centering ability.

Burklein et al in 2017[13] reported that WaveOne, maintained the original curvature than One Shape in severely curved canals in extracted teeth well. The results of this study are in agreement with several previous studies Burklein et al in 2012[14], (You & Cho)[77], Capar et al in 2014[16].

In the study conducted by V. H. Tambe et al in 2014[70], the canal transportation after instrumentation with One Shape rotary file, primary WaveOne gold reciprocating file and ProTaper system was compared, and it was concluded that WaveOne gold system showed less canal transportation and better centering ability as compared with other systems tested.

The difference between One Shape and Reciproc may be attributed to the different working motions and the different rotational speeds. OneShape was used with a rotational speed of 400 rpm whilst Reciproc instruments operate at about 282–300 rpm with a 150-158-degrees counterclockwise rotation followed by a 30-34-degrees clockwise rotation as studied by Kim et al in 2011[77].

Hyflex-EDM is a new development in rotary endodontics where in these files are produced using an innovative manufacturing process called Electrical discharge machining, the combination of flexibility, fracture resistance and cutting efficiency of the Hyflex-EDM make it possible to reduce the number of files required for cleaning while preserving the anatomy. The built in shape memory of Hyflex-EDM files reverts stress during canal preparation by changing their spiral shape. A normal autoclaving process is enough to return the files to their original shape and fatigue resistance[25].

Ozyurek.T et al in 2017[54] conducted a study to compare the shaping ability of Reciproc, WaveOne GOLD and Hyflex-EDM nickel-titanium (NiTi) files made of different NiTi alloys in S-shaped simulated canals, The results of his study revealed that the use of WaveOne and Reciproc instruments resulted in significantly less canal straightening and significantly less apical transportation than the use of Hyflex-EDM instruments. Pier et al in 2017[59] showed that physical and mechanical properties of electrical discharge machining can render root canal instruments Hyflex EDM more flexible and fatigue resistant than those made from conventionally Martensitic NiTi.

Several studies have reported similar results such as Oliveira et al in 2017 [53]. However, Peters et al in 2004[58] demonstrated that there is no constant pattern as regards the direction of apical transportation. You et al in 2017[77] also reported that apical transportation could change direction according to the apical position evaluated.

The objectives of Reciprocating file system was to reduce the working time and cost and improve safety of the shaping procedure. Recently, the WaveOne–Gold and Reciproc - reciprocating file systems have been launched. WaveOne Gold, the reciprocating single file systems with specific features includes modified convex triangular cross section at the tip end and convex triangular cross section at the coronal end, This design improves instruments flexibility. Tip is modified to follow canal curvature accurately, the variable pitch flutes along the length of the instruments and special gold treatment done to improve the instruments fatigue resistance. This unique design and property minimize the canal transportation and has better canal centering ability.[6]

The radial lands in combination with the reciprocating working motion are claimed to keep the WaveOne instrument centered whilst advancing apically into the root canal. Reciproc instruments have an S-shaped cross-section with two sharp cutting edges along the entire working part. Obviously, instruments having this S-shaped cross-sectional design are characterized by a relatively good shaping ability when used either in full clockwise rotation Burklein et al in 2017[13,14] or in a reciprocating motion.

According to Carvalho GM et al in 2015[17] WaveOne and Reciproc are used in a reciprocal motion and this working motion has been associated with well-centered preparations and reduced incidence of procedural errors. Furthermore, this motion extends the lifespan of instruments in comparison with continuous rotation. The majority of the samples evaluated had apical transportation after preparation, irrespective of the instrumentation system used. However, the mean apical transportation values, both for WaveOne and for the Reciproc system, were lower than 0.06 mm and clinically irrelevant.

The differences may be explained by the different design features of the instruments used. WaveOne instruments have variable cross-sections along the working part that change from a concave triangular cross-section with radial land at the tip to a neutral rake angle with a triangular convex cross section in the middle part and near the shaft Burklein et al in 2012[14].

Reciproc has non cutting tip with S shaped cross section produced with M-wire Nickel –Titanium. Increased cyclic fatigue resistance is achieved through use of this alloy produced in an innovative thermal-treatment process.

Mathieu Goldberg et al in 2012[34] evaluated the centering ability of WaveOne gold in curved canals and observed excellent results with low apical transportation without any blockage or separation. This corroborates the results of Kim et al in 2011[77], who showed that WaveOne and Reciproc demonstrated significantly higher cyclic fatigue and torsional resistance than other rotary files.

Dhingara et al in 2015[21] compared single file systems Reciproc, One Shape and WaveOne using CBCT. He concluded that reciprocating motion is better than rotary motion in all the three parameters of canal transportation, cross-sectional area and cervical dentinal thickness.

Mittal et al in 2016[50] assessed the canal transportation and centering ability of Reciproc and One Shape file systems using CBCT. He showed that One Shape and

Reciproc performed similar in terms of canal transportation and canal centering ability.

Likewise, You & Cho 2011[77] using simulated canals in resin blocks found that WaveOne and Reciproc produced similar canal straightening and maintained the original canal curvature equally good and better than ProTaper.

According to Ingle, the occurrence of up to 0.15 mm of canal transportation has been considered acceptable and should not be above 0.30 mm at the apical end. In this study all file systems showed canal transportation of −0.04 mm to + 0.046 mm, which is within the acceptable range.

In this study, after instrumentation, the direction of apical transportation was also verified, which showed greater tendency towards to the lateral (outer) region of the root canal for Group I, Group II systems. In apical thirds One Shape file cause more canal transportation than Hyflex-EDM, WaveOne Gold, Reciproc

In this present study continuous rotary andreciprocating motion produces no significant difference, in canal centering ability as there is no statistically significant difference between Hyflex-EDM, One Shape and WaveOne Gold, Reciproc at 4mm,8mm from CEJ. However WaveOne Gold shows better canal centering ability than Hyflex-EDM, One Shape, Reciproc at 12mm,but not statistically significant different among the groups.

At Coronal 1/3rd level, Group I HYFLEX-EDM showed significantly higher mean canal transportation and lower centering ability, as compared to Group II One Shape, Group III WaveOne gold, Group IV Reciproc. But no statistically significant difference was seen among the groups.

At middle 1/3rd level, Group I HYFLEX-EDM showed significantly lower canal centering ability, higher mean canal transportation and as compared to Group II One Shape, group III WaveOne gold Group IV Reciproc, but there is no statistically significance difference, but not statistically significant difference between among the groups.

At apical level, Group I Hyflex-EDM showed significantly higher mean canal transportation and lower centering ability, as compared to Group II One Shape, Group III WaveOne gold, Group IV Reciproc, which is statistically significant between Group IV WaveOne Gold (P= 0.04).

DENTINAL CRACK FORMATION

Under SEM observation the percentage of dentinal crack were evaluated.

Order of dentinal cracks in coronal third of the canal were as follows

One Shape >Reciproc> WaveOne Gold = Hyflex-EDM

Order of dentinal cracks in middle third of the canal were as follows

One Shape > Reciproc>Hyflex-EDM =WaveOne Gold

Order of dentinal cracks in apical third of the canal were as follows

One Shape > Reciproc >WaveOne Gold>Hyflex-EDM

Rotary files can produce various degrees of radicular dentinal defects such as craze lines or incomplete cracks, when compared to reciprocating files. In the present study continuous rotation shows more dentinal micro cracks than the reciprocation system, as there is a statistically significant difference between Hyflex EDM and One Shape at 4mm, 8mm, 12mm from CEJ. ($P<0.005$)

In reciprocation there is no statistically significant difference between WaveOne gold and Reciproc at all the levels from CEJ. The tip design of rotary instruments, cross-sectional geometry, constant or variable pitch and taper, and flute form could be related to crack formation. Eugenio Pedull A (2016)[28] et al conducted a study on Effects of 6 Single-File Systems on Dentinal Crack Formation, the study concluded that the flexibility of nickel-titanium instruments because of heat treatment seems to have a significant influence on dentinal crack formation. Hy-Flex EDM and WaveOne Gold caused less micro cracks than the other instruments tested.

WaveOne Gold produced less micro cracks than One Shape even if the same reciprocating movement was used to activate both of these instruments. Therefore, these results suggest that shaping motion has no or at least a limited and unpredictable role on micro crack formation is reasonable that the synergistic effect of kinematic and other factors such as NiTi alloy and geometric features influence micro cracks. Damla kirici et al in 2017[18].

The major number of micro cracks was observed in the apical section (3 mm) for all tested instruments, which is in agreement with previous studies Ozyurek T et al in 2017[54]. For HEDM, oneshape, WaveOne Gold, and Reciproc the variable taper may explain the reduced number of micro cracks in the given sections.

In particular, HEDM caused less micro cracks than other instruments, except WaveOne Gold, which, in turn produced less cracks than One Shape Jamleh (2015)[42]. In another study by Mittal et al in 2017[58], Reciproc working in reciprocating movement caused cracks in only 5% of teeth, whereas One Shape working in continuous rotation caused cracks in 35% and 50% of teeth, respectively. Burklein et al in 2017[13] used Reciproc files up to size 40/0.06, whereas Mittal et al in 2017[58] used up to 25/ 0.08.

Hyflex-EDM, WaveOne gold presented with the least number of dentinal cracks in this study. M-wire technology imparts more flexibility to Waveonegold instruments and the Electro Design machining of Hyflex-EDM might contribute to lesser dentinal cracks in this group. Also, the investigated WaveOne Gold primary files have a non-cutting modified tip and a unique cross-sectional design along the length of their active portions (a modified convex triangular cross-section at the tip end and a convex triangular cross-section at the coronal end.

in this study Reciproc files work in a reciprocating movement similar to the balanced force technique and caused cracks in 5% of teeth only. In this study, the WaveOne Gold, Reciproc file with an apical size of # 25.08 caused significantly less cracks than the OneShape file with an apical size of # 25.06[32]. Despite the difference in cross-sectional design, it may be that the reciprocating motion caused less dentinal damage than the continuous rotation motion. The variable taper of Hyflex-EDM shows more dentinal crack than WaveOne Gold primary file with taper of 6%25.

Active rotating movement results in a high level of stress concentrations in root canal walls that may result in crack formation. Reciprocating motion was found to be more centered in the canal, and by repeating the CW and CCW rotation, reciprocating motion allows continuous release of the file when it is engaged in the inner surface of the root canal during the cutting and shaping procedure[17]. Furthermore, flexural and torsional stresses acting on the dentin are also reduced as the CCW motion disengages the instrument blades and reduces stresses. There is no difference in the magnitude of canal transportation between rotary and reciprocating instruments at all the levels.

- ✓ One Shape files showed more Dentinal cracks at all the levels of the canal when compared to other files. Reciproc file showed lesser dentinal cracks then One Shape.
- ✓ WaveOne Gold & Hyflex EDM shows less Dentinal cracks at all the levels of the canal when compared to other files.
- ✓ Hyflex EDM showed lesser dentinal cracks than WaveOne Gold in the apical 3rd.

  Thus the reciprocation system is capable of safely preparing the root canals, respecting their original anatomies with few procedural errors.

Summary

SUMMARY

The aim of this study is to evaluate and compare the Canal centering ability, Apical transportation, Dentinal crack formation in the mesio-buccal root of maxillary first molar at coronal, middle and apical third using four different single file system. The two rotary files selected for the study were- **HYFLEX-EDM (Group I) and One Shape (Group II) and two Reciprocation files selected were -WAVEONE-GOLD (Group III) and RECIPROC (Group IV).** Canal centering ability and apical transportation were assessed using **CBCT** and dentinal crack formation following instrumentation was evaluated using **SEM.**

One hundred and twenty freshly extracted human maxillary first molars were selected as per inclusion criteria and de-coronated at the level of CEJ using a diamond disc. The palatal and disto-buccal roots were separated from the tooth and the mesio-buccal roots were taken for instrumentation process. These 120 specimens were randomly divided into four groups each containing 30 teeth. Pre instrumentation scanning was done using a Cone Beam Computed Tomography to determine mesio-distal thickness of canal. Following this the specimens were instrumented according to the manufacturer instructions.

After instrumentation, specimens were again scanned using the same parameters as done in the initial scanning. All the pre-instrumentation and post – instrumentation CBCT values were tabulated and the statistical analysis was done using SPSS(20) software.

CANAL CENTERING ABILITY: The CBCT value arrived results showed that the canal centering ability was maintained better at coronal third by Hyflex-EDM and at middle and apical third by WaveOne gold. There was no statistically significant difference regarding canal centering ability among the four groups.

APICAL TRANSPORTATION: As per the CBCT value Apical transportation was least for WaveOne Gold compared to Reciproc, but both these reciprocatary files caused canal transportation towards furcation side. Hyflex-EDM showed the highest apical transportation value than One Shape towards the lateral wall of the canal with statistically significant difference seen between Hyflex-EDM and WaveOne Gold. ($P<0.02$)

DENTINAL CRACK: The analysis of development of dentinal crack following instrumentation was evaluated using SEM, One Shape files showed more Dentinal cracks at all the levels of the canal (i.e coronal, middle, apical 3^{rd}) compared to other file systems. This was followed by Reciproc. WaveOne Gold and Hyflex EDM showed less Dentinal cracks formation at all the levels of the canal except in the apical 3^{rd} were Hyflex EDM was found to show lesser crack than WaveOne Gold.

Conclusion

CONCLUSION

- Among the four experimental groups, Two rotary single file system and Two Reciprocal system there was no statistically significant difference observed in the canal centering ability at coronal third, middle third and apical third.
- WaveOne Gold showed the least apical transportation followed by Reciproc, OneShape.
- Hyflex-EDM showed a statistically significant difference with WaveOne Gold file.
- Dentinal crack was found to be highest for OneShape file at coronal 1/3rd, middle 1/3rd, apical 1/3rdcompared with all other files, followed by Reciproc.
- HYFLEX-EDM and WaveOne Gold showed least dentinal crack with HYFLEX-EDM performing better in apical 1/3rd.

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