Republic of Iraq
Ministry of Higher Education
And Scientific Research
University of Baghdad
College of Dentistry

The effect of root canals instrumented with three rotary Ni-Ti systems on the push-out bond strength of GuttaFusion® versus single cone obturation technique
(*An In vitro Study*)

A Thesis
Submitted to the council of the College of Dentistry at the University of Baghdad in Partial Fulfillment of the Requirements for the Degree of Master Science in Conservative Dentistry

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2017 A.D. 1438 A.H.

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

وَأَنزَلَ اللَّهُ عَلَيْكَ الْكِتَابَ وَالْحِكْمَةَ
وَعَلَّمَكَ مَا لَمْ تَكُن تَعْلَمُ وَكَانَ فَضْلُ
اللَّهِ عَلَيْكَ عَظِيمًا

صدق الله العظيم

(سوره النساء) ايه ١١٣

Dedicatin

To my wonderful family and family in law...
A special feeling of gratitude to my loving parents, whose love and prayrs make me able to get such success and without them I could not be here...
To my precious uncle (Dr. Waleed) for support me all the way...
To my Dearly Husband (Ali) who always belived I could change the dream to truth and for his motivation for making me who Iam…
To my lovely children (Yahya and Fatima)…
To my brothers, sisters and all friends whose real feeling and encouragement always supported me I could not have done all this without them.

Rafal Saeed

Acknowledgments

Praise be to Allah, Lord of the worlds, The Beneficent, The Merciful, it is by His Grace and Blessings that this current study has come to exist.

I would like to take the opportunity to express my great appreciation & gratitude to *Prof. Dr. Hussain F. Al-Huwaizi*, the Dean of the College of Dentistry, University of Baghdad, for his continuous encouragement & scientific support to all postgraduate students.

I am also expressing my thanks and gratitution to Prof. Dr. Nidhal H. Ghaib, Assistant Dean for Scientific Affairs, for her help and support.

My special thanks and respect to *Prof. Dr. Adel F. Ibraheem*, the head of the Department of Conservative Dentistry, for his support, generous help & his ability to create a positive atmosphere in conservative department.

I would like also to express my sincere gratitude & truthful thanks to my academic supervisor *Asst. Prof. Dr. Raghad Al-Hashimi* who has participated generously, sharing openly his views, experiences & his precious time, also for his continuous support, guidance & valuable comments during planning, designing & implementation of this study.

Sincere appreciation to the committee of post graduate studies in the Department of Conservative Dentistry*: Prof. Dr.Abdul-Karim J. Al-Azzawi, Asst. Prof. Dr. Abdullah M. Wajeeh, Asst Asst. Prof. Dr. Manhal A. Majeed. Asst. Prof. Dr. Mohammed R. Hameed & Asst. Prof. Dr. Zainab M. Abdul-Ameer,* who manifested their distinguished skills in our field & for their scientific support.

I would like also to express my sincere gratitude to engeeneer *Dr. Bahaa* for his scientific information and help during the prepareation of the reasrch.

Many deepest thanks to my precious parents, brothers (*Nufel and Raafel)*, sisters *(Nafel& Rusel)* and my wonderful uncle *Dr. Waleed* for their support &

encouragement through all the phases of the research. I offer my regards & grateful to my darling husband *Dr. Ali* for his understanding when I spent numerous hours reading & for his truly support, tips, unlimited help & encouragement.

Many deepest thanks to my new family in law *Dr. Hussein Al-Taher, Tahreer, Abaas, Dr. Ban and Hyfaa.*

Finally, my deepest greeting and respect to my friends& colleagues in the postgraduate study in the Department of Conservative for their help and support.

Abstract

Three-dimensional seal of the root canal system is one of the fundamental goals of successful endodontic treatment. Therefore, the present study was carried out to assess the push-out bond strength of two obturation systems, Single cone and GuttaFusion® for root canals instrumented by three Nickel-Titanium rotary systems including WaveOne, ProTaper Next and ProTaper Universal.

Sixty extracted human mandibular premolars were used in the current study. The teeth were decoronated and left the root with 15mm length; the roots were divided randomly into three main groups, twenty roots in each group according to instrumentation technique with different rotary systems: The roots in the (Group I) were instrumented with WaveOne files, (Group II) was instrumented with ProTaper Next system and (Group III) was instrumented with ProTaper Universal system. For each group, the same irrigation regimen was used, 3 mL of 5.25% Sodium hypochlorite was followed by 3 mL of 17% Ethylene Diamine Tetra Acetic Acid for one minute then the canals were flushed 3 ml of distilled water.

All groups were divided randomly into two subgroups of ten samples each, (Group I A, II A, III A) were obturated with single cone gutta-percha and (Group I B, II B, III B) were filled with GuttaFusion®. TotalFill BC sealer was used for all groups.

After that, the roots were placed in an incubator for seven days at 100% humidity and 37°C humidity,then the roots were embedded in clear acrylic resin and each root sectioned into three sections of 2mm thick (apical, middle and coronal). The specimens were fixed on the base that prepared from acrylic rod and the load was applied by the punch in apico-coronal direction using a universal testing machine at speed of 0.5mm/min. The push-out bond strength value represented by (MPa) unit was calculated by dividing the load on the surface area in collaboration with AutoCAD system software program.

The data were analyzed statistically using two ways ANOVA and LSD test. The results showed highly significant differences ($P < 0.001$) among the main groups that instrumented with different rotary systems (Wave One, ProTaper Next and ProTaper Universal system). There were highly significant differences ($P < 0.001$) between the two obturation techniques of the subgroups (single cone versus GuttaFusion®). The coronal third slices of the groups showed highest value of bond strength in comparison to the middle thirds and apical thirds. In the meantime, the middle third slices showed bond strength higher than the apical thirds for all groups.

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List of Abbreviations

Abbreviation	Criteria
3-D	Three-Dimensional
AutoCAD	AutoComputerized Aided Design
CCW	Counter clockwise
CW	Clockwise
Df	Degree of freedom
EDTA	Ethylene Diamine Tetraacetic Acid
GF®	GuttaFusion®
MPa	Mega Pascal
NaOCl	Sodium hypochlorite
Ni-Ti	Nickel-Titanium
PTN	ProTaper Next
PTU	ProTaper Universal
SD	Standard Deviation
SE	Standard Error
WO	WaveOne
Rpm	Revoluation per minute
Ncm	Newton centimeter

INTRODUCTION

Introduction

Three-dimensional seal of the root canal system is the fundamental goal of endodontic treatment. Owing to fill the root canal space adequately, innovations of new obturation materials have been considerably studied (Schilder, 2006).

It has been reported that inappropriate sealing may result in voids within the root canal system that permit bacterial micro-leakage which can potentially reduce the chance of successful treatment (Kim *et al.*, 2010).

One of the main criteria to evaluate the clinical efficacy of recently introduced materials is ideal adhesion of root canal filling material to the dentinal wall, and the push-out bond strength test is one of the techniques used to evaluate the adhesion, which is supposed to create conditions similar to clinical condition (Gogos *et al.*, 2004).

Push-out is widely accepted method to measure the bond strength of intra-canal materials (Goracci *et al.*, 2004), since there is no enough evidence yet to support the ability of filling materials for sealing the canal (Li *et al.*, 2014a), therefore they can be evaluated in vitro in term of bond strength (Goracci *et al.*, 2004).

In this study, rotary instrumentation over ISO manual technique was used due to its simplicity and time saving that based on crown-down concept (Schäfer *et al.*, 2013). Therefore, three rotary systems were employed for preparing the root canals including, WaveOne (reciprocation motion), ProTaper Next (continuous rotation) and ProTaper Universal (continuous rotation) due to its improved cutting efficiency and safety in comparison with stainless steel files (Yin *et al.*, 2008).

On the other hand, with the widespread use of rotary Ni-Ti instruments and matched-taper gutta-percha cones, the single-cone obturation technique has become popular (Gordon *et al.*, 2005). Consequently, gutta-percha is not the ideal filling material for root canals system; although it has satisfied most of the criteria for an ideal root filling material. In general, gutta-percha exhibits minimal toxicity, allergenicity and tissue irritability when it is placed within the root canal space (Li *et al.*, 2014a). Nevertheless, gutta-percha is not adhered to the root canal wall compromising the concept of three-dimensional seal therefore; another obturation technique has been introduced over the past decade to improve the seal of the root canal system.

Thus, hand carrier obturation is another option for obturation of a prepared canal with a GuttaFusion® (VDW, Germany) in which the core made from chains of crosslinked polymer of gutta-percha that coated with flowable gutta-percha without need for metal or plastic core . The benefit of carrier is to condense gutta-percha which is heated by special device to improve its flow into the root canal (http://www.vdw-dental.com/).

With a view to enhance the marginal sealing properties of root canal system, hydrophilic sealer has been used for all groups. TotalFill which is ceramic based sealer (Brasseler, Savannah, USA) is a premixed, a slow-setting and injectable endodontic sealer, and its nanoparticle size to flow into canal irregularities and dentinal tubules. It is hydrophilic and use moisture in dentinal tubules to initiate and complete its setting reaction. Moreover, no shrinkage occurs on setting, this is resulting in a gap-free interface between the core material, sealer, and dentine (Hess *et al.*, 2011). As described by the manufacturer, BC sealer is based on a calcium silicate composition includes, tri- and di–calcium silicates, calcium phosphate monobasic, calcium hydroxide and zirconium oxide (Malhotra *et al.*, 2014).

Aims of the study

1. To evaluate and compare the push-out bond strength of root canals obturated with GuttaFusion® and TotalFill BC sealer versus single cone obturation material and TotalFill BC sealer after the instrumentation of canals with (WaveOne, ProTaper Next and ProTaper Universal) at different sites (coronal, middle and apical).
2. To analyze the failure mode for the aforementioned experimental groups.

REVIEW OF LITERATURE

CHAPTER ONE

Review of Literature

1.1. Non-surgical endodontic treatment:

European society of Endodotology (2006) defined non-surgical treatment as a branch of dentistry that deals with the diagnosis, causes, prevention, treatment and prognosis of diseases of the dental pulp, usually by removal of the dental nerve and other tissue of the pulp space and its replacement with suitable obturation material.

Establishing a perfect diagnosis with designing a correct treatment plan is significantly relied upon applying knowledge of dental anatomy with performing a thorough debridement, disinfection, and adequate obturation of the entire root canal system. Initially emphasis was based on complete obturation and sealing the pathways of communication between the root canal and its surrounding structure. However, no technique or material provides a seal that is impervious to moisture either from the apical or coronal regions (Ingle, 2002).

A 3-D seal of the root canal space is need to be one of the essential elements for achieving successful treatment in collaboration with developing an accurate cleaning and shaping and good filling with selected obturation material and technique (Sabeti *et al.*, 2006).

Root canal treatment involves three basic phases which are (Cohen and Burns, 2002):

1. Diagnostic phase.
2. Preparatory phase (cleaning and shaping).
3. Obturation phase

1.2. Cleaning and shaping

Over four decades ago, Schilder was introduced the concept of the root canal system cleaning and shaping (Cohen and Burns, 2006). The concept of cleaning is defined by Beer (2006) as preparation and mechanical debridement of root space content and rinsing of tissue debris out of the space after chemical dissolution with selected irrigation.

On the other hand, the concept of shaping could be defined as enlargement of endodontic space to provide space for placing the filling materials and facilitate 3-D cleaning by allowing easy access to files and irrigants during the shaping process in order to prevent reinfection of the root canal space and failure of the treatment (Goldman *et al.*, 1988).

It has been reported that the mechanical objectives of cleaning and shaping (described by Schilder, 1974) are:

1. Continuously tapering canal should be developed that mimic the original shape of radicular space.
2. Making the preparation in multiple planes which introduces the concept of "flow". This objective preserves the natural canal curve.
3. The resistance form of the canal to hold the core material obtains by continuous taper up to apical third in order to make the canal wider coronally and narrower apically.
4. Maintain the position of the foramina with gentle enlargement and transportation of foramina should be avoided.
5. Keep the apical opening as small as possible where; its enlarement contributes to several iatrogenic problems leading to its surface area increases four folds by doubling the file size apically Figure (1.1) .

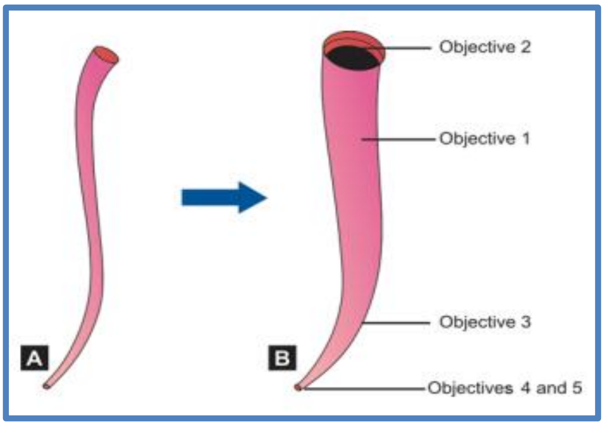

Figure 1.1: Mechanical objectives of cleaning and shaping (Schilder, 1974)

The biological objectives of cleaning and shaping (Cohen and Kenneth, 2006) are:

1. Infected pulp tissue should be removed.
2. Access to irrigate the apical area of root canal.
3. Access for delivery of medicament and for obturation.
4. Maintain the integrity of root.

A previous literature review on studies dealing with the apical limit of instrumentation and obturation has been done by Ricucci in (1998), where detected to be at cemento-dentinal junction around 0.5-1mm from radiographic apex which is the end of root determined radiographically.

Since the beginning of modern day endodontics; multiple concepts, strategies and techniques have been developed for preparing canals. Throughout the years, a purpose of files has emerged for cleaning and shaping canals. The discipline of endodontics is progressing from using a long series of stainless steel hand files and many rotary Gates Glidden drills to integrating Ni-Ti files with different generations for canals instrumentation (Ruddle *et al.*, 2013).

1.3. Nickel-titanium shaping movement:

Nitinol, a Ni-Ti alloy for shaping canals was proposed by Walia *et al.*, in 1988 as it was more flexible 2 to 3 times compared to stainless steel of the same file sizes. By the mid-1990s, the first commercially available Ni-Ti rotary files had marketed (Thompson, 2000). Different cross sectional geometry of each Ni-Ti file has benefits and weaknesses for example a triangle, rectangle, slender-rectangle or square. Square cross sectional files have the highest flexural stiffness and screw-in force followed by the rectangular ones, the triangular ones and the slender rectangle ones (Versluis *et al.*, 2012; Ha *et al.*, 2014).

1.3.1. Mechanical classification of Ni-Ti generation

1.3.1.1. First generation:

The principles of first generation Ni-Ti files are based on possessing fixed tapers of 4% and 6% over the length of their active blades as well as passive cutting radial lands which encouraged taper lock that may lead to separation of files within the root canal space (Bryant *et al.*, 1999). The preparation objectives can be achieved by numerous files in this generation of technology. GT files (DENTSPLY Tulsa Dental Specialties) became available by the mid to late 1990s, providing a fixed taper on a single file of 6%, 8%, 10%, and 12% (Kramkowski and Bahcall, 2009).

1.3.1.2. Second generation:

In 2001, the second generation of Ni-Ti rotary files has been marketed (Machtou and Ruddle, 2004). The critical distinction of this generation was active cutting edges that require a fewer instruments to fully prepare a canal. File lines with alternating contact points was provided by Endo Sequence (Brasseler USA) and BioRaCe (FKG Dentaire) to discourage taper lock and the resultant screw effect (Schäfer and Vlassis, 2004). Although this feature is intended to lessen taper lock, these file lines still have a fixed tapered design over their active portions. When ProTaper (Dentsply Tulsa Dental Specialties) has been introduced on the market in 2001 by utilizing multiple increasing or decreasing percentage tapers on a single file. In progressively tapered design, each file's cutting action is set to a particular area of the canal and give a shorter sequence of files (Ruddle, 2001).

During this period, it has been clinically reported that electro-polishing dulls the sharp cutting edges. Intrinsically, the advantages of electro-polishing were offset since it was leading to more undesirable inward pressure needed to advance a file to length. Excessive inward pressure, especially when utilizing fixed tapered files, invites taper lock, the screw effect, and excessive torque on a rotary file during work (Boessler *et al.*, 2009).

1.3.1.2.1. ProTaper Universal system

Conventional Ni-Ti wire is used in the construction of PTU which has been widely used in treatment of root canal (Gagliardi *et al.*, 2015). Each instrument has changing percentage tapers over the length of its cutting blades are a unique feature of the PTU files (Cohen and Burns, 2006). Significantly improve flexibility; cutting efficiency and safety are due to progressively tapered design (Ruddle, 2001). Another feature of the ProTaper instruments relates to their convex, triangular cross-section as seen in Figure (1.2) (Bürklein *et al.*, 2012) that decreases the rotational friction between the file blade and dentine while enhances the cutting action (West, 2001).

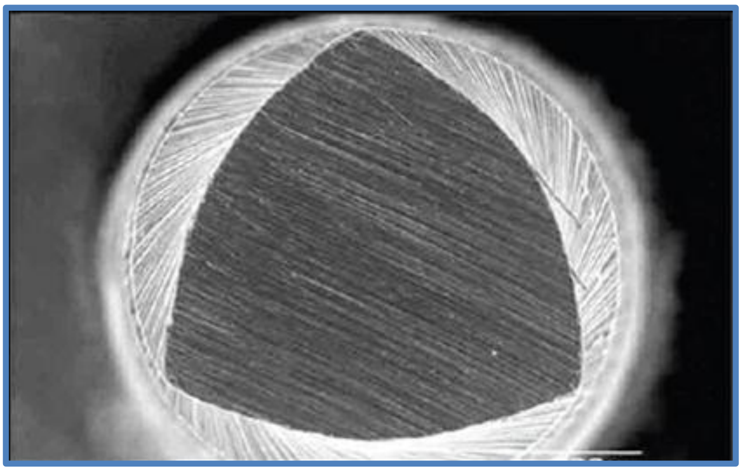

Figure 1.2: Cross section of PTU (Pocketdentistry.com)

Each PTU file has a modified guiding non cutting tip. In addition, the flat tip allows this instrument to safely follow the ensured portion of a canal while enhances the file ability to find its way through soft tissue and debris (Blum *et al.*, 2003). Moreover, file screwing into the canal is reduced by a balancing helical angle and pitch over their cutting blades. Accordance with universally recognized guide lines; the PTU files can be used at 150-300 rpm in electrical hand pieces (Cohen and Burns, 2006). However, it has been found that PTU instruments work at maximum 275-300 rpm and at maximum torque (5.2 Ncm) (Berutti, 2004). The PTU system is comprised of just three shaping and five finishing files.

S1 (shaping file) has purple identification ring and S2 (shaping file) has white identification ring on their handles. Both files have D0 diameters of 0.17 mm and 0.20 mm, respectively, and their D14 maximal flute diameters approach 1.20 mm. SX named as auxiliary shaping file that has no identification ring on its gold-colored handle and, with 19 mm length which useful when space is restrictive. The SX file has a D0 diameter of 0.19 mm and a D14 diameter approaching 1.20 mm. Increasing larger percentage tapers over the length of their cutting blades was the feature of the shaping files which allowing each instrument to engage, cut and prepare a specific area of the canal and perform its own crown down work. Because SX has a much quicker rate of taper between D1 and D9 as compared to the other ProTaper Shaping files, it is primarily used to optimally shape canals in anatomically shorter teeth (Berutti *et al.*, 2003).

While the finishing files are F1, F2, F3, F4 and F5 have yellow, red, blue, double black, and double yellow identification rings on their handles corresponding to D0 diameters of 0.20, 0.25, 0.30, 0.40 and 0.50 mm, respectively as seen in Figure(1.3). The F1, F2, F3, F4 and F5 files have fixed tapers of 7%, 8%, 9%, 6% and 5% in their apical extents respectively (Berutti *et al.*, 2003).

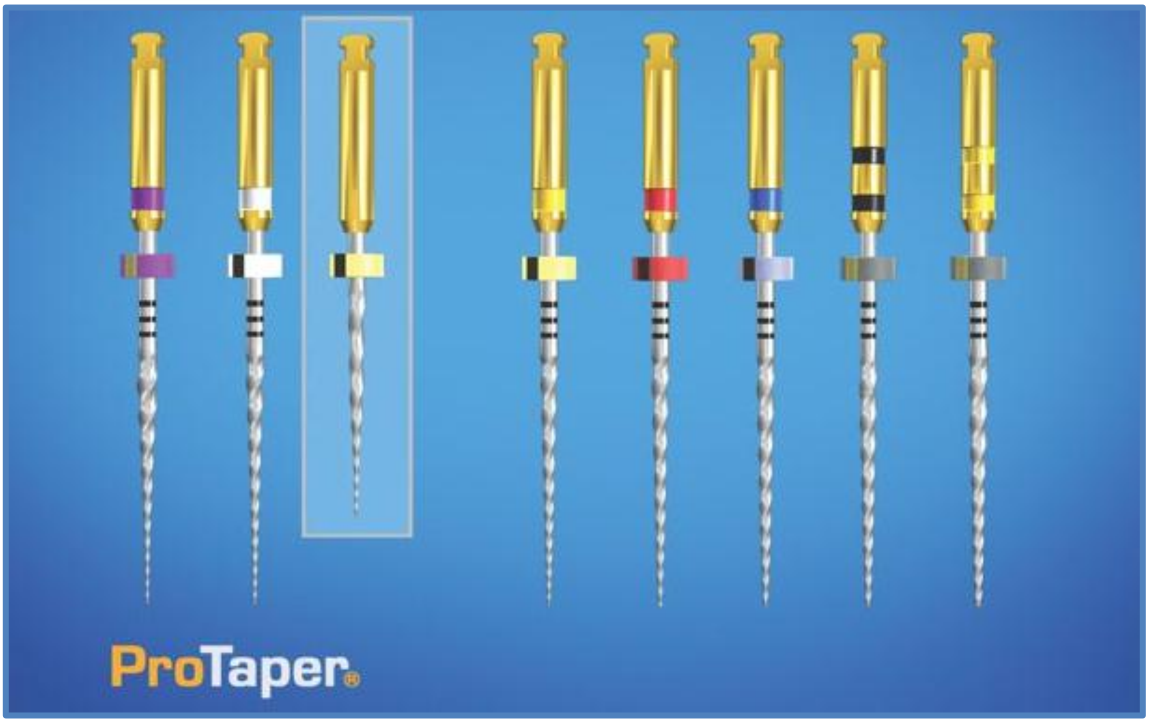

Figure 1.3: PTU system (Ruddle *et al*., 2009)

The SX is designed to flare orifice of the root canal; whereas S1 enlarges and prepares the coronal one-third and S2 enlarges and prepares the middle one-third of the root canal. Although, both instrument optimally prepare the coronal two third of the root canal, they do progressively enlarge its apical one third. The F1, F2 and F3 finish the apical one-third and further enlarge the middle one-third of root canals. In general, only one finishing file is needed to prepare the apical one third of the canal (Capar *et al*., 2014).

Unlike the PTU Shaping files, finishing files have progressively decreasing percentage tapers from D4 to D14. In addition, larger cutting blades and decreasing percentage tapers over a portion of a file's significantly improves flexibility, decreases the risk of file lock, and prevents over enlargement of the canal (Berutti *et al*., 2003).

1.3.1.3. Third-generation

The hallmark of third generation of mechanical shaping files is the improvements in Ni-Ti metallurgy which was introduced on the market by 2007. The benefits of Ni-Ti metallurgy are to reduce cyclic fatigue failure with greater flexibility to improve safety when rotary Ni-Ti instruments work in more curved canals. The manufacturing of metallurgy alloy is based on thermally heated files (Gutmann and Gao, 2012). The desired phase transition point between martensite and austenite can be identified to produce a more clinically optimal metal than conventional Ni-Ti itself. Twisted File (Axis/SybronEndo); HyFlex CM (Coltène); are the main examples of this generation.

1.3.1.4. Fourth-generation:

The principle of this generation is advancement in canal preparation procedures utilizes reciprocation with single file concept which is a kinematic motion of instrument that means a repetitive back-and-forth motion. Firstly, the concept of reciprocation is not new as it has been developed in the late 1950s by Blanc, a French dentist, who was first introduced this technology. However, angle of reciprocating movement was equal in the clockwise (CW) and counter clockwise (CCW) degrees of rotation. Initialy, reciprocating file utilized an equal bidirectional movement required more inward pressure to progress so, it limited in auguring debris out of the canal and not cut efficiently compared to full rotation file. Therefore, reciprocation angles have been innovated to be unequal bidirectional angles to improve the cutting efficiency and effectively auger debris out of the canal (Yared, 2008).

Wave One (Dentsply) and Reciproc (VDW, German company) are the most popular single file concept.

1.3.1.4.1. WaveOne

There is improving in the strength and resistance to cyclic fatigue by up to nearly four times in comparison with other brands of rotary NiTi files (Johnson *et al*., 2008). However, WO is made of M-wire, therefore shaping the canal completely accomplished by a single file system in a reciprocating mode from Densply, Maillefer (Berutti *et al*., 2011). It provides the perfect shape for 3-D obturation (West, 2008). At present, there are three files of the WO as seen in Figure (1.4) available in lengths of 21, 25 and 31mm are:

1. WO Small file used in fine canals. The tip size is ISO 21 with a continuous taper of 6%.
2. WO Primary file used in the majority of canals. The tip size is ISO 25 with an apical taper of 8% that reduce towards the coronal end (Capar *et al*., 2014).
3. WO Large file can be used in large canals. The tip size is ISO 40 with an apical taper of 8% that reduce towards the coronal end.

Figure 1.4: WO system (Webber *et al*., 2011)

The instruments are designed to work with a reverse cutting action. The CCW engaging angle is 5 times the CW disengaging angle. Strategically, after 3 CCW and CW cutting cycles, the file would have rotated 360° as seen in Figure (1.5). Moreover, file advancement, engagement and cutting the dentine are done by CCW movement while, CW movement disengages the file from dentine.

Figure 1.5: Angle of reciprocation of WO (Yared, 2008).

In addition, WO tip has a modified convex triangular cross-section which changes to a convex triangle similar to PTU near the shaft as seen in Figure (1.6) (Bürklein *et al.*, 2012).

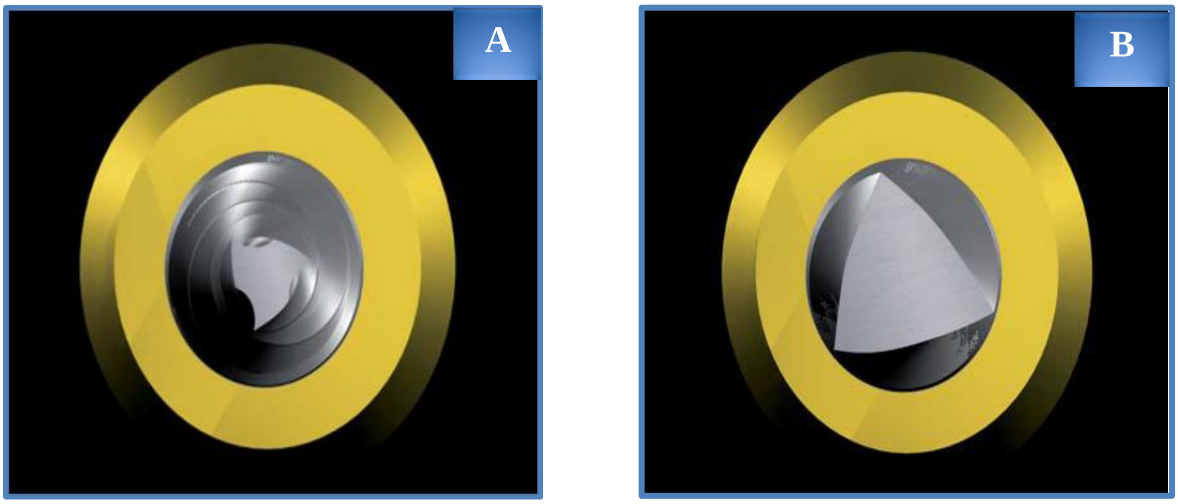

Figure 1.6: WO cross section: A: Modified convex triangular cross section apically, B: Convex triangular cross section coronally (Webber *et al.*, 2011)

All instruments used inside root canals should be single use because there is a possibility of cross-contamination associated with the inability to completely clean and sterilize endodontic instruments (Letters *et al.*, 2005) and to reduce instrument fatigue. Once sterilizeed, the plastic color coding in the handle becomes deformed. Thus, the file is preventing from being placed back into the hand piece.

In past study found that WO demonstrated reciprocation has better performance than continuous movements with multi-file system (ex, PTU and PTN) (Giuliani *et al.*, 2014). There were different results from some studies about shaping ability of PTU, WO and PTN; in which, Capar et al. demonstrated that there was no significant difference of centering ratio and canal transportation among PTU, WO and PTN (Capar *et al.*, 2014). While Yoo and Cho concluded that WO followed the original pathway better than PTU (Yoo and Cho, 2012).

1.3.1.5. Fifth generation

The centre of rotation is offset by fifth generation. This offset design serves to further minimize the engagement between the file and dentine (Hashem *et al.*, 2012). In addition, an offset design is improved flexibility along the active portion of a ProTaper Next (Dentsply Tulsa Dental Specialties) and enhanced auguring debris out of a canal. Commercial examples are Revo-S, One Shape, and the PTN file system (Elnaghy, 2014).

1.3.1.5. 1. ProTaper Next

PTN is most efficient, safest and simplest file systems. The most proven design features from the past, coupled with the most technological advancements currently available. In PTN technique, all files are used in the sequence always follows the ISO color progression regardless of the length, diameter, or curvature of a canal. PTN has an off-centred rectangular cross section which makes the file rotated in a unique asymmetric motion like a snake Figure (1.7) (Elnaghy, 2014).

Figure 1.7: Off-centred rectangular cross section of PTN (Densplymea.com)

There are five files available, for shaping canals, in different lengths, called X1, X2, X3, X4, and X5. In sequence, these files have yellow, red, blue, double black, and double yellow identification rings on their handles, corresponding to sizes 17/04, 25/06, 30/07, 40/06, and 50/06, respectively as seen in Figure (1.8) (Blum *et al.*, 2003).

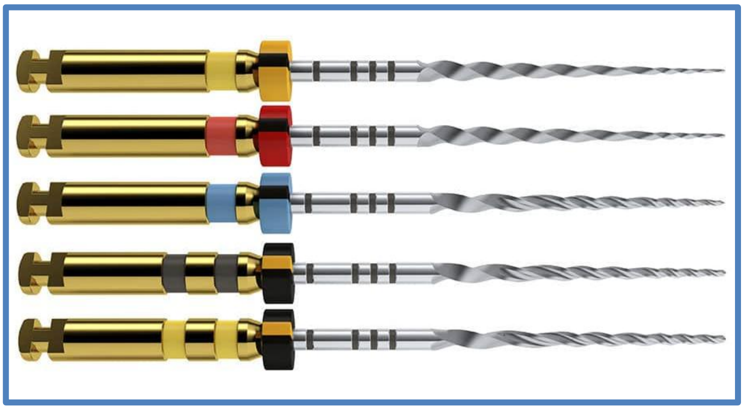

Figure 1.8: PTN system (Medicalexpo.com)

The tapers are not fixed over the active portion of any given PTN file. X1 and X2 have an increasing taper at the apical section while a decreasing percentage taper at the coronal section (Capar *et al.*, 2014). whereas the PTN X3, X4, and X5 files have a fixed taper from D1 to D3, then a decreasing percentage tapered design over the rest of their active portions.

Thus, progressive percentage tapers on a single file, M-wire technology and the offset design are represented the convergence of three significant design features. PTN files are used at 300 rpm and a torque of 2.0 to 5.2 Ncm, based on the method of use (Blum *et al.*, 2003). X1 is a square cross section in the last 3 mm to strengthen the instruments core in apical part. Precession or swagger is asymmetric rotary motion that allows the file to experience a rotational phenomenon (Scianamblo *et al.*, 2014).

Van der Vyver and Scianamblo in 2013 stated the outstanding benefits of this design which are:

1. It reduces the engagement between the instrument and the dentine walls.
2. Root canal preparation is done in a very fast and effortless manner.
3. The swaggering motion of PTN produces irrigation activation during preparation, leading to more efficient debris removal.
4. There is a smooth transition between the different sizes of instruments.
5. There is less stress on the file.
6. Fewer instruments are require to prepare a radicular space due to a larger envelope of motion (larger canal preparation size) compared to a similarly sized instrument.

It has been reported that the least transportation at apical section in severely curved canals was resulted with PTN instrumentation compared with WO and PTU and PTN better maintain the canal curvature than PTU and WO, so it showed a better shaping ability than PTU and WO at the curved section of root canals. On the other hand, PTN rectangular cross-section together with a decreasing taper at the coronal section had higher screw-in force and flexural rigidity than PTU and WO (Wu *et al.*, 2015). Although all the files had a tendency to straighten the apical curvature in multi-curved canals, it was found that the coronal curvature could better be preserved by PTN than PTU and WO (Berutti *et al.*, 2011).

1.4. Endodontic irrigants

Root canal irrigants play a vital role in the success of endodontic treatment by removing the necrotic and inflamed tissue from the radicular canal accomplished with either hand and/or instrumentation techniques (Haapasalo *et al.*, 2010). Despite technological advances in the ability to shape root canals, at least 35% of canal surfaces remain un-instrumented. Therefore, cleaning of the canal in terms of soft tissue removal and elimination of bacteria relies heavily on the adjunctive action of chemically active irrigating solutions. Thus, instrumentation of the root canal system must always be supported by use of antimicrobial irrigating solutions due to the anatomic complexity of pulp space (Peters *et al.*, 2001).

Desired functions of irrigating solutions include remove debris, reduce instrument friction during preparation, facilitate dentine removal; also, it acts as lubricant, dissolve inorganic tissue (dentine) and organic matter (Peters *et al.*, 2001). Violich and Chandler, in 2010 defined an aggregation of inorganic and organic substances or debris produced by grinding or burnishing the dentine as the smear layer. It is forming a carpet lining found on the surface of the cut dentine and intra-tubular zones. This layer protects bacteria in root dentine from antimicrobial agents, while it blocks the entrance to dentinal tubules (Torabinejad *et al.,* 2002).Therefore, root canal irrigant should kill or reduce bacteria, yeasts, endodontic pathogen and biofilms which mean it possesses a board antimicrobial spectrum and should dissolve pulp tissue remnants,dissolve a smear layer once formed or prevent its formation during instrumentation and do not irritate or damage vital periapical tissue an have no caustic or cytotoxic effects (Zehnder, 2006).

1.4.1. Sodium hypochlorite

Sodium hypochlorite (NaOCI) possesses both strong antimicrobial and proteolytic activity therefore, it is considered the most ideal irrigant for use throughout instrumentation and it has the unique ability to dissolve necrotic tissue (Naenni *et al.*, 2004). It is an inexpensive lubricant and antiseptic that has been used in dilutions ranging from 0.5% to 5.25%. However, free chlorine in Sodium hypochlorite breaks down proteins into amino acids during dissolving vital and necrotic tissue. In addition, it was reported that decreasing Sodium hypochlorite toxicity, antibacterial effect and ability to dissolve tissues could be achieved by decreasing the concentration of the solution. While, Sodium hypochlorite effectiveness is increased by increasing its volume or warming it (Johnson and Noblett, 2009).

The results of *in vitro* study showed that the most effective irrigation regimen is 5.25% NaOCl, whereas irrigation with 1.3% and 2.5% NaOCl is ineffective in removing some type of bacteria from infected dentine cylinders for the same time interval (Retamozo *et al.*, 2010).

1.4.2. Ethylene Diamine Tetra Acetic Acid (EDTA)

EDTA is a chelating agent that demineralizes the inorganic component of dentine by removing calcium ions. It has been found that EDTA can remove the smear layer created during root canal instrumentation but it does not dissolve its organic matter (Baumgartner& Cuenin, 1992). Therefore, EDTA irrigation is used in companion with NaOCl to remove the smear layer (Connell *et al.*, 2000). There is evidence that the amount of available free chlorine is reduced by chemically interact of EDTA with NaOCI. Therefore, it potentially inhibits tissue dissolution and the antibacterial activity; so, canals can be thoroughly rinsed with EDTA after canal shaping is complete (Niu *et al.*, 2002). Increased adhesiveness of endodontic sealers to dentine depends on the contact surface area which can be enhanced by using of EDTA followed (NaOCl) solution (Torabinejad *et al.*, 2002: Hu *et al.*, 2010) and EDTA has the best results for adhesiveness of sealer to root canal wall and it reduces microleakage (Sousa-Neto *et al.*, 2002) since, the use of EDTA had improved the adhesiveness of different sealer (Nunes *et al.*, 2008; Haragushiku *et al.*, 2010).

Whilest, longer exposure to EDTA causes excessive removal of both peritubular and intra-tubular dentin (Shabahang *et al.*, 2008).Moreover, there are two type of EDTA, the aqueous solutions and the paste-type EDTA; so, the paste-type lubricants were less effective than aqueous solutions for reducing stresses generated during rotary Ni-Ti instrumentation. Also, fluid irrigants tended to flush dentine debris away from the instrument while pastes type tended to adhered debris to the grooves in endodontic files leading to clogging of the grooves with dentine chips (Peters *et al.*, 2005).

1.5. Endodontic sealer

Endodontic sealer is used to fill the space between the obturation material and dentine surface, also it filled the porosity within the filling material and accessary canals to obtain hermetical apical seal. In addition, sealer acts as a lubricant to assist in the seating of the core material (Skinner& Himel, 1987). Sealers play a fundamental role in the root canal sealing with control of remaining microorganisms and fill inaccessible areas of instrumented canals (Ørstavik, 2005). However, core material alone cannot fill the radicular space completely leaving residual space between the core material and dentine surface that can be filled with a root canal sealer (Grande *et al.*, 2007; Chang *et al.*, 2015).

1.5.1. Requirements of endodontic sealer

Grossman in 1976 listed the ideal properties of a good root canal sealer:

1- It provides a good adhesion with the canal wall whilst setting; therefore it should exhibits tackiness when mixed.

2- It should provide a hermetic seal.

3-It should be radiopaque.

4- Very fine powder particles should be mixed easily with the liquid.

5- It should not shrink when setting.

6- It should not discolor tooth structure.

7- It should be bacteriostatic.

8- It should be exhibit a slow set.

9- It should be insoluble in tissue fluids and soluble in a common solvent.

10- It should be tissue tolerant (non-irritating to peri-radicular tissue).

Retrievable root canals sealers can be classified into two groups based on their constituents are:

A. Eugenol-containing sealers (Zinc oxide-eugenol sealers)

B. Non-eugenol-containing sealars are including:

1. Calcium hydroxide-based sealer.
2. Resin-based sealer.
3. Glass ionomer-based sealer.
4. Silicon-based sealer.
5. Calcium silicate-based sealer.

1.5.2. Adhesion to tooth structure

Improvement the seal ability might be expected by the good adhesion of the sealer to dentinal surface and core material. Moreover, the root canal filling often may loosen by manipulations of restoration; therefore, bond of root canal filling to the walls should be a major factor of interest during preparation for post space (Cobankara *et al.*, 2006). For two main reasons adhesion of root canal filling to the dentinal walls appears desirable. It must remove any void that permits fluid leakage between core material and dentine in static situation, while in dynamic situations this adhesion enable obturation material to resistance dislodgement during subsequent manipulations (Van Meerbeek *et al.*, 2010). Because sealer interaction with either dentine or core material may vary according to their chemical composition, therefore difference in the adhesion properties of endodontic sealers may be expected (Lee *et al.*, 2002).

1.5.2.1. Factors affecting the adhesion of obturation materials to dentine

Saleh *et al*., in 2002 mention these factors are:

1) The adherent surface (core material and dentine).

2) The smear layer.

3) The type of the sealer.

4) The sealer ability to wet the surfaces.

5) Adherent surface cleanliness.

6) Stresses caused by differences in thermal expansion coefficients and dimensional changes during setting of the sealer.

1.5.2.2. Effect of smear layer on adhesion.

The smear layer is a layer of scrap on the dentine surface and has been shown to be crammed to some of the dentinal tubules (White *et al.*, 1984). Smear layer acts as a reservoir for pathogens and limits the entrance of sealer tags to dentinal tubules. Therefore, the ability of root canal sealer to fill dentinal tubules may be enhanced by removal of the smear layer (Eldeniz *et al.*, 2005).

According to Shahravan *et al.*, in 2007 who found that smear-free obturated canals leaked significantly less than groups with intact smear layer.

The explanations for removing the smear layer are:

1. Great portion of smear layer consists of water so; it has an unpredictable diameter and volume.
2. The necrotic tissue and bacteria (organic material) and inorganic particles of calcified tissue are making up the majority of the smear layer (Mader *etal.*, 1984).
3. Bacteria can penetrate deeper into the dentinal tubules; so smear layer acts a substrate for the bacteria.
4. It may limit the optimum penetration of disinfecting agents, medicaments, and root canal filling materials into dentinal tubules (Violich & Chandler, 2010).

1.5.3. Sealing ability of sealer

Sealers are used to form apical fluid tight seal by filling the spaces between the core material and the wall of the canal and it obturated lateral canals and multiple foramina (Kazemi *et al.*, 1993). Irritation of periapical tissue may be due to presence of micro-organism in the space between the core material and dentine wall (Kardon *et al.*, 2003). In addition, healing of apical periodontitis was increased with both adequate root obturation and adequate restorative treatment (Gillen *et al.*, 2011). The 3-D seal was affected by the sealer rather than form of root canal (Juhasz *et al.*, 2006).

1.6. TotalFill Bioceramic-based root canal sealer

TotalFill BC sealer has been developed for endodontic use, mainly as repair cements (Leal *et al.*, 2011) and as root canal sealers (Louchine *et al.*, 2011). A combination of calcium silicate and calcium phosphate are the main chemical composition of TotalFill BC sealer since, aluminum free sealer composed of calcium silicates, calcium phosphate monobasic, calcium hydroxide, zirconium oxide (radioopacifier), various filler and thickening agents to deliver the sealer in the form of a premixed paste. However, the material is available in premixed calibrated injectable syringes with intra-canal tips (Pawar *el al.*, 2014).

TotalFill BC is biocompatible and effective antimicrobial agents (ph 12.8). Moreover, it has dimensional stability and does not shrink upon setting. Consequently, it remains non resorbable inside the root canal and creates bond between dentinal wall and filling material by capacity of forming hydroxyapatite during the setting process (Zhang *et al.*, 2009; Loushine *et al.*, 2011). However, during the setting reaction is utilizing moisture within the canal because it is hydrophilic sealer. Therefore, the setting time depends on the presence of moisture in dentinal tubules and may range from 4 hours to 10 hours (Hess *et al.*, 2011). Manufacturer advocates injecting the sealer into the coronal one third to one half of the canal and then seating the master cone. Koch & Brave, in 2009 discussed many benefits of bioceramics in both surgical (for example, perforation repair and resorption repair) and nonsurgical endodontics (for example, pulp capping and as sealer). Some of physical properties of TotalFill BC sealer were mentioned in Table (1.1).

Table 1.1: Physical properties of TotalFill BC sealer (Zhou *et al.*, 2013)

Flow (ISO 6876\2001)	23.1 mm
Film thickness (ISO 6876\2001)	22mm
Working time	1440min
Setting time	2.7 hour
Solubility (ISO 6876\2001)	2.9%
Dimensional change (ISO 6876\2001)	0.087%

The calcium silicates in the powder hydrate to produce a calcium silicate hydrate gel and calcium hydroxide. The calcium hydroxide reacts with the phosphate ions to precipitate hydroxyapatite and water. The water continues to react with the calcium silicates to precipitate additional gel-like calcium silicate hydrate. Moreover, dentine is composed of approximately 20 % (by volume) water, and this water initiates the setting of the material and ultimately results in the formation of hydroxyapatite (Koch *et al.*, 2013). Moreover, ability of an endodontic sealer to adhere to the root canal walls and promote the union of cones to each other and to the dentine is defined as its adhesion (Mohammadi *et al.*, 2013).

Perfectly filled the root canal space with a solid mass consists of different materials and interface refers to as Mono-block (Thakur *et al.*, 2013). Reinforcement of the tooth against fracture and a 3-D filling of root canal and accessory canal represent the present concept of obturation (Mathew and Rajan, 2014).

The classification of obturation monoblocks can be classified in the root canal space into primary, secondary and tertiary, depending on the number of interfaces between the bulk core material and the bonding substrate as seen in Figure (1.9). One interface extends circumferentially between the root canal wall and the material is a primary monoblock. Two circumferential interfaces, one between the sealer and the core material and the other between the sealer and dentine are secondary monoblocks. A third circumferential interface is introduced between the bonding substrate and the abutment material called tertiary monoblocks (Gaitan-Fonseca *et al.*, 2013). Howover, BC sealer is a nanoparticle size enables it to flow into dentinal tubules and canal irregularities to create a gap-free interface between the core material, sealer, and dentine (Kossev & Stefanov, 2009; Hegde and Arora, 2015). Self-adhesive nature of sealer and its ability to produce a chemical bond with dentine by hydroxyapatite production during setting led to achieve a monoblock cocept (Gade *et al.*, 2015).

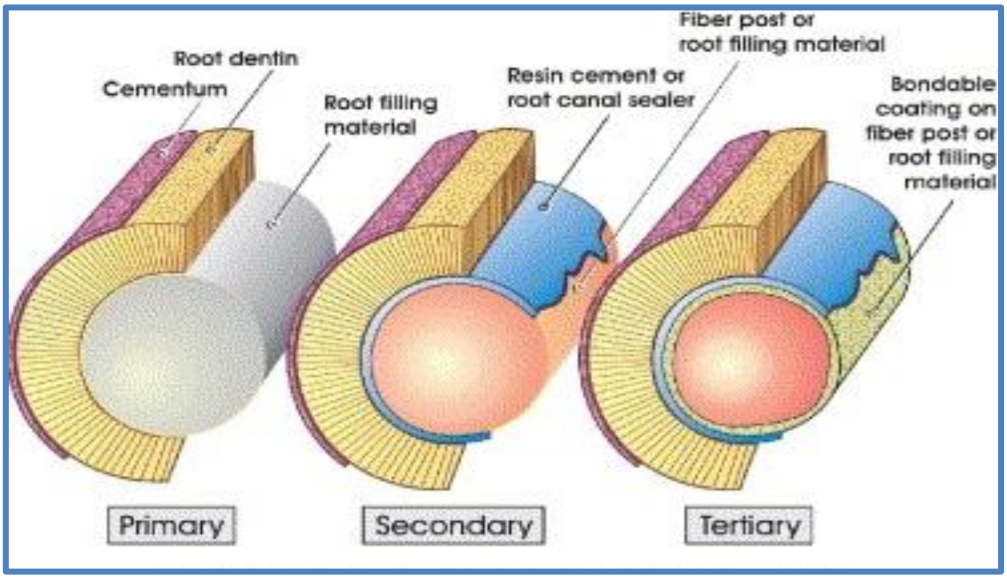

Figure 1.9: Classification of obturation monoblocks (Sciencedirect. com)

1.7. Root canal obturation material

Over two centuries a variety of materials were utilized for endodontic obturation, particularly to fill the canal space, include amalgam, lead balsam, bamboo, copper, paraffin oxy-chloride of zinc, plaster of Paris, asbestos, gold of iron, tin foil. However, no one of these materials meets the requirements of an ideal root canal obturation material. The canal system should be sealed apically, laterally and coronally. Various methods and materials are advocated to create this option (Braniste, 2013).

1.7.1. Functions of an ideal root canal obturation material

Sundqvist& Figdor, in 1998 stated the functions associated with a core material as seen in Figure (1.10), which are:

1. Providing a seal against bacterial ingrowth from the oral cavity to stop coronal leakage.
2. Entombment of living microorganisms and their by-products.
3. Accumulation of stagnant fluid would prevent.

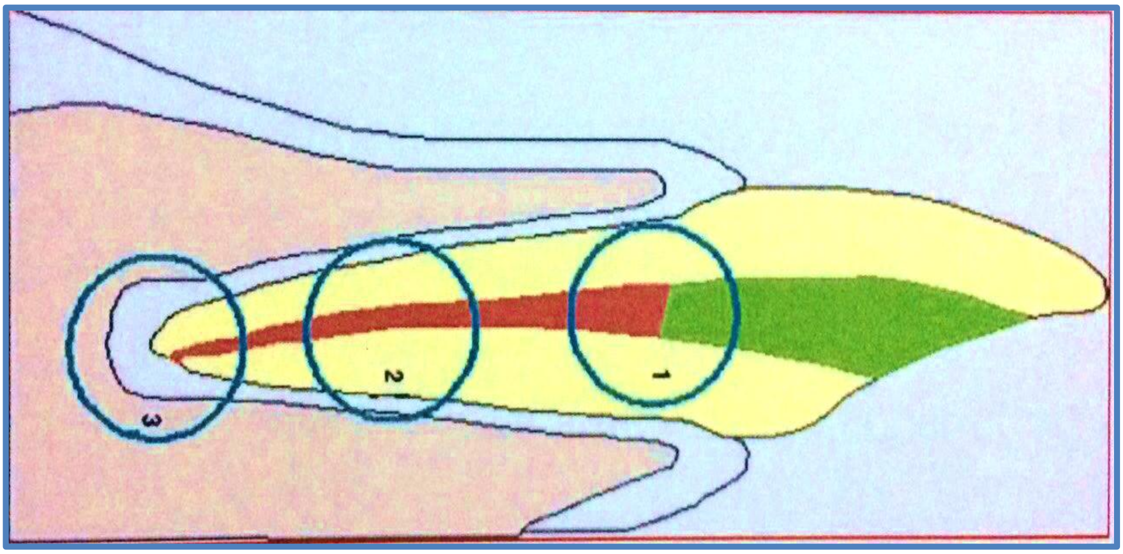

Figure 1.10: Primary function of a root canal obturation (Sundqvist and Figdor, 1998)

1.7.2. Requirements of an ideal root canal obturation material

Grossman in (1988) outlined the properties of an ideal core material:

1. Easy manipulation with ample working time.
2. Radio-opacity and discernibility in radiograph.
3. No shrinkage following insertion (dimensional stability).
4. Seal the canal laterally as well as apically.
5. Lack of porosities.
6. Bacteriostatic.
7. Inability to produce irritation of the peri-radicular tissues.
8. Lack of corrosion or oxidization.
9. Not discolor the tooth structure.
10. Easy removal from the root canal.
11. Sterility.

1.7.3. Objective of root canal obturation

Total obturation of the root canal space is the objective of root canal treatment as described by Dr. Schilder. Also, insurance the health of the attachment apparatus against breakdown of endodontic origin by sealing of the complex root canal system from the periodontal bone (Schilder, 2006). The technical quality of the root canal obturation is significantly correlated with the outcome of endodontic treatment (Nair, 2006).

1.8. Gutta-percha root canal obturation material

Gutta-percha is the most commonly used as a solid, inert core filling material in conjunction with sealer in order to obtain a fluid-tight seal of the root canal space (Ørstavik, 2005). Gutta-percha is the trans-isomer of polyisoprene; its chemical structure is 1, 4 trans-polyisoprene. Presence of gutta-percha in two crystallins forms alpha and beta; alpha phase is obtained directly from the tree without undergoing any chemical processing, while beta phase is undergo to several chemical steps to prepare it (Goodman *et al.*, 1974). However, Manufacturing at various temperature is achieved the various phases since, the alpha form is considered runny, having a low viscosity, tacky and sticky. The gamma form is amorphous in nature and less stable; however, it is similar to alpha form. The beta form is solid, has a higher viscosity and compactible and it is a form most commonly found and which may be compacted and compressed in a solid mass as gutta-percha cones. The material can change to the alpha-phase and become pliable and tacky when heated, therefore, it is used successfully in thermoplastic obturation techniques (Braniste, 2013). Gutta-percha becomes soft at approximately 40-49° C. Transformation from the beta to alpha usually occurred between 42 and 49. Alpha change to amorphous state occurred usually between 53° C and 59 ° C depending on the compound structure. Moreover, gutta-percha expands of approximately 1-3% and contraction of 3-5% when heated (Schilder *et al.*, 1974). In addition, gutta-percha points contain approximately 19-20% gutta-percha as trans-polyisoprene polymer, 50-78% zinc oxide with small percentages of antioxidants, coloring agents, waxes and metalic salts (Gutmann & Witherspoon 2002). The ability to control length in cold lateral condensation, as well as, exhibits a very low toxicity, ability to adapt to canal irregularities in thermoplasticized techniques are the main advantages of gutta-percha (Ingle *et al.*, 2008).

1.9. Techniques of obturation with gutta-percha

1. Lateral condensation technique.
2. Warm vertical compaction technique.
3. Continuous wave compaction technique
4. Thermoplastic injection technique.

5. Single cone obturation technique.
6. Carrier based obturation technique.
7. Thermomechanical compaction technique.
8. Solvent technique (Ingle, 2002).

1.9.1. Single cone obturation technique

In the 1980s, introduction of some filling techniques lead to development of single cone obturation technique, due to standardization of endodontic instruments and filling points (Pereira *et al.*, 2012). Ni-Ti instrumentation of a root canal and the using of these cones with a sealer may provide 3-D obturation of the root canal with short time (Gordon *et al.*, 2005).

The single cone technique consists of filling root canal system with a single master cone at room temperature with varying thickness of sealer layer, depending on the adaptation of the single cone to the walls of the canal as seen in Figure (1.11) (Wu *et al.*, 2006).

Figure 1.11: Single cone obturation technique (Animated teeth.com. 2013)

However, larger master cone that best match the geometry of the last nickel-titanium rotary file (NiTi) is used in this technique while neither accessory points nor lateral condensation are required with master point. Thus, the technique minimizes the pressure applied to the root canal walls while speeds the root canal filling (Zmener *et al.*, 2005*;* Pereira *et al.*, 2012*)*. A uniform mass result from the combination of single cone and endodontic cement owing to prevent failures observed among multiple cones (Gomes *et al.*, 2006*)*. However, lack of gutta-percha homogeneity, high endodontic cement percentage at the apical portion of the root, apical extrusion of the gutta-percha and poor adaptation to the root canal walls are some disadvantages of lateral condensation and warm vertical compaction; therefore, the single cone technique was developed to overcome these disadvantages (Tasdemir *et al.*, 2009; Pereira *et al.*, 2012).

Because of simplicity of the single cone technique than the lateral condensation, the operator is less subjected to fatigue; however, such considerations should be subordinated to the main objective to provide the best treatment for the patient (Tasdemir *et al.*, 2009; Pereira *et al.*, 2012). It was found in past study that the single cone obturations have not been well regarded because of the use of large amounts of sealer and the main disadvantages of this technique are sealer porosities, contraction of sealer during setting and dissolution of the sealer (Whitworth, 2005).

1.9.2. Carrier based gutta-percha obturation

Obturation is one of the important steps in the root canal treatment due to providing apical and coronal seal, in addition to seal the irrigularities inside the canal system. 3-D obturation of the whole root canal system by making the filling as close as possible to cemento-dentinal junction was the definition of root canal obturation as described by American Association of Endodontists (American Association of Endodontists, 1994). It is found that microorganism and their toxins initiate and exacerbate the disease of periapical area (Kakehashi *et al.*, 1965, Nair 2004); Therefore, endodontic intervention is need to stop or treat the disease to reduce the level of microbes to as a low as possible. Thus, a hermetic seal of radicular canals is one of the main endodontics objectives, which are important to maintain the sterilization of root canals that obtained during instrumentation of the canal.

Abundant techniques are developed for root canal obturation for example: cold lateral condensation, vertical wam condensation, thermoplasticized gutta-percha and flow-able obturation materials. However, it was reported that no significant differences between the outcomes of tooth filled with different techniques trials (Peters *et al.*, 2004). Historically, Schilder in 1967 presented the warm vertical compaction concept of gutta-percha in order to fill irregularities of the canal.

Afterward, Ben Johnson in 1978 introduced the use of thermally plasticized gutta-percha.

Later in the 1990s a solid core was coated with gutta-percha that correspond to size of ISO standardized file and to taper of nickel-titanium rotary files and example of Carrier based obturation systems are Thermafil Dens-Fil (Dentsply, Maillefer, Tulsa, OK), Soft-Core (Axis Dental Coppell TX). However, the lack of apical control is the common problem reported by clinicians using carrier based obturation systems (Gutmann *etat*., 1993), in addition, failure to obturate oval-shaped canals completely (De Dous *et al.*, 2008), and the difficulty of carrier removal in retreatment case; therefore, groove is including in the current carriers to accelerate the carriers removal. (Wesselink 2003, Gutmann *et al.*, 2006). Gutta Fusion® (VDW, Germany) was used in this study as an example of carrier based obturation material.

1.9.2.1. GuttaFusion®

On days, there is a concentration on the use of the carrier based gutta-percha obturation material. However, GuttaFusion® is warm 3D obturation and the gutta-percha is the only structure of the obturator without need for metal or plastic core; that means the GuttaFusion® is entirely made from gutta-percha. Therefore, chains of crosslinked polymer gutta-percha was made the interior core of the obturator in order to obtain carrier stability while, flowable gutta percha is used to cover the gutta-percha core as seen in Figure (1.12). The benefit of carrier is to enhance adaptation of heated gutta-percha into the dentinal tubules. Special obturators for Reciproc® are available in sizes R25, R40 and R50 (http://www.vdw-dental.com/).

Figure 1.12: GuttaFusion® obturation material (Dentalzon. com)

1.9.2.1.1. Benefits of GuttaFusion®

1. Good condensation of warm gutta-percha in ramifications, irrigularities and isthmi lead to homogeneous obturation of the whole endodontic space.
2. The specially developed handle for tweezers is enabling precise placement of the obturator even in posterior teeth.
3. The handle can be separated easily without any need for additional instruments.
5. Post space preparation is simple due to easy removal of gutta-percha.
6. Fast retreatment.
7. Simple to use.
8. Reliable.

1.9.2.1.2. Use of GuttaFusion®

Correct obturator is selected after shaping and cleaning of the endodontic system. Enlargement of the canal space must be minimum 25\06 in order to provide enough room and taper for the GuttaFusion® (Gutmann, 2011). Next, obturator is heated by special oven in less than one minute which has ability to warm two obturators simultaneously; therefore GuttaFusion® oven must set to heat Obturator. Then the oven gives visual and acoustic warning signals. Subsequently, the obturator takes out from the obturater holders by pushing the handle down so, the handle is raised and the obturator can be released easily. In addition, oven cleaning is simple due to its special design (http://www.vdw-dental.com/). Then, sealer is applied to the coronal third of the canal, proper heating of the carrier and careful placement are important for the obturation. Afterward, the heated obturator is inserted to full working length of the canal. Moreover, the cross-linked gutta-percha core has enough strength to push the warm gutta-percha into irregularities and severely curved canal. Afterward remove excess gutta-percha by moving the obturator side to side (Gutmann, 2011). It was reported that dentists found GuttaFusion® as reliable obturation material due to the special handle design for tweezers which is responsible for accurate obturator placement. Another study found that GuttaFusion® is more time-saving than lateral condensation, therefore, it is efficient. In addition, more than 90% of dentists were said that the GuttaFusion® was more convenient in comparasion with lateral condensation (Internal data, VDW Munich, 2012).

Moreover, Neuhaus, *et al* in 2016 evaluated the adaptation and homogeneity in the apical region of three obturation materials Guttafusion® and Thermafil (warm obturation material) and the single cone technique. It has been established that both warm carrier based system showed significantly better adaptation and homogeneity than single cone technigue (Neuhaus *et al.*, 2016).

1.10. Push-out test

A popular method for determining the effectiveness of adhesion between core material and tooth structure is defined as bond strength testing. There are many methods for measuring the adhesion of obturation material to root canal wall, but none has yet been widely accepted (Gogos *et al.*, 2004).

The tensile strength testis sensitive, with the result that small in the specimen or in stress distributionduring load applicatonnnnnn have a substantial influence on the results (Van Noort *et al.*,1991).In contrast,, A major wproplem with shear testing is that it is difficult to closely align the shear-loading device with the bond interface. The load is offset at some distance from the bonded interface, resulting in unpredictabletorque loading on the the specimen (Watanabe *et al.*, 2000). The adhesive capacity of endodontic sealers was evaluating as test dentine surface of the root (Sousa-Neto *et al.*, 2005). A universal testing machine is using load to push the obturation material out of the canal since; this test is reproducible and more reliable and allow standardization (Ørstavik, 1983). Consequently, this test allows obturation material to be evaluated even when bond strengths are low also; it is easy to align samples for testing (Ungor *et al.*, 2006). It is a more suitable for evaluating intra-canal obturation materials bond strength and also, assessment of regional differences in bond strength among root levels (Goracci *et al.*, 2004). Successful endodontic treatment is depending on the adhesion of obturation material to the root canal wall which is advantageous for two reasons. First, it must remove any void that permit fluid leakage between core material and dentine in static situation and the second reason is enabling obturation material to resist its dislodgement during subsequent manipulation in dynamic situations (Van Meerbeek *et al.*, 2010). Amara et al in 2012 was stated that push-out test is popular method for measuring the effectiveness of adhesion between dentine wall and intra-canal material (Amara *et al.*, 2012). Although, the bond strength of different dental materials is measured by micro-tensile bond strength test (Armstrong *et al.*, 2010). Unfortunately, intra-canal obturation materials cannot be measured by the tensile bond strength test method because of premature bond failures and the large variation in test result (Soares *et al.*, 2008). The load in push-out test is applied through a punch that attached in the universal testing machine. The punch must cover most of the obturation material without touching the canal wall (Jainaen *et al.*, 2007).

There are many studies about push-out bond strength test were carried out for example: push-out bond strength of different obturation material after instrumentation of the canal with manual PTU and found that this test was more accurate in determination of bond strength of the sealer to root canal wall (Al-Ani and Al-Huwaizi, 2011). Many obturation systems were proposed to the endodontics as to approach the good sealing ability and adhesion to dentin so, Naser and Al- Zaka, in 2013 used the push-out test to evaluate the bond strength of four different obturation materials to intraradicular dentin after instrumentation of the roots with rotary EndoSequence system.

Also, Pawer *et al.*, in 2016 used this test to assess the bond strength of root fillings made with C-Point and BC sealer versus gutta-percha and AH Plus after the instrumentation of oval canals with the Self-Adjusting File versus WO files.

Finally, Hanna *et al.*, in 2016 used push-out test to evlaute the bond strength of three warm obturation techniques: Warm Vertical Compaction, GuttaCore, GuttaFusion.

MATERIALS & METHODS

CHAPTER TWO

Materials and Method

2.1. Materials and equipment

The materials, instruments and equipment that were used in this study included the following items Figure (2.1).

2.1.1. Materials

1. Cold cure orthodontic acrylic (Sofa dental, Czech Republic).
2. Disposable latex gloves (Broche medikal, Malaysia).
3. Distilled water (Iraq).
4. EDTA (Dental Produits Dentaires SA, Switzerland) Exp. Date: 02-2018, Lot no.: 8417DG.
5. Gauze (CMC, Commer Medical Care Gmbh, Germany) Exp. Date: 12-2019.
6. GuttaFusion® (VDW, Germany) Exp. Date: 07-2020, Lot no.: 0000099273.
7. NaOCl (Cerkamed, Poland) Exp. Date: 04-2018.
8. Normal saline (Pioneer company for pharmaceutical industries, Iraq) Exp. Date: 10-2018.
9. Plastic vials for samples storage (Iraq).
10. ProTaper Next gutta-percha size #40 (X4) (Dentsply, Maillefer, Switzerland) Exp. Date: 10-2019, Lot no.: 145099H.
11. ProTaper Next paper point size # 40/06 (Dentsply, Maillefer, Switzerland) Exp. Date: 07-2019, Lot no.: DE 150201.
12. ProTaper Universal gutta-percha size #40 (F4) (Dentsply, Maillefer, Switzerland) Exp. Date: 05-2019, Lot no.: 109190H.
13. ProTaper Universal paper point 40/06 (Dentsply, Maillefer, Switzerland) Exp. Date: 07-2020, Lot no.: 010715.
14. Silicon impression material (Heavy body) (Protesit, Italy) Exp. Date: 07-2018.

15. Silicone rubber material (OOMOO® Smooth-On, East Texas)
16. Sixty extracted human permanent mandibular premolars.
17. Sticky wax (Kerr, Switzerland).
18. TotalFill BC sealer (Brasseler, Savannah, USA) Exp. Date: 09-2017, Lot no.: 15003SP.
19. WaveOne gutta-percha size # 40/08 (Dentsply, Maillefer, Switzerland) Exp. Date: 05-2018, Lot no.: 995856G.
20. WaveOne paper point size # 40 (Dentsply, Maillefer, Switzerland).
21. X-ray films (Ergonom. X, Italy) Exp. Date: 03- 2018, Lot no.: 0459.

2.1.2. Instruments

1. Barbed broaches (Dentsply, Maillefer, Switzerland) Exp. Date: 07- 2018, Lot no.:1227477022
2. Clear cast acrylic rod (Plastic Corp, USA).
3. Curette (PD, Switzerland).
4. Cement slab (Dentiraq, China).
5. Cement spatula (Dentiraq, China).
6. Curette (PD, Switzerland).
7. Dental tweezers (Medesey, Italy).
8. Diamond disc (San-I polishing silicon disc, Taiwan).
9. Digital caliper (Ingco, China).
10. Disposable syringe (3ml\needle gauge) (Loughborough, Leicestershire, UK).
11. Endodontic hand plugger (Medesey, Italy).
12. Endodontic ruler (Dentsply, Maillefer, Switzerland).
13. Finger spreader kit (Dentsply, Maillefer, Switzerland).
14. K-file size #15 (Dentsply maillefer, Switzerland) Exp. Date: 01- 2018, Lot no.:8042810.

15. K-files size # 10 (Dentsply maillefer, Switzerland) Exp. Date: 05- 2018, Lot no.:5343551.
16. Magnifying lens (Straight-Shank glass, Hao-ming, China).
17. Porcelain jar (China).
18. ProTaper Next files from X1to X4 (Dentsply, Maillefer, Switzerland). Exp. Date: 04- 2019. Exp. Date: 12- 2020, Lot no.:1290994.
19. ProTaper Universal files from S1 to F4 (Dentsply, Maillefer, Switzerland). Exp. Date: 02- 2018, Lot no.:10351.
20. WaveOne files primary and large file (Dentsply, Maillefer, Switzerland). Exp. Date: 09- 2019, Lot no.:1168597.

2.1.3. Equipment

1. Dental surveyor (BEGO, Germany).
2. Dental vertical arm (Local manufacturing, Iraq).
3. Endo-motor X. smart plus (Densply, Maillefer, Switzerland).
4. GuttaFusion® oven (VDW, Germany).
5. Sectioning machine (Hobby mate, New York).
6. Incubator (Memmert, Gemmany).
7. Light cure unit (Quayle dental, UK).
8. MT-4 diamond cut off saw (MTI Corporation, USA).
9. Stereomicroscope microscope (Hamilton, Altay Co, Germany).
10. Universal Instron testing machine (Tinius Olsen, UK).

Figure 2.1: some of the materials, instruments and equipment employed in the present study

2.2. Methods

2.2.1. Teeth selection:

For this study, sixty freshly extracted human permanent mandibular premolars teeth were selected from different health centers according to specific criteria. The age was in range of (18-24 years) while gender and extraction reason was not considered in the current study.

The criteria for teeth selection were including the following: straight root, mature and roots devoid of any resorptions (Naser and Al-Zaka, 2013; Pawer *et al.*, 2016).

Then, a magnifying eye lens (10X) was used to verify the root surfaces and any visible cracks or fractures were recognized by using a light cure device (Al- Ani and Al-Huwaizi, 2011).

At room temperature, all teeth were stored in distilled water after extraction. Then, sharp periodontal curette was used to remove remnants of soft tissue on the root surface (Naser and Al-Zaka, 2013).

2.2.2. Teeth sectioning:

After the length of the root was determined with a marker, the root was held with a pressing machine by which the tooth was positioned parallel to the floor with the crown away from the operator to facilitate sectioning.

In Nanotechnology department / University of Technology / Baghdad tooth sectioning was carried out using diamond cut off saw with the use of the water coolant to minimize the formation of smear and reduce heat of the tooth during sectioning (Ehsani *et al.*, 2013) Figure (2.2).

Figure 2.2: Sectioning of the tooth

Sectioning of each root was perpendicular to the long axis of the root to obtain a straight-line access for the canal preparation and obturation procedure. This diamond disc (0.35 mm thickness) actually made accurete cut with15mm length of the root (Garcia *et al.*, 2014). At the same time the length of roots was verified by digital caliper to ensure that it was 15 mm as shown in the Figure (2.3).

Figure 2.3: Measuring the length of tooth with a digital caliper

Then, the tissue of the pulp was removed with a barbed broach and a size 10 k-file was used to ensure straight canal, patency and central position of apical foramina by advancing it into the canal until it was visualized at the apical foramen to determine the exact location of the apical foramen (Al- Ani and Al-Huwaizi, 2011).

Plastic containers were cut into length of 13 mm with a diamond disc to obtain molds for the silicon rubber base impression material. This container was loaded with a silicon rubber base impression materials (heavy-body) that held the roots in its center. Firstly, the root was temporarily fixed with sticky wax to the vertical arm which acts as a dental surveyor and at the same time, the plastic container also temporarily fixed with sticky wax to ensure centrally location of the root within the freshly mixed heavy body which was mixed according to the manufacturer's instructions (base and catalyst) Figure (2.4).

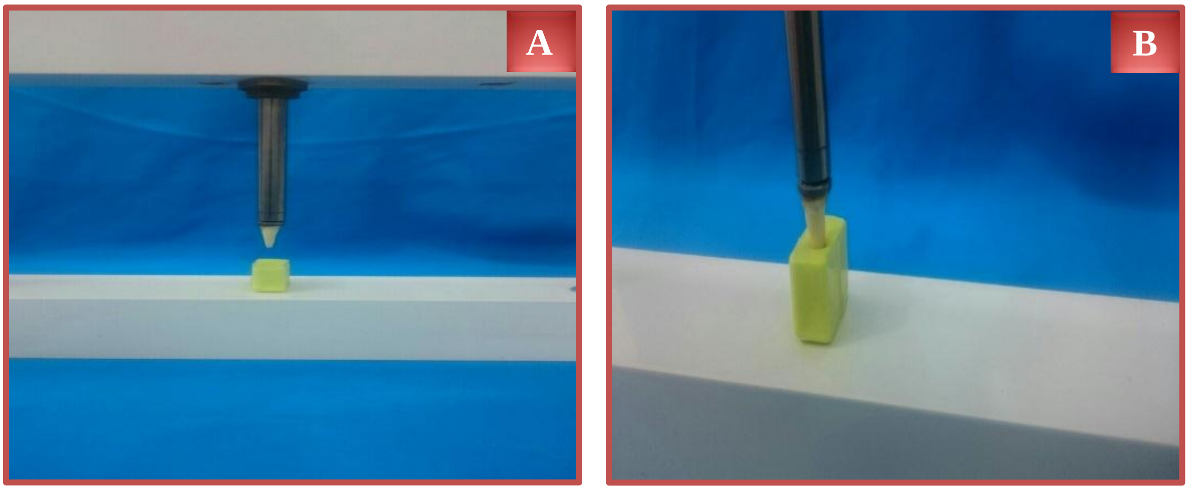

Figure 2.4: Centrally placement of root in silicon impression material A: before inseration, B: during insertion

So, 3mm of root was appeared outside from the plastic container and the remainder part of root was embedded in heavy material to facilitate removal of the root from the impression block after complete of obturation Figure (2.5).

Figure 2.5: appearing 3mm of the root from the plastic container

Then, a small block was formed after leaving the heavy body to set, this facilitated handling of the roots during preparation and filling technique (Al-Ani and Al-Huwaizi, 2011).

2.2.4. Samples grouping

The roots were divided randomly into three main groups according to instrumentation techniques. Each group was divided into two subgroups (A, B) according to obturation techniques so, there were six subgroups, each subgroup of 10 roots Figure (2.6):

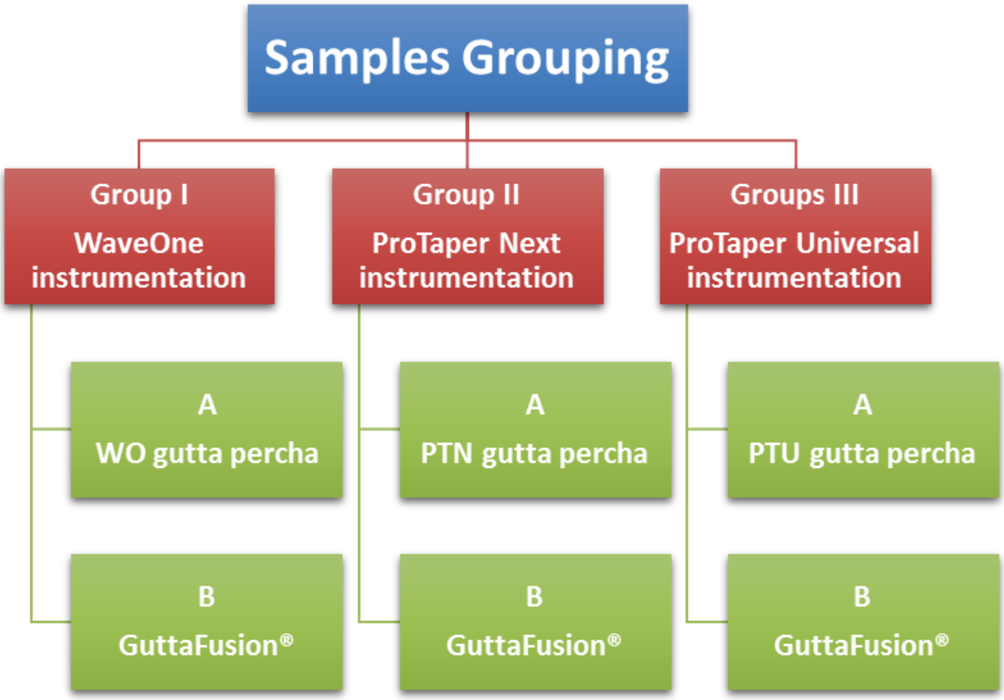

Figure 2.6: Samples grouping

2.2.5. Samples instrumentation

A size 15 k-file was used to obtain a glide path before the preparation, the full working length was reached by the file then a small stroke was used. A reproducible glide path was confirmed by the file that introduced to the full working length then withdrawn few millimeters and light finger pressure should be able to slide the file back to working length (Van der Vyver and Scianamblo, 2014).

The root canals were prepared with crown down technique using three rotary systems, endo-Motor (X. smart plus) (Dentsply Maillefer) was used to operate the files and the endo-motor already set at appropriate speed and torque for each system.

Group I WaveOne instrumentation

The instrumentations were performed with a progressive slight force in the apical direction and an outward circumferential brushing motion in 2–3 mm cycles until the working length was reached (Bürklein *et al.,* 2012).

Twenty samples were instrumented with WO System. Firstly the primary file (red one) 25/06 was worked in the endo-motor X-smart plus several times until the file became lose. This file was used to provide glide path for a large WO file 40/08 which was also used with a brushing motion and each file removed regularly, wiped, cleaned with cotton roll and irrigated the canal and continued; between each file removal out of the canal (Bürklein *et al.,* 2012).

The irrigation protocol for all groups was total volume of 3ml of 5.25% NaOCl for nearly 5 min before, during and after instrumentation of the canal by inserting the needle (3 ml gauge 23) to 5mm depth coronally into the canal and slowly push the NaOCl and the canal was verified by size 10 k-file to lose the debris and recapitulate the canal remnant (Ruddle, 2014).

Then, 3 ml of 17% aqueous EDTA solution for 1 min was used to remove the smear layer. NaOCl is strong oxidizing agent so; the canal was rinsed with 3 ml of distilled water to prevent NaOCl crystal formation to increase the bond strength of obturation material (Pawer *et al.*, 2016)**.** In general, file was used in a brushing motion and used for one time then discarded. Steps of WO instrumentation as seen in Figure (2.7).

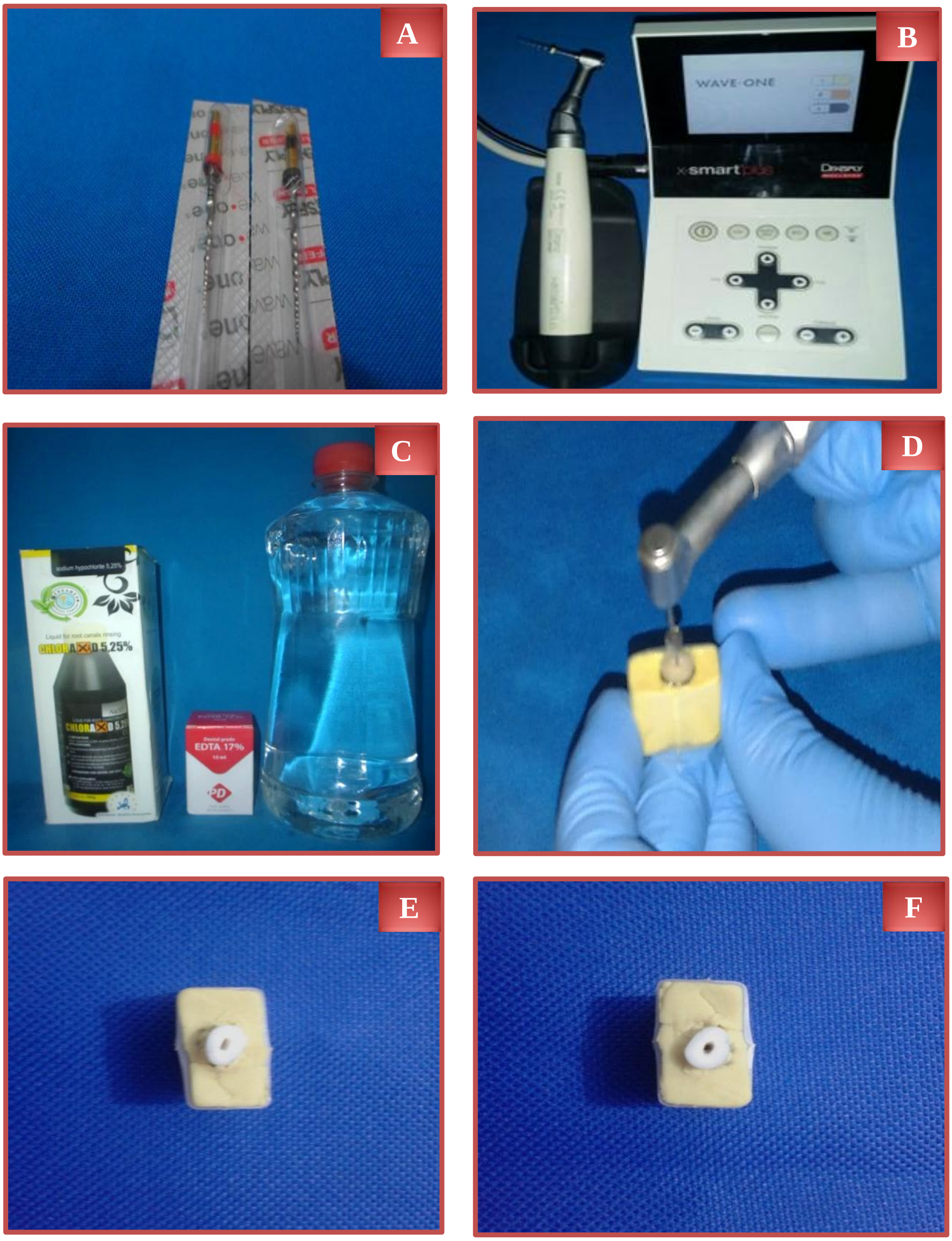

Figure 2.7: Steps of WO instrumentation: A: WO file size # 25 and # 40, B: WO instrumentation with endo-motor X-smart plus, C: Irrigation solutions, D: During instrumentation, E: Sample before instrumentation with WO system, F: Sample after instrumentation with WO system.

Group II Pro Taper Next instrumentation

Twenty samples were instrumented with PTN system. X1 20/04 was working at speed of 300 rpm and torque of 2.0Ncm after irrigatation of the canal with 5.25% NaOCl. After several times the file became loose then, the file was removed from the canal and the canal has been irrigated with NaOCl to flush the debris out the canal.

Next, another files namely X2 25/06, X3 30/07, were used at the same torque and speed to provide glide path for X4 40/06 and after each file, the canal was verified by size 10 k-file to lose the debris and recapitulated the canal (Bürklein *et al*., 2012) as seen in Figure (2.8). In general, each file used three times only.

Figure 2.8: Steps of PTN instrumentation: A: PTN files, B: PTN instrumentation with endo-motor X-smart plus, C: Sample before instrumentation with PTN X4, D: Sample after instrumentation with PTN X4

Groups III ProTaper Universal instrumentation

Twenty samples were instrumented with PTU file. Firstly the canal was instrumented with S1 17/04with endo-motor X-smart plus which was worked at speed of 250 rpm and torque of 3.0 Ncm then, S2 20/02 was used with speed of 250 rpm and torque of 1.0 Ncm and F1 20/07 was worked at speed of 250 rpm and torque of 1.5 Ncm while F2 25/08, F3 30/09, F4 40/06 were used respectively at constant speed 250 rpm and constant torque 2.0 Ncm. All these files except F4 were used to provide glide path for F4 (Bürklein *et al*., 2012) as seen in Figure (2.9). The files were used in a brushing motion and used for three times then discarded.

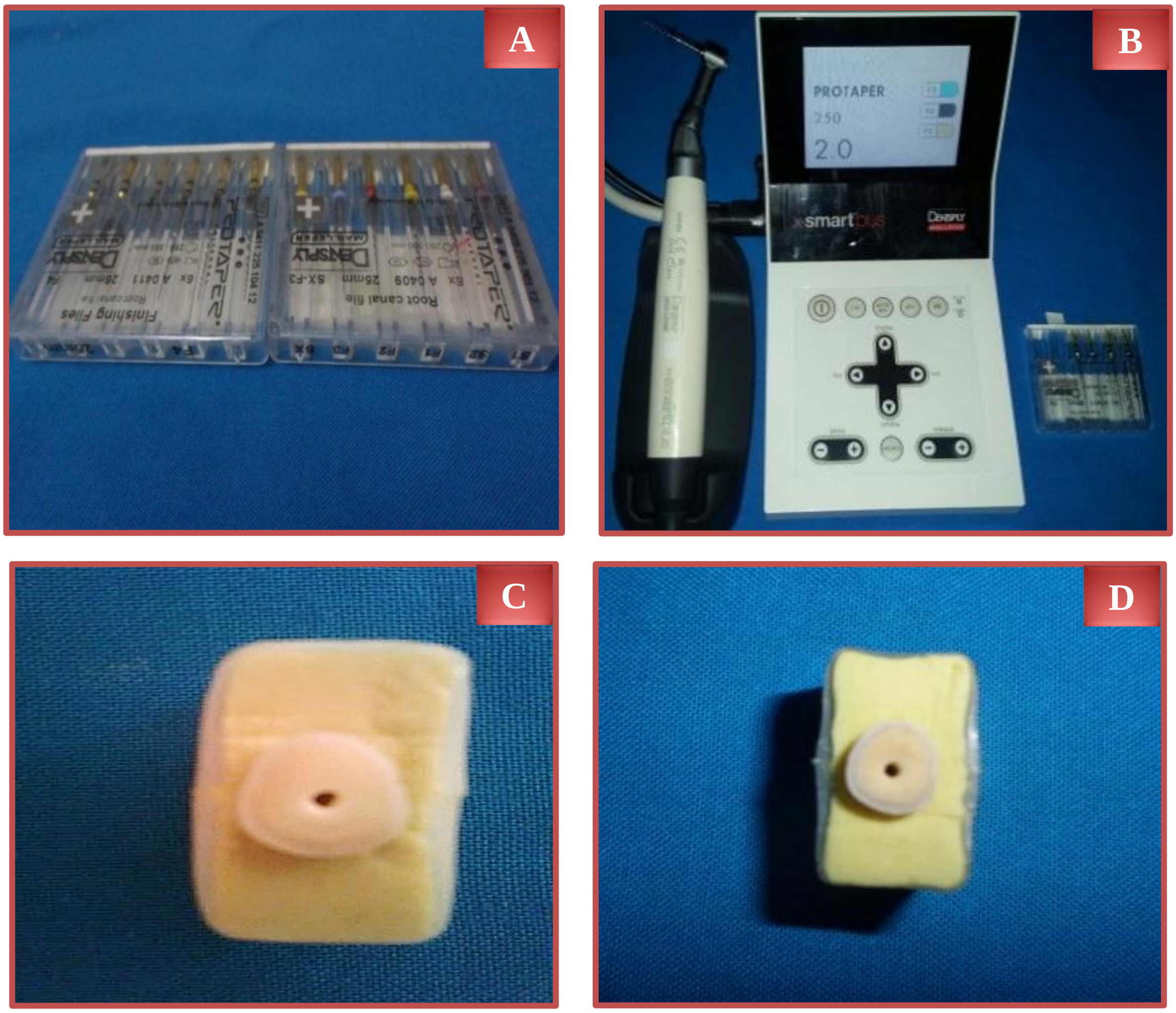

Figure 2.9: Steps of PTU instrumentation: A: PTU files, B: PTU instrumentation with endo-motor X-smart plus, C: Sample before instrumentation with PTU F4, D: Sample after instrumentation with PTU F4

2.2.5. Samples obturation:

GROUP I A, II A, III A

SINGLE CONE OBTURATION TECHNIQUE

For all groups, after the phase of instrumentation was completed, the canals were dried with a corresponding paper point size # 40. At this time, the canal was ready for obturation with single cone gutta percha size #40 and TotalFill sealer.

Firstly, the length of single cone gutta-percha size #40 was deteremined with endodontic ruler by stopper to ensure it was 15 mm length. Then, single cone gutta-percha was inserted slowly into the canal to ensure it reached to full working length of the canal with tag back.

For all groups, the TotalFill BC sealer was dispensed in the same manner. The syringe cap was removed from TotalFill BC sealer syringe and intra-canal tip (0.012mm) was attached with clockwise twist to the syringe hub. Then, this tip was marked with marker at 5mm (only this length was inserted inside the corornal third of the root canal). According to the manufacturer’s instructions, BC sealer was smoothly dispensed in a small amount (one calibration marking) through its intra-canal syringe tip into the root canal; the intra-canal tip was pulling slowely out of the canal during compressing the plunger of the syringe as seen in Figure (2.10). Then, hand file size #15 was coated with a thin layer of TotalFill BC sealer that dispensed on glass slab. Then, this file was lightly coated the canal wall along the working length with existing sealer by two time counter clockwise rotation (Al- Ani and Al-Huwaizi, 2011).

Figure 2.10: Insertion of TotalFill sealer

After that, WO single cone gutta perch size #40 has been slowly inserted into the canal all the way to the full working length as seen in Figure (2.11). A heated plugger was used to cut the cone at the orifice level.Then this plugger was used to condense the master cone in all groups (Schäfer *et al*., 2013).The same researcher applied the same pressure by plugger to the gutta-percha.

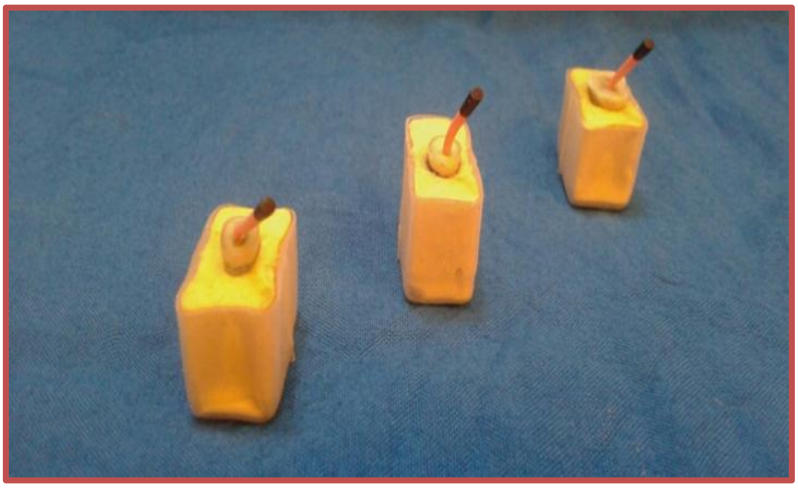

Figure 2.11: single cone obturation technique

II.Group I B, IIB, IIIB obturation with GuttaFusion®:

After complete of instrumentation, the canals were dried with a corresponding paper point size #40. Next, the canal was ready for obturation with GuttaFusion® and TotalFill sealer as seen in the figure 2.12. Firstly, the length of GuttaFusion® obturation size #40 was deteremined with endodontic ruler by stopper to ensure it was 15 mm length. Afterward, the holder of GuttaFusion® oven was pushed down in order to make the holder raised to hold the GuttaFusion® obturator. Then, the holder pushed down in order to start thermoplasticizing the obturator. However, GuttaFusion® was heated for few seconds since using specific oven equipped with three temperature degrees (1, 2 and 3) (range from 105-180^{o}C).

Thus, GuttaFusion® oven was set the heat of obturator at two. This oven had ability to warm two obturators simultaneously.Then the oven gaves visual and acoustic warning signals which indicated that the obturator was ready to be used after 20 sec. Afterward, the obturator was taken out from the obturater holders which can be released easily by pushing it down and the GuttaFusion® was inserted slowly in firm manner and in apical direction with rate of 2-3mm so average time from orifice to the full working length of the canal was 6-7 sec.

Afterward, the excess material out the canal orifice was extruded by bending the obturator to right and left until separation took place and the core material was condensated with plugger by the same researcher (Hanna *et al.*, 2016).

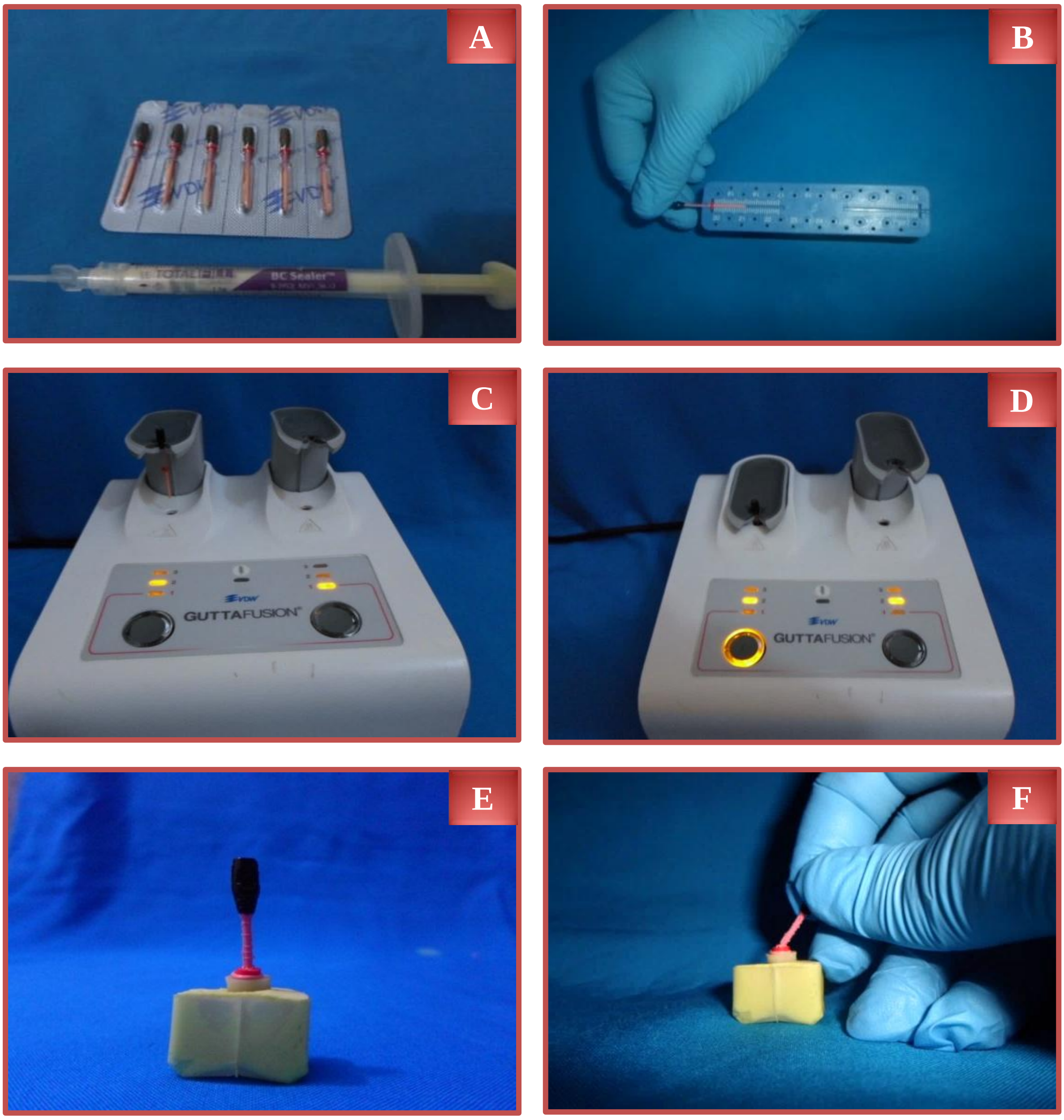

Figure 2.12: Obturation with GuttaFusion®: A: GuttaFusion® and TotalFill sealer, B: Endodontic ruler was used to measure the length of master cone, C: GuttaFusion® oven with GuttaFusion® before press the handle, D: GuttaFusion® oven with GuttaFusion® after press the handle E: GuttaFusion® was used to fill the canal, F: GuttaFusion® separation

Then, the root radiographed within their silicon rubber base mold to ensure adequate obturation (used periapical radiograph ready made film) as seen in Figure (2.13).

After that, heavy body impression material was used due to ease of removal of the root from this material; then, moistened gauze was used to wrap each root after removal from silicon rubber base impression material therefore; Afterward, all samples were stored in an incubator for 7 days at 100% humidity and 37 ◦ C to ensure complete setting of the sealer (Ertas *et al.*, 2014).

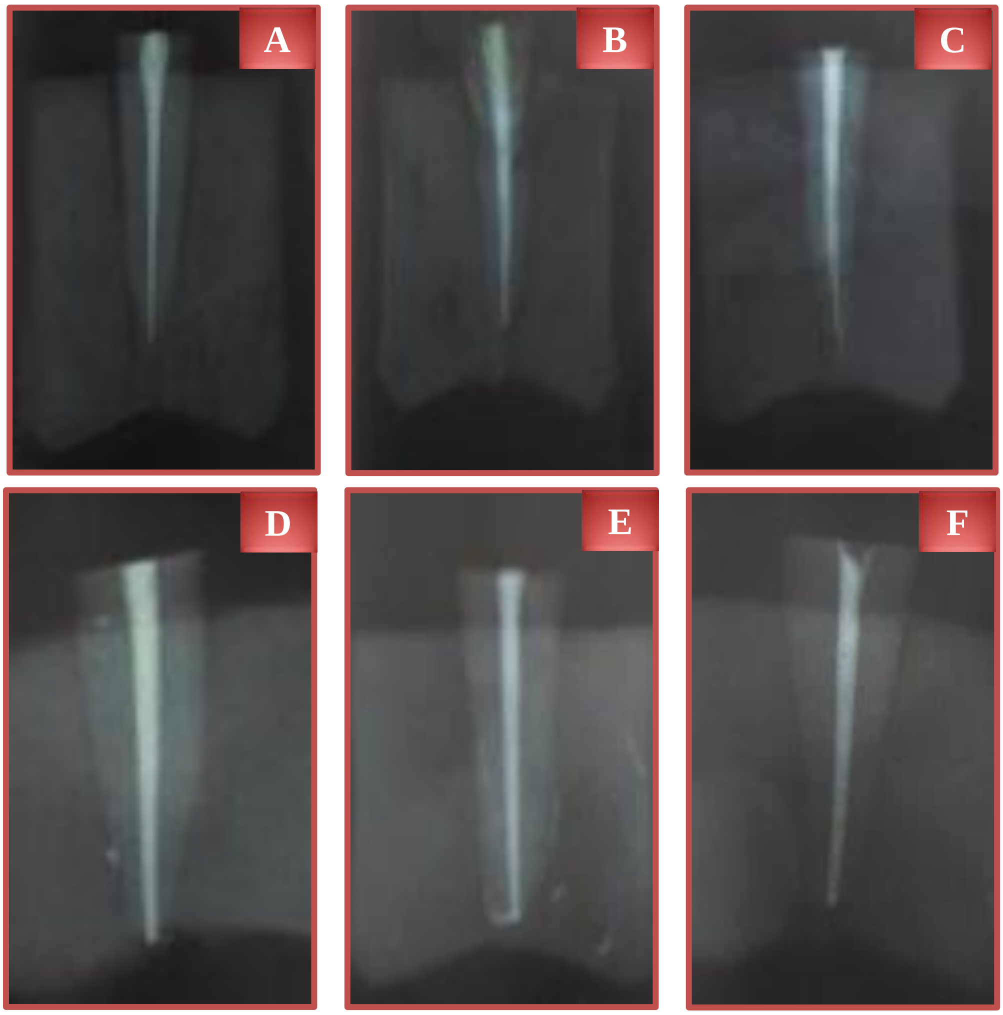

Figure 2.13: Radiographs of the obturated roots: A: WO instrumentation and single cone technique, B: PTN instrumentation and single cone technique, C: PTU instrumentation and single cone technique, D: WO instrumentation and GuttaFusion® obturation, E: PTN instrumentation and GuttaFusion® obturation, F: PTU instrumentation and GuttaFusion® obturation.

2.2.6. Root Sectioning:

After the period of storage, the samples were embedded in clear orthodontic resin (Al-Kahtani *et al.*, 2013). Firstly, a cylinder mold with four holes was prepared from silicon material (OOMOO® Smooth-On, East Texas); each hole has 25mm depth and 10 mm width. In general, the cylinder width was 6 cm as seen in Figure (2.14)

Figure 2.14: Mold made from silicon material

The root was inserted in the base (Centre) of each hole with the aid of dental surveyor; however, the coronal surface of the root was fixed with sticky wax to the dental surveyor to ensure accurate and central placement of the root and perpendicular sectioning to the long axis of the roots. As recommended by the manufacturers, the acrylic was prepared by mixing powder and liquid. Evaporation of monomer was prevented by covering the jar. Afterward, the material was left for few minutes to reach the workable stage. Then, the freshly prepared cold cure acrylic paste was loaded in cylinder hole and pushed with spatula to ensure the acrylic block devoid from any void and complete coverage of the root with acrylic as seen in Figure (2.15) (Pane *et al.*, 2013)

Then the acrylic sample was removed from the silicon cylinder and the root with acrylic was cut off using diamond disc after complete setting of the acrylic samples.

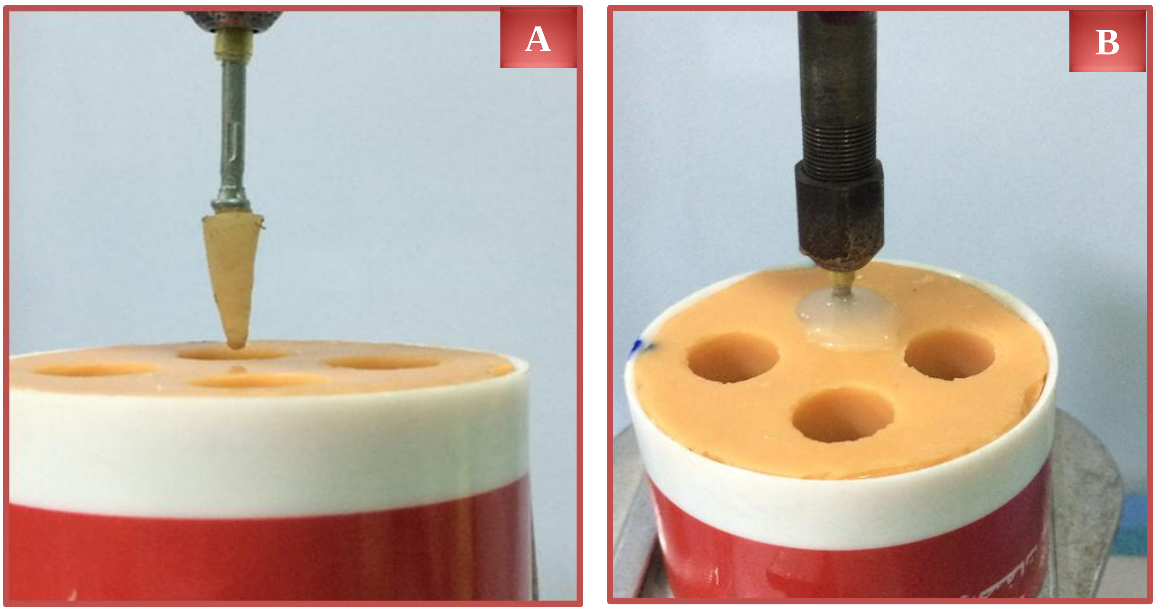

Figure 2.15: Central placement of the root in a cylinder hole with the aid of dental surveyor A: Before placement of the root, B After placement of the root

A waterproof pen was used to mark the acrylic blocks to serve as a guide in sectioning of the roots so, three points were put on the acrylic block at 3, 7 and 11 mm from the apex. Then, at each third of the root, the slices were deteremined with digital caliper and marker. After that, sectioning was carried out with the diamond disc (0.7 mm thickness) as seen in Figure (2.16) to obtain 2 mm cut; since cuts were made at the line of the marker. The first section was 3-5 mm from the apex. After that, sectioning took place to obtain the middle section (7-9 mm from the apex) and the coronal section (11-13mm from the apex). So, the specimen were at 3-5 mm, 7-9 mm and 11-13 mm from the apex. Therefore, each specimen was 2mm in thickness as seen in Figure (2.17) and (2.18). However, diamond disc was used for sectioning in the presence of water coolant to reduce the smear formation during the sectioning process (Ehsani *et al.*, 2013).

Figure 2.16: Measuring the thickness of the disc with digital caliper

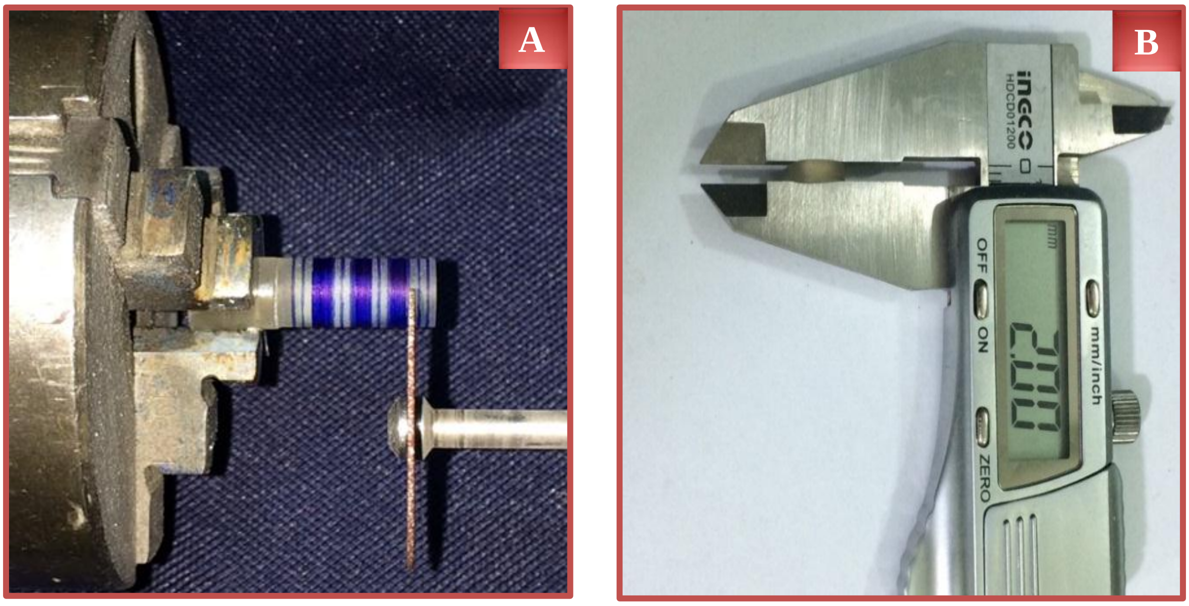

Figure 2.17: Sectioning of the specimen: A: Cutting the speicman with a disc, B: Measuring the specimen with digital caliper

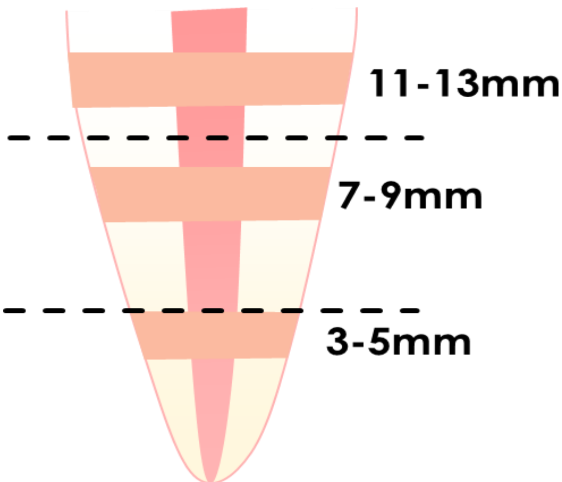

Figure 2.18: A diagram showed the position of each section

All samples were examined after sectioning and any slice with oval shaped canal or voids within the sealer should be discarded. Each sample of each group was numbering to calculate the bonded surface area of the canal by using Auto CAD program while the apical side of each speciman was marking by marker.

At that time each group consisted of 30 specimens with a total of 180 specimens included in the study. Some of the specimens were showed in Figure (2.19).

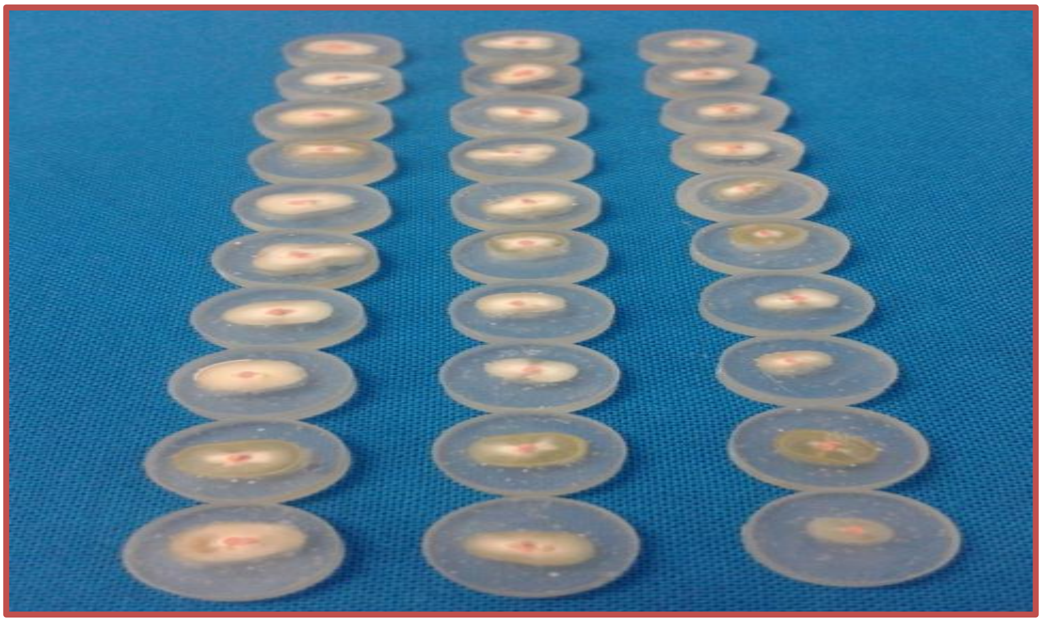

Figure 2.19: Some of root sections

2.2.7. Push-out bond strength test

The push out test was performed by applying the load to the apical aspect of each slice via a cylindrical plunger mounted on a universal testing machine managed by computer software.

However, the root canal in all groups was obturated with size #40 master core; three plungers were prepared to face the apical side of each section which was smaller than the coronal side however, the canal walls should not be touched by plungers. However, a plunger should cover most of the filling material with nearly 0.2 mm away from the dentine wall. Plunger with diameter 0.8 mm was used in the coronal slices, while the plunger used in the middle slices was 0.6 mm in diameter and its diameter in the apical slices was 0.4mm as seen in figure 2.20 (De-Deus *et al.*,2013).

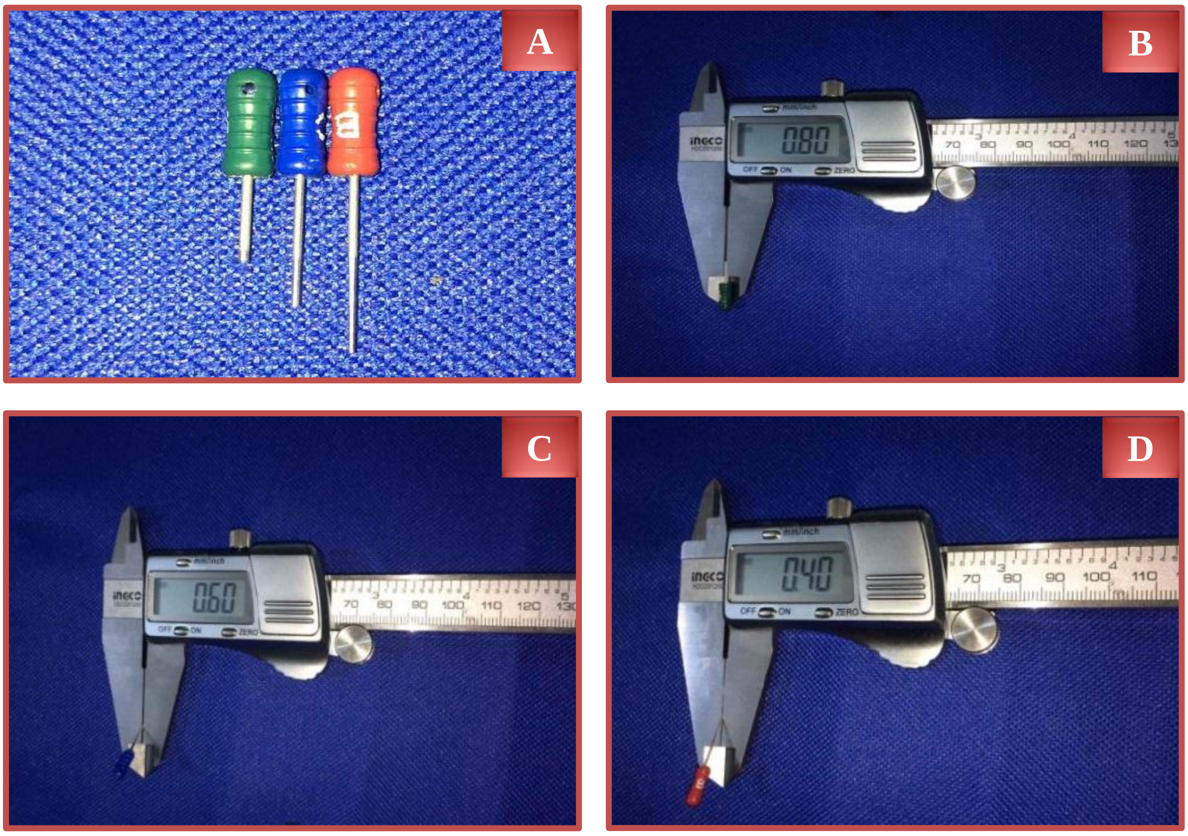

Figure 2.20: Plunger used for push-out test, A: Plunger with three tip diameter, B: 0.8 mm for coronal slice, C:0.6 mm for middle slice, D: 0.4mm for apical slice

The researcher prepared cylindrical molds to serve as a base for a specimen that made from acrylic rod (ready made) with a 3 cm width and 2.3 cm height. Circular depression was made on the upper aspect of the base which was 1cm in diameter (nearly the same diameter of the specimen) and this circular depressions has a central hole that extend along the base hight of 3mm in diameter to provide clearance for the obturatring material when it dislodged from the root slices. However, this base was clear so the gutta-percha easily showed when it pushed out the canal as seen in Figure 2.21

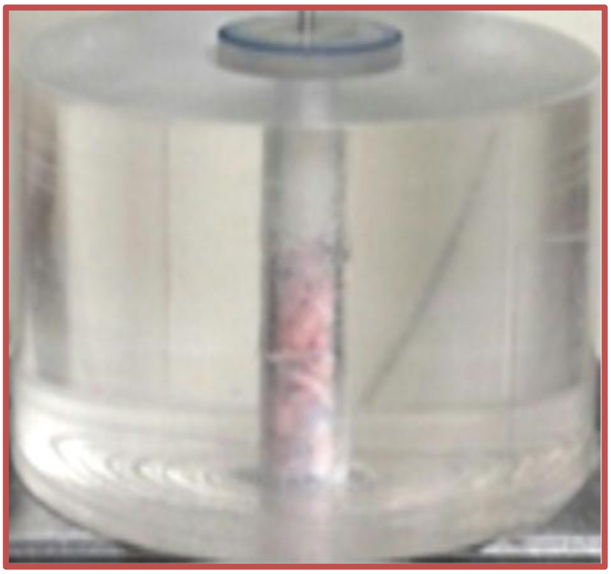

Figure 2.21: Holding the specimen with the cylindrical Base

The push-out force was applied to the obturating material in an apical-coronal direction by a universal testing machine (Figure 2.22). The plunger was centralized on the apical surface of each slice with the aid of magnification lens to avoid its contact with dentine wall. Firstly, the area of the bonded area was calculated by auto CAD program in University of Technology in Baghdad. Fristly, the apical and coronal side of each slice were digitally photographs and from each photograph calculated the circumference of the obturation material of the coronal aspect and apical aspect and then used this rule to calcutate the bonded surface area:

$$\text{bonded surface area} = 0.5 * (circumference\ of\ coronal\ aspectof\ obturation\ material + circumference\ of\ apical\ aspect\ of\ obturation\ material) * thickness$$

Next, Micro push-out testing was performed at a crosshead speed of 0.5 mm/min until bond failure occurred **(Türker *et al.*, 2013).** Push-out strength data were determined in MPa by dividing the force in Newton by the bonded surface area in mm^2 **(Gessi *et al.*, 2005).**

Push-out strength= force/ bonded surface area

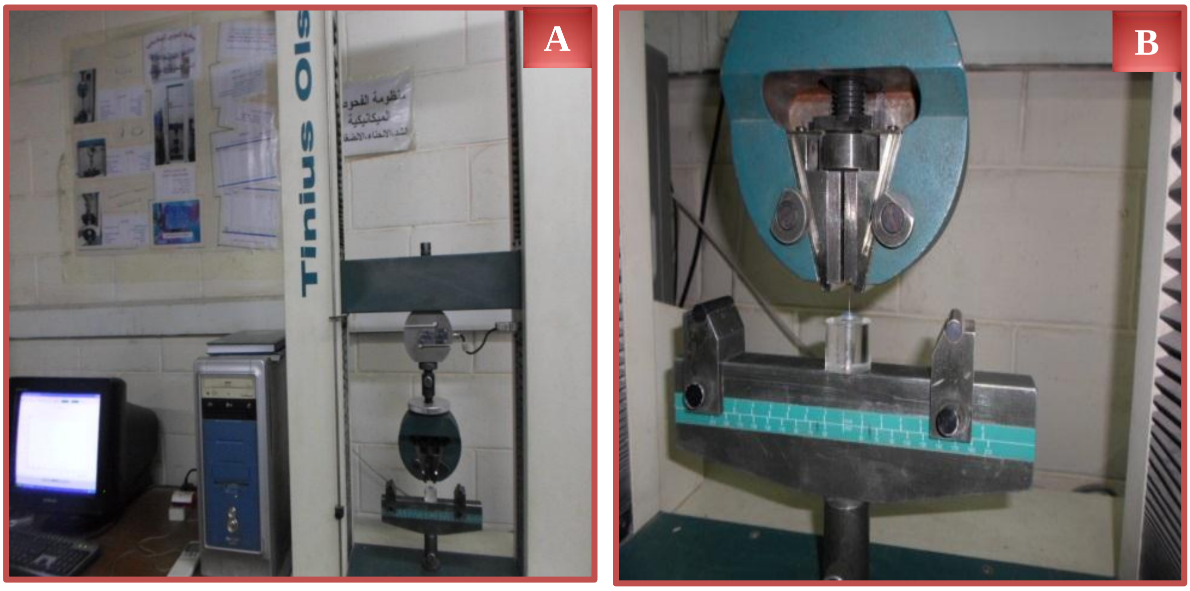

Figure 2.22: Universal testing machine A: Universal testing machine with computer software, B: during push-out test

2.2.8. Analysis of failure mode:

Stereomicroscope (25 X) was used to analyze the samples after complete the push-out strength testing, for determination the failure type as followings: **(El Sheikh *et al.*, 2011)**

- If the failure was either at sealer/gutta-percha or between the sealer/dentine, it was termed as (Adhesive failure)
- If the failure was within either the core material or the sealer, it was termed as (Cohesive failure)
- If the failure had both cohesive and adhesive type, it was termed as mixed failure.

2.2.9. Statistical analysis:

SPSS (statistical package of social science) software was used to analyze the collected data. However, the following statistics were used in this study:

A- Descriptive statistics: including mean, standard deviation, standard error, minimum and maximum, statistical tables and graphical presentation by bar charts.

B- Inferential statistics which include:

1- Analysis of variance of mean (Two ways ANOVA): to test any statistically significant difference among all groups.

2-Least significant difference test (LSD): was performed for multiple comparisons between groups.

P value >0.05 NS (Non significant)

P value $\leq$ 0.05 S (Significant)

P value <0.001HS (Highly significant)

RESULTS

CHAPTER THREE

Results

3.1. Push-out bond strength for all groups

The push-out bond strength values of all groups were measured in (MPa) and presented in appendices I, II, III, IV, V, VI.

3.1.1. Descriptive statistics

The descriptive statistic includes mean values, standard deviation (SD), maximum (Max) and minimum (Min) of push-out bond strength for two obturation systems at different levels Table (3.1) and Figure (3.1).

Table 3.1: Descriptive statistics of push out bond strength (Mean, ±SD, Max, Min) of tooth sites by groups and subgroups

Site	Group	Subgroup							
		Single cone (A)				Gutta Fusion (B)			
		Min.	Max.	Mean	±SD	Min.	Max.	Mean	±SD
Apical	WaveOne	1.87	2.80	2.46	0.30	3.30	4.26	3.61	0.29
	ProTaper Next	1.23	2.09	1.65	0.33	3.19	4.06	3.47	0.28
	ProTaper. Universal	1.74	2.65	2.22	0.33	4.22	5.20	4.51	0.30
	Total	1.23	2.80	2.11	0.47	3.19	5.20	3.86	0.55
Middle	WaveOne	2.32	3.24	2.65	0.29	3.45	4.37	3.94	0.34
	ProTaper Next	1.46	2.29	1.88	0.31	3.36	4.31	3.78	0.34
	ProTaper Universal	2.00	2.96	2.40	0.36	4.46	5.37	4.84	0.30
	Total	1.46	3.24	2.31	0.45	3.36	5.37	4.19	0.57
Coronal	WaveOne	2.54	3.28	2.82	0.28	3.55	4.40	4.02	0.29
	ProTaper Next	1.56	2.36	1.96	0.27	3.75	4.38	4.00	0.22
	ProTaper Universal	2.25	3.14	2.68	0.30	4.55	5.35	5.02	0.29
	Total	1.56	3.28	2.49	0.47	3.55	5.35	4.35	0.55

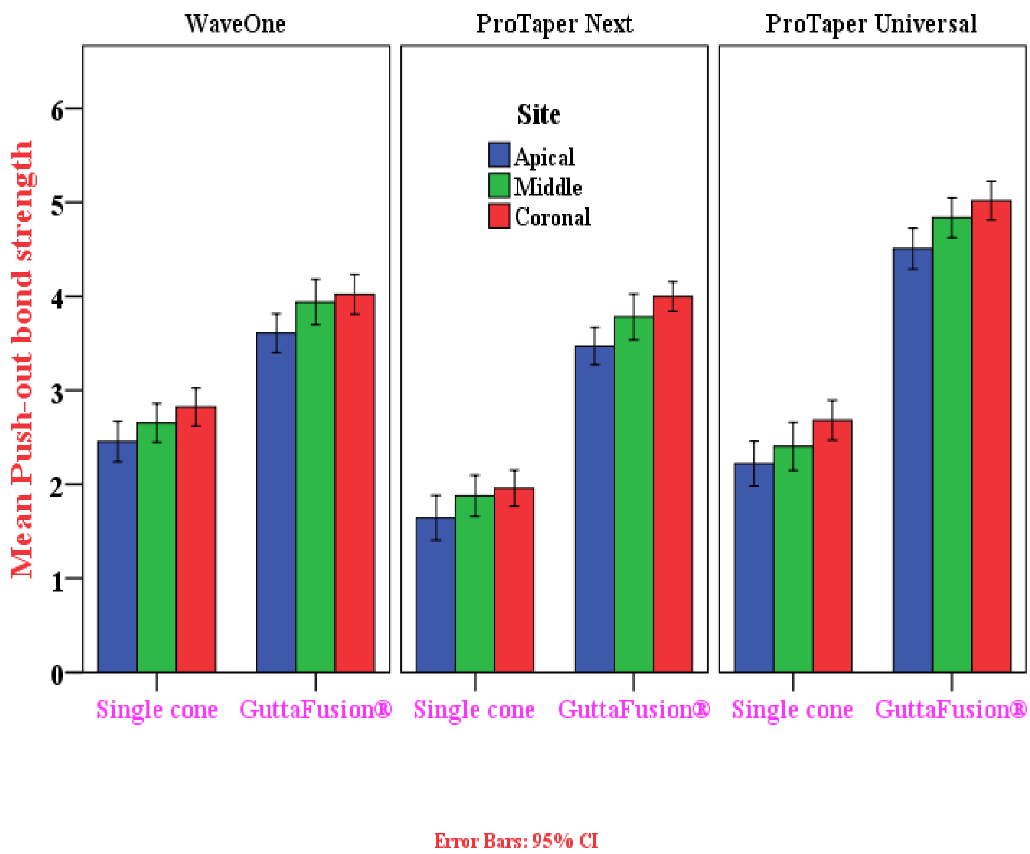

Figure 3.1: The mean values of push-out bond strength of two obturation systems

From Table and Figure (3.1) both the highest and lowest mean value of push-out bond strength of two obturation systems were seen at (TotalFill BC sealer and GuttaFusion® after instrumentation of canal with ProTaper Universal)(5.35) and (TotalFill BC sealer and single cone obturation technique after instrumentation of canal with ProTaper Next)(1.23) respectively and the mean value of the coronal third of each group showed a high value of bond strength than the middle third, and the latter showed a high value of bond strength than the apical third.

3.1.2. Inferential statistics:

Analysis of variance (two ways ANOVA) test was used to determine the presence of statistically significant differences for the mean value of push-out bond strength of two obturation systems after canal instrumented with different rotary system at different sites Table 3.2. From Table (3.2) two ways ANOVA test showed that among each site, there is highly significant effect of group, subgroup (P<0.001) and interaction effect of Group* Subgroup on the variability of push-out bond strength.

Table 3.2: Comparison of the push-out bond strength among Groups and subgroups at different sites by using two ways ANOVA

Site	ANOVA	Sum of Squares	Df	Mean Square	F-test	Sig.
Apical	Group	6.564	2	3.282	34.930	.000
	Subgroup	46.253	1	46.253	492.302	.000
	Group * Subgroup	3.252	2	1.626	17.305	.000
Middle	Group	6.318	2	3.159	30.396	.000
	Subgroup	52.659	1	52.659	506.731	.000
	Group * Subgroup	3.295	2	1.648	15.854	.000
Coronal	Group	7.579	2	3.789	49.718	.000
	Subgroup	51.764	1	51.764	679.159	.000
	Group * Subgroup	3.481	2	1.741	22.838	.000

For multiple comparisons between groups; the least significant difference test (LSD) was used.

From Table (3.3) and Figure (3.2) by using two way ANOVA and LSD comparison, It was found at each site that PTU Groups had the highest mean of push-out bond strength (3.36, 3.62, 3.85) followed by WO Groups (3.03, 3.29, 3.42) . While, PTN Groups(2.55, 2.83, 2.97) showed the lowest push-out out bond strength with highly significant difference among them. The number mentioned from apical to coronal.

Table3.3: Effect of Groups (Instrumentation techniques) on variability of push-out bond strength by using two way ANOVA and LSD test at each site.

Site	Group	Mean	SE	F	Df	Sig.	LSD
Apical	WaveOne [1]	3.032	.069	34.930	2	0.000	1 X2=0.000
	ProTaper Next[2]	2.558	.069				1X3=0.001
	PT.Universal[3]	3.364	.069				2X3=0.000
Middle	WaveOne [1]	3.297	.072	30.396		0.000	1 X2=0.000
	ProTaper Next[2]	2.830	.072				1X3=0.002
	PT.Universal[3]	3.621	.072				2X3=0.000
Coronal	WaveOne [1]	3.423	.062	49.718		0.000	1 X2=0.000
	ProTaper Next[2]	2.979	.062				1X3=0.000
	PT.Universal[3]	3.850	.062				2X3=0.000

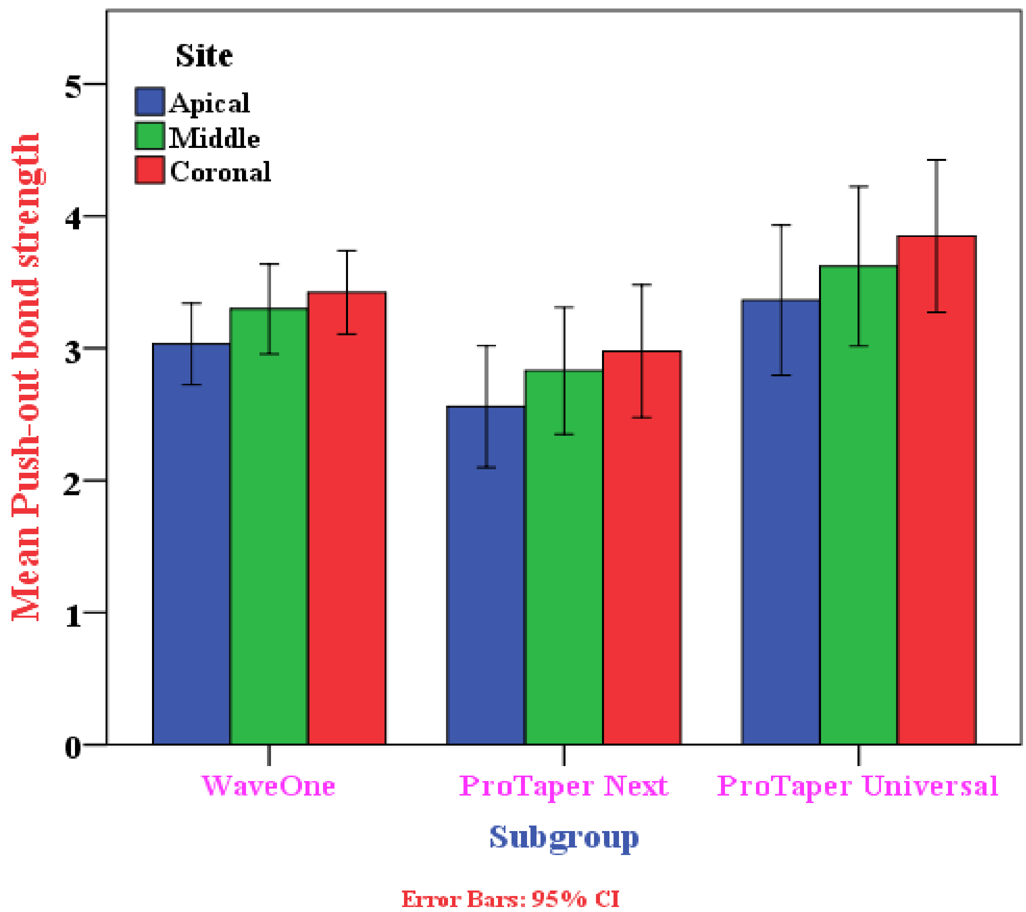

Figure 3.2: Push-out bond strength means among Groups at different levels with their error bars.

From Table (3.4) and Figure (3.3), it was found that at each site GuttaFusion® has the highest bond strength mean than single cone obturation technique with highly significant difference.

Table 3.4: Effect of subgroups (obturation techniques) on variability of push-out bond strength by using two ways ANOVA at each site

Site	Subgroup				F	Df	Sig.
	Single cone		GuttaFusion®				
	Mean	SE	Mean	SE			
Apical	2.107	.056	3.863	.056	492.302	1	0.000
Middle	2.312	.059	4.186	.059	506.731		0.000
Coronal	2.488	.050	4.346	.050	679.159		0.000

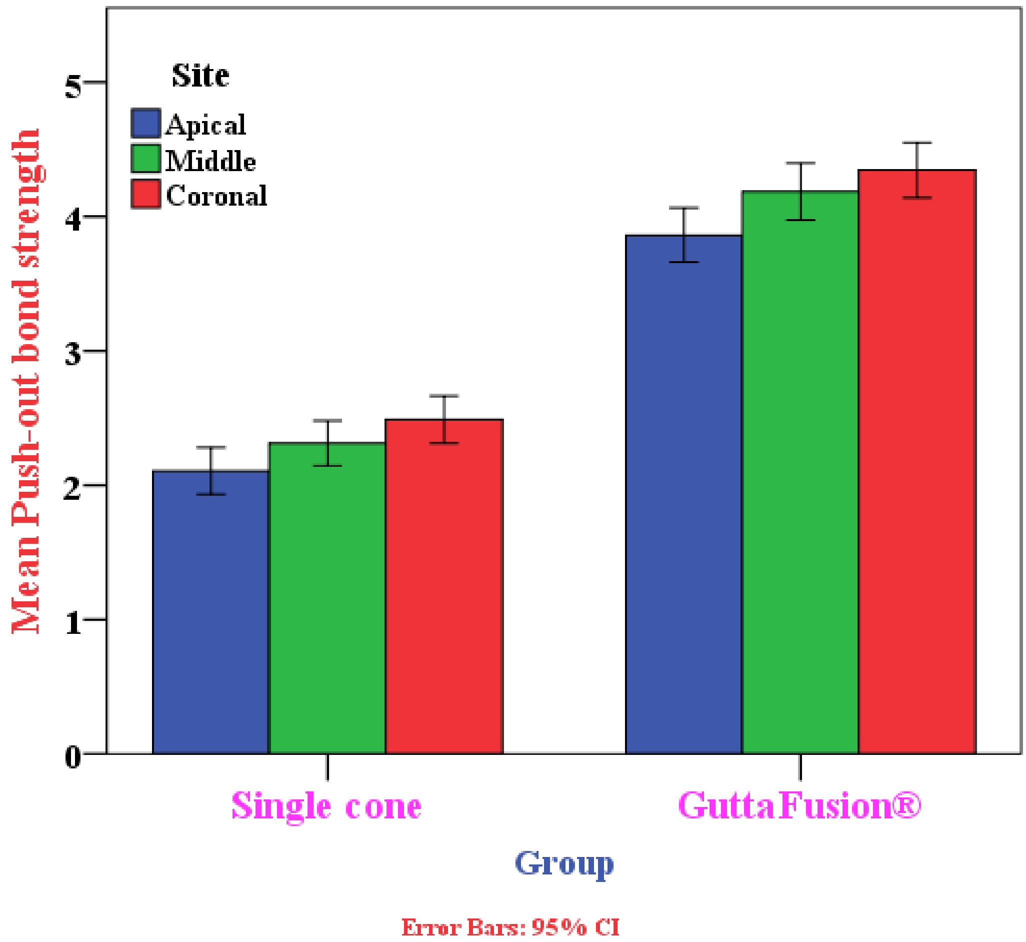

Figure 3.3: push-out bond strength means among subgroups with their error bars

Table 3.5: Push-out bond strength variability of Groups in each subgroup by site by using two ways ANOVA

Site	Group	Subgroup							
		Single cone				GuttaFusion			
		Mean	SE	F	Sig.	Mean	SE	F.	Sig.
Apical	WaveOne	2.455	.097	18.484	0.000	3.609	.097	33.751	0.000
	ProTaper Next	1.645	.097			3.471	.097		
	PT. Universal	2.220	.097			4.508	.097		
Middle	WaveOne	2.654	.102	15.056	0.000	3.940	.102	31.194	0.000
	ProTaper Next	1.879	.102			3.781	.102		
	PT. Universal	2.404	.102			4.837	.102		
Coronal	WaveOne	2.824	.087	28.233	0.000	4.022	.087	44.322	0.000
	ProTaper Next	1.959	.087			3.999	.087		
	PT. Universal	2.682	.087			5.017	.087		

In Table (3.5), at each site and in single cone subgroup, WaveOne system showed the highest mean value of push out bond strength followed by ProTaper Universal system while ProTaper Next system was the least with highly significant difference. While when the obturation material was GuttaFusion®, ProTaper Universal system showed the highest mean value of push-out bond strength followed by WaveOne system while ProTaper Next system was the least with highly significant difference.

The least significant difference test (LSD) was used; for multiple comparisons between groups.

The result of LSD test showed that at each site and each Subgroup; there was highly significant difference between Groups except between WO and PTU in single cone obturation technique and WO and PTN in GutaFusion® however the results were found to be statically not significant as seen inTable(3.6) and Figure (3.4).

Table 3.6: LSD tests for push-out bond strength among Groups by subgroups at three sites

Site	Subgroup	Group	Group	Sig.
Apical	Single cone	WaveOne	ProTaper Next	.000
			ProTaper Universal	.092
		ProTaper Next	ProTaper Universal	.000
	GuttaFusion	WaveOne	ProTaper Next	.319
			ProTaper Universal	.000
		ProTaper Next	ProTaper Universal	.000
Middle	Single cone	WaveOne	ProTaper Next	.000
			ProTaper Universal	.089
		ProTaper Next	ProTaper Universal	.001
	GuttaFusion	WaveOne	ProTaper Next	.275
			ProTaper Universal	.000
		ProTaper Next	ProTaper Universal	.000
Coronal	Single cone	WaveOne	ProTaper Next	.000
			ProTaper Universal	.255
		ProTaper Next	ProTaper Universal	.000
	GuttaFusion	WaveOne	ProTaper Next	.853
			ProTaper Universal	.000
		ProTaper Next	ProTaper Universal	.000

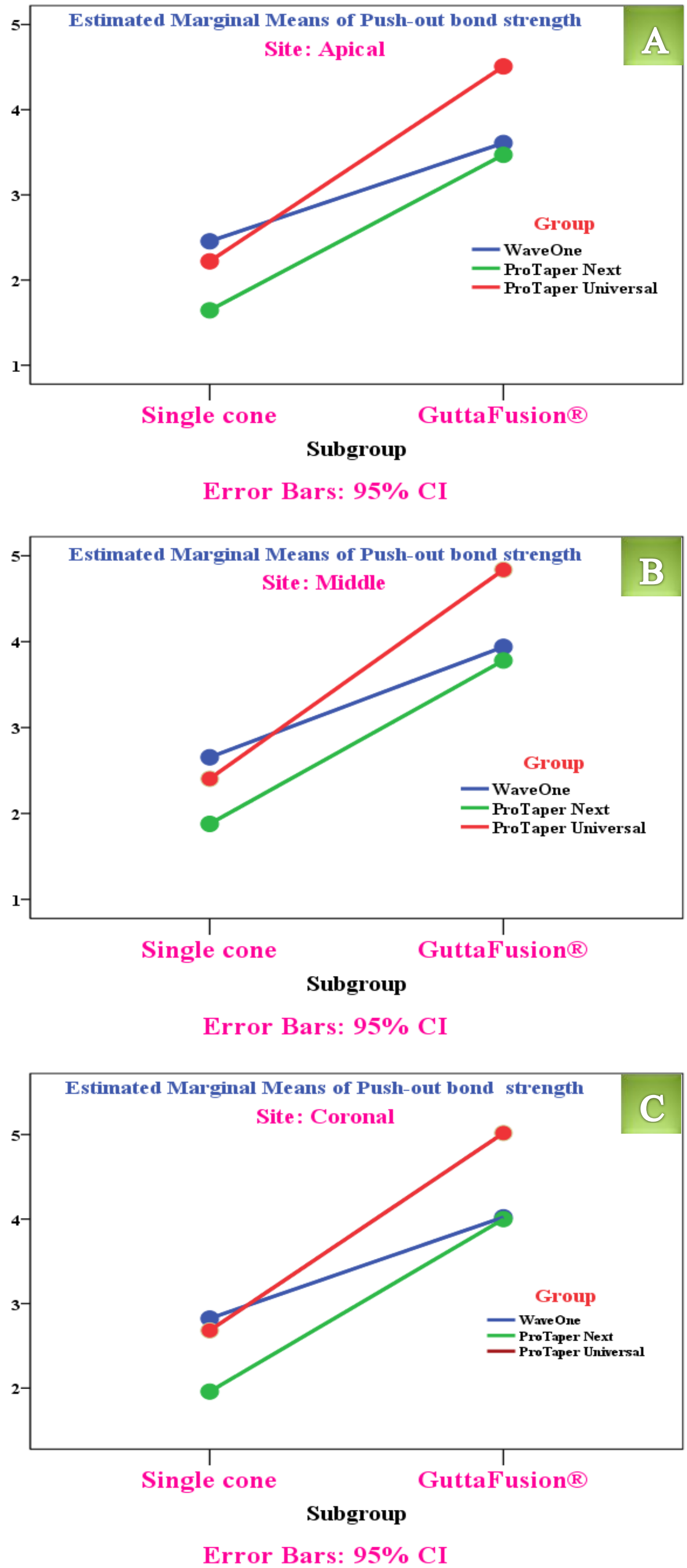

Figure 3.4: Interaction effect of Estimated Marginal Means (EMMEANS) of push-out bond strength by groups and subgroups at each site (A: apical, B: middle and C: coronal)

3.2. Analysis of failure modes

The analysis for failure modes for push-out bond strength is presented in table 3.8. The predominant mode of failure in groups I A, II A, III A (single cone obturation technique) was adhesive mainly at dentine/sealer interface. While the predominant mode of failure in groups I B, II B, III B (GuttaFusion ® obturation) was mixed as seen in Figure (3.5).

Table 3.8: Failure mode for different groups

Groups	Adhesive	Cohesive	Mixed
Group I A	57%	20%	23%
Group II A	73%	5%	22%
Group III A	70%	10%	20%
Group I B	16%	21%	63%
Group II B	26%	30%	44%
Group III B	13%	30%	57%

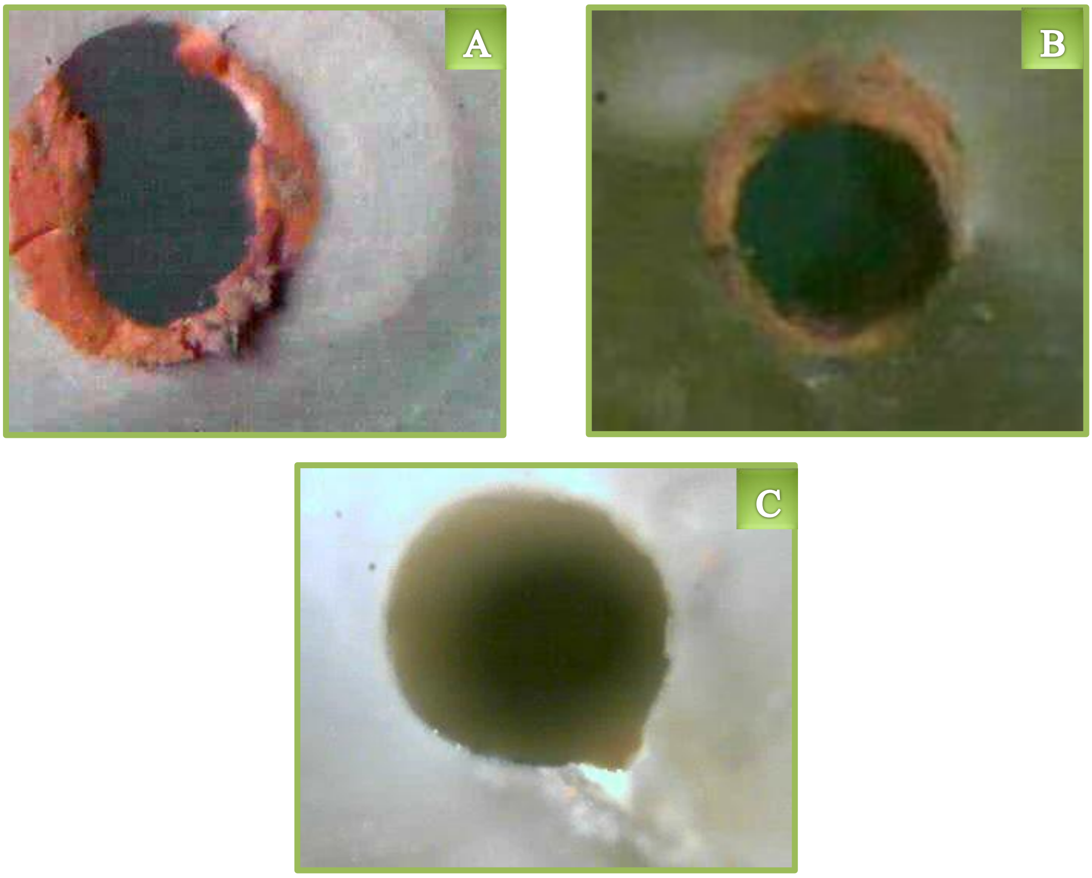

Figure 3.5: Stereomicroscope was used to show the failure mode: A: Mixed failure, B: Cohesive failure, C: Adhesive failure

DISCUSSION

CHAPTER FOUR

Discussion

Three-dimensional seal of root canal space is one of the fundamental goals of successful endodontic treatment, therefore various obturation materials and techniques were developed to fill the root canal system and obliterate any voids or space within it in order to prevent reinfection of the tooth with bacteria and their by-product (Schilder, 2006). In this study, push out bond strength was used; since this test is a more suitable for evaluation the bond strength of intra-canal obturation materials and also, assessment of regional differences in bond strength among root levels (Goracci *et al.*, 2004). In other words, this test is more popular in measuring the effectiveness of adhesion between dentine wall and intra-canal material (Amara *et al*., 2012).

The irrigation regimen

The root canals in the current study was irrigated with 5.25% NaOCl, 17% EDTA and distilled water. The correlation of both NaOCl and EDTA solutions is considered to be the gold base in the chemo-mechanical preparation of the root canal system (Dagna *et al.*, 2011). This irrigation regimen was used commonly in endodontic treatment since; NaOCl was used to dissolve the organic component of root canal space. While, EDTA was used to remove the smear layer by acting on its inorganic components and decalcified the peritubular and intertubular dentine (Goldman *et al.*, 1982; wadhwani *et al.*, 2011).

Rotary instrumentation

In this study, rotary instrumentation over ISO manual technique was used due to its simplicity and time saving (Schäfer *et al.*, 2013). Therefore, three rotary systems were employed for preparation the root canals including, WaveOne (reciprocation motion), ProTaper Next (continuous rotation) and

ProTaper Universal (continuous rotation) due to its improved cutting efficiency and safety in comparison with stainless steel files (Yin *et al.*, 2008). After completion of instrumentation, the canal was ready for obturation.

TotalFill BC sealer used for all groups

Next, TotalFill BC sealer (Brasseler, Savannah, USA) was used in this study since, it has been reported to have hydrophilic properties that were enabling the sealer to use moisture of the root canal for completing setting reaction (Pawar *el al*., 2014).

In addition, BC was adapted perfectly to dentine and formation a chemical bond with inorganic phase of dentine (Malhotra *et al.*, 2014). This sealer was used to fill the gaps between the core material and the dentine; so, this was reducing leakage and contamination of endodontic space (Ørstavik, 2005; Li *et al.*, 2014a). For obturation purpose, an inert material (gutta-percha) is widely used in conjunction with sealer in order to obtain fluid-tight seal of the root canal space (Ørstavik, 2005).

Core material

In this study, half of the groups was obturated with single cone technique, that uses larger master cones that closely match the geometry of the last rotary NiTi files that used during instrumentation, thereby it was facilitating the root canal filling since, it was a simple and efficient way (Nagas *et al.*, 2009; Pereira *etal*. 2012). Another technique for obturating the rest of the groups was carrier based obturation technique. Previously, this technique was providing 3D seal of the root canal space by using metal cores such as gold wire, silver points and endodontic files covered with heat softened gutta-percha. Nowadays, plastic obturators or crosslinked gutta-percha was replaced the metal core of carrier based obturation material to increase the adaptation of gutta-percha to dentine and to enhance gutta-percha flow into accessary canals so, the other half of the groups was obturated using Gutta Fusion® and (Li *et al.*, 2014b).

Storage of the specimen after obturation

Then, Storage of the groups for 7 days did not influence the resistance to dislodgement only to complete the setting reaction of the BC sealer (Collares *et al.*, 2013).

Sectioning of each root into three slices

Next, preparation of specimen was performed by sectioning the root into thin slices of 2mm thick from different sites (Kremeier *et al.*, 2008; Demiryüirek *et al.*, 2010; Barbizam *et al.*, 2011).

There was increasing in dislodgement resistance of specimen that had thicknesses more than 1 mm compared with specimens had 1 mm or less thickness because the frictional resistance of material retained in the endodontic space increased with increasing thickness of speciman (Nunes *et al.*, 2008, Hashem *et al.*, 2009, Shokouhinejad *et al.*, 2010, Baldissera *et al.*, 2012, Neelakantan *et al.*, 2011). In the present study, the root had a constant length of 15 mm therefore; three root slices have been sectioned from each third of the root, apical, middle and coronal. When the thickness of specimen was 1mm or less; there is increased chance of sealer detachment during sectioning. Therefore, each section has standardised thickness of 2mm to prevent premature debonding of sealer (Gesi *et al.*, 2005; Kremeier *et al.*, 2008).

Push-out test

The push-out bond strength test was used to obtain bond strength of filling material at different levels within the root, since; it was regarded as preferable method for obtaining the adhesion strength of oturation materials to the canal wall (Amara *et al.*, 2012).Push-out force was applied on the filling material in an apico-coronal direction by different punch sizes used at three sites of each root. The difference in the pin size was (0.4, 0.6, 0. 8) to provide coverage of as much as possible of the obturation material (nearly 0.2mm away from the dentine wall) (De-Deus *et al.*, 2013). Then, the punch was mounted on a Laryee universal testing machine. After centralization of the punch with aid of magnification lens; the punch was faced apical surface of the sample to prevent contact with the root wall. The preferred crosshead speed was 0.50 mm/min, due to its better results since, high crosshead speed might result in low push-out bond strength (Sirisha *et al.*, 2014).

The highest and lowest mean value of push-out bond strength of obturation systems

The result of the present study showed that, the highest and lowest mean value of push-out bond strength of obturation systems were Group III B (obturation with BC sealer and GuttaFusion® after instrumentation of the canal with PTU) and Group II A (obturation with BC sealer and single cone obturation technique after instrumentation of the canal with PTN) respectively. This could be related to greater adaptation of gutta-percha to the irregularities of the endodontic space in the carrier based obturation techniques; since, these irregularities filled with both the sealer and gutta-percha (Bhandi, 2013).

Effect of Groups and subgroups on bond strength of obturation materials

In general, there is highly significant effect of Groups (WO, PTN and PTU instrumentation system), subgroups (single cone and GuttaFusion® obturation material) and interaction effect of Group by Subgroup on the variability of push-out bond strength.

Effect of Groups (instrumentation techniques) on bond strength of obturation materials

It was found that at each site (PTU groups) have the highest mean of push-out bond strength followed by (WO groups). While (PTN groups) were showed the lowest push-out bond strength with highly significant difference among them (regarding the instrumentation techniques).

However, each system has different fabrication materials, movements, and cross section that effected on the push-out bond strength. In general, both WO and PTN systems are made of M-wire while, PTU is made of conventional Ni-Ti wire; WO works in a reciprocating mode and only one file may need to complete canal preparation (Berutti *et al.*, 2011). In contrast, to PTN (rotational movement) is a successor to PTU (rotational movement). In addition, Both systems consist of series of files that used sequentially to prepare the canal and PTN rotated in a unique asymmetric motion like a snake due to its cross section of an off-centred rectangle (Elnaghy *et al.*, 2014).While, the cross section of WO is modified convex triangular apically and convex triangular cross section coronally (Webber *et al.*, 2011) and the cross section of PTU is convex triangular (Ruddle, 2001).

Effect of subgroups (obturation techniques) on bond strength of obturation materials

In general, it was found that the groups obturated with carrier based obturation materials (Guttafusion®) showed a highly significant difference in comparison to the cold obturation material (single cone gutta-percha). This could be explained that carrier based obturation technique allowed thermoplastic gutta-percha to flow better into lateral canals and at the same time, this filling had fewer voids and it could be replicated the root surface better than single cone technique. More recent studies reported that canals obturated with carrier based techniques had the highest gutta-percha content within the obturated canal system (Li *et al.*, 2014b).

On the other hand, single cone obturation technique could be attributed to the decreased sealing ability of obturation materials when the thickness of sealer increased regardless of the instrumentation technique (Monticelli *et al.*, 2007; Robberecht *et al.*, 2012).

Single cone obturation technique

Initialy, single cone obturation technique was consisted of placement of master cone obturation material for matching the last file taper and size used in instrumentation (Monticelli *et al.*, 2007).This technique might be led to the higher film thickness of BC sealer of single cone obturation technique when compared with carrier based obturation techniques. This increasing in the thickness of the sealer was leading to decrease the bond strength of the obturation material (Bürklein *et al.*, 2012).

Group I A showed highly significant difference in comparison with Group II A

In this study, Group I A (WO instrumentation, single cone obturation material) showed highly significant difference in comparison with Group II A (PTN instrumentation, single cone obturation material). It might be due to the effect of instrumentation technique on the bond strength of the obturation materials since, the taper of WO Large file (black) 40/.08 is 8% and this was different from taper of PTN that 6%. This leading to increase in the final preparation taper than PTN final tapers; thus improves irrigant replacement. In addition, enlargement the apical portion of the root (especially the last 3 mm) to an 8% taper is important to enhance removal of smear layer with the use of EDTA to enhance a best sealing ability of obturation materials and long-term successful treatment (Boutsioukis *et al.*, 2010; Zogheib *et al.*, 2012).Another reason might be related to the movement of file since,single file reciprocation has better performance than continuous movements with multi-file system (ex, PTU and PTN) (Giuliani *et al.*, 2014) or this result could be related to modified convex triangle cross section of WO that provides the perfect shape for 3-D obturation with gutta-percha (Letters et al., 2005); while the cross section of PTN is off-centred rectangle that produce a unique asymmetrical rotary motion; only contacts the wall at two points (www.tulsadental.dentsply.com).

Group III A showed highly significant difference in comparison with Group II A

While, Group III A (PTU instrumentation, single cone obturatation material) showed highly significant difference in comparison with Group II A (PTN instrumentation, single cone obturation material). Although, the taper (06) and the continuous rotation were the same for both (PTU, PTN).The different results could be related to difference in cross section or mode of rotation since, PTU has a convex triangle cross section and symmetric rotation while, PTN has a patented, off-centred rectangular cross-section and asymmetric 'Swaggering' rotation (www.dentsply.com.au). Another explanation for this, PTN had fewer number of instruments that required to completely prepare root canals than PTU (Ruddle *et al.*, 2013) resulting in some debris accumulation within the canal that might occlude some of the dentinal tubules and therefore, it reduced the formation of sealer tag within the dentinal tubules and inturn, it reduced the sealing ability of filling materials. This result disagree with (Li *et al.*, 2014 c) who indicate that the PTN is more efficient in cleaning and shaping the canal than PTU. In addition, Kustarci has reported that if the file insertion time increased (PTU); more debris would be compacted more tightly along dentine walls and then difficult to be flushed out of the canal compared with PTN (Kustarci *et al.*, 2008).

Group I A showed no significant difference in comparison with Group III A

Also, the present study found that Group I A (WO instrumentation, single cone obturation material) showed no significant difference in comparison with Group III A (PTU instrumentation, single cone obturation material). This might be related to absence of a significant difference with 0.06 and 0.08 taper (Zogheib *et al.*, 2012).

GuttaFusion® obturation material

Moreover, carrier based obturation material had good adaptation and allowed the penetration of gutta-percha within the root irregularities and accessory canal. Therefore, in general regardless of instrumentation technique, the groups that obturated with GuttaFusion® showed highly significant difference of push-out bond strength mean values in comparison with single cone techniques due to formation of numerous gutta-percha tags inside the dentinal tubule leading to interactions with root canal (Migliau *et al.*, 2014). This disagreed with Lawson who found sealer evaporation by heat generated during obturation technique might resulting in a highly viscous sealer which had a limited flow capacity into the dentinal tubules therefore, lower bond strength value of obturation material was expected (Lawson *et al.*, 2008).

Group III B showed highly significant difference in comparison with Group I B

Moreover, Group III B (PTU instrumentation, GuttaFusion®obturation material) showed higher push-out bond strength mean value in comparison with Group I B (WO instrumentation, GuttaFusion® obturation material). Thus might be due to use of multiple files in some cases to shape and finish the canal completely resulting in more cleaned canal (Ruddle *et al.*, 2013). Therefore, this could lead to open dentinal tubules leading to its penetratation by the hydrophilic sealer that utilized moisture of the canal for completing setting reaction (Pawar *et al.*, 2014). This result disagreed with Boutsioukis *et al.*,in 2010 who indicated that an increasing in root canal taper (in case of WO) enhanced irrigant replacement whilest reduced the risk for irrigant extrusion compared to the tapered root canals with a smaller apical preparation size(in case of PTU) . Also this result disagreed with Zogheib *et al.*, in 2012 who found that enlarging the apical third (last 3 mm) of root canals to an 8% taper is necessary to produce a better sealing capacity therefore; it was leading to long-term success for our root canal obturations and this result could be related to their differences in mode of movement, cross section and also differences in taper on single files as discussed above

Group I B showed no significant difference in comparison with Group II B

In contrast, there were no significant difference between Group I B and II B (canal instrumented with WO and PTN and obturated with Gutta-Fusion®) because in previous study on the shaping ability of rotary instrumentation; it was found that there was no significant differences between ProTaper Next and the WaveOne (Ozsu *et al.*, 2014). This agreed with Zogheib *et al.*, in 2012 who found that there was no significant difference between 0.06 and 0.08 tapers. This disagreed with Wu *etal* 2000 who found that reciprocation has better performance than continuous movements (Wu *et al.*, 2000).

Group III B showed highly significant difference in comparison with Group II B

While, Group III B (PTU instrumentation, GuttaFusion® obturation material) showed highly significant difference in comparison with Group II B (PTN instrumentation, GuttaFusion® obturation material). This might be related to difference in cross section or mode of rotation since, PTU has a convex triangle cross section and symmetric rotation while, PTN has a patented, off-centred rectangular cross section and asymmetric 'Swaggering' rotation (www.dentsply.com.au). Another explanation for this, PTN had fewer numbers of instruments that are required to completely preparing root canals than PTU (Ruddle *et al.*, 2013). In addition, the tapers are not fixed over the active portion of any given PTN files; X1 and X2 have an increasing taper at the apical section while a decreasing percentage taper at the coronal section whereas the PTN X3, X4, and X5 files have a fixed taper from D1 to D3, then a decreasing percentage tapered design over the rest of their active portions (Capar *et al.*, 2014) unlike the PTU in which, the shaping files show increasing percentage tapers over the length of their cutting blades whereas, the finishing files have progressively decreasing percentage tapers from D4 to D14(Berutti *et al.*, 2003). All these differences led to difference in values of push-out bond strength of PTN and PTU.

This result disagreed with (Kustarci *et al.*, 2008) and (Li *et al.*, 2014 c) who indicate that the PTN is more efficient in cleaning and shaping the canal than PTU.

Comparison among the bond strength of three third slice of each root

In this study, it was found that, at each subgroup, the lowest values of bond strength in the apical third, independent of whichever instrumentation and obturation technique used. However, in apical portions of the root canals, there is reduction in the amount and diameter of the dentinal tubules (Al Kadhi, 2008; Ebrahimi *et al.*, 2014). Another reason for this was limited accessibility to the irrigating solutions for removing the apical debris leaving part of the smear layer that impaired the penetration of sealer into the dentinal tubules and reduced the contact of obturation material with dentine walls (Prado *et al.*, 2012; Tuncel *et al.*, 2015) .In addition, difficultly of sealer to flow along the entire root length; so,it might not wet the dentine completely,this in turn was reducing the bond strength of apical third of the canal (Weis *et al*. 2004).

Therefore, the apical third showed the lowest value of push-out bond strength for all groups; this disagreed with Babb *et al.*, in 2009 who found that variations in density of tubules along the root canal are insufficient to alter the adhesion of the sealing material.

Independent of the preparation technique and obturation material, the coronal third showed the highest value of bond strength than the middle third and the apical third showed the lowest value of bond strength due to differences in the internal anatomy of each level of the root canal as explained above (Al Kadhi, 2008; Ebrahimi *et al.*, 2014); this finding disagreed with Sly *et al.*, in 2007 who found that the location in the canal, does not provide significant differences.

Failure mode determination

After that, each slice was examined under stereomicroscope with magnification X 25 to determine the mode of failure. In general, adhesive failures were observed either when the dentine surface was completely without a sealer or when the dentine surface was completely covered by the sealer; cohesive failures occurred within the filling material or the sealar and mixed failures occurred when both adhesive and cohesive modes were found.

In this study the predominant mode of failure for canal instrumented with different rotary system (WaveOne, proTaper Next, ProTaper Universal system and obturated with single cone gutta percha) was adhesive failure at dentine /

sealer interface. this may be related to the amount of sealer that was high relative to cone volume since, the sealer was not compacted against the root canal wall resulting in void that may be facilitated the separation of sealer from dentine surface (Robberecht *et al.*, 2012). In addition, the same groups showed fewer mixed failures and cohesive failure mainly within the sealer when compared to the other techniques.

However, the predominant mode of failure for canal instrumented with previous rotary systems and obturated with GuttaFusion® was mixed; this may be due to a thin layer of sealer that might be incorporated in the dentinal tubule with slight expansion due to the hydrophilic nature of BC sealer (Pawar *et al.*, 2014) and the thermoplastic gutta percha that penetrated into the dentinal tubules resulting in well adapted root obturations (Migliau *et al.*, 2014). Creation of monoblock concept led to high bond strength which needs more force to remove the obturation material from the canal surface leading to mixed failure followed by cohesive failures mainly within the GuttaFusion® due to pentration of TotalFill BC sealer in the dentinal tubule and then that adhesive failure. Adhesive failure was less frequent at all the sections of all groups that obturated with GuttaFusion®.

CONCLUSIONS & SUGGESTIONS

CHAPTER FIVE

Conclusions and Suggestions

5.1 Conclusions

Under the circumstances of the present study, the following results have been found:

1. Highly significant difference was seen among WO, PTN and PTU (the main groups) regardless of obturation materials.
2. Push out bond strength is affected by the obturation technique. GuttaFusion® (carrier based obturation materials) showed the highest bond strength mean values than single cone obturation material regardless of instrumentation techniques.
3. Both the instrumentation technique and obturation materials ere significantly affecting the push-out bond strength values of root fillings. The highest value was recorded in root canals instrumented with PTU System and filled with GuttaFusion® and BC sealer, whereas the lowest bond strength was noted in canals instrumented with PTN and filled with single cone gutta-percha and BC sealer
4. The coronal third slices of the groups showed a highest value of bond strength in comparison to the middle thirds and apical thirds. In the meantime, the middle third slices showed bond strength higher than the apical thirds for all groups.

5.2 Suggestions

It is in need to carry out further studies on the following topics:

1. The effect of instrumentaion of oval shaped canals with different kinematic motions on the dislocation resistance of self expandable obturation system versus GuttaFusion®.
2. A volumetric analysis using Cone Beam Computed Tomography of single cone obturation technique versus GuttaFusion®.
3. Study the effect of push out bond strength of other type of carrier based obturation system.
4. The effect of irrigant solutions on the push-out bond strength of GuttaFusion® versus single obturation technique.
5. A scan electron microscopy evaluation of dentinal adaptation of root canal filled with single cone obturation technique versus GuttaFusion®.

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APPENDICES

Appendix I: Push out bond strength values in MPa of group I A (WaveOne gutta percha and TotalFill sealer) after instrumented with WaveOne files

Tooth No.	Apical	Middle	Coronal
1	2.44	2.82	2.55
2	2.25	2.50	2.61
3	2.78	2.62	3.05
4	2.17	2.91	2.54
5	2.75	2.32	2.78
6	2.80	2.43	2.59
7	2.48	2.59	2.82
8	2.63	3.24	3.28
9	2.38	2.78	3.26
10	1.87	2.33	2.76
Mean	2.46	2.65	2.82

Appendix II: Push out bond strength values in MPa of group II A (ProTaper Next gutta percha and TotalFill sealer) after instrumented with ProTaper Next system

Tooth No.	Apical	Middle	Coronal
1	1.52	1.74	1.56
2	2.09	1.54	2.36
3	1.26	1.76	1.70
4	1.98	1.46	1.89
5	1.38	2.23	2.34
6	1.65	1.61	1.68
7	1.41	2.29	2.01
8	2.05	1.92	1.98
9	1.88	1.99	1.95
10	1.23	2.25	2.12
Mean	1.64	1.88	1.96

Appendix III: Push out bond strength values in MPa of group III A (ProTaper universal gutta percha and TotalFill sealer) after instrumented with ProTaper Universal system

Tooth No.	Apical	Middle	Coronal
1	2.18	2.08	2.78
2	2.38	2.00	2.86
3	1.74	2.86	3.08
4	2.65	2.54	2.33
5	2.42	2.96	2.54
6	1. 95	2.76	2.46
7	1.77	2.19	3.14
8	2.48	2.40	2.75
9	2.59	2.03	2.63
10	2.04	2.22	2.25
Mean	2.22	2.40	2.68

Appendix IV: Push out bond strength values in MPa of group I B (Gutta Fusion® and TotalFill sealer) after instrumented with WaveOne files

Tooth No.	Apical	Middle	Coronal
1	4.26	4.37	4.28
2	3.45	3.77	3.98
3	3.72	4.21	4.19
4	3.39	4.25	3.78
5	3.68	4.14	3.55
6	3.30	3.67	4.40
7	3.59	3.83	3.94
8	3.85	3.49	4.13
9	3.33	4.22	3.64
10	3.52	3.45	4.33
Mean	3.61	3.94	4.02

Appendix V: Push out bond strength values in MPa of group II B (Gutta Fusion and TotalFill sealer) after instrumented with ProTaper Next system

Tooth No.	Apical	Middle	Coronal
1	3.51	4.07	3.83
2	4.06	3.85	3.77
3	3.35	3.54	3.92
4	3.21	4.29	4.25
5	3.19	4.31	3.88
6	3.28	3.66	3.75
7	3.82	3.77	4.38
8	3.52	3.45	3.91
9	3.41	3.51	4.21
10	3.36	3.36	4.09
Mean	3.47	3.78	4.00

Appendix VI: Push out bond strength values in MPa of group III B (Gutta Fusion® and Totalfill Sealer) after instrumented with ProTaper Universal system

Tooth No.	Apical	Middle	Coronal
1	4.30	4.46	5.31
2	4.86	4.84	5.17
3	4.48	5.37	4.88
4	4.39	5.12	5.35
5	4.28	4.69	5.25
6	4.46	4.57	4.72
7	4.56	5.07	4.55
8	5.20	4.79	4.68
9	4.33	4.96	5.05
10	4.22	4.50	5.21
Mean	4.51	4.84	5.02

الخلاصة

ختم ثلاثي الأبعاد لنظام قناة الجذرهو أحد الأهداف الأساسية للمعالجة اللبية. وقد أجريت هذه الدراسة لتقييم قوة الدفع للخارج لقوة ارتباط أنظمة مختلفة استخدمت لختم القنوات الجذرية التي تم تحضيرها باستخدام ثلاثة أنظمة دواره مصنوعة من النيكل والتيتانيوم والتي تتضمن:
(WaveOne, ProTaper Next, ProTaper Universal).

ستين جذرمقلوع من الضواحك السفلية تم قطعه و ترك الجذر مع طول 15ملم. ثم قسمت الجذور بشكل عشوائي إلى ثلاث مجموعات رئيسية، كان هناك عشرون جذر في كل مجموعة رئيسية، والتي تم تحضيرها باستخدام انظمه دوارة مختلفة وفقا للمجموعات: تم تحضيرأسنان المجموعة الرئيسية الأولى مع WaveOne والمجموعة الرئيسية الثانية تم تحضيرها باستخدامProTaper Next اما المجموعة الرئيسية الأخيرة فقد حضرت باستخدامProTaper Universal .لكل مجموعة تم استخدام نفس نظام الغسل باستخدام 3 مل من هيبوكلوريت الصوديوم بتركيز5.25% ثم يتم غسلها ب3 مل من 17٪ EDTA لمدة دقيقة واحدة ثم تغسل القنوات ب3 مل من الماء المقطر.

بعد ذلك تقسم المجموعة الأولى بشكل عشوائي إلى مجموعتين فرعيتين لكل منهما عشرة عينات، و تملأ المجموعة الفرعية الاولى مع تقنية المخروط الاحادي وتملأ المجموعة الفرعية الثانية مع®GuttaFusion وأيضا قسمت المجموعة الثانية إلى مجموعتين فرعيتين، و تملأ المجموعة الفرعية الاولى مع تقنية المخروط الاحادي ، بينما تملأ المجموعة الفرعية الثانية مع GuttaFusion® . ثم تقسم المجموعة الثالثة عشوائيا إلى مجموعتين فرعيتين. واحدة تملأ مع تقنية المخروط الاحادي و الاخرى تملأ مع GuttaFusion® .

بعد ذلك، وضعت الجذور في الحاضنة لمدة سبعة أيام، ثم صبت الجذور بمادة الاكريليك الشفافة وكل جذر قطعت منه ثلاثة اجزاء ذات سمك 2ملم (القمي والوسطي و العنقي)وثبتت هذه العينات على قاعدة صنعت من الاكريلك و سلط عليها الحمل في الاتجاه القمي-العنقي باستخدام جهاز اختبار عالمي بسرعة 0.5 ملم/ دقيقة. تم احتساب اعلى قوة ارتباط لمادة الحشوة قبل ازاحتها التي تقاس بوحدة ميغاباسكال عن طريق قسمة قوة الحمل على المساحة التي يتم احتسابها باستخدام برنامج(AutoCAD) .

تم إجراء التحليل الإحصائي باستخدام (Two ways ANOVA and LSD)وأظهرت النتائج اختلاف كبير بين المجموعات الرئيسية التي حضرت مع انظمة دوارة مختلفة (WaveOne, ProTaper Next, ProTaper Universal)، وكانت هناك اختلافات كبيرة جدا بين التقنيتين المستخدمة لملأ قنوات الجذورالمجموعات الفرعية (مخروط احادي مقابل® Gutta-Fusion) و

بالنسبة لاجزاء الجذر فقد اظهر الجزءالعنقي قيمة اعلى لقوة ارتباط حشوة الجذر من الجزء الوسطي وأظهر هذا الأخير قيمة عالية لقوة ارتباط حشوة الجذرمن الجزء القمي.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بغداد
كلية طب الأسنان

دراسة مختبرية لتاثير تحضير القنوات الجذرية مع ثلاثه انظمة دواره مصنوعة من نيكل تيتانيوم على مقاومة انفصال ماده ®GuttaFusion بالمقارنة مع المخروط الاحادي

رسالة مقدمة الى
مجلس كلية طب الأسنان / جامعة بغداد كجزء من متطلبات نيل شهادة الماجستير
في معالجة الاسنان

من قبل
رفل سعيد امين
بكالوريوس في طب وجراحة الفم والاسنان

بأشراف
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دكتوراه معالجة اسنان

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