COMPARISON AND EVALUATION OF THE AMOUNT OF DENTIN REMOVAL BY PROTAPER GOLD, HYFLEX EDM, ESX (BRASSELER) AND VORTEX BLUE ASSESSED BY CONE BEAM COMPUTED TOMOGRAPHY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

MAY 2020

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY
CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"COMPARISON AND EVALUATION OF THE AMOUNT OF DENTIN REMOVAL BY PROTAPER GOLD, HYFLEX EDM, ESX (BRASSELER) AND VORTEX BLUE ASSESSED BY CONE BEAM COMPUTED TOMOGRAPHY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr.R. ANIL KUMAR, M.D.S.,** Professor & Head of the Department of Conservative Dentistry and Endodontics, Ragas Dental College and Hospital, Chennai.

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This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY – CONSERVATIVE DENTISTRY AND ENDODONTICS, BRANCH IV**. It has not been submitted (partial or full) for the award of any other degree or diploma.

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LIST OF ABBREVATIONS

S.NO	ABBREVATIONS	EXPANSION
1.	ISO	International Standards Organization
2.	NiTi	Nickel Titanium
3.	EDM	Electric Discharge Machining
4.	CM	Controlled Memory
5.	ESX	Endosequence Express
6.	CT	Computed Tomography
7.	CBCT	Cone Beam Computed Tomography
8.	RDT	Remaining dentin thickness
9.	EDTA	Ethylene diamine tetra acetic acid
10.	RVG	Radiovisiography
11.	kV	Kilovoltage
12.	mA	Milliampere
13.	μm	Micrometer

14.	Mm	Millimeter
15.	N/cm	Newton/centimeter
16.	SPSS	Statistical Package for the Social Sciences
17.	SD	Standard Deviation

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5.	ENDODONTIC EXPLORER
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8.	HYFLEX® EDM
9.	ESX (BRASSELER)
10	VORTEX BLUE
11.	X SMART ENDOMOTOR
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Introduction

INTRODUCTION

Apical periodontitis is an inflammatory lesion in the periodontal tissues that is caused mostly by bacterial elements derived from the infected root canal system of teeth.[1] It is a sequelae to initial pulpal inflammation that has progressed into necrosis of the pulp tissue by bacterial colonization, eventually leads to inflammatory changes in the periradiclar tissues. The endodontic environment in an infected condition is composed of poly microbial species, predominantly dominated by anaerobic species. The host defence mechanism to eliminate the bacterial species is limited as the dental pulp space being a constricted chamber lacking microcirculation.

The treatment strategy for apical periodontitis is the eradication of bacteria from the root canal space. This is achieved by a combination of mechanical debridement, chemical irrigation and use of intracanal medicaments followed by obturation of the root canal space.

The main goal of shaping the radicular space is to eliminate microorganisms on the canal surface mechanically, completely remove the pulp tissue, increase the capacity of the root canal to permit irrigating solutions to reach the apical region of the root for effective disinfection and to shape the canal to receive the root filling material i.e. gutta-percha.[2] The root canal preparation should have a continuously tapering funnel from the coronal access cavity to theroot apex. The cross-sectional diameter of the preparation should be narrower at every point apically and wider at each point as the access cavity is approached.[3]

Root canal instrumentation is carried out either manually or by engine driven (rotary) instruments. Manual instruments comprise of ISO standardized 0.02 tapered files and reamers which are made out of stainless steel alloy. These files were used to perform conventional step-back (telescopic) technique involving initial apical third preparation followed by middle and coronal third preparation. The cross sectional designs are square and triangular for K-files and reamers respectively. They are manufactured from tapered metal blanks which are twisted counter clockwise to produce flute design. These files are used in either a filing (rasping) or a reaming (drilling) motion to bring about the cutting action.[4] The aim of instrumentation is to centrally enlarge the root canal without excess removal of dentinal tissue and the weakening of root structure. The stainless steel files are used in a sequence of increasing tip diameter and tapers to achieve a step back preparation. As the taper increase the thickness of the files also increases, the flexibility of the file is eventually reduced thus making it stiffer. When employed in curved canals these files cause straightening of curved canals and results in apical enlargement. Instrumentation/procedural errors such as canal transportation, zipping, elbowing, ledging, strip and root perforations and file breakage may occur during instrumentation. These procedural errors will influence the treatment outcome.[5]

By 1980, instruments were manufactured with modified tip design, as the sharpness of the instrument tip and the tip's effect in penetration and cutting increased the chances for ledging and transportation of the preparation which deviates from the natural canal anatomy. Powell et al in 1988 stated stainless steel files due to its metallic memory tend to return to a straight position, thus increases the chances of transportation or ledging and eventually perforate. Canal centrality is also lost. Reduction in tip angle maintained the file tip in the centre of the canal and cuts evenly on all the sides of the canal.[6] Rounded tipped files were developed by Roane et al but had least efficiency.[7]

In order to overcome the drawbacks of stainless steel files, first hand held NiTi endodontic instruments were introduced in the year 1988, by Walia et al, Brantley and Gerstein by machining orthodontic wires. The two main properties of NiTi alloys are shape memory and superelasticity. According to Thompson, the special properties of NiTi alloys are associated with solid state phase change which occurs during stress application or change in temperature (martensitic phase to austenitic phase). The first NiTi rotary instruments, with the ISO-standard 0.02 taper, were introduced in 1992, designed by Dr. John McSpadden. In 1994, Dr.Johnson introduced the ProFile .04 and Profile .06 NiTi rotary systems, a paradigm shift from the ISO standardized 0.02 taper file system.[8]

Currently, more than 160 automated instrumentation systems are available, manufactured with different NiTi alloys, heat-treated or otherwise, with both superelastic and shape-memory properties and using rotational or reciprocating kinetics, centric or eccentric motion.

ProTaper Gold (Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) NiTi rotary system was introduced and developed with proprietary advanced metallurgy. It features a progressively tapered design that claimed to improve the cutting efficiency and safety. Protaper Gold rotary files features the same exact geometries as ProTaper Universal (PU; DentsplyMaillefer, Ballaigues, Switzerland). Protaper Gold system has been metallurgically enhanced through heat treatment technology. Protaper Gold files exhibit a convex triangular cross-section and progressive taper.[9]

HyFlex EDM®; (Coltene/Whaledent AG, Altst€atten, Switzerland) is a third-generation single file that was introduced with an innovative manufacturing process using electric discharge machining (EDM) followed by Controlled Memory (CM) treatment. The cross-sectional design of HyflexEDM® instrument is variable, rectangular towards the tip and roughly triangular towards the shaft. In previous studies, these instruments showed very high resistance to cyclic fatigue compared to instruments produced by CM technology and M-wire.[10]

Recently, Brasseler (USA) introduced the ESX rotary file system, representing an evolution of the EndoSequence system. There are numerous similarities to the EndoSequence system, including fabrication with conventional nickel-titanium alloy, triangular cross-sectional file geometry, alternate contact points, surface electropolishing, and a preliminary Expeditor file (15.05) also intended to estimate canal size despite its difference in tip and taper. It has a novel tip design which boasts an anti-ledging and anti-perforating centering mechanism. The ESX rotary system is basically a two file system, where a glide path is created by an Expeditor file followed by complete canal shaping by a single ESX file.

The Vortex Blue (Dentsply Tulsa Dental speciality, USA) rotary system utilizes a special Ni-Ti wire processing method to produce a distinctive “blue colour” titanium oxide surface layer. These instruments exhibits greater flexibility with controlled shape memory and improved fatigue resistance. They have a cutting blade with triangular cross-section and variable helical angle. This facilitates debris removal through its coronal portion with less number of flutes and increases strength and minimizes dentinal cracking at its more fluted apical portion.[11]

Regardless of the instrumentation technique whether manual or rotary, cleaning and shaping procedures will lead to dentin removal from the root canal walls. Use of rotary files with greater taper produces flared root canals by decreasing the amount of remaining root dentin thickness. This will increase the potential for vertical root fracture of the treated tooth.

In the past, methods for the assessment of remaining root dentin thickness included radiographic method, serial sectioning technique, photographic assessment, scanning electron microscope, and computer manipulation technique.[12] These methods were destructive in nature and accurate repositioning of the specimens was difficult. Also, radiographic method provided 2D images of 3D objects. Furthermore, the interpretation of radiographs can be influenced by several confounding factors, including regional anatomy and superimposition of teeth and the surrounding dentoalveolar structures. The structures visualized by radiographs are also subject to geometric distortions.[13]

The non destructive imaging techniques include computed tomography, micro CT, cone beam computed tomography (CBCT), spiral CT. They provide 3D view of the object.Cone-beam computed tomography (CBCT) has come up as a boon since it can measure dentin thickness of root canal walls, because of its non-invasive nature, three-dimensional (3D) view, accuracy, and reliability, thus serving as a crucial diagnostic tool to gauge the RDT.[14]

Thus, acknowledging the importance of preserving the remaining dentin thickness after mechanical instrumentation of the root canals, the purpose of this study is to compare and evaluate the amount of dentin removal by Protaper Gold, Hyflex EDM, ESX (Brasseler) and Vortex blue assessed by Cone Beam Computed Tomography.

Aim and Objectives

AIM AND OBJECTIVES

AIM:

- To compare and evaluate the amount of dentin removal by Protaper Gold, Hyflex EDM, Vortex Blue and ESX (Brasseler) assessed by Cone Beam Computed Tomography.

OBJECTIVES:

- To evaluate the amount of dentin removed at buccal, palatal, mesial & distal aspect at 2mm, 6mm & 10mm from the root canal orifice by ProTaper Gold, Hyflex EDM, ESX (Brasseler) & Vortex Blue.
- To compare the amount of dentin removal by ProTaper Gold, Hyflex EDM, ESX (Brasseler) & Vortex Blue rotary file systems.
- To evaluate which file system has removed the most dentin and which has removed least amount of dentin.

Review of Literature

REVIEW OF LITERATURE

Ebihara (2011)[15] evaluated the bending properties and shaping abilities of nickel–titanium endodontic instruments processed by heat treatment. K3 files were heated for 30 min at 400°C (group 400), 450 °C (group 450) and 500 °C (group 500). Files that were not heat treated served as controls. A cantilever-bending test was used to evaluate changes in specimen flexibility caused by heat treatment. Curved root canal models were prepared. The time required for preparation, deformation and fracture were recorded. Pre- and postoperative images were superimposed. The amount of resin removed from both the inner and the outer sides of the curvature in the apical 6 mm were determined. It was concluded that heat treatment of files might improve their flexibility, making them more effective for preparation of curved canals.

Brandon Yamamura et al (2012)[16] evaluated the transportation and centering ability of EndoSequence and Vortex files in mesial roots of mandibular molars by using micro– computed tomography imaging. Sixteen extracted mandibular molars with mesiobuccal and mesiolingual canals with separate foramina were used. Pre-instrumentation scans of all teeth were taken, and the teeth were divided into 2 groups. In group 1, the mesiobuccal canals were instrumented with Vortex files and the mesiolingual canals with

EndoSequence files. In group 2, the mesiobuccal canals were instrumented with EndoSequence files and the mesiolingual canals with Vortex files. Two file sizes were compared, 30/.04 and 40/.04. Post-instrumentation scans were performed, and the two scans were compared to determine centering ability and transportation. The amount of transportation at 1, 3, and 5 mm was similar for both file types in both file sizes. Transportation toward the furcation area at 7 mm was greater with the 30/.04 Endosequence files compared with the Vortex 30/.04 files ($P < .05$), but there was no difference in size 40/.04 files.

Ahmed Abdel RahmanHashem et al (2012)[17] compared the effect of 4 rotary NiTi preparation systems, Revo-S (RS; Micro-Mega, Besancon Cedex, France), Twisted file (TF; SybronEndo, Amersfoort, The Netherlands), ProFile GT Series X (GTX; Dentsply, Tulsa Dental Specialties, Tulsa, OK), and Pro-Taper (PT; DentsplyMaillefer, Ballaigues, Switzerland), on volumetric changes and transportation of curved root canals. Forty mesiobuccal canals of mandibular molars with an angle of curvature ranging from 25° to 40° were divided according to the instrument used in canal preparation into 4 groups of 10 samples each: group Revo-S, group Twisted File, group Profile GT series, and group ProTaper. Canals were scanned using an i-CAT CBCT scanner (Imaging Science International, Hatfield, PA) before and after preparation to evaluate the volumetric changes. Root canal transportation and centering ratio were evaluated at 1.3, 2.6, 5.2, and 7.8 mm from the apex. It was revealed that the Twisted File system showed superior shaping ability in curved canals. Revo-S and Profile GT series were better than ProTaper regarding both canal transportation and centering ability.

Cláudia Bohrer Flores (2012)[18] introduced a method to standardize the acquisition of images before and after preparing root canals by using cone-beam computed tomography (CBCT). Sixteen mandibular molars were included in acrylic resin blocks. Samples were inserted in a stable wood box, which was filled with plaster and served as a guide to reinsert the samples. The apparatus was used for the CBCT examination before and after cervical flaring of root canals. The software IcatVision® was used to equalize the images before and after instrumentation with two computers operating at the same time. The measurements between root canal center and the furcation area were determined. It was revealed that the proposed method assures the same positioning of the samples before and after root canal preparation. It is extremely important, as any mesiodistal or buccolingual movement can produce a different topogram for comparison procedures.

Danya Hashem et al (2013)[19] investigated in an ex-vivo model the reduction in patient radiation dose while maintaining accurate linear measurements by comparing cone-beam computed tomography (CBCT) scans taken at 360° versus 180° rotation, with porcine jaw specimens as a reference standard. CBCT scans of 12 sectioned porcine hemi-mandibles at 360° and 180° rotations were taken with standardized clinical exposure parameters. To assess inter-observer variability, 6 assessors who were blinded to the degree of rotation took linear measurements of anatomic structures on each scan. The measurements were repeated after 2 weeks to assess intra-observer variability. Accuracy of measurements was judged against the corresponding measurements taken from the porcine jaw specimens. It was concluded that a CBCT image sufficient to make accurate clinical measurements with a reduced radiation exposure may be obtained by using 180° rotation of the CBCT tube head.

Gianluca Plotino et al (2014)[20] evaluated the difference in cyclic fatigue resistance between Vortex Blue (Dentsply Tulsa Dental, Tulsa, OK) and Profile Vortex nickel-titanium (Dentsply Tulsa Dental) rotary instruments. Two groups of nickel-titanium endodontic instruments, ProFile Vortex and Vortex Blue, consisting of identical instruments in tip size and taper (15/.04, 20/.06, 25/.04, 25/.06, 30/.06, 35/.06, and 40/.04) were tested. Ten instruments from each system and size were tested for cyclic fatigue resistance, resulting in a total of 140 new instruments. All instruments were rotated in a simulated root canal with a 60° angle of curvature and a 5-mm radius of curvature of a specific cyclic fatigue testing device until fracture occurred. The number of cycles to failure and the length of the fractured tip were recorded for each instrument in each group. In conclusion, Vortex Blue showed a significant increase in cyclic fatigue resistance when compared with the same sizes of ProFile Vortex.

Jason Gagliardi (2015)[21] evaluated the shaping characteristics of the ProTaper Gold system (PTG; Dentsply Maillefer, Ballaigues, Switzerland) and compared it with that of the ProTaper Next (PTN, Dentsply Maillefer) and ProTaper Universal (PTU, Dentsply Maillefer) systems using micro–computed tomographic imaging. Twenty-four mandibular first molars with two separate mesial canals were matched anatomically using micro–computed tomographic scanning Canals were prepared with PTG, PTU, or PTN rotary systems to F2 or X2 instruments, respectively, and scanned again. Co-registered images were evaluated for 2- and 3-dimensional morphometric measurements of canal transportation, centering ability, untouched canal walls, and remaining dentin thickness. ProTaper Gold and ProTaper Next produced less transportation and maintained more dentin than ProTaper Universal. ProTaper Next had less canal wall contact than ProTaper Gold and ProTaper Universal, but all file systems were able to instrument moderately curved mesial root canals of mandibular molars without clinically significant errors.

Pradeep Solete et al (2015)[22] evaluated the remaining dentin thickness of teeth after cleaning and shaping the root canal using three rotary instrumentation techniques using cone-beam computed tomography (CBCT). This in vitro study was done with 30 premolar samples with 20° curvature. The study is divided into three groups and CBCT was taken to measure the shortest distance from the root canal outline to the closest adjacent root surface was measured at each level from the cement-enamel junction (CEJ)

(1,3,5and7mm) before and after root canal instrumentation. It was observed that M two has removed less amount dentin when compared to ProTaper Universal and ProTaper Next system at 1 and 3 mm. It was concluded that ProTaper Universal and ProTaper Next should be used judiciously, as it causes higher thinning of root dentin of the root when compared with M two.

Premlata Devi et al (2016)[23] compared the cleaning efficacy of manual instrumentation, ProTaper Next and Hyflex EDM Rotary file systems. Sixty mandibular premolar teeth were selected and their pulp tissue was removed after coronal access. The root canals were filled with a dye (India ink) and allowed to dry for 48 hours. The specimens were randomly divided into three experimental groups, Group One: Stainless steel K file (n = 20), Group Two: ProTaper Next (n = 20), Group Three: Hyflex EDM (n = 20). Instrumentation was done with Stainless steel K file Hand, ProTaper Next and Hyflex EDM rotary instruments. The teeth were longitudinally sectioned and evaluated according to the amount of remaining dye. It was revealed that Hyflex EDM showed better cleaning efficacy when compared to other instrumentation techniques, especially in middle and apical one-third.

AmrElnaghy (2016)[9] evaluated and compared the shaping ability of ProTaper Gold (PG) (PG; Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) system with ProTaper Universal (PU) (PU; Dentsply Maillefer, Ballaigues, Switzerland) using Cone Beam Computed Tomography (CBCT) imaging. Forty mesiobuccal canals of mandibular first molars with curvatures of 25−30° were divided into two experimental groups (n = 20) according to the rotary nickel–titanium (NiTi) file system used in canal instrumentation as follows: Group PG and group PU. Canals were scanned before and after instrumentation using CBCT scanner to evaluate root canal transportation and centering ratio at 3, 5, and 7 mm from the apex and volumetric changes. It was revealed that the PG and PU NiTi rotary systems showed similar root canal shaping abilities in the preparation of mesial canals of mandibular first molars.

Iacono F et al (2016)[24] compared the phase transformation behaviour, the microstructure, the nano-hardness and the surface chemistry of electro-discharge machined HyFlex EDM instruments with conventionally manufactured HyFlex CM. New and laboratory used HyFlex EDM were examined by X-ray diffraction (XRD) and differential scanning calorimetry (DSC). Nano-hardness and modulus of elasticity were also investigated using a maximum load of 20 mN with a minimum of 40 significant indentations for each sample. Raman spectroscopy and field emission-scanning electron microscope (FE-SEM) were used to assess the surface chemistry of HyFlex EDM. HyFlex CM were subjected to the same investigations and used as a comparison. It was concluded that HyFlex EDM revealed peculiar structural properties, such as increased phase transformation temperatures and hardness.

Sankhe DD et al (2017)[25] evaluated the effect of HyFlex EDM, which is a new rotary system on root dentin during root canal preparation. Fourteen single rooted premolars were selected and divided into two groups, Group 1-ProTaper Universal and Group 2-HyFlex EDM. All the specimens were de-coronated. Roots of each specimen were sectioned at 3mm, 6mm and 9mm and were then viewed under stereomicroscope for dentinal defects. HyFlex EDM showed lowest percentage of defects in root dentin. Thus, HyFlex EDM is more efficient in root canal preparation than that of ProTaper Universal thereby preventing dentinal defects or microcracks leading to root fractures.

Amandeep Dosanjh et al (2017)[26] examined the effect of different temperatures on the cyclic fatigue of nickel titanium rotary files. Three groups of nickel titanium rotary files (EF group [EdgeFile; EdgeEndo, Albuquerque, NM], VB group [Vortex Blue; Dentsply Tulsa Dental Specialties, Tulsa, OK], and ESX group [ESX; Brasseler USA, Savannah, GA]) of size 25 with a .04 taper and 25-mm length were tested in a metal block that simulated a canal curvature of 60° and a 5-mm radius curvature. The block was submerged in a water bath filled with water at 3°C, 22°C, 37°C, and 60°C. At each temperature, 30 files from each group were rotated at 500 rpm in the block. The number of cycles to fracture (NCF) was calculated. In this in vitro study, temperature was found to significantly affect the cyclic fatigue of nickel-titanium rotary files. At each tested temperature, NCF was the highest for the EF group followed by the VB group and lowest for the ESX group.

Jorge Rubio et al (2017)[27] compared the shaping ability of 10 rotary and reciprocating systems (F360, F6SkyTaper, HyflexEDM, iRace, Neoniti, O.Shape, P.Next, Reciproc, Revo-S, WaveOneGold) with AutoCAD. It was revealed that in cutting area, ProTaper Next and Reciproc were superior in the coronal third, Neoniti and Hyflex EDM in the middle and apical thirds, and Neoniti and Reciproc overall. Regarding root canal anatomy preservation, all the systems obtained similar results. In non-instrumented areas, the systems were similar in the coronal third, but Reciproc, Neoniti and Wave One Gold were better in the middle third and ProTaper Next, Reciproc, Hyflex EDM, Neoniti, and Wave One Gold were better in the apical third.

Hyun-Jin Park et al (2017)[28] compared the root canal volume change and canal transportation by Vortex Blue (VB; Dentsply Tulsa Dental Specialties), ProTaper Next (PTN; Dentsply Maillefer), and ProTaper Universal (PTU; Dentsply Maillefer) nickel-titanium rotary files in curved root canals. Thirty canals with 20°–45° of curvature from extracted human molars were used. Root canal instrumentation was performed with VB, PTN, and PTU files up to #30.06, X3, and F3, respectively. Changes in root canal volume before and after the instrumentation, and the direction of canal transportation at 1, 3, and 5 mm from the root apex were measured by using micro-computed tomography. In conclusion, PTN produced less amount of transportation than PTU at 3 mm level, all 3 file systems showed similar level of canal volume change and transportation, and VB file system could prepare the curved canals without significant shaping errors.

Xu et al (2017)[29] evaluated the accuracy of cone-beam computed tomographic (CBCT) to measure dentin thickness and its potential of predicting the remaining dentin thickness after the removal of fractured instrument fragments. Twenty-three human mandibular molars were selected, and 4-mm portions of #25/.06 taper K3 files (SybronEndo, Orange, CA) were fractured in mesial canals. The teeth were then scanned using a micro–computed tomographic (micro-CT) system and a CBCT unit. Dentin thickness was measured and compared between both micro-CT and CBCT images to study the accuracy of CBCT readings. Then, the process of removing the fragments was simulated in CBCT images using the MeVisLab package (MeVis Research, Bremen, Germany); the predicted minimal remaining dentin thickness after removal was measured in different layers using VG Studio MAX software (Volume Graphics, Heidelberg, Germany). Data were compared with the actual minimal remaining dentin thickness acquired from micro-CT images, which were scanned after removing fractured instruments using the micro-trepan technique. The study showed that CBCT imaging could measure dentin thickness accurately. Furthermore, using CBCT images, it is reliable and feasible to forecast the remaining dentin thickness after simulated instrument removal.

Shaikh et al (2017)[30] measured the dentin thickness and dentin volume changes for post space preparation with cone-beam computed tomography (CBCT). Ten maxillary central incisors were scanned, before and after root canal and post space preparation, with Orthophos XG three-dimensional hybrid unit. Thirteen axial section scans of each tooth from orifice to apex and dentin thickness for buccal, lingual, mesial, and distal were measured using proprietary measuring tool and thereafter subjected to statistical analysis. It was concluded that CBCT axial section scan for direct measurements of root dentin thickness can be guideline before and after post space preparation for selection of drill length and diameter.

Gülşah Uslu et al (2018)[31] compared the cyclic fatigue resistance of 2Shape, Twisted File (TF) and EndoSequence Xpress (ESX) nickel-titanium rotary files at intracanal temperature (35°C). Twenty 2Shape TS1 (25/.04), 20 TF (25/.04) and 20 ESX (25/.04) files were tested for cyclic fatigue at intracanal temperature (35°C). All the instruments were rotated in artificial canals which were made of stainless steel with an inner diameter of 1.5 mm, 60° angle of curvature and a radius curvature of 5 mm until fracture occurred; the time to fracture was recorded in seconds using a digital chronometer and the number of cycles to fracture (NCF) for each file was calculated. It was concluded that the cyclic fatigue resistance of 2Shape files at the intracanal temperature is higher than that of TF and ESX files.

TahaÖzyürek et al (2018)[32] compared the cyclic fatigue resistances of HyFlex EDM (HEDM), WaveOne Gold (WOG), Reciproc Blue (RB), and 2Shape (TS) NiTi systems having different metallurgic properties. HEDM, WOG, RB, and TS instruments were rotated in artificial canals which were made of stainless steel with an inner diameter of 1.5 mm, 45°, and 90° angles of curvatures and a radius of curvature of 5 mm until fracture occurred, and the time to fracture (TTF) was recorded in seconds. RB NiTi files showed statistically higher cyclic fatigue resistance in artificial canals with 45° and 90° than the other NiTi files tested. Moreover, the increase in the angle of curvature of artificial canals negatively affects the cyclic fatigue resistance.

Ali Imad Al-Asadi et al (2018)[33] evaluated the canal transportation and centering ability of three nickel-titanium single file rotary systems by cone beam computed tomography (CBCT). Thirty permanent maxillary first molar with a range of mesiobuccal canals curvature from 20-30 degree were selected and assigned into three groups (n=10), according to the biomechanical preparation system used: Hyflex EDM (HF), Reciproc blue (RB) and OneShape (OS). The sampled were scanned by CBCT after being mounted on customized acrylic base and then rescanned after the instrumentation. It was concluded that the three single rotary systems reported a degree in canal transportation and centric ratio but the Hyflex EDM reported the least one.

Jyothi Mandava et al (2018)[34] evaluated the incidence of dentinal microcracks formation after root canal shaping procedures with HyFlex EDM and Vortex Blue rotary systems comparing with that of hand instrumentation using micro-computed tomography. Mandibular first molar teeth (n=60) having 50° to 20°mesial root curvature were scanned using high resolution micro-CT imaging before root canal preparation to identify the presence of dentinal defects. Post-instrumentation cross-sectional images were taken and increased number and type of root defects were assessed and recorded. It was revealed that HyFlex EDM has shown greater increase in post instrumentation dentinal defects followed by Vortex Blue rotary system and hand instrumentation resulted in minimal defects.

Anil K Tomer et al (2018)[35] compared and evaluated the remaining dentin thickness of root canals with ProTaper Gold, NeoEndo and Revo-S systems using cone beam computed tomography for analysis. Forty five extracted human mandibular molars having single canal and straight root were collected. Teeth were randomly assigned to three groups (n=15). Samples were de-coronized by maintaining root length. Pre-instrumentation cone beam computed tomography scan was done after stabilizing the samples on wax blocks. The working length was determined at 1 mm short from the apical foramen by using an ISO 15 K-file tip protruding at apical foramen. Preparation was carried out according to the manufacturer’s instructions. After instrumentation, root canals were irrigated with 2ml of 3% sodium hypochlorite solution followed by 2 ml of 17% EDTA solution. Final irrigation was done with 5ml of saline. Post instrumentation cone beam computed tomography scans of all samples in the 3 groups were acquired. It was concluded that ProTaper Gold file system removed more dentine than Revo- S and NeoEndo file system.

Mohammad A. Al-Omari et al (2018)[36] compared the shaping ability of the ProTaper Gold (PTG) and Wave One Gold (WOG) systems in simulated L and S shaped root canals. Forty L and S shaped root canals in resin blocks were randomly divided into four groups (n = 10). Each canal was prepared to the standard working length (16 mm) and enlarged to an apical size 25 using PTG set of files in the sequence S1, S2, F1, and F2 at a speed of 300 rpm and a torque of 2.5 N cm until each file reached the working length. For Wave One Gold, primary file was used in a reciprocating motion until the working length was achieved. The canals were photographed before and after instrumentation using different colors. The two images were superimposed, five points were selected, and canal widths were measured. It was reported that the Wave One Gold system demonstrated better shaping ability, fewer canal aberrations, and more rapid preparation than the ProTaper Gold system.

Prasad K Musale et al (2019)[37]studied the amount of dentin removal in primary mandibular first and second molars instrumented with hand and rotary files using cone-beam computed tomography (CBCT). Sixty primary mandibular molars were divided into two groups: Group I was prepared by manual instrumentation using K-type files and Group II was prepared with rotary instrumentation using 0.04 Hero Shaper Classics. Both these groups were further divided into two subgroups, namely (a) primary mandibular first molar and (b) primary mandibular second molar. All the root canals were prepared up to size 30 using the stepback technique. They were mounted on silicone-based impression material and subjected to CBCT scans for the evaluation of dentin removal before and after instrumentation. Dentin removal was calculated by superimposing images using the In vivo 5.1 Anatomage software. Rotary technique serves as an efficient alternative to the traditional manual instrumentation by overcoming its shortcomings in terms of conservation of the remaining dentin thickness and the time required for its preparation.

Ahmed K Turkistani et al(2019)[10] evaluated and compared the shaping ability of HyFlex™ EDM (HFEDM) and ProTaper Next (PTN) rotary instruments in curved root canals by using micro-computed tomography (micro-CT) imaging. A total of 22 mandibular molar teeth having separate mesial canals with 20° to 30° curvatures were randomly divided into two groups and instrumented with HyFlex EDM (OneFile) or ProTaper Next (X1 and X2). Pre- and post-instrumentation micro-CT scans were obtained. Mesiodistal canal transportation and centering ability were evaluated in four cross-sections (2, 4, 6, and 8 mm from apex). Changes in canal volume and surface area were measured for a 10-mm standardized area of interest.

HyFlexEDM and ProTaper Next files were safe to use in curved canals and showed similar shaping ability, while respecting the original anatomies. HyFlex EDM One-File performed better at the vicinity of the danger zone in terms of mesiodistal canal transportation and centering ability.

Shalini Singh et al (2019)[38] assessed the shaping ability of 2 Shape and ProTaper Gold using Cone Beam Computed Tomography (CBCT). Thirty freshly extracted mandibular first molars were selected, and Pre instrumentation CBCT imaging was performed to attain mesial and distal dentin wall measurements followed by chemo-mechanical preparation using the following NiTi files: 2S and ProTaper Gold. Post instrumentation CBCT imaging was performed for evaluation of the volume of removed dentin, apical transportation, and centering ratio. It was revealed that Two-shape (2S) maintained better original canal anatomy and volume of removed dentin was also less during chemo-mechanical preparation when compared to ProTaper Gold.

Mônica S de Albuquerque et al (2019)[39] compared root canal transportation, centering ability, and amount of dentin removed after root instrumentation with different rotary and reciprocating systems, using micro-computed tomography (micro-CT). Forty curved mesial canals of lower molars were selected and divided into four experimental groups (n = 10) according to the system used: ProTaper Next (PTN), Wave One Gold (WOG), Prodesign Logic (LOG), and Vortex Blue (VTX). The roots were scanned before and after instrumentation using micro-CT, with a 16μm isotropic resolution. For canal transportation, no significant differences were verified between the groups at 6 mm or 9 mm from the apex. At the apical third, Prodesign Logic had a smaller mesial deviation when compared with ProTaper Next. A significant difference was found at the apical and coronal thirds, though with Prodesign Logic having the best centering ability at the apical third and the worst one at the coronal third. All systems caused a greater wear at the coronal third (9 mm), decreasing at the apical one (3 mm), with statistically significant differences. Prodesign Logic removed less dentin from the apical third (3 mm) than did the other instruments.

Youssef A. Algarni et al (2019)[11] assessed and compared the effect of file systems manufactured with different Ni-Ti technologies on root dentin micro-cracking as a measure for integrity. Root specimens of seventy premolar with single root canal of equal length were divided into seven equal groups (n=10) according to the canal preparation system used. G1 (ProTaper universal), G2 (ProTaper next), G3 (ProTaper gold), G4 (Vortex Blue), G5 (XP Shaper), G6 (Hand K- files) and G7 left unprepared (control). The specimens were thereafter horizontally sectioned at three levels from root apex and accordingly groups were subdivided into 3 subgroups. Sub g1 (3 mm), sub g2 (6 mm) and sub g3 (9 mm). The root sections were dye stained and examined under stereo light microscope for crack detection. The results revealed that The XP shaper and Vortex blue file systems have a tendency to cause fewer dentinal cracks compared with the ProTaper Universal, ProTaper Next and ProTaper Gold file systems.

Ove A. Peters et al (2019)[40] compared the preparation ability of two root canal instrumentation systems in oval-shaped canals using micro-computed tomography. Thirty extracted, single-rooted, human mandibular premolars with radiographically similar canal morphology were selected, allocated into two groups (N = 15) and prepared with TRUEShape or Vortex Blue (VB). Each sample was subjected to three scans (20µm resolution): pre-preparation and after preparation to sizes #30 and #40. Three-dimensional data sets were evaluated for canal volume, surface area and surface treatment. It was concluded that the mechanical preparation ability of TRUEShape in oval-shaped canals was similar to that of Vortex Blue. While TRUEShape significantly enhanced surface treatment, neither file system was able to contact or completely prepare the entire root canal surface in oval-shaped canals.

P Sai Kiran Reddy et al (2020)[41] compared and evaluated the amount of remaining dentin thickness in cervical, middle and apical third after instrumentation with stainless steel K -file [Hand instrumentation] and Neo Endo flex rotary file system by using Cone-beam computed tomography (CBCT)**.** Ten freshly extracted human mandibular single-rooted teeth were selected. IOPA of all the teeth were taken to know the internal morphology. Teeth with simple morphology and single straight root canal were selected.

Teeth were randomly assigned to two groups of five samples each. group1: K-file (stainless steel hand instrumentation) group 2: Neo Endo flex (rotary file system). Pre instrumentation CBCT scan was taken for two groups by stabilizing the samples on wax blocks. Dentin thickness values measured at the cervical, middle, and apical third. The Access cavity was prepared, and canal patency was checked using 10 K-file by placing the file up to apical foramen. Working length was determined using the same file 1mm short of the apical foramen. Root canal instrumentation was done in two groups with hand files and rotary file system respectively, according to the manufacturer's instructions. Finally, root canals were irrigated with 2 ml of normal saline. Postoperative CBCT scan was taken for two groups at cervical, middle, and apical third. It was concluded that Stainless steel K-type file (Hand instrumentation) files showed more remaining dentin thickness than Neo Endo (Rotary file system).

Materials and Methods

MATERIALS AND METHODS

ARMAMENTARIUM:

- Extracted bifurcated maxillary first premolars (Fig 1)
- No.2 Modelling Wax (The Hindustan Dental Products, India) (Fig 2)
- High speed Airotor handpiece (NSK) (Fig 3)
- Endo access bur (Dentsply, Tulsa Dental) (Fig 4)
- Endodontic explorer (DG-16; Hu-Friedy, Chicago, IL) (Fig 5)
- Stainless steel (SS) K-files : sizes- 10,15, 20mm (Mani ,Inc, Japan) (Fig 6)
- PROTAPER GOLD™(Dentsply Maillefer, Ballaigues, Switzerland) (Fig 7)
- VORTEX BLUE (DENTSPLY Tulsa Dental Specialties Inc., Tulsa OK) (Fig 8)
- HyFlex® EDM (Coltene/Whaledent Inc) (Fig 9)
- ESX (Brasseler, USA®) (Fig 10)
- X Smart Endomotor (Dentsply Maillefer) (Fig 11)
- 2ml syringe with a 27-gauge needle (Unolok, Hindustan syringes and medical devices LTD, India)
- 5.25% sodium hypochlorite (Prime dental PVT LTD, India) (Fig 12)
- 17% EDTA gel (Prime dental PVT LTD, India) (Fig 13)

- Normal saline BP 0.09% (Fig 14)
- RVG unit (SOPIX IMAGING) (Fig 15)
- KODAK 9000 3D limited field CBCT unit (CareStream Dental) (Fig 16)
- HP desktop computer equipped with ITKSNAP software (www.itksnap.org, USA)

METHODOLOGY

A total of 40 extracted human maxillary first premolars (Fig 1) that showed no caries, cracks, or developmental defects were used in this study. Teeth were extracted for orthodontic reasons, and their use in research was approved by the ethics committee.

Upper and lower occlusal rims were fabricated with No.2 Modelling wax (Fig 2). Each premolar tooth was embedded vertically into the fabricated rims to a level of 2 mm below the CEJ (Fig 17).

Preliminary CBCT scan was done using KODAK 9000 limited field cone beam computed tomography (CBCT) (CareStream Dental) machine (Fig.16) at Quality Diagnostics, Alwarpet, Chennai. The field of view was set at 8 cm in diameter and 8 cm in height. The scan was set at 85 kV, 8 mA, with a voxel size of 200µm. A desktop computer equipped with ITKSNAP (www.itksnap.org

USA) software and supporting hardware was used to make the dentin thickness measurements of both the pre-instrumentation and post-instrumentation images.

Pre-operative dentin thickness was measured within the axial plane at three specific locations (2.0, 6.0 & 10.0 mm from the canal orifice of the tooth) along the canal wall for each respective tooth (Fig. 18a, 19a, 20a, 21a).

In all the samples access cavity preparation was done conventionally using Endo access bur (Dentsply, Tulsa Dental)(Fig.4). Size 10 K-files (Mani ,Inc, Japan) (Fig.6) were inserted through the buccal canals 1 mm beyond the apical foramen to establish apical patency. Canal lengths were determined with size 10 K-files and RVG (Fig.16). The working length (WL) was established 1 mm shorter than the radiographic apex. No attempt was made to locate or shape the palatal canals because their larger canal diameter which was unfavourable for the study.

The teeth were randomly divided into 4 groups according to the NiTi file systems used: Protaper Gold group (n = 10), Hyflex EDM group (n = 10), and ESX group (n = 10), Vortex Blue (n=10).

Group 1: (n=10) Protaper Gold rotary file system (Fig.7)

After establishing initial glide path, orifices were widened with S_x orifice opener with 300rpm rotational speed at 3N/cm torque using X Smart (Dentsply

Maillefer) endomotor (Fig.11). Then the canals were sequentially prepared with Protaper Gold shaping files S1, S2 followed by finishing file F1 upto the working length.

Group 2: (n=10) HyFlex EDM rotary file system with variable taper (Fig.8)

After verifying the canal patency, orifices were widened with HyFlex EDM orifice opener #25/.12 with 500rpm rotational speed at 2.5 N/cm torque using X Smart (Dentsply Maillefer) endomotor. Then the canals were prepared sequentially with #10/.05 glide path file followed by Hyflex EDM #20/.04 and #25 Hyflex EDM shaping one file having variable taper, according to the manufacturer's recommendations upto the working length.

Group 3: (n=10) ESX rotary file system (Fig.9)

The working length was established followed by initial glide path using 15 size k-file (ESX Brassaler). Initial filing was done using #15/.04 followed by #25/.04 with 500rpm rotational speed at 2.0 N/cm torque using X-Smart (Dentsply Maillefer) endomotor upto the working length.

Group 4: (n=10) Vortex Blue rotary file system (Fig.10)

After establishing initial glide path, the working length was estimated in both the root canals. Vortex Blue files were used in a sequential order with

#15/.04, # 20/.04 and # 25/.04 files at 500rpm at a torque of 1.5 N/cm and worked upto the working length.

Between instrumentation of each canal, recapitulation was done using #10/.02 hand files to maintain the working length. During instrumentation, 17% EDTA gel (13) was used to remove smear layer and the canals were irrigated with 3ml of 5.25% sodium hypochlorite (12) using 27gauge needle (Unolok, Hindustan syringes and medical devices LTD. India). Final flush was done with 2 ml of 0.09% normal saline (14). All the shaping procedures were performed by a single operator. Throughout the experimental period, all roots were kept moist in distilled water to avoid any artifact by dehydration.

After chemo-mechanical preparation of the root canals, all root specimens were imaged again by CBCT scanner. The dentin thickness was measured at levels 2.0, 6.0 & 10.0 mm from the root canal orifice using ITKSNAP software (Fig. 18b, 19b, 20b, 21b). The results for each group was recorded, tabulated and statistically analyzed.

METHODOLOGY FLOW CHART

A total of forty maxillary first premolar teeth were selected

(n= 40)

↓

Pre-Operative CBCT scans were taken

↓

The dentin thickness was measured using ITK-SNAP (www.itksnap.org, USA) software

↓

Standard access cavities were prepared using Endo access bur (Dentsply, Tulsa Dental) and working lengths were determined by using RVG with 15 size K-files placed in the canals

↓

Teeth were randomly distributed into four groups

Protaper Gold	Hyflex EDM	ESX [Brasseler]	Vortex Blue
(n =10)	(n =10)	(n =10)	(n =10)

↓

↓

The root canals in each sample groups were instrumented upto the determined working length using the respective rotary files with each tooth instrumented for about 3mins with multiple strokes coupled with irrigation

↓

Post-operative CBCT scans of the tooth samples were taken

↓

ITK-SNAP (www.itksnap.org, USA) software was used for post-operative dentin thickness measurements

↓

Results were obtained

↓

Data were statistically analysed using One Way ANOVA and Tukey’s post hoc test

↓

Interpretation of data

Figures

ARMAMENTARIUM

Figure 1: Teeth Samples (Extracted bifurcated maxillary first premolars)

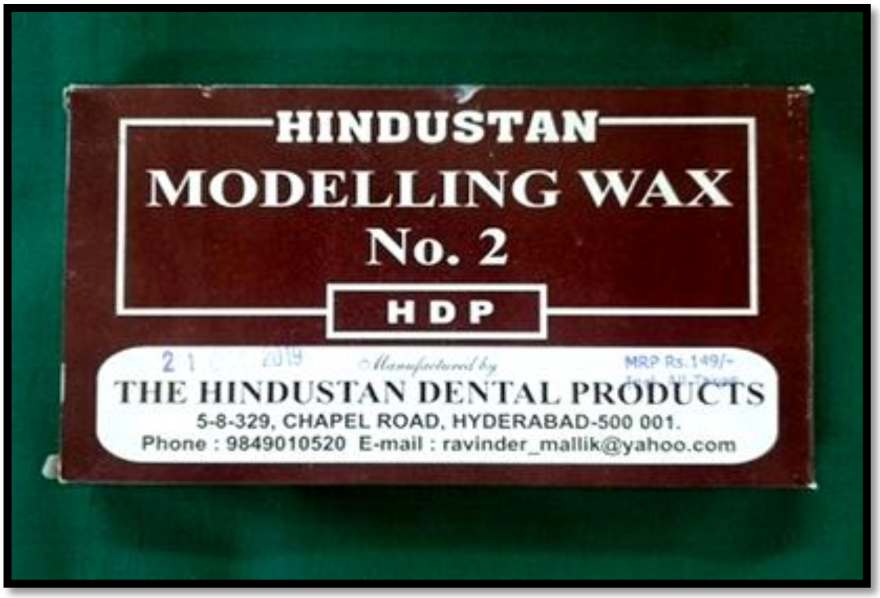


Figure 2: Modelling Wax

Figure 3 High speed Airotor handpiece

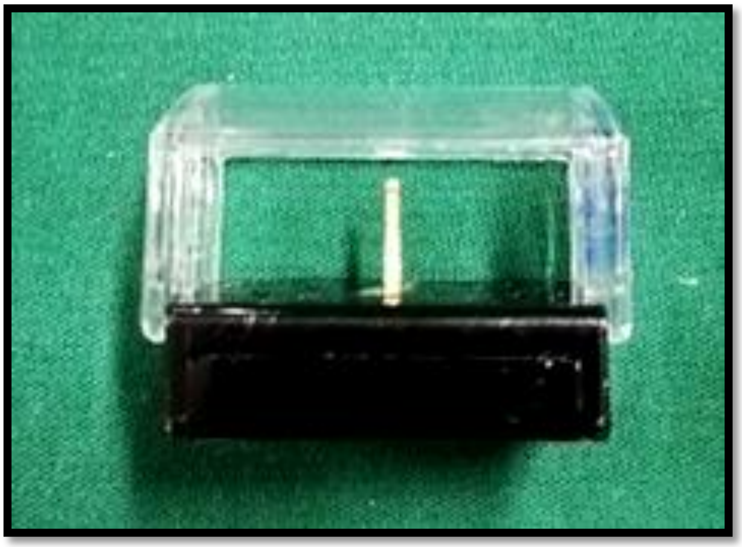


Figure 4: Endo access bur

Figure 5: DG-16 Endodontic Explorer

Figure 6: Stainless steel K-file

Figure 7: PROTAPER GOLD

Figure 8: HyFlex® EDM

Figure 9: ESX (Brasseler)

Figure 10: Vortex Blue

Figure 11: Xsmart Endomotor

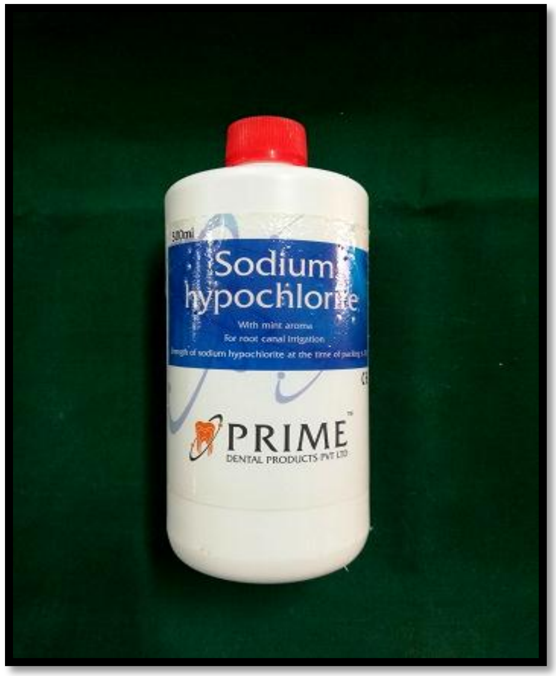


Figure 12: 5.25% sodium hypochlorite

Figure 13: 17% EDTA gel

Figure 14: 0.09% Normal saline

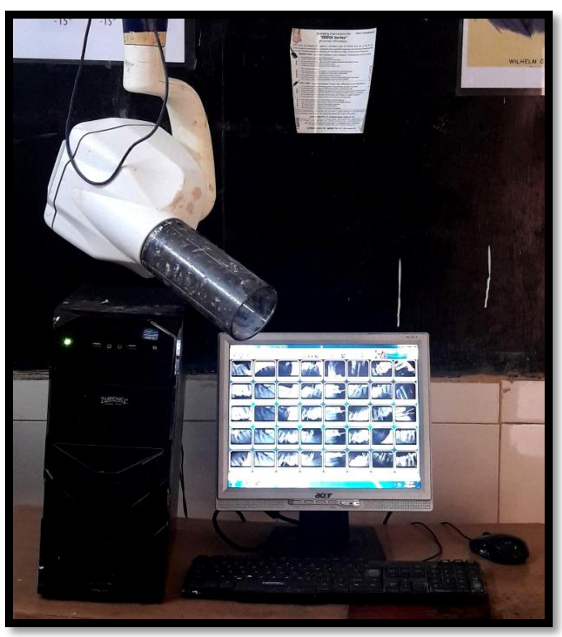


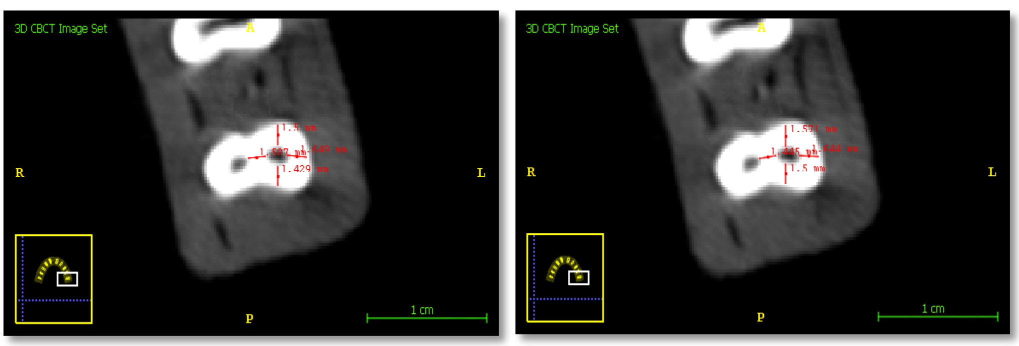
Figure 15: RVG Unit

Figure 16: KODAK 9000 3D limited field CBCT unit

Figure 17: Teeth samples embedded on occlusal rim

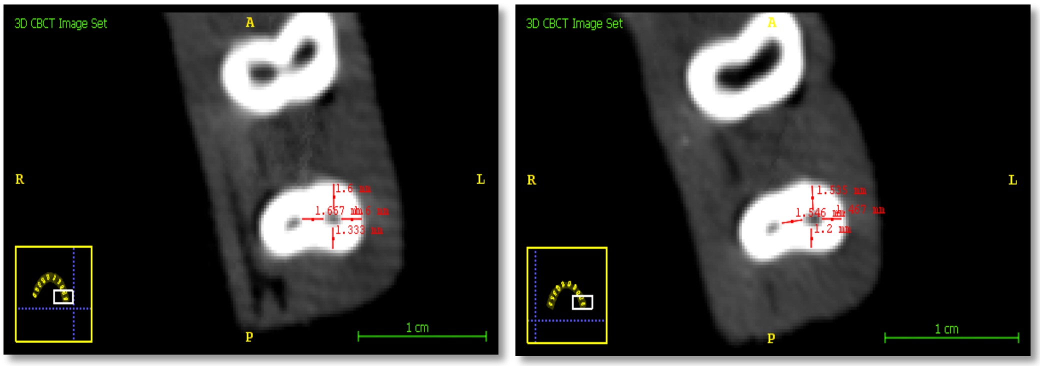
(a) **(b)**

Figure 18: Pre- and Post-operative dentin thickness measurements of Protaper Gold group



(a) **(b)**

Figure 19: Pre- and Post-operative dentin thickness measurements of Hyflex EDM Group



(a) **(b)**

Figure 20: Pre- and Post-operative dentin thickness measurements of ESX (Brasseler) Group

(a) (b)

Figure 21: Pre- and Post-operative dentin thickness measurements of Vortex Blue Group

Results

RESULTS

The collected data were analysed using IBM.SPSS statistics software version 23.0. To describe about the data descriptive statistics frequency analysis, percentage analysis were used for categorical variables and the mean & S.D were used for continuous variables. To find the significant difference in the multivariate analysis the one way ANOVA with Tukey's Post-Hoc test was used. In both the above statistical tools the probability value 0.05 is considered as significant level.

Table 1 shows the mean and SD of amount of dentin removal in each group (ProTaper Gold, ESX, Hyflex EDM & Vortex Blue) at various aspects (buccal, palatal, mesial & distal) at a level of 2mm from the root canal orifice. At buccal aspect (p = 0.001), ProTaper Gold shows the highest mean value [0.370(±0.213)], followed by ESX [0.268(±0.008)], Hyflex EDM [0.198(±0.005)] & Vortex Blue [0.175(±.003)]. At palatal aspect (p = 0.008), ProTaper Gold shows the highest mean value [0.375(±.247)], followed by ESX [0.275(±0.096)], Hyflex EDM [0.198(±0.007)] & Vortex Blue [0.117(±0.008)]. At mesial aspect (p = 0.250), ProTaper Gold shows the highest mean value [0.286(±0.190)], followed by ESX [0.213(±0.160)], Hyflex EDM [0.197(±0.009)] & Vortex Blue [0.178(±0.005)]. At distal aspect (p = 0.137), ESX [0.303(±0.131)] shows the highest mean value, followed by ProTaper Gold [0.276(±0.024)], Hyflex EDM [0.196(±0.006)] & Vortex Blue [0.176(±0.01)]. The mean values obtained by Oneway ANOVA shows that at a level of 2mm, amount of dentin removal(mm) was highly significant at buccal & palatal aspect ($p<0.01$) and found no statistical significance at mesial & distal aspects ($p>0.05$).

This result shows that, amount of dentin removal at a level of 2mm from root canal orifice is more at buccal and palatal aspect than at mesial and distal aspect. This also shows that among the four test groups, ProTaper Gold has removed more dentin followed by ESX, Hyflex EDM & Vortex Blue (Graph 1).

Table 2 shows the mean and SD of amount of dentin removal in each groups (ProTaper Gold, ESX, Hyflex EDM & Vortex Blue) at various aspects (buccal, palatal, mesial & distal) at a level of 6mm from the root canal orifice. At buccal aspect ($p = 0.447$), ProTaper Gold shows the highest mean value [0.301 (±0.014)], followed by ESX [0.194 (±0.376)], Hyflex EDM [0.193 (±0.006)] & Vortex Blue [0.178 (±0.006)]. At palatal aspect ($p = 0.042$), ESX [0.263 (±0.007)] shows the highest mean value, followed by ProTaper Gold [0.249 (±0.159)], Hyflex EDM [0.190 (±0.011)] & Vortex Blue [0.174 (±0.008)]. At mesial aspect ($p = 0.0005$), ProTaper Gold shows the highest mean value [0.288 (±0.027)], followed by ESX [0.208 (±0.094)], Hyflex EDM [0.189 (±0.005)] & Vortex Blue [0.173 (±0.007)]. At distal aspect ($p = 0.0005$), ProTaper Gold shows the highest mean value [0.335 (±0.165)] followed by ESX [0.288 (±0.025)], Hyflex EDM [0.171 (±0.060)] & Vortex Blue [0.172 (±0.005)]. The mean values obtained by Oneway ANOVA shows that at a level of 6mm, amount of dentin removal(mm) has no statistical significance at buccal aspect ($p>0.05$), where as it was significant at palatal aspect ($p<0.05$) and highly significant at mesial & distal aspects ($p<0.01$).

This result shows that, amount of dentin removal at a level of 6mm from root canal orifice is more at palatal, mesial and distal aspects than at buccal aspect. This also shows that among the four test groups, ProTaper Gold has removed more dentin followed by ESX, Hyflex EDM & Vortex Blue in all aspects except the palatal aspect where ESX has removed more dentin (Graph 2).

Table 3 shows the mean and SD of amount of dentin removal in each groups (ProTaper Gold, ESX, Hyflex EDM & Vortex Blue) at various aspects (buccal, palatal, mesial & distal) at a level of 10mm from the root canal orifice. At buccal aspect ($p = 0.0005$), ProTaper Gold shows the highest mean value [0.299 (±0.011)], followed by ESX [0.269 (±0.008)], Hyflex EDM [0.193 (±0.006)] & Vortex Blue [0.172 (±0.005)]. At palatal aspect ($p = 0.0005$), ProTaper Gold shows the highest mean value [0.297 (±0.008)], followed by ESX [0.260 (±0.016)], Hyflex EDM [0.186 (±0.007)] & Vortex Blue [0.170 (±0.006)]. At mesial aspect ($p = 0.0005$), ProTaper Gold shows the highest mean value [0.287 (±0.028)], followed by ESX [0.259 (±0.019)], Hyflex EDM [0.194 (±0.007)] & Vortex Blue [0.174 (±0.008)]. At distal aspect ($p = 0.0005$), ProTaper Gold [0.296 (±0.009)] and ESX [0.295 (±0.098)] shows similar higher mean values followed by Hyflex EDM [0.176

(±0.057)] & Vortex Blue [0.172 (±0.006)]. The mean values obtained by Oneway ANOVA shows that at a level of 10mm, amount of dentin removal (mm) is highly statistically satisfied at all aspects (buccal, palatal, mesial & distal) ($p<0.01$).

This result shows that, amount of dentin removal at a level of 10mm from root canal orifice is similar at all aspects (buccal, palatal, mesial & distal). This also shows that among the four test groups, ProTaper Gold has removed more dentin followed by ESX, Hyflex EDM & Vortex Blue in all aspects except the distal aspect where both ProTaper Gold & ESX shows similar amounts of dentin removal (Graph 3).

Based on the Oneway ANOVA test, a multiple comparison of the significant variables was done using Tukey's post-hoc test.

Table 4 shows multiple comparisons of significant variables at a level of 2mm from root canal orifice.

At the buccal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, no significant difference in the mean values of dentin removal was observed between ProTaper Gold group and ESX group ($p=0.157$, $p>0.05$), whereas a highly significant difference in the mean values were observed between ProTaper Gold group and Hyflex EDM ($p=0.005$, $p<0.01$) and also with Vortex Blue ($p=0.001$, $p<0.01$).

Thus, it was found that ProTaper Gold file system had better dentin removal at the buccal aspect at a level of 2mm from canal orifice when compared with Hyflex EDM and Vortex Blue and removed almost same amount of dentin from the canal walls when compared with ESX group (Graph 1a).

2. Whereas, while comparing ESX group with Hyflex EDM and Vortex Blue groups, no significant difference in the mean values of dentin removal was observed in each file systems ($p=0.467$ and $p=0.224, p>0.05$ respectively).

This shows that ESX file system removed almost same amount of dentin at buccal aspect when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed ($p=0.962$, $p>0.05$).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at buccal aspect at a level of 2mm from canal orifice.

i.e, Based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE.**

At the palatal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, no significant difference in the mean values of dentin removal was observed between ProTaper Gold group and ESX group ($p=0.349$, $p>0.05$), whereas a significant difference in the mean values were observed between ProTaper Gold group and Hyflex EDM ($p=0.024$, $p<0.05$) and a highly significant difference between ProTaper Gold group with Vortex Blue ($p=0.010$, $p<0.01$).

Thus, it was found that ProTaper Gold file system has significantly better dentin removal at the palatal aspect at a level of 2mm from canal orifice when compared with Vortex Blue and a significantly better dentin removal with Hyflex EDM and removed almost same amount of dentin from the canal walls when compared with ESX group (Graph 1b).

2. Whereas, while comparing ESX group with Hyflex EDM and Vortex Blue groups ,no significant difference in the mean values of dentin removal was observed in each file systems ($p=0.568$ and $p=0.360$,$p>0.05$ respectively).

This shows that ESX file system removed almost same amount of dentin at buccal aspect when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed ($p=0.984$, $p>0.05$).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at buccal aspect at a level of 2mm from canal orifice.

i.e, based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE**

Table 5 shows multiple comparisons of significant variables at a level of 6mm from root canal orifice.

At the palatal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, no significant difference in the mean values of dentin removal was observed between ProTaper Gold group with ESX group($p=0.980$,$p>0.05$) and Hyflex EDM($p=0.356$, $p>0.05$), whereas a significant difference in the mean values were observed between ProTaper Gold group and Vortex Blue($p=0.048$,$p<0.05$).

Thus, it was found that ProTaper Gold file system showed significantly better dentin removal at the palatal aspect at a level of 6mm from canal orifice when compared with Vortex Blue and removed almost same amount of dentin from the canal walls when compared with Hyflex EDM and ESX file systems (Graph 2b).

2. Whereas, while comparing ESX group with Hyflex EDM and Vortex Blue groups ,no significant difference in the mean values of dentin removal was observed in each file systems (p=0.187 and p=0.762, p>0.05 respectively).

This shows that ESX file system removed almost same amount of dentin at palatal aspect when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed (p=0.970, p>0.05).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at palatal aspect at a level of 6mm from canal orifice.

i.e, based on amount of dentin removal, **ESX > PROTAPER GOLD > HYFLEX EDM > VORTEX BLUE**

At the mesial aspect of root canal:

1. While comparing ProTaper Gold group with other groups, highly significant difference in the mean values of dentin removal was observed between ProTaper Gold group with ESX group ($p=0.005, p<0.01$), Hyflex EDM ($p=0.0005, p<0.01$) and Vortex Blue ($p=0.0005, p<0.01$).

Thus, it was found that ProTaper Gold file system had very significantly better dentin removal at the mesial aspect at a level of 6mm from canal orifice when compared with ESX, Hyflex EDM and Vortex Blue file systems (2c).

2. Whereas, while comparing ESX group with Hyflex EDM and Vortex Blue groups ,no significant difference in the mean values of dentin removal was observed in each file systems ($p=0.832$and $p=0.397, p>0.05$ respectively).

This shows that ESX file system removed almost same amount of dentin at mesial aspect when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed ($p=0.879$, $p>0.05$).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at mesial aspect at a level of 6mm from canal orifice.

i.e, based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE**

At the distal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, no significant difference in the mean values of dentin removal was observed between ProTaper Gold group ESX group($p=0.635, p>0.05$) and a significant difference in the mean values of dentin removal was observed between ProTaper Gold and Vortex Blue($p=0.030, p<0.05$) .

Thus, it was found that ProTaper Gold file system had significantly better dentin removal at the distal aspect at a level of 6mm from canal orifice when compared with Hyflex EDM and Vortex Blue file systems and no significant difference in the mean values of dentin removal with ESX file systems ($p=0.635, p>0.05$) (Graph 2d).

2. Whereas, while comparing ESX group with Hyflex EDM and Vortex Blue groups ,highly significant difference in the mean values of dentin removal was observed in each file systems ($p=0.001$ and $p=0.001, p<0.001$ respectively).

This shows that ESX file system removed very significantly more amount of dentin at distal aspect when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed ($p=1.00$, $p>0.05$).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at distal aspect at a level of 6mm from canal orifice.

i.e, based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE**

Table 6 shows multiple comparisons of significant variables at a level of 10mm from root canal orifice.

At the buccal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, high significant difference in the mean values of dentin removal was observed with all other groups: ESX group ($p=0.0005$,$p>0.01$), Hyflex EDM ($p=0.0005$, $p<0.01$) and with Vortex Blue ($p=0.0005$, $p<0.01$).

Thus, it was found that ProTaper Gold file system had very significantly better dentin removal at the buccal aspect at a level of 10mm from canal orifice when compared with ESX, Hyflex EDM and Vortex Blue file systems (Graph 3a)

2. Whereas, while comparing ESX group with Hyflex EDM and with Vortex Blue, high significant difference in the mean values of dentin removal was observed with Hyflex EDM ($p=0.0005$, $p<0.01$) and with Vortex Blue ($p=0.0005$, $p<0.01$).

Thus, it was found that ESX file system had very significantly better dentin removal at the buccal aspect at a level of 10mm from canal orifice when compared with Hyflex EDM and Vortex Blue file systems.

3. And while comparing Hyflex EDM with Vortex Blue ,high significant difference in the mean values of dentin removal was observed when compared with Vortex Blue ($p=0.0005$, $p<0.01$).

Thus, it was found that Hyflex EDM file system had very significantly better dentin removal at the buccal aspect at a level of 10mm from canal orifice when compared with Vortex Blue file systems.

i.e, based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE**

At the palatal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, high significant difference in the mean values of dentin removal was

observed with all other groups: ESX group (p=0.0005, p>0.01), Hyflex EDM (p=0.0005, p<0.01) and with Vortex Blue (p=0.0005, p<0.01).

Thus, it was found that ProTaper Gold file system had very significantly better dentin removal at the palatal aspect at a level of 10mm from canal orifice when compared with ESX, Hyflex EDM and Vortex Blue file systems.

2. Whereas, while comparing ESX group with Hyflex EDM and with Vortex Blue, high significant difference in the mean values of dentin removal was observed with Hyflex EDM (p=0.0005 , p<0.01) and with Vortex Blue (p=0.0005 , p<0.01).

Thus, it was found that ESX file system had very significantly better dentin removal at the palatal aspect at a level of 10mm from canal orifice when compared with Hyflex EDM and Vortex Blue file systems (Graph 3b).

3. And while comparing Hyflex EDM with Vortex Blue, high significant difference in the mean values of dentin removal was observed when compared with Vortex Blue (p=0.0007 , p<0.01).

Thus, it was found that Hyflex EDM file system had very significantly better dentin removal at the palatal aspect at a level of 10mm from canal orifice when compared with Vortex Blue file systems.

i.e, based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE**

At the mesial aspect of root canal:

1. While comparing ProTaper Gold group with other groups, high significant difference in the mean values of dentin removal was observed with all other groups: ESX group ($p=0.0006$, $p>0.01$), Hyflex EDM ($p=0.0005$, $p<0.01$) and with Vortex Blue ($p=0.0005$, $p<0.01$).

Thus, it was found that ProTaper Gold file system had very significantly better dentin removal at the mesial aspect at a level of 10mm from canal orifice when compared with ESX, Hyflex EDM and Vortex Blue file systems (Graph 3c).

2. Whereas, while comparing ESX group with Hyflex EDM and with Vortex Blue, high significant difference in the mean values of dentin removal was observed with Hyflex EDM ($p=0.0005$, $p<0.01$) and with Vortex Blue ($p=0.0005$, $p<0.01$).

Thus, it was found that ESX file system had very significantly better dentin removal at the mesial aspect at a level of 10mm from canal orifice when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed ($p=0.061$, $p>0.05$).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at mesial aspect at a level of 10mm from canal orifice.

i.e, based on amount of dentin removal, **PROTAPER GOLD > ESX > HYFLEX EDM > VORTEX BLUE**

At the distal aspect of root canal:

1. While comparing ProTaper Gold group with other groups, no significant difference in the mean values of dentin removal was observed between ProTaper Gold group and ESX group ($p=1.000$,$p>0.05$), whereas a highly significant difference in the mean values were observed between ProTaper Gold group and Hyflex EDM ($p=0.0005$,$p<0.01$) and Vortex Blue ($p=0.0005$,$p<0.01$).

Thus, it was found that ProTaper Gold file system had very significantly better dentin removal at the distal aspect at a level of 10mm from canal orifice when compared with Hyflex EDM and Vortex Blue and removed almost same amount of dentin from the canal walls when compared with ESX group (Graph 3d).

2. Whereas, while comparing ESX group with Hyflex EDM and with Vortex Blue, high significant difference in the mean values of dentin removal was observed with Hyflex EDM ($p=0.0005$, $p<0.01$) and with Vortex Blue ($p=0.0005$, $p<0.01$).

Thus, it was found that ESX file system had very significantly better dentin removal at the distal aspect at a level of 10mm from canal orifice when compared with Hyflex EDM and Vortex Blue file systems.

3. While comparing Hyflex EDM group with Vortex Blue group, no significant difference in the mean values of dentin removal was observed ($p=0.999$, $p>0.05$).

Thus it was found that Hyflex EDM and Vortex Blue file systems removed almost same amount of dentin from canal walls at distal aspect at a level of 10mm from canal orifice.

i.e, based on amount of dentin removal, **PROTAPER GOLD = ESX > HYFLEX EDM > VORTEX BLUE**

Tables and Graphs

TABLE 1:MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) BY ONEWAY ANOVA

Multiple comparison at 2mm by One-way ANOVA						
		N	Mean	S.D	F-value	P-value
BUCCAL	PROTAPER GOLD	10	.370	.213	6.797	0.001 **
	ESX	10	.268	.008		
	HYFLEX EDM	10	.198	.005		
	VORTEX BLUE	10	.175	.003		
PALATAL	PROTAPER GOLD	10	.375	.247	4.571	0.008 **
	ESX	10	.275	.096		
	HYFLEX EDM	10	.198	.007		
	VORTEX BLUE	10	.177	.008		
MESIAL	PROTAPER GOLD	10	.286	.190	1.428	0.250 #
	ESX	10	.213	.160		
	HYFLEX EDM	10	.197	.009		
	VORTEX BLUE	10	.178	.005		
DISTAL	PROTAPER GOLD	10	.303	.131	1.961	0.137 #
	ESX	10	.276	.244		
	HYFLEX EDM	10	.196	.006		
	VORTEX BLUE	10	.176	.010		
# No Statistical Significance at P>0.05 level ,** Highly Significant at P < 0.01 level						

TABLE 2: MULTIPLE COMPARISONS BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) BY ONEWAY ANOVA

Multiple comparison at 6mm by One-way ANOVA						
		N	Mean	S.D	F-value	P-value
BUCCAL	PROTAPER GOLD	10	.301	.014	0.908	0.447 #
	ESX	10	.194	.376		
	HYFLEX EDM	10	.193	.006		
	VORTEX BLUE	10	.178	.006		
PALATAL	PROTAPER GOLD	10	.249	.159	3.015	0.042 *
	ESX	10	.263	.007		
	HYFLEX EDM	10	.190	.011		
	VORTEX BLUE	10	.174	.008		
MESIAL	PROTAPER GOLD	10	.288	.027	10.717	0.0005 **
	ESX	10	.208	.094		
	HYFLEX EDM	10	.189	.005		
	VORTEX BLUE	10	.173	.007		
DISTAL	PROTAPER GOLD	10	.335	.025	8.763	0.0005 **
	ESX	10	.288	.165		
	HYFLEX EDM	10	.171	.060		
	VORTEX BLUE	10	.172	.005		
# No Statistical Significance at P>0.05 level ,** Highly Significant at P < 0.01 level * Statistical Significance at P < 0.05 level						

TABLE 3: MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) BY ONEWAY ANOVA

Multiple comparison at 10mm by One-way ANOVA						
		N	Mean	S.D	F-value	P-value
BUCCAL	PROTAPER GOLD	10	.299	.011	581.525	0.0005 **
	ESX	10	.269	.008		
	HYFLEX EDM	10	.193	.006		
	VORTEX BLUE	10	.172	.005		
PALATAL	PROTAPER GOLD	10	.297	.008	341.252	0.0005 **
	ESX	10	.260	.016		
	HYFLEX EDM	10	.186	.007		
	VORTEX BLUE	10	.170	.006		
MESIAL	PROTAPER GOLD	10	.287	.028	90.120	0.0005 **
	ESX	10	.259	.019		
	HYFLEX EDM	10	.194	.007		
	VORTEX BLUE	10	.174	.008		
DISTAL	PROTAPER GOLD	10	.296	.009	15.196	0.0005 **
	ESX	10	.295	.098		
	HYFLEX EDM	10	.176	.057		
	VORTEX BLUE	10	.172	.006		

TABLE 4: MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) BY TUKEY HSD

Multiple Comparisons - Tukey HSD							
Dependent Variable			MD	Std. Error	P-value	95% C.I LB	95% C.I UB
BUCCAL	PROTAPER GOLD	ESX	.102600	.048	0.157 #	-.026	.231
		HYFLEX EDM	.172600*	.048	0.005 **	.044	.301
		VORTEX BLUE	.195800*	.048	0.001 **	.067	.324
	ESX	HYFLEX EDM	.070000	.048	0.467 #	-.058	.198
		VORTEX BLUE	.093200	.048	0.224 #	-.035	.222
	HYFLEX EDM	VORTEX BLUE	.023200	.048	0.962 #	-.105	.152
PALATAL	PROTAPER GOLD	ESX	.099800	.059	0.349 #	-.060	.260
		HYFLEX EDM	.177100*	.059	0.024 *	.017	.337
		VORTEX BLUE	.198300*	.059	0.010 **	.038	.358
	ESX	HYFLEX EDM	.077300	.059	0.568 #	-.083	.237
		VORTEX BLUE	.098500	.059	0.360 #	-.061	.258
	HYFLEX EDM	VORTEX BLUE	.021200	.059	0.984 #	-.139	.181
** Highly Sig P < 0.01 , * Sig P < 0.05 and # No Sig P > 0.05 levels							

TABLE 5: MULTIPLE COMPARISONS BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) BY TUKEY HSD

Multiple Comparisons - Tukey HSD

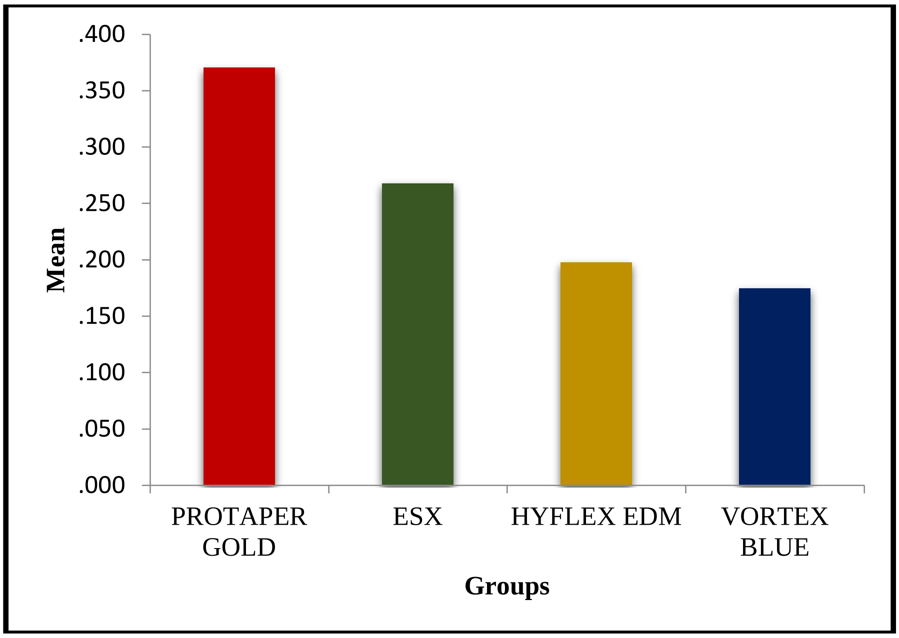
Dependent Variable			MD	Std. Error	P-value	95% C.I	
						LB	UB
PALATAL	PROTAPER GOLD	ESX	-.013900	.036	0.980 #	-.110	.082
		HYFLEX EDM	.059400	.036	0.356 #	-.037	.155
		VORTEX BLUE	.075300	.036	0.048 *	-.021	.171
	ESX	HYFLEX EDM	.073300	.036	0.187 #	-.023	.169
		VORTEX BLUE	.089200	.036	0.762 #	-.007	.185
	HYFLEX EDM	VORTEX BLUE	.015900	.036	0.970 #	-.080	.112
MESIAL	PROTAPER GOLD	ESX	.079640*	.022	0.005 **	.021	.139
		HYFLEX EDM	.098200*	.022	0.0005 **	.039	.157
		VORTEX BLUE	.114500*	.022	0.0005 **	.055	.174
	ESX	HYFLEX EDM	.018560	.022	0.832 #	-.041	.078
		VORTEX BLUE	.034860	.022	0.397 #	-.024	.094
	HYFLEX EDM	VORTEX BLUE	.016300	.022	0.879 #	-.043	.075
DISTAL	PROTAPER GOLD	ESX	-.047270	.040	0.635 #	-.154	.059
		HYFLEX EDM	.116800*	.040	0.027 *	.010	.223
		VORTEX BLUE	.115100*	.040	0.030 *	.008	.222
	ESX	HYFLEX EDM	.164070*	.040	0.001 **	.057	.271
		VORTEX BLUE	.162370*	.040	0.001 **	.056	.269
	HYFLEX EDM	VORTEX BLUE	-.001700	.040	1.000 #	-.108	.105

** Highly Sig P < 0.01 , * Sig P < 0.05 and # No Sig P > 0.05 levels

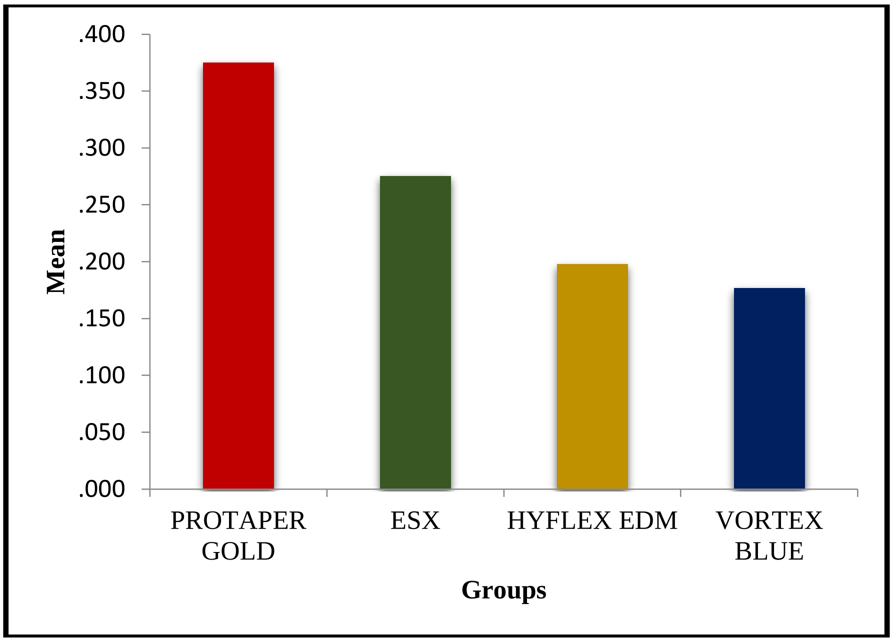
TABLE 6: MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) BY TUKEY HSD

Multiple Comparisons - Tukey HSD							
Dependent Variable			MD	Std. Error	P-value	95% C.I	
						LB	UB
BUCCAL	PROTAPER GOLD	ESX	.030100*	.004	0.0005 **	.021	.040
		HYFLEX EDM	.106000*	.004	0.0005 **	.096	.116
		VORTEX BLUE	.126500*	.004	0.0005 **	.117	.136
	VORTEX BLUE	HYFLEX EDM	.075900*	.004	0.0005 **	.066	.085
		VORTEX BLUE	.096400*	.004	0.0005 **	.087	.106
	HYFLEX EDM	VORTEX BLUE	.020500*	.004	0.0005 **	.011	.030
PALATAL	PROTAPER GOLD	ESX	.037300*	.005	0.0005 **	.025	.050
		HYFLEX EDM	.110900*	.005	0.0005 **	.098	.123
		VORTEX BLUE	.126900*	.005	0.0005 **	.114	.139
	ESX	HYFLEX EDM	.073600*	.005	0.0005 **	.061	.086
		VORTEX BLUE	.089600*	.005	0.0005 **	.077	.102
	HYFLEX EDM	VORTEX BLUE	.016000*	.005	0.007 **	.004	.028
MESIAL	PROTAPER GOLD	ESX	.028100*	.008	0.006 **	.007	.049
		HYFLEX EDM	.092400*	.008	0.0005 **	.071	.114
		VORTEX BLUE	.113000*	.008	0.0005 **	.092	.134
	ESX	HYFLEX EDM	.064300*	.008	0.0005 **	.043	.086
		VORTEX BLUE	.084900*	.008	0.0005 **	.064	.106
	HYFLEX EDM	VORTEX BLUE	.020600	.008	0.061 #	-.001	.042
DISTAL	PROTAPER GOLD	ESX	.001100	.025	1.000 #	-.067	.070
		HYFLEX EDM	.120100*	.025	0.0005 **	.052	.189
		VORTEX BLUE	.123900*	.025	0.0005 **	.055	.192
	ESX	HYFLEX EDM	.119000*	.025	0.0005 **	.050	.188
		VORTEX BLUE	.122800*	.025	0.0005 **	.054	.191
	HYFLEX EDM	VORTEX BLUE	.003800	.025	0.999 #	-.065	.072
** Highly Sig P < 0.01 , * Sig P < 0.05 and # No Sig P > 0.05 levels							

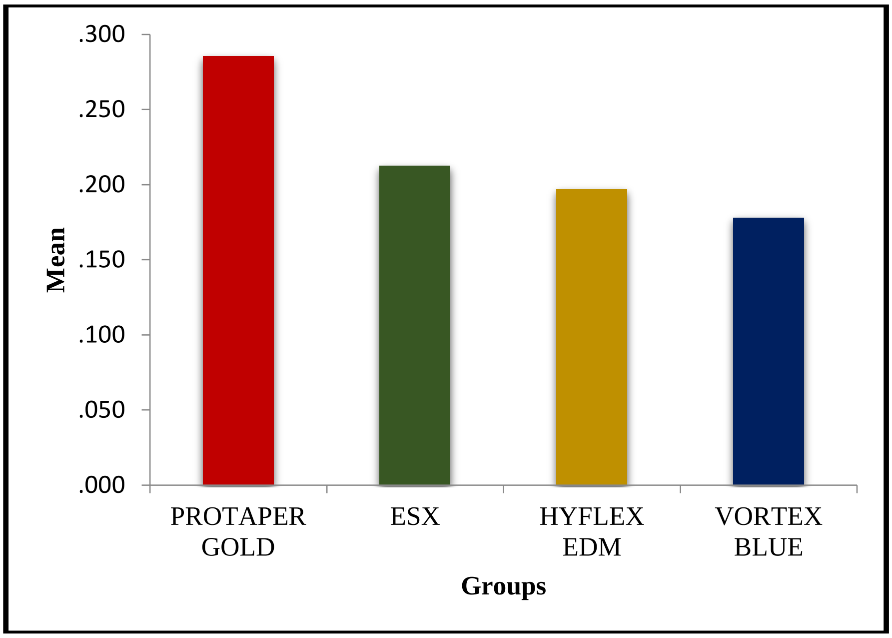
GRAPH 1: MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) AT VARIOUS ASPECTS



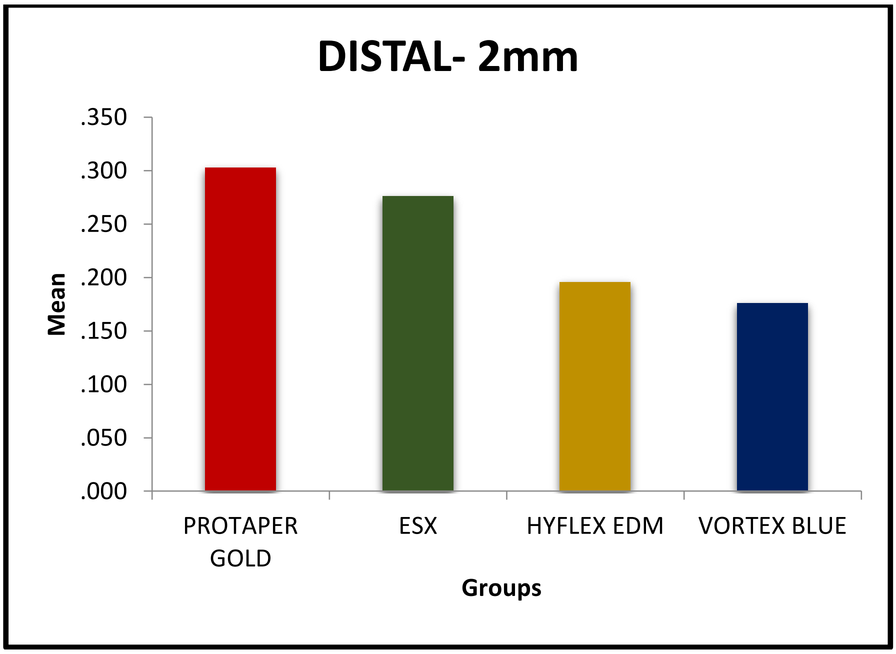
1A. MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) AT BUCCAL ASPECT



1B. MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) AT PALATAL ASPECT

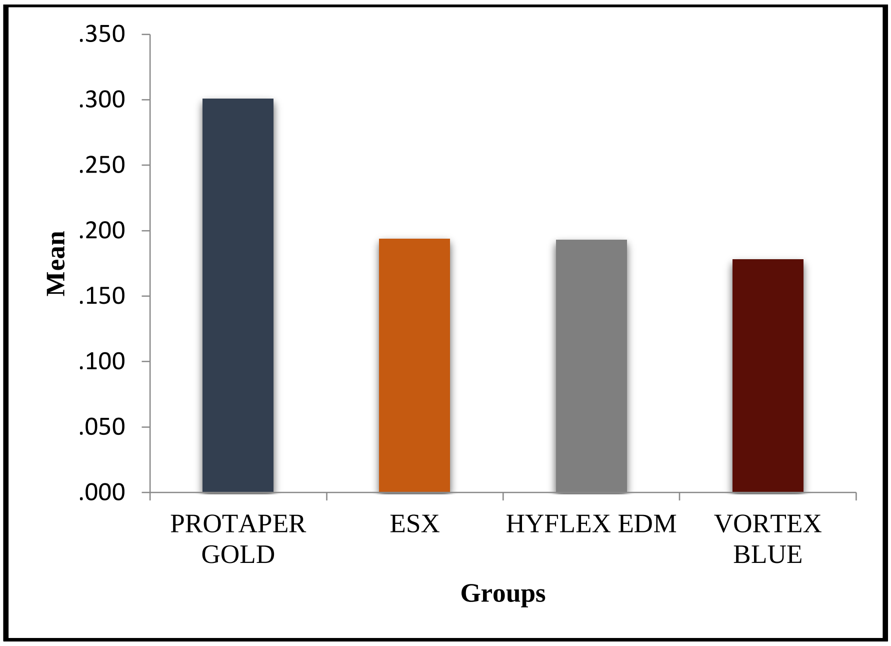


1C. MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) AT MESIAL ASPECT

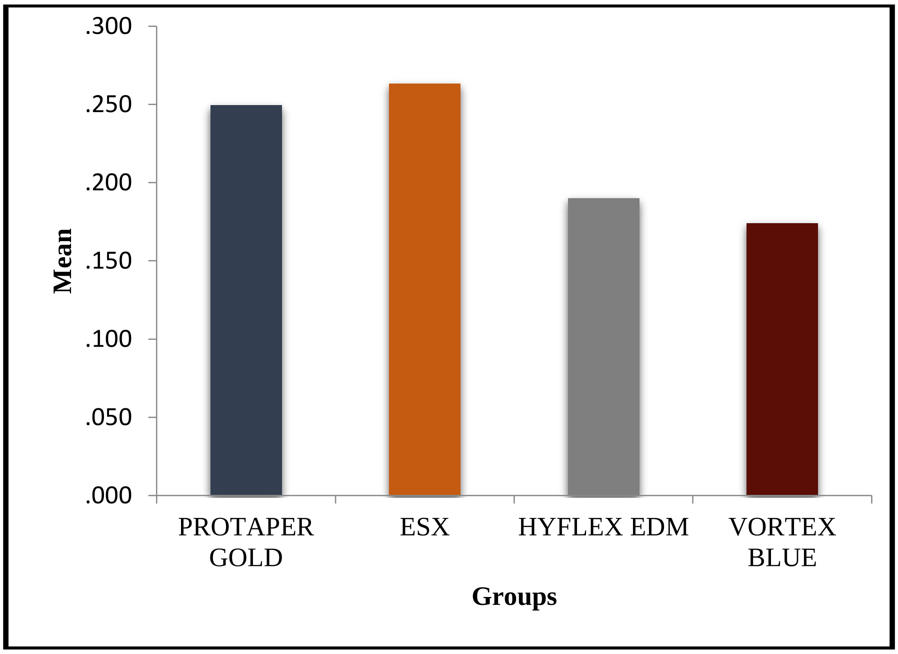


1D. MULTIPLE COMPARISONS BETWEEN GROUPS AT 2mm (FROM ROOT CANAL ORIFICE) AT DISTAL ASPECT

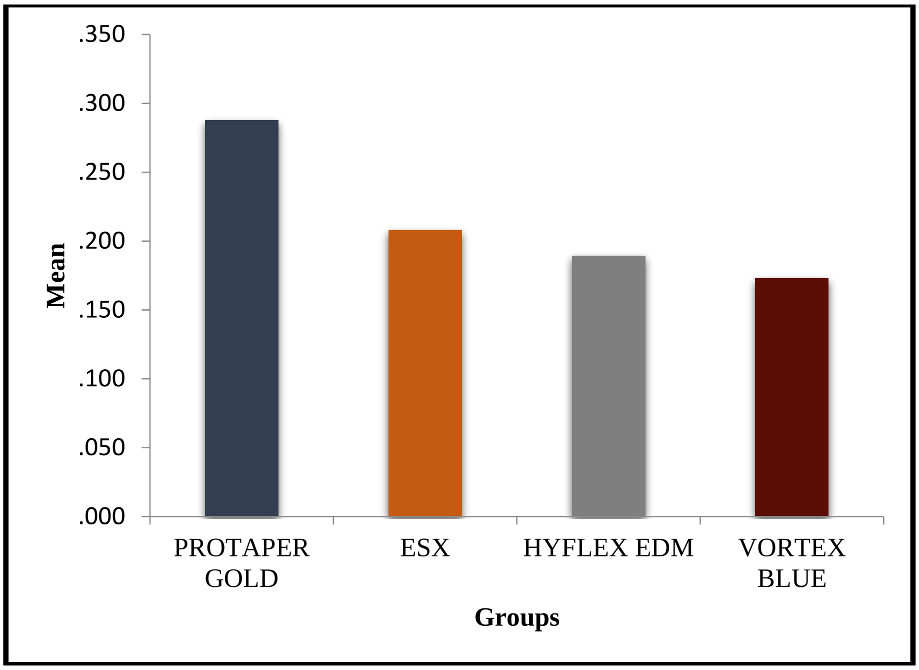
GRAPH 2: MULTIPLE COMPARISONS BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) AT VARIOUS ASPECTS



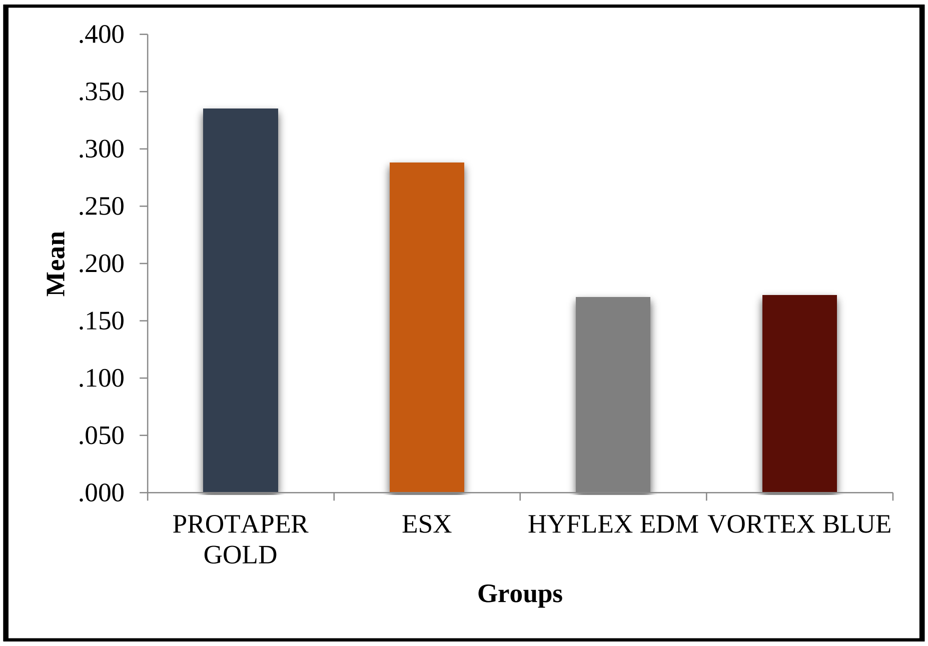
2A. MULTIPLE COMPARISON BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) AT BUCCAL ASPECT



2B. MULTIPLE COMPARISON BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) AT PALATAL ASPECT

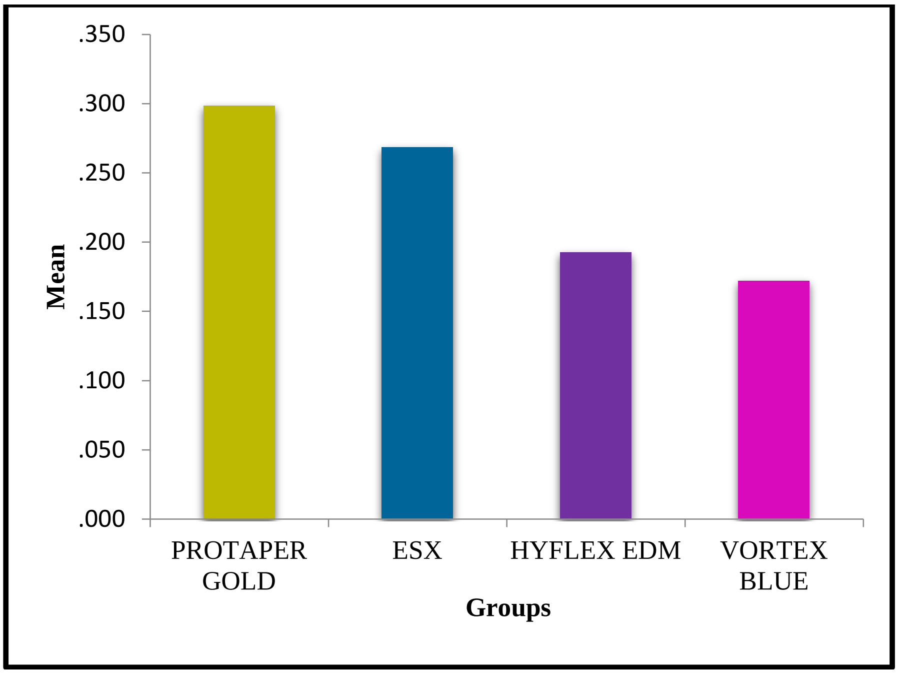


2C. MULTIPLE COMPARISON BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) AT MESIAL ASPECT

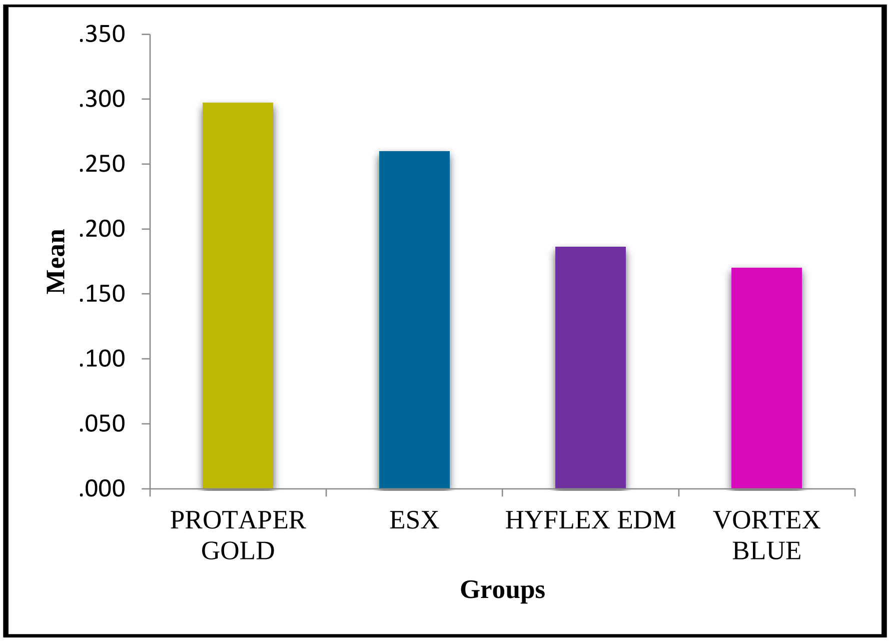


2D. MULTIPLE COMPARISON BETWEEN GROUPS AT 6mm (FROM ROOT CANAL ORIFICE) AT DISTAL ASPECT

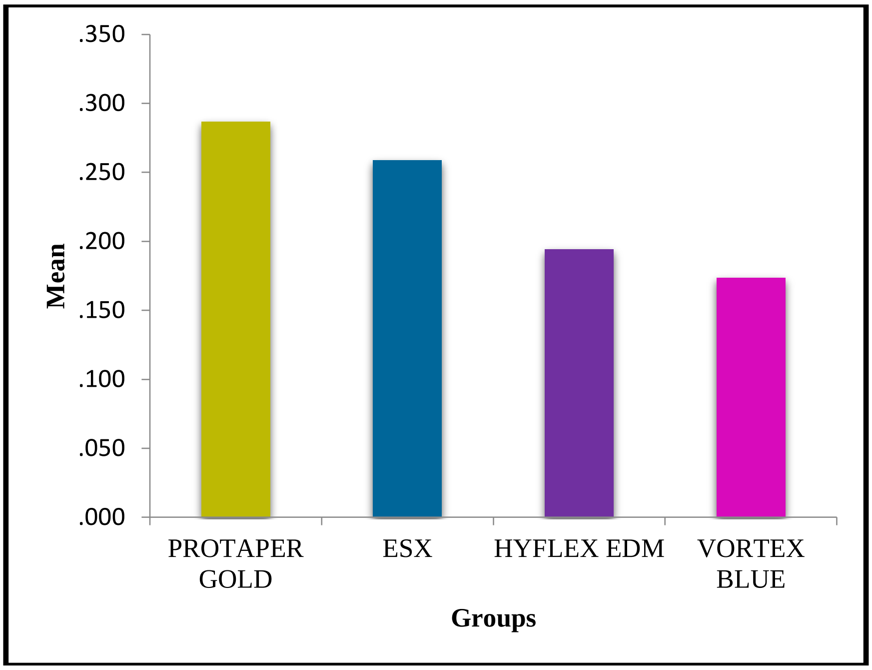
GRAPH 3: MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) AT VARIOUS ASPECTS



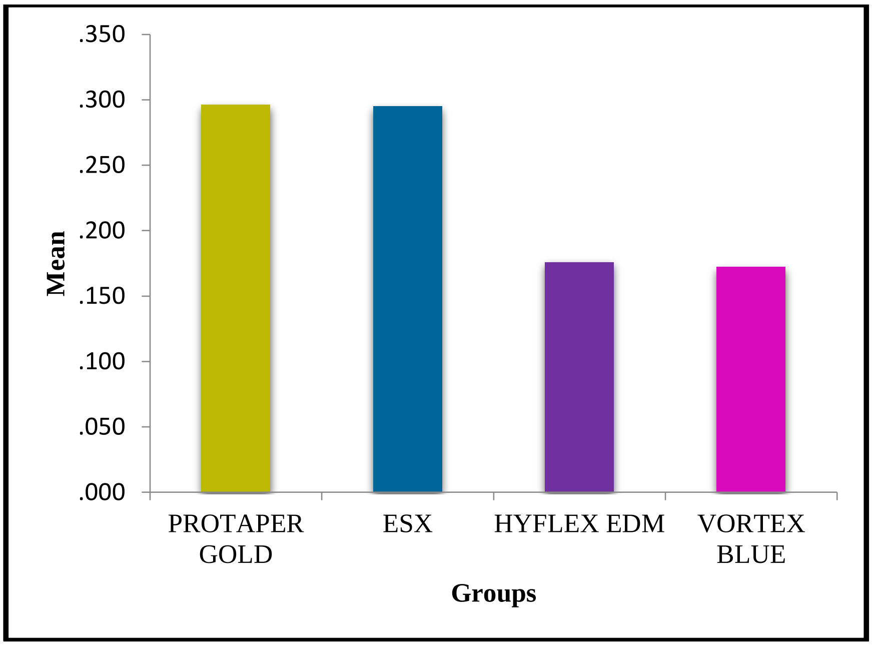
3A. MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) AT BUCCAL ASPECT



3B. MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) AT PALATAL ASPECT



3C. MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) AT MESIAL ASPECT



3D. MULTIPLE COMPARISONS BETWEEN GROUPS AT 10mm (FROM ROOT CANAL ORIFICE) AT DISTAL ASPECT

Discussion

DISCUSSION

W.D. Miller (1984) was the first investigator to find the presence of bacteria in inflamed pulp tissues. Since then, microorganisms have been considered as an important agent for the development of inflammation in the dental pulp.[42] However, the ultimate importance of bacteria was not demonstrated until Kakehashi *et al* (1965) conducted his investigations and concluded that bacteria harbored in the root canal system are the causative factors in endodontic disease.[43] This conclusion was also supported by Moiler *et al* (1981), Sundquist *et al* (1979) and Bhakdi (1991) where they demonstrated that bacterial by-products could induce bone breakdown and cause periradicular infection.[44]

Apical periodontitis is an inflammatory response, usually against bacteria and their products located within the root canal system.[43,44] The process starts after pulp necrosis, when bacteria invade and colonize the root canal system. As a consequence of necrosis, the endodontic environment becomes a selective habitat for the establishment of a mixed microbiota conspicuously dominated by anaerobic bacteria. In later stages of the infectious process, bacterial organizations resembling biofilms can be observed on the canal walls. Bacteria colonizing the necrotic root canal come in contact with the periodontal ligament via apical or lateral foramen, induce damage and give rise to inflammatory changes.[45] Thus it seems logical that their (bacteria) elimination or reduction will lead to successful endodontic therapy. This is achieved only through the proper access and thorough debridment of the inflamed, infected, degenerated, or necrotic pulp tissue which are the main objectives of endodontic therapy.[46]

Cleaning and shaping of root canal system is an important phase of endodontic therapy as it creates the space that allows irrigants and antibacterial medicaments to more effectively eradicate bacteria and eliminate its byproducts.[47] According to Schilder (1974), the clinical goal of cleaning and shaping is to satisfy the biological and mechanical objectives. Biological objective is achieved through total debridement of the root canal. The properly prepared canals should feel smooth in all dimensions when the tip of a small file is pushed against the canal walls. This indicates that the files have contacted and planed all accessible canal walls. The mechanical objective is to maintain or develop a continuously tapering funnel form with the smallest diameter at the apex and the widest diameter at the orifice.[48]

In the past, several techniques have been described and designed to produce the desired tapered preparation. Initially, Ingle in 1961 introduced the standardized technique where all instruments were introduced to full working length.[49] The technique relies on the inherent shape of the instruments to impart the final shape to the canal. This method was satisfactory in straight canals, but was quite unsuitable for curved canals. Due to inherent stiffness of large size files, they become less flexible and led to iatrogenic errors like ledging, zipping, elbow formation, perforation and loss of working length owing to compaction of dentin debris, in curved root canals.[50]

In order to overcome the procedural errors during preparation of the curved root canals, Clem and Weine in 1969 devised the step-back technique which was further modified by Mullaney in 1974.[50] In this technique, the apical region is first enlarged using K-files to a final master apical file size of 25 or 30; each successively larger instrument is then inserted 1.0 mm short into the canal so that a progressive taper is formed. The step-back preparation is superior to standardized technique in moderately curved canals, but in the severely curved root canals, problems still existed.[51]

Later in 1980, Georig introduced the step-down technique where the coronal aspect of the root canal is widened and cleaned before the apical part. The advantages of this method over the step back includes permitting straighter access to the apical region of the root canal, elimination of dentinal interferences found in the coronal 2/3rd of the root canal, removal of pulp tissue debris and microorganisms before apical instrumentation. Hence, the step-down technique is now the most widely used technique for root canal preparation.[52]

Abou Rass, Glick and Frank (1980) introduced a method called "anti curvature filing" to prevent excessive dentin removal from the curvature of thin roots. In this technique a precurved hand file is used to file the canal away from the danger zone.[53]

Later, Roane (1985) introduced the balanced force technique which recognizes the fact that instruments are guided by the canal walls when rotated. The main advantages of the balanced force technique are good apical control of the file tip as the instrument does not cut over the complete length, good centering of the instrument because of the non-cutting safety tip, and no need to pre-curve the instrument.[54] Roane & Sabala in their further studies described good results for the preparation of curved canals with or without minimal straightening[55]. However, studies by Benenati FW and Roane reported a relatively high incidence of procedural errors such as root perforations or instrument fractures.[56]

Stepback and stepdown techniques were regarded as traditional manual preparation techniques but there are only few comparative studies on these two techniques. Thus there is no definite proof that 'classical' stepdown techniques are superior to stepback techniques. Calhoun and Montgomery in their comparative study stated that the balanced force technique, which is a stepdown technique as well, resulted in less straightening than stepback or standardized techniques.[57] Luiten DJ et al in another comparatative study evaluated the apical canal transportation of four techniques and concluded that no difference between stepback and crowndown was detected in terms of straightening, but crowndown produced more ledges.[58] Furthermore two separate studies by Turek T, Langeland[59] and McKendry DJ[60] concluded that using the Balanced force technique, less residual debris was found in the apical part of curved root canals than following preparation with the crown-down pressureless or stepback technique. Although stepback preparation resulted in a larger increase in canal diameter and more dentin removal than balanced force preparation.[60]

Traditionally, simple endodontic hand files were the primary means of shaping root canal system and they played a major role in the negotiation, initial shaping and prevention of iatrogenic events in endodontic therapy. These files were made of carbon steel or stainless steel. Stainless steel instruments have inherent stiffness that increases as the size of the instruments increases. Hence, while preparing curved root canals using simple hand instruments, some degrees of canal transportation may happen which leads to ledge formation and zip perforation. Therefore, while preparing curved canals, stainless steel instruments must be pre-curved for use, which effectively prevents them from being used in a rotary motion. An instrument that is too stiff will cut more on the convex (outer) side than on the concave (inner) side, thereby straightening the curve.[61]

In order to overcome these shortcomings rotary endodontic instruments have been used as an adjunct for endodontic therapy. NiTi instruments are highly flexible and elastic. These files were shown to have two to three times the elastic flexibility in bending and torsion, as well as superior resistance to torsional fracturing when compared to similar stainless-steel instruments. Most innovative outcome was that, these files which are manufactured out of NiTi alloy could prepare curved canals mechanically, utilizing a continuous rotary motion.[62]

The superior mechanical properties of nickel-titanium alloys are attributed to its unique metallurgical characteristics. NiTi "shape memory metal alloy" can exist in two different temperature-dependent crystal structures called martensite (lower temperature or daughter phase) and austenite (higher temperature or parent phase). When the material is in its martensite form, it is soft and ductile and can easily be deformed, while austenitic NiTi is quite strong and hard.[61]

According to Thompson et al (2000), the phase transformation behaviour of Ni–Ti alloy is influenced by many factors, such as changes in composition, machining characteristics and differences in heat treatment. It has also been suggested that heat treatment is an important procedure that can be used to manifest the original mechanical properties of NiTi alloy by releasing crystal lattice defects and contributing to changes in the phase transformation behavior.

It was in late 1988, that Walia *et al* introduced NiTi, a corrosion resistant alloy in endodontics for manufacturing rotary instruments. From then, NiTi rotary instruments have undergone revolutionary changes in terms of manufacture and physical characteristics. Furthermore, the type of alloy, the cross-sectional design, shape, degree of taper and the number of instruments used in each group have been modified to develop a NiTi rotary instrument which cuts and removes the dentin strongly and also is fracture resistant even in narrow, curved root canals. Another purpose was to simplify the cleaning and shaping procedure and to reduce the number of instruments used, along with preserving the original shape of the root canals.[62]

Based on various modifications, NiTi rotary files are categorized as five generations. First generation NiTi rotary instruments were introduced in the market during the mid-1990s. The most important characteristic of these NiTi rotary files were having a passive cutting radial lands along with fixed tapers (0.04-0.06) over the full working lengths. Later in 2001, second generation files were introduced. These instruments had active cutting edges with greater cutting efficiency, so the number of instruments required to achieve complete cleaning and shaping was almost less in comparison with the previous generation.

In the late 2007, the manufacturers introduced the third generation of NiTi rotary files. It was manufactured by applying heating and cooling technologies on NiTi alloys to improve safety of these instruments, especially in the curved root canals. The heating and cooling procedures resulted in an alloy which is resistant to cyclic fatigue and also have reduced the risk of instrument separation. Applying M-wire and R-phase technologies and Electrical Discharge Machining methods, make instruments with high memory shapes and low risk of separation.

The reciprocation theory of canal preparation has led to the development of fourth generation NiTi rotary instruments. Instead of full rotation, the reciprocating instruments have movements in which clockwise and counterclockwise degrees of rotation are quite equal. The use of a single file technique to achieve thorough cleaning and shaping at this phase was another success which was derived from the reciprocation phenomenon.

In fifth generation file system, the efficiency of canal shaping has been improved by offsetting the center of rotation. This offset design reduces the taper lock or the screwing effect which causes instrument separation. Despite the reciprocation theory which was the basis for the fourth generation, the file systems those belongs to the fifth generation offer proper root canal shaping by continuous clockwise rotation of the instruments.[61]

In this study, amount of dentin removal by four different file systems have been compared; ProTaper Gold (Fig.7), Hyflex EDM (Fig.8), ESX (Brasseler) (Fig.9) & Vortex Blue (Fig.10).

Dentsply International was the first company to offer heat treatment technology on their mechanical files. They first released file brands using M-Wire, Blue Wire and then Gold Wire which is a post-machining process that makes files significantly more flexible and resistant to fracture. Such a technology was used for the manufacture of a novel file system known as ProTaper Gold (Fig.7), which was evolved from its predecessor, ProTaper Universal.[63]

ProTaper Gold files were developed with proprietary advanced metallurgy and have a progressively tapered design that is claimed by the manufacturer to enhance cutting efficiency and safety. They have a convex triangular cross-section and progressive taper. This navigates challenging curves in the apical region of the canal.[36]

In the ProTaper Gold (PTG) system, there are 2 Shaping files (S1 and S2) and 1 Auxiliary Shaping file (SX). S1 & S2 have D0 diameters of 0.17 mm and 0.20 mm respectively, modified guiding tips, and 9% and 12% increasing tapers over their active portions respectively and the SX file has an overall length of 19 mm. Five ProTaper Finishing files named F1, F2, F3, F4, and F5 have D0 diameters of 0.20, 0.25, 0.30, 0.40, and 0.50 mm respectively. In this file system, the finishing files namely F1, F2 and F3 have fixed tapers of 7%, 8% and 9% respectively.[63]

HyFlex EDM (Fig.8) files were introduced in 2013 by Coltene/Whaledent. The main feature of these files is that they are manufactured via an electric discharge machining (EDM) process. The EDM is a noncontact thermal erosion procedure used in engineering for the manufacturing of parts that would be difficult to machine with conventional techniques. The removal of material is performed by pulsating electric current discharges that flow between an electrode and the workpiece and that are immersed in a dielectric medium. The electric current partially melts and evaporates small portions of the material in a well-controlled and repeatable manner. The material is therefore superficially removed leaving an isotropic surface, characterized by regularly distributed craters.[24] Additionally, the EDM process produces a non-directional surface finish, thereby avoiding early material failure that results from conventional grinding techniques.[64]

As a result of EDM process, the file is extremely flexible and with variable cross-sectional design (Quadratic at tip, trapezoidal in middle and triangular cross-section at the top) which contributes to high fracture resistance and also controls the materials memory which can significantly reduce the risk of ledging, transportation and perforation[23]. Hyflex EDM files are manufactured using Controlled Memory alloy technology like the HyFlex CM (Coltene/Whaledent AG) NiTi files. It has a tip size of 25 with a constant 0.08 taper in the apical 4mm of the instrument but reduces progressively upto 0.04 taper in the coronal portion.[34]

Vortex Blue (Fig.10) instruments (Dentsply Tulsa Dental) were introduced in 2011 and it uses a new proprietary method for processing of NiTi wire which results in a distinctive blue color because of a visible titanium oxide layer. This claims to reduce shape memory with respect to standard NiTi files, which try to revert to their original straight shape because of the shape memory characteristics of standard NiTi. This property gives the Vortex Blue files the ability to maintain the shape given to them.[20]

These instruments are produced by complex heating and cooling procedures and exhibit greater fatigue resistance and improved flexibility with controlled shape memory. They have variable helical angle cutting blade with triangular cross-section. The lower helical angle (less flutes) in the coronal portion of the file facilitates efficient debris removal and the higher helical angle (more flutes) in the apical portion facilitates increased strength with minimal chance for dentinal cracks formation.[34]

Vortex Blue instruments are made by using 508 nitinol and after machining they undergo a complex heating and cooling treatment and obtains a shape memory alloy in another proprietary thermo-mechanical treatment. Its austenite finish temperature is around 38 °C. Studies have showed that Vortex Blue instruments had the 2-stage specific transformation behavior, indicating that reverse transformation of the alloy passes through the intermediate R-phase, which reflects the complex phase transformation behavior tracking back to the manufacturing process.[20]

Brasseler introduced the ESX (Fig.9) rotary file system (Brasseler USA), representing an evolution of the EndoSequence system. The ESX rotary file system is characterized by a performance enhancing ‘booster tip’ comprised of six cutting edges within the first millimeter of the instrument. The novel tip design boasts an anti-ledging and anti-perforating centering mechanism and is claimed to allow for fewer instruments and larger diameter increases. As such, following the creation of a glide path by the Expeditor, a single ESX file is intended to complete canal shaping. The ESX rotary system is thus, in its basic form, a two file system.

The Booster-Tip is present on all four ESX Finishing files (25, 35, 45, 55 all in 0.04 taper). The booster tip utilizes flat transition angles from the rounded non-cutting tip to advance to the triangular shank, thus creating six cutting edges and a narrower tip. This change in tip design creates a doubling of the cutting edges at tip. This combination creates a guiding element to the tip with the benefit of reduced potential for ledging.

Regardless of the rotary instruments used, cleaning and shaping procedures invariably lead to dentine removal from the canal walls and flaring the canals excessively decreases the dentin thickness. Residual dentin thickness indicates the mechanical limits of instrumentation, to enlarge the diameter of the root canal that would not significantly weaken the dentinal walls.[65]

A direct relationship exists between the remaining dentin thickness and the strength of the root. The remaining dentin thickness is important because the amount of remaining dentin enables the endodontically treated teeth to resist from fracture. Trabert et al in his study supported the same and concluded that over preparation of the root canal space decreases the ability of the tooth to withstand trauma and thus amount of tooth structure that remains after endodontic and post preparation is of prime importance.[66]

Gutmann and Ritaano et al in two separate studies stated that a minimal radicular dentin thickness of 0.2 mm is considered critical. If the canal wall thickness is below this threshold, there is a risk of vertical root fracture during canal obturation.[67, 68] According to Katz et al, at least 1 mm of root dentin should remain in all root aspects along its entire length after all intra-radicular procedures are completed.[69] Trope and Ray investigated 36 extracted roots and concluded that it was logical to remove as little dentin as possible during instrumentation, and that the use of GG burs in the coronal third of the root should be reassessed.[70]

In the present study, buccal roots of extracted two-rooted maxillary first premolars (Fig,1) were used. Dummer et al in his study evaluated the use of extracted teeth for in-vitro studies and concluded that extracted teeth compromises the standardization of samples due to the variations in root anatomy and in dentin hardness. However, it enables SEM investigation of canal cleanliness and provides conditions close to the clinical situation.

Simulated canals in resin blocks are a method to standardize conditions with regard to the degree and radius of curvature and abrasiveness. Their use does not reflect the action of instruments in root canals of natural teeth. Kum et al. (2000) pointed out that the resin material is not ideal for a study of rotary instruments because it does not respond in the same way as dentin, and if instruments are used in a grinding action, the generated heat may sometimes soften the resin material so that cutting blades may bind and consequently fracture.(Thompson & Dummer 1997).[71]

P.Neelakandan et al, in their study found that buccal roots of both maxillary first and second premolars showed the maximum variations. Thus endodontic treatment of maxillary first premolars represented as one of the most difficult teeth to be treated. Pilo R & Tamse A (1998) reported that, fracture of endodontically treated teeth increases proportionally with an increase in the amount of root dentin removal especially in maxillary and mandibular premolars, due to their narrow mesio-distal width.[72,12]

Nathanson et al according to his findings stated that, a reduction of greater than 1 mm in the remaining dentin thickness at the mesio-distal direction from the CEJ to 5 mm apically has serious clinical applications, alerting the clinician to preserve the mesio-distal width as much as possible and not to introduce posts beyond the minimal length necessary for retention.[73] Also one of the unique anatomical features of maxillary premolars is the presence of deep mesial root concavities, which increased fracture susceptibility due to lower dentin thickness. This anatomical feature may present endodontic difficulties such as perforation of the dentinal wall during preparation of the root canals.

The evaluation of root canal instrumentation is necessary to determine the remaining dentin thickness and to observe if the principles of canal preparation had been followed. Considering the previous studies, the residual dentin thickness and the risk zones of the root canal walls can be analysed using radiographs, microscopic analyses, silicone impressions, muffle system, endodontic cube, multi-slice computed tomography, cone-beam computed tomography and micro-computed tomography.[18] In the present study, Cone Beam Computed Tomography has been used as a tool to assess the amount of dentin removed after instrumentation using four different rotary file systems during cleaning and shaping procedure.

Furthermore, studies by Raiden G et al revealed that a radiograph showed greater thickness than were actually present. Therefore, radiographs should not be considered as a reliable method for this task.[74] Zuckerman et al reported sectioning of the tooth as a method to directly measure the canal wall thickness[29]. Later, Patel S and Dawood A stated that CBCT being a non-destructive method allows evaluation of root canal preparation without sectioning the specimen, allowing the same can be used for further studies or as their own control.[75]

Measurement of distance on CBCT images was evaluated by Kobayashi et al and the results from his study indicated that CBCT gives more accurate measurements than spiral computerized tomography in measuring distance between points.[76]

Several methods have been proposed for standardization of image acquisition. It is extremely important to standardize the position of samples for obtaining images by CBCT because any displacement of the sample in both bucco-lingual and mesio-distal directions will not provide pre- and post instrumentation image superimposition. Bramante (1987) suggested a method in which images obtained from root slices were superimposed to detect alterations that were produced after root canal preparation.[77] Zaia et al. (2000), Wu (2005) and Sauáia et al. (2010) modified the previously described methodology and suggested to include the teeth in acrylic resin.[78,79,80] Coutinho Filho et al (2008) used a plastic tube and a metallic strip to guide the slices repositioning.[81] Whereas in the current study, upper and lower occlusal rims were fabricated with No.2 Modelling wax and each tooth sample was embedded vertically into the fabricated rims to a level of 2 mm below the CEJ and stabilized (Fig.17).

In this study, the amount of dentin removal by four different NiTi rotary file systems in the buccal roots of forty bifurcated maxillary first premolars using Cone Beam Computed Tomography were compared and evaluated. Four different file systems used were ProTaper Gold, Hyflex EDM, Vortex Blue and ESX. Amount of dentin removed at different levels (2mm, 6mm & 10mm) from the root canal orifice at various aspects (buccal, palatal, mesial & distal) was measured (Fig.18-21).

The amount of dentin removal indicates the aggressiveness of the instrument. In the present study it was found that there was a statistically significant difference in the amount of dentin removed by ProTaper Gold in all aspects at various levels of the root canal. The mean amount of dentin removal by ProTaper Gold was the highest at a level of 2mm, 6mm & 10mm. From the evaluation of above results it is found that ProTaper Gold shows the highest amount of dentin removal. The above findings are in agreement with various studies which were previously conducted (Table 1-3) (Graph 1-3).

Paque et al (2010) in his study confirmed that ProTaper Gold has greater cutting ability in the coronal and middle thirds of the root canal system. It was explained that this could probably be related to the sharp cutting edges of the convex triangular cross-sectional design and its flute design that combines multiple tapers within the shaft up to 19%.[82]

. Anil K Tomer et al conducted a study to evaluate the remaining dentin thickness after root canal preparation using ProTaper Gold, Neoendo and

Revo-S systems using CBCT and found that ProTaper Gold file system removed more dentin than Revo- S and NeoEndo file system.[35]

M. Ozgur Uyanik et al in his study investigated changes in root canal volume after chemo-mechanical preparation with three different rotary NiTi systems and found that, ProTaper removed significantly more dentin than Hero Shaper and RaCe.[83]

The aggressive cutting characteristics of ProTaper Gold can be attributed to its progressively tapered design which clinically serves to significantly improve flexibility & cutting efficiency. Another unique feature of this instrument is its convex triangular cross section which reduces the contact area between the blade of the file and dentin; thus enhancing the cutting efficiency. The above findings were supported by Ruddle CJ et al where he represents ProTaper NiTi rotary files as a revolutionary progression in root canal preparation procedures.[84]

In the current study it was found that, Vortex Blue removed least amount of dentin compared to other rotary file systems (Table 1-6) (Graph 1-3). Vortex Blue is composed of M-wire alloy and has greater flexibility and resistance to cyclic fatigue. These characteristics may explain the results obtained by Vortex Blue. Monica et al in her study, comparing the amount of dentin removal after preparation using various files also came up to the same conclusion that Vortex Blue removed less dentin at the middle and coronal thirds.

Present study also reveals that ProTaper Gold is found to remove more dentin in all aspects at all levels except the distal aspect at 6mm level and palatal aspect at 10mm level where ESX was found to remove more dentin than ProTaper Gold (Table 2) (Graph 2b). This finding is in association with a study by Amanda Pioch (2016) who compared the cutting efficiency of ESX, Endosequence, and Profile instruments using the true tooth replica and found that cutting efficiency was shown to be significantly greater for the ESX rotary system as compared to both EndoSequence and ProFile. Also it was revealed that, the EndoSequence and ESX, both non-landed instruments with a negative rake angle, demonstrated more dentin removal compared to the ProFile system, which is landed and fabricated with a neutral rake angle.[85]

There was no much significant difference in dentin removal by ESX and Hyflex EDM. Ozyurek et al (2017) conducted an *in vitro* study on the shaping ability of Reciproc, WaveOne Gold, and HyFlex EDM single-file systems in simulated S-shaped canals and it was 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 resin removal than the Reciproc NiTi files.[32]

In this study, on comparing the four file systems, ProTaper Gold, Hyflex EDM, ESX (Brasseler) & Vortex Blue, it was found that ProTaper Gold removed more amount of dentin followed by ESX (Brasseler). Hyflex EDM and Vortex Blue file systems showed similar amount of dentin removal, of which Vortex Blue file system removed the least amount of dentin during chemo-mechanical preparation in the buccal root of maxillary first premolar teeth.

Summary

SUMMARY

The aim of this *in vitro* study was to compare and evaluate the amount of dentin removal by ProTaper Gold, Hyflex EDM, ESX (Brasseler) & Vortex Blue rotary file systems which were assessed by using Cone Beam Computed Tomography.

In this study, a total of 40 human maxillary first premolars that showed no caries, cracks, or developmental defects were used. Each premolar tooth was embedded vertically into fabricated occlusal rims to a level of 2 mm below the CEJ. Pre-operative dentin thickness was measured within the axial plane at three specific locations (2.0, 6.0 & 10.0 mm) from the canal orifice of the tooth along the canal wall for each respective tooth using KODAK 9000 limited field cone beam computed tomography (CBCT). Desktop computer equipped with ITKSNAP (www.itksnap.org USA) software and supporting hardware was used to make dentin thickness measurements.

In all samples, access cavity preparation was done conventionally using Endo access bur and working length (WL) was established 1 mm shorter than the radiographic apex using a size 10 K-flile. The teeth were randomly divided into 4 groups according to the NiTi file systems used: ProTaper Gold group (n = 10), Hyflex EDM group (n = 10), and ESX group (n = 10), Vortex Blue (n=10). Chemo-mechanical preparation of the root canals was done using respective files according to the manufacturer's instructions. All root

specimens were imaged again by CBCT scanner. The dentin thickness was measured at levels 2.0, 6.0 & 10.0 mm from the root canal orifice using ITKSNAP software. The results for each group were recorded, tabulated and statistically analyzed using IBM.SPSS statistics software version 23.0.

Conclusion

CONCLUSION

Within the limitations of this study, it was concluded that,

- ProTaper Gold is found to remove more dentin in all aspects (buccal, palatal and mesial) at all levels (2mm,6mm & 10mm) except in the distal aspect at 6mm level where ESX was found to remove more dentin and also ESX showed similar amount of dentin removal in palatal aspect at 10mm level.
- On comparing ProTaper Gold, Hyflex EDM, ESX (Brasseler) & Vortex Blue, it was found that ProTaper Gold removed more amounts of dentin at all levels followed by ESX (Brasseler). Whereas, Hyflex EDM and Vortex Blue file systems showed similar amount of dentin removal.
- ProTaper Gold showed the highest amount of dentin removal at all levels and Vortex Blue file system has removed the least amount of dentin from all levels during chemo-mechanical preparation in the buccal root of maxillary first premolar teeth.

Bibliography

BIBLIOGRAPHY

1. **Metzger Z, Abramovitz I**.

   Periapical lesions of endodontic origin.

   In: Ingle's Endodontics, 6th edn (Ingle JI, Bakland LK, Baumgartner JC, eds). Hamilton, Ontario: BC Decker, 2008;494–519.

2. **B. Suresh Chandra, V. Gopikrishna**.

   Shaping and Cleaning of the radicular space. 2014

   Grossman's Endodontic Practice; 13th edition.

3. **Schilder H**;

   Dent. Clin. North Am., 75:269, 288, 1974

4. **Ove.A. Peters, Ravi.S.Koka.**

   Preparation of coronal and radicular spaces.

   Ingle's 6th ed.

5. **Weine FS, Kelly RF, Lio PJ.**

   The effect of preparation procedures on original canal shape and on apical foramen shape.

   Journal of Endodontics 1(8):255-62, 1975.

6. **Steven E. Powell, Perry D. Wong.**

   A comparison of the effect of modified and nonmodified instrument tips on apical canal configuration. Part II.

   JOE.1988; 14:224-228

7. **James B. Roane, Cycle Sabala.**

Clockwise or counterclockwise.

JOE 1984. 10:349-353

8. **S. A. Thompson.**

An overview of nickel–titanium alloys used in dentistry.

International Endodontic Journal, 2000; 33:297–310

9. **Amr M Elnaghy, Shaymaa E Elsaka.**

Shaping ability of ProTaper Gold and ProTaper Universal files by using cone‑ beam computed tomography.

Indian Journal of Dental Research 2016

10. **Ahmed K Turkistani, Madiha M Gomaa.**

Shaping Ability of HyFlex EDM and ProTaper Next Rotary Instruments in Curved Root Canals: A Micro-CT Study.

The Journal of Contemporary Dental Practice 2019

11. **Youssef A. Algarni , Mohamed I. Elshinawy.**

Comparative Evaluation of Root Dentin Integrity after Root Canal Preparation with Rotary File Systems of Different Ni-Ti Alloys.

Ann Med Health Sci Res. 2019;9: 614- 620

12. **Pilo R, Tamse T.**

Residual dentin thickness in mandibular premolars preparedwith gates glidden and ParaPost drills.

J ProsthetDent 2000; 83:617-623

13. **Musale PK, Mujawar SA.**

Evaluation of the efficacy of rotary vs. Hand files in root canal preparation of primary teeth *in vitro* using CBCT.

Eur Arch Paediatr Dent 2014;15:113-20.

14. **Selvakumar H, Anandhan V, Thomas E, Swaminathan K, Vijayakumar R.**

Evaluation of canal transportation and centering ability of K 3 (0.02%) and K 3 (0.04%) with hand K-files in primary teeth using spiral computed tomography.

J Indian Soc Pedod Prev Dent 2014;32:286-91.

15. **Ebihara A, Yahata Y, Miyara K, Nakano K, Hayashi Y, Suda H.**

Heat treatment of nickel-titanium rotary endodontic instruments: Effects on bending properties and shaping abilities.

Int Endod J. 2011;44(9):843–9.

16. **Yamamura B, Cox TC, Heddaya B, Flake NM, Johnson JD, Paranjpe .**

Comparing canal transportation and centering ability of endosequence and vortex rotary files by using micro-computed tomography.

J Endod 2012;38(8):1121–5.

17. **Hashem AAR, Ghoneim AG, Lutfy RA, Foda MY, Omar GAF.**

Geometric analysis of root canals prepared by four rotary NiTi shaping systems.

J Endod 2012;38(7):996–1000.

18. **Flores CB, Machado P, Montagner F, Gomes BPF de A, Dotto GN, Schmitz M da S**.

A methodology to standardize the evaluation of root canal instrumentation using cone beam computed tomography.

Brazilian J Oral Sci. 2012;11(2):84–7.

19. **Hashem D, Brown JE, Patel S, Mannocci F, Donaldson AN, Watson TF, et al.**

An in vitro comparison of the accuracy of measurements obtained from high- and low-resolution cone-beam computed tomography scans.

J Endod 2013;39(3):394–7.

20. **Plotino G, Grande NM, Cotti E, Testarelli L, Gambarini G.**

Blue treatment enhances cyclic fatigue resistance of vortex nickel-titanium rotary files.

J Endod 2014;40(9):1451–3.

21. **Gagliardi J, Versiani MA, De Sousa-Neto MD, Plazas-Garzon A, Basrani B.**

Evaluation of the shaping characteristics of ProTaper Gold, ProTaper NEXT, and ProTaper Universal in curved canals.

J Endod. 2015;41(10):1718–24.

22. **Ramanathan S, Solete P.**

Cone-beam Computed Tomography Evaluation of Root Canal Preparation using Various Rotary Instruments: An in vitro Study.

J Contemp Dent Pract. 2015;16(11):869–72.

23. **Premlata Devi T, Sh P, Kumar Dharmani U, Sanjeeta N, B S D.**

Comparative Evaluation of Cleaning Efficacy of the Root Canal By K-File and Protaper Next, Hyflex Edm Rotary System an in Vitro Study.

J Evol Med Dent Sci. 2016;5(100):7365–9.

24. **Pirani C, Iacono F, Generali L, Sassatelli P, Nucci C, , et al.**

HyFlex EDM: Superficial features, metallurgical analysis and fatigue resistance of innovative electro discharge machined NiTi rotary instruments.

Int Endod J. 2016;49(5):483–93.

25. **Sankhe DD**

Evaluation of effect of HyFlex EDM on root dentin during root canal preparation- A stereomicroscopic study

Int J Med and Dent Sci 2017;6(2):1525-1528.

26. **Dosanjh A, Paurazas S, Askar M.**

The Effect of Temperature on Cyclic Fatigue of Nickel-titanium Rotary Endodontic Instruments.

J Endod 2017;43(5):823–6.

27. **Rubio J, Zarzosa JI, Pallarés A.**

Usporedba učinkovitosti 10 rotacijskih i recipročnih endodontskih sustava: In vitro istraživanje u AutoCAD-u.

Acta Stomatol Croat. 2017;51(3):207–16.

28. **Park H-J, Seo M-S, Moon Y-M.**

Root canal volume change and transportation by Vortex Blue, ProTaper

Next, and ProTaper Universal in curved root canals.

Restor Dent Endod. 2018;43(1):1–10.

29. **Xu J, He J, Yang Q, Huang D, Zhou X, Peters OA, et al.**

Accuracy of Cone-beam Computed Tomography in Measuring Dentin Thickness and Its Potential of Predicting the Remaining Dentin Thickness after Removing Fractured Instruments.

J Endod 2017;43(9):1522–7.

30. **Shaik JA, Reddy RK.**

Review Article Prevention and Treatment of White Spot Lesions in Orthodontic Patients.

Contemp Clin Dent. 2017;8(September):11–9.

31. **Uslu G, Özyürek T, Gündoğar M, Yılmaz K.**

Cyclic fatigue resistance of 2Shape, Twisted File and EndoSequence Xpress nickel-titanium rotary files at intracanal temperature.

J Dent Res Dent Clin Dent Prospects [Internet]. 2018;12(4):283–7.

32. **Özyürek T, Gündoğar M, Uslu G, Yılmaz K, Staffoli S, Nm G, et al.**

Cyclic fatigue resistances of Hyflex EDM, WaveOne gold, Reciproc blue and 2shape NiTi rotary files in different artificial canals.

Odontology 2018;106(4):408–13.

33. **Al-Asadi AI, Al-Hashimi R.**

In-vitro Assessing the Shaping Ability of Three Nickel-Titanium Rotary Single File Systems by Cone Beam Computed Tomography.

Int J Med Res Heal Sci. 2018;7(2):69–74.

34. **Mandava J, Yelisela RK, Arikatla SK, Ravi RC.**

Micro-computed tomographic evaluation of dentinal defects after root canal preparation with hyflex edm and vortex blue rotary systems.

J Clin Exp Dent. 2018;10(9):e844–51.

35. **Tomer AK, Miglani A, Chauhan P.**

An In-Vitro Evaluation of Remaining Dentine Thickness through Cbct Using Different Files.

IOSR J Dent Med Sci. 2017;16(2):121–4.

36. **Abdulrahman Abdullah Al-Dhbaan, Mohammad A. Al-Omari, Shibu Thomas Mathew, Mohammad Abdul Baseer.**

Shaping ability of ProTaper gold and WaveOne gold nickel-titanium rotary file in different canal configurations.

Saudi Endodontic Journal 2018

37. **Prasad K Musale et al**

Comparative assessment of dentin removal following hand and rotary instrumentation in primary molars using cone-beam computed tomography; *Jnl. Indian Society of Pedodontics and Preventive Dentistry, 2019, 37:80-86*

38. **Singh S, Gupta T, Pandey V, Singhania H, Pandey P, Gangavane S.**

Shaping ability of two-shape and ProTaper Gold Files by using Cone-beam computed tomography.

J Contemp Dent Pract. 2019;20(3):330–4.

39. **de Albuquerque MS, Nascimento AS, Gialain IO, de Lima EA, Nery JAF, de Souza Araujo PR, et al.**

Canal transportation, centering ability, and dentin removal after instrumentation: A micro-CT evaluation.

J Contemp Dent Pract. 2019;20(7):806–11.

40. **Ove A. Peters.**

Root canal preparation in mandibular premolars with TRUShape and Vortex Blue: A micro-computed tomography study.

Aust Endod J 2019; 45: 12–19

41. **P Sai Kiran Reddy, S Datta Prasad, C Sunil Kumar.**

A Comparative Evaluation of Remaining Root Dentin Thickness Using Hand and Rotary System Through Cone-Beam Computed Tomographic Analysis - An *in vitro* Study.

ACTA Scientific Dental Sciences, 2020

42. **Dudeja PG, Dudeja KK, Srivastava D, Grover S.**

Microorganisms in periradicular tissues: Do they exist? A perennial controversy.

J Oral Maxillofac Pathol 2015; 19:356-63

43. **Kakehashi S, Stanley H, Fitzgerald R.**

The effect of surgical exposures of dental pulps in germ-free and conventional laboratory rats.

Oral Surg Oral Med Oral Pathol 1965; 20:340.

44. **Sundqvist G.**

Bacteriological studies of necrotic dental pulps.

Umea University Odontological Dissertations No. 7. Umea, Sweden: University of Umea, 1976.

45. **José F. SIQUEIRA Jr Isabela N. RÔÇAS,**

Bacterial Pathogenesis and Mediators in Apical Periodontitis,

Braz Dent J (2007) 18(4): 267-28

46. **Gutmann J.**

Clinical, Radiographic and histologic perspective in endodontics.

Dent Clin North Am 1992; 36:379 –92.

47. **Engstrom B, Segerstad L, Ramstrom G, Frostell G.**

Correlation of positive cultures with the prognosis for root canal treatment.

Odontol Revy 1964; 15:257

48**. Ingle JI,**

Endodontics. 5th Edition ed. Hamilton, London: BC Decker, Inc 2002.

49. **Ingle JI.**

A standardized endodontic technique utilizing newly designed instruments and filling materials.

Oral Surg Oral Med Oral Pathol 1961.,14:83-91.

50. **Weine FS, Kelly RF, Lio PJ.**

The effect of preparation procedures on original canal shape and on apical foramen shape.

Journal of Endodontics 1975,1(8):255-62.

51. **Walton RE.**

Histologic evaluation of different methods of enlarging the pulp canal space.

Journal of Endodontics 1976. 2(10):304-11

52. **Morgan LF, Montgomery S.**

An evaluation of the crown-down pressureless technique.

J Endod 1984 10(10):491-8,.

53. **Abou-Rass M, Frank AL, Glick DH.**

The anticurvature filing method to prepare the curved root canal.

J Am Dent Assoc 1980; 101:792-4.

54. **Ruddle C.**

Cleaning and shaping the root canal system.

In: Cohen S, Burns R, eds. Pathways of the Pulp, 8th edn. St Louis, MO: Mosby, 2002: 231–292.

55. **Roane JB, Sabala CL, Duncanson MG Jr**.

The ‘balanced force’ concept for instrumentation of curved canals.

J Endod 1985: 11: 203–211.

56. **Benenati FW, Roane JB, Biggs JT, Simon JH.**

Recall evaluation of iatrogenic perforations repaired with amalgam and gutta-percha.

J Endod 1986: 12: 161–166.

57. **Calhoun G, Montgomery S.**

The effects of four instrumentation techniques on root canal shape.

J Endod 1988: 14: 273–277.

58. **Luiten DJ, Morgan LA, Baumgartner JC, Marshall JG.**

A comparison of four instrumentation techniques on apical canal transportation.

J Endod 1995: 21: 26–32.

59. **Turek T, Langeland K.**

A light microscopic study of the efficacy of the telescopic and the Giromatic preparation of root canals.

J Endod 1982: 8: 437–443.

60. **McKendry DJ.**

Comparison of balanced forces, endosonic and stepback filing instrumentation techniques: quantification of extruded apical debris.

J Endod 1990: 16: 24–27.

61. **Maryam Kuzekanani.**

Nickel–Titanium rotary instruments: Development of the single-file system.

J Int Soc Prevent Communit Dent 2018: 8: 386-390

62. **Markus Haapasalo & Ya Shen.**

Evolution of nickel–titanium Instruments: from past to future.

Endodontic Topics 2013, 29, 3–17

63. **Drs. Clifford J. Ruddle, Pierre Machtou and John D. West.**

Endodontic canal preparation: New innovations in glide path management and shaping canals.

Dentistry today. 2014

64. **Dr. Christia M. Aoun, Pr. Walid B. Nehme.**

Review and classification of heat treatment procedures and their impact on mechanical behavior of endodontic files.

International Journal of Current Research, 2017: 9: 51300-51306

65. **Zuckerman O, Katz A, Pilo R, Tamse A et al.**

Residual dentin thickness in mesial roots of mandibular molars prepared with Light speed rotary instruments and Gates- Glidden reamers.

Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2003; 96:351-5.

66. **Trabert I S, Caputo A A, Alon-Rass M.**

Tooth fracture: a comparison of endodontic and restorative treatments.

Journal of Endodontics 1978;4:341-4.

67. **Gutmann J.**

Root canal preparation with rotary instruments.

Contemporary Endod 10:11–12.

68. **Riitano F.**

Anatomic endodontic technology (AET)—A crowndown root canal preparation technique: Basic concepts, operative procedure and instruments. *Int Endod J 38:575–587.*

69. **Katz A, Kohn SW, Tamse A, Zuckerman A.**

Residual dentin thickness in bifurcated maxillary premolars after root canal and dowel space preparation.

Endod J. 2006; 32(3):202-205.

70. **Trope M, Ray HL.**

Resistance to fracture in endodontically treated roots.

Oral Surg Oral Med Oral Pathol 1992;73:99-102.

71. **B.Jodway & M. Hulsmann.**

A comparative study of root canal preparation with NiTi-TEE and K3 rotary Ni-Ti instruments.

International Endodontic Journal, 2006, 39, 71–80

72. **Pilo R, Corcino G, Tamse A.**

Residual dentin thickness in mandibular premolars prepared by hand and rotatory instruments.

J Endod 1998: 24: 401–405.

73. **Nathanson D, Ashayeri N.**

New aspects of restoring the endodontically treated tooth.

Alpha Omegan 1990;83:76-80.

74. **Raiden G, Koss S, Costa L, et al.**

Radiographic measurement of residual root thickness in premolars with post preparation.

J Endod 2001;27:296–8.

75. **Patel S, Dawood A, Ford TP, Whaites E.**

The potential applications of cone beam computed tomography in the management of endodontic problems.

Int Endod J. 2007; 40: 818-30.

76. **Kobayashi K, Shimoda S, Nakagawa Y, Yamamoto A.**

Accuracy in measurement of distance using limited cone-beam computerized tomography.

International Journal of Oral and Maxillofacial Implants 2004;19:228-31.

77. **Bramante CM, Berbert A, Borges RP.**

    A Methodology for Evaluation of Root Canal Instrumentation.

    J Endod. 1987; 13: 223-5.

78. **Zaia AA, Ferraz CCR, Yoshinari GH, Souza Filho FJ.**

    A Simple Method for the Analysis of Root Canal Preparation

    J Endod. 2000; 26: 172-4.

79. **Wu MK, Van der Sluis WM, Wesselink PR;**

    The risk of furcal perforation in mandibular molars using Gates-Gliddendrills with anticurvature pressure.

    Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005; 99: 378-82.

80. **Sauáia TS, Gomes BPFA, Pinheiro ET, Zaia A A, Ferraz CCR, Souza-Filho FJ, Valdrighi L.**

    Thickness of dentine in mesial roots of mandibular molars with different lengths.

    Int Endod J. 2010; 43: 555-9.

81. **Coutinho-filho T, de Deus G, Gurgel-Filho ED, Rocha-Lima AC, Dias KRC, Barbosa CA.**

    Evaluation of the risk of a stripping perforation with gatesglidden drills: serial versus crown-down sequences.

    Braz Oral Res. 2008; 22: 18-24.

82. **Paqué F, Balmer M, Attin T, Peters OA.**

Preparation of oval shaped root canals in mandibular molars using nickel titanium rotary instruments: A micro computed tomography study.

J Endod. 2010; 36:703-7

83. **M.Ozgur Uyanik, Zafer C. Cehreli, Burce Ozgen Mocan, and Fugen Tasman Dagli.**

Comparative Evaluation of Three Nickel-Titanium Instrumentation Systems in Human Teeth Using Computed Tomography.

JOE 2006

84. **F.Perez, M. Schoumacher & J. F. Peli.**

Shaping ability of two rotary instruments in simulated canals: stainless steel ENDOflash and nickel-titanium HERO Shaper.

International Endodontic Journal, 2005; 38, 637–644.

85. **Amanda Pioch.**

Cutting Efficiency of ESX, EndoSequence, and ProFile Instruments Using the TrueTooth Replica.

Oregon Health & Science University OHSU Digital Commons. Scholar Archive 2016.

Annexures

ANNEXURE –I

RAGAS DENTAL COLLEGE & HOSPITAL
(Unit of Ragas Educational Society)
Reconized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai
2/102, East Coast Road, Uthandi, Chennai - 600 119. INDIA
Tele : (044) 24530002, 24530003 - 06. Principal (Dir) 24530001 Fax : (044) 24530009

TO WHOM SO EVER IT MAY CONCERN

Date: 24th January, 2020

Place: Chennai

From
The Institutional Review Board,
Ragas Dental College and Hospital,
Uthandi,
Chennai- 119

The project titled "Comparison and evaluation of the amount of dentin removal by Protaper Gold, Hyflex EDM, ESX (Brasseler) & Vortex Blue assessed by Cone Beam Computed Tomography." submitted by **Dr. Suraj U** has been approved by the Institutional Review Board of Ragas Dental College And Hospital.

DR. N.S.AZHAGARASAN, MDS
Member secretary,
The Institutional Review Board
Ragas Dental College And Hospital
Uthandi,
Chennai-119

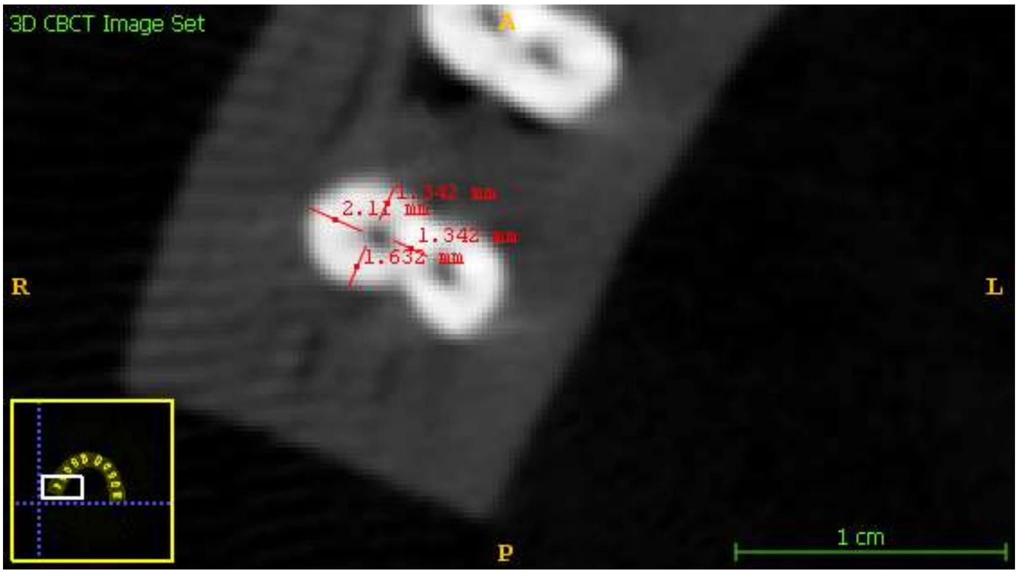
ANNEXURE – III

URKUND

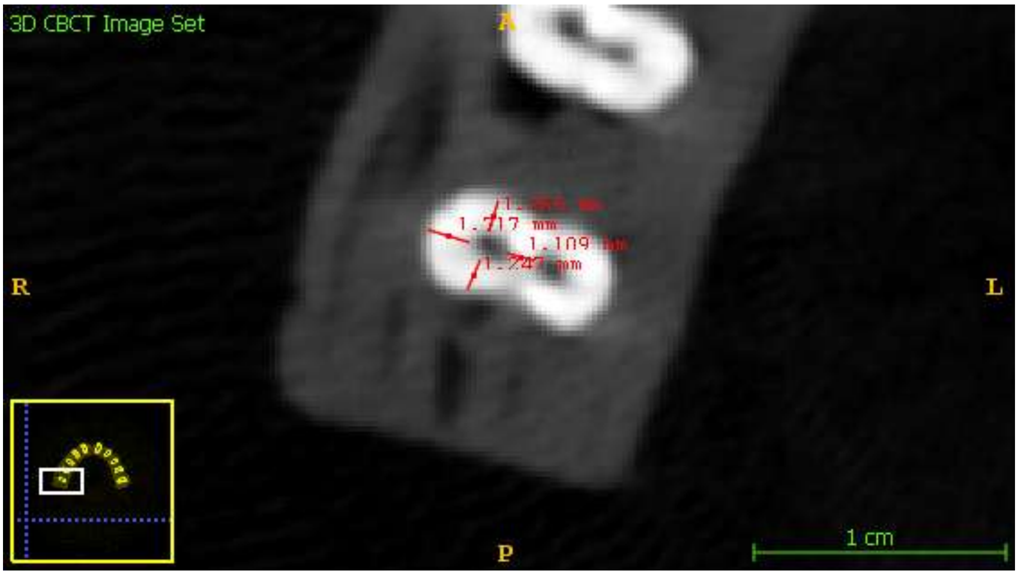
Urkund Analysis Result

Analysed Document:	Suraj U Thesis.docx (D63061619)
Submitted:	1/27/2020 7:24:00 PM
Submitted By:	srjmenon11@gmail.com
Significance:	4 %

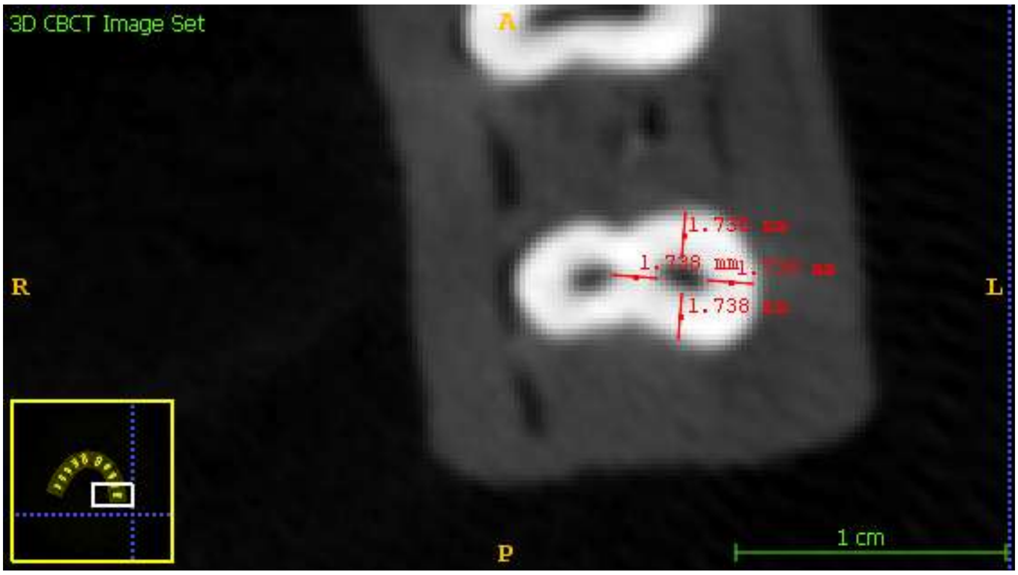
ANNEXURE –II



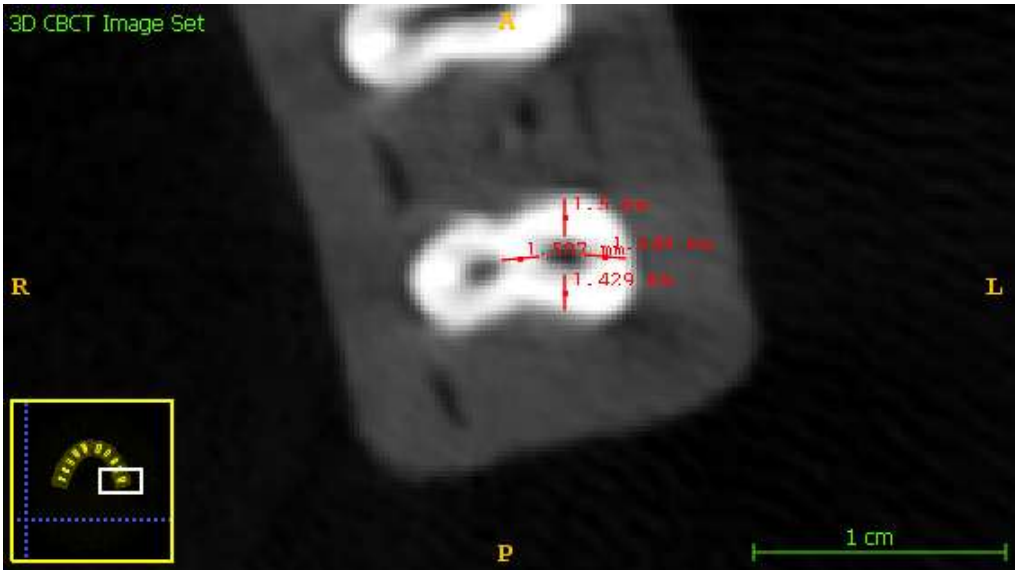
Pre-operative dentin thickness measurements of ProTaper Gold group



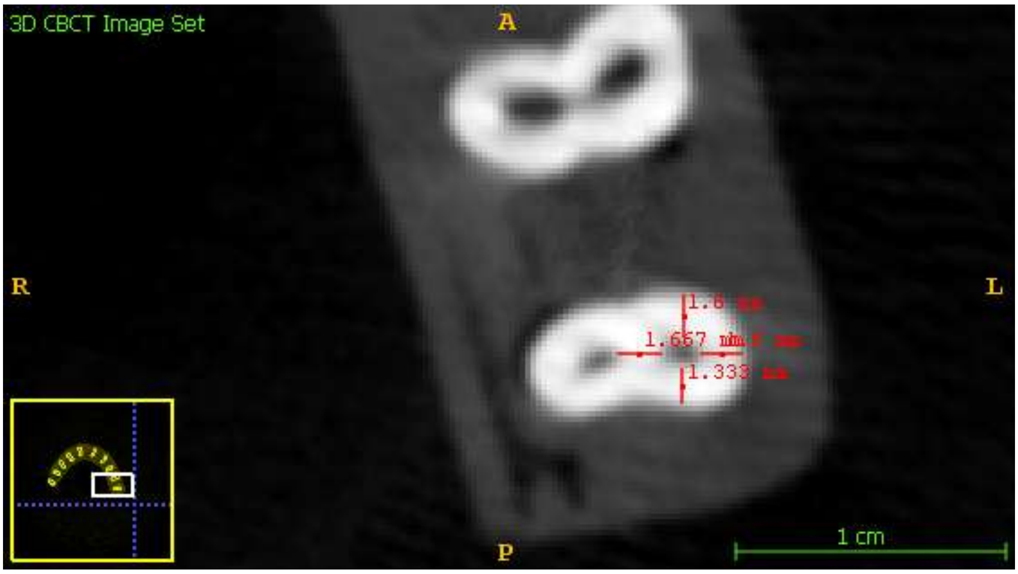
Post-operative dentin thickness measurements of ProTaper Gold group



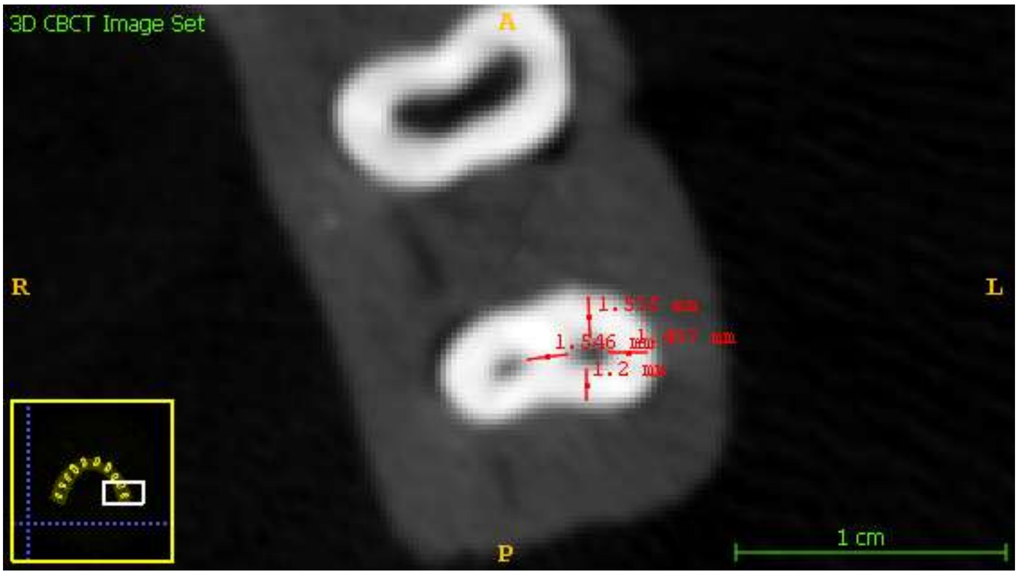
Pre-operative dentin thickness measurements of Hyflex EDM Group



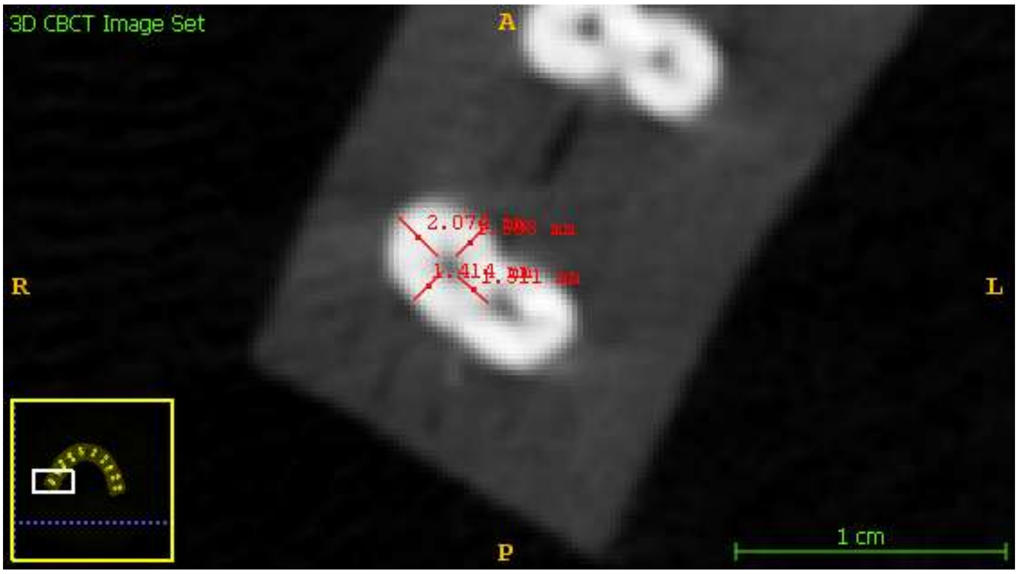
Post-operative dentin thickness measurements of Hyflex EDM Group



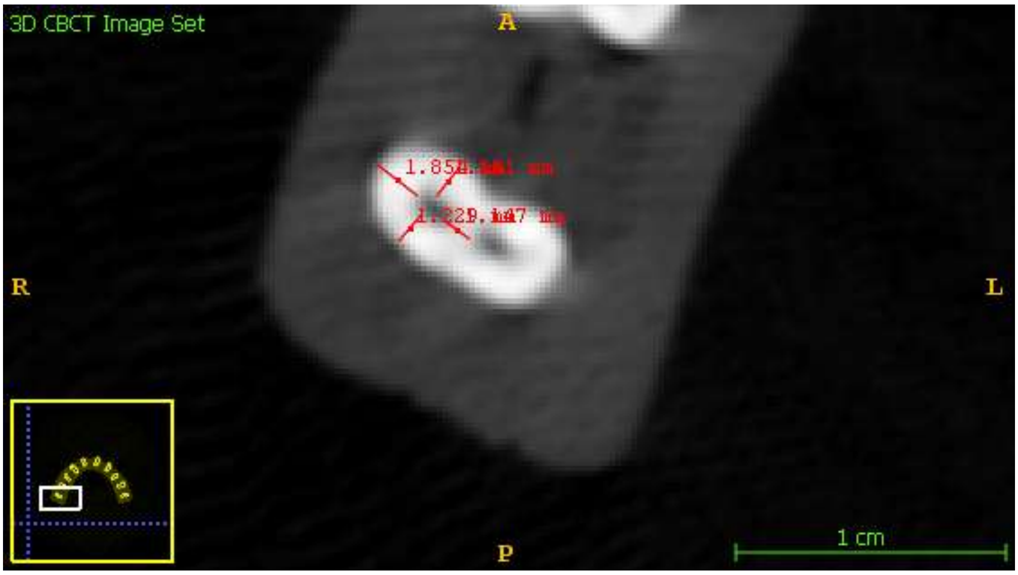
Pre-operative dentin thickness measurements of ESX (Brasseler) Group



Post-operative dentin thickness measurements of ESX (Brasseler) Group



Pre-operative dentin thickness measurements of Vortex Blue Group



Post-operative dentin thickness measurements of Vortex Blue Group