Self adjusting file

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THE SELF-ADJUSTING FILE

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"Knowledge has to be improved, challenged,

and increased constantly, or it vanishes."

Peter Druck

Contents:

LIST OF ABBREVIATIONS AND ACRONYMS

SICE Second International Congress of Endodontics

AAE American Association of Endodontics

CDMD Council on Dental Materials and Methods

ADA American Dental Association

ISO International Organization for Standardization

SAF self-adjusting file

RPM revolutions per minute

NiTinol Nickel Titanium Navol Ordinance Laboratory

RTN rotary nickel titanium system

EDTA ethylendiaminetetraacetic acid

NaOCl sodium hypochlorite

MTAD mixture of tetracycline, an acid and a detergent

CHX chlorhexidine

PGFA gutta-percha filled area

Micro-CT micro-computed tomography

VRF vertical root fracture

1. INTRODUCTION

Even though it may seemed that endodontics wasn't science with high jumps in development due to the lack of visibility and unique shape and configuration of root canals, the recent decade has produced great changes which resulted in new instruments and concepts on how to adequately prepare root canal for filling. Over the past few decades, instrument design has been considerably modified, as well as alloy processing. These discoveries have altered the whole perspective of root preparation even though the biological objectives of root canal treatment have not changed over the years. The introduction of NiTi rotary system represented a major leap in the development of endodontic treatment, with a wide variety of sophisticated instruments presently available. Today, there is a new generation of rotary instruments which have made one step forward with their design, concept, and perhaps even changed the whole base of future endodontics and what it should be. It is called self-adjusting file and its name gives a clue about where future endodontics is headed (1).

2. THE AIM OF THIS WORK

The aim of this thesis is to provide an insight on how the development of endodontic instruments in dental medicine went from simple hand pieces to machine driven instruments, and to give detailed information about the new technique of cleaning and shaping root canals.

The first part of the thesis walks you through the history of endodontic instruments, their design, configuration and their purpose, and the second part concerns the self-adjusting file, a new discovery in endodontic treatment. This thesis sums it all up, from general specification to the studies based on clinical trial and comparisons with well-known ProTaper and ProFile.

It also serves as a reminder on how important and necessary irrigation is, and its activity in the root canal walls, smear layer and microorganisms that can diminish our efforts in making it suitable environment for good filling.

As we all know, not every tooth is a textbook example, so this thesis draws attention to all kinds of pulp anatomy, from calcifications inside pulp chamber to varieties in directions, lengths, diameters, relationships in multi-rooted teeth and how this can make our work a lot harder. With new instruments like SAF these once called problems can now become manageable obstacles.

3. HISTORY OF ENDODONTIC INSTRUMENTS

The manufacture of the first instruments for endodontic use dates back to 1875. These early instruments, made by hand from thin steel wires, performed more or less the function of modern barbed broaches. In accordance with the lack of sophistication of that time, more importance was given to obturation of the canal space rather than to cleaning and advancements in bacteriology at the turn of the last century. With the arrival of dental radiology, local anesthesia and advancements in bacteriology at the turn of the last century, a new era opened in endodontic therapy. In 1932, G. V. Skillen stated that it was necessary to curette the canal walls to remove the pulp debris. His belief was that all residual tissue became degenerative and would lead to failure of canal therapy. Skillen and his contemporaries were occupied with establishing standards for the methods of root canal cleaning, which at the time had not been standardized. Grove designed “standardized instruments and gold cones”. His intent was to prepare the radicular canal space according to precise norms of shape, size, and conicity. Jasper developed silver cones corresponding to the sizes of the files that were in use at that time. In 1955 Ingle was the first to finally express the need for the standardization of canal instruments, which he advocated again in 1958 at the Second International Conference of Endodontics (SICE) in Philadelphia. In 1961, Ingle established a basic, standardized shape for endodontic instruments and a standardized endodontic technique using newly-designed obturation instruments and materials. He substituted stainless steel for carbon steel and introduced color-coded instruments that were smaller (06 and 08) and larger

(110-150) than those in use at the time. In 1965, the American Association of Endodontists (AAE) adopted the terminology and nomenclature of the proposed standardized system, and in June 1976 the Council on Dental Materials and Devices (CDMD) of the American Dental Association (AAD) approved the specification # 28, which established the classification norms, required physical properties, procedures for investigation, sampling tests, and preparation for the distribution of root canal files and reamers. The system of standardization and agreements among the various manufacturers to observe them is, therefore, a fairly recent development (2). Edward Maynard has been credited with the development of the first endodontic hand instrument. Notching a round wire (in the beginning watch springs, later piano wires), he created small needles for extirpation of pulp tissue. In 1885, the Gates Glidden drill were introduced and in 1915 the K-files. In 1889, William H. Rollins developed the first endodontic hand piece for automated root canal preparation and used specially designed needles with a 360 degree rotation and speed limited to 100 rpm in order to avoid instrument fracture. In 1892, Oltramare used fine needles with a rectangular cross-section, mounted into a dental hand piece and passively introduced into the root canal to the apical foramen, followed by the rotation started. The Cursor filing contra-angle was developed in 1928 by W&H (Burmoos, Austria) which combined rotational and vertical motion of the file. In 1958, W&H Company started marketing The Racer-hand piece in Europe with a vertical file motion. Later, in 1964, MicroMega (Besancon, France) started marketing the Giromatic in Europe with a reciprocal 90 degree rotation. Endodontic hand-pieces such as the Endolift (Kerr, Karlsruhe, Germany) with a combined vertical and 90 degree rotational motion and similar devices were marketed during this period. A period of modified endodontic hand pieces began with the introduction of the Canal Finder System (now distributed by S.E.T., Grobenzell, Germany) by Levy. The Canal Finder was the first endodontic hand-piece with a partially flexible motion. The amplitude of the vertical file motion depended on the rotary speed and the resistance of the file inside the root canal, and changing into a 90 degree rotational motion with increasing resistance. It was an attempt to make the root canal anatomy or at least the root canal diameter one main influencing factor on the behavior of the instrument inside the canal. The Excalibur hand-piece (W&H), with laterally oscillating instruments, had a major impact on canal preparation. NiTi rotary instruments introduced later, use a 360 rotation at low speed and offer new perspectives for root canal preparation that have the potential to avoid some of the major drawbacks of traditional instruments and devices (3).

4. CLASSIFICATION OF ENDODONTIC INSTRUMENTS

Endodontic instruments are traditionally divided into four categories:

1. exploring
2. extirpating
3. enlarging (cleaning and shaping), and
4. filling

ISO-FDI (*Fédération Dentaire Internationale*) grouped root canal instruments according to their method of use:

Group I: *Hand use only* for example, K- and H-files, reamers, broaches etc.

Group II: *Latch type Engine driven*: same design as Group one but can be attached to hand-piece.

Group III: *Drills or reamers Latch type Engine driven* for example Gates-Glidden, Peeso reamers.

Group IV: *Root canal points* like gutta-percha, silver point, paper point.

Natural anatomy dictates the usual places for canals, but pulp stones, dystrophic calcifications and restorations can alter the actual configuration encountered (4).

4.1. ENDODONTIC EXPLORER

The endodontic explorer is used to locate orifices, and serves as a tool to remove calcification.

4.2. BARBED BROACH

The barbed broach is an extirpating, not an enlarging, instrument. It is formed from a tapered round shaft by lifting up portions of metal of the shaft almost at a right angle to the shaft. These elevated barbs engage the pulp tissue and remove it from the canal. In its use, the largest broach in size that will fit freely or loosely in the canal is selected.

A broach must not engage the canal walls as it is advanced, or the pressure on the barbs will flatten them against the shaft; as the instrument is withdrawn, the barbs will then embed themselves in the walls, making it difficult or impossible to remove the broach. Because the barbs are "nicked" out of the shaft this is an extremely fragile instrument, and will break easily if misused. It must fit loosely.

Files are the mos common instruments used for cleaning and shaping the root canal system. Traditionally they are manufactured from stainless steel in the form of a filament with a round cross-section. First, they are ground in such a way as to have a quadrangular cross-section and then twisted clock wise to achieve the definitive form. The number of spirals per mm (pitch) for stainless steel files can very slightly depend on the manufacturers but is always more (generally double) than that of the reamers; their blades are furthermore positioned perpendicular to the long axis of the instrument, giving files a particularly efficient cutting action during filing (5).

4.3. K-TYPE FILE

The K-type file was first introduced at the turn of the century (1901) and receiving its name from the holder of its original patent, the Kerr Manufacturing Company. The K-type file is manufactured by twisting or grinding a square or triangular tapered shaft so that the cutting edges are almost perpendicular to the long access of the instrument. The K-file works on the "pull" stroke,i.e., by scraping the canal walls as it is withdrawn from the canal. It is advanced to the full working length when rotated 1/4 to 1/2 turn clockwise, and withdrawn while being pressed against one of the walls. The process is repeated against each of the walls in turn until the canal is sufficiently enlarged to proceed to the next size instrument. It is preferable to utilize an instrument to the maximum extent possible before proceeding to the next instrument in the series. The file must be cleaned repeatedly during use (4).

4.4. REAMER

Reamers are generally obtained by twisting a steel wire with a triangular or quadrangular cross-section. Compared to K-Files, the reamers have less spirals per mm (about half) and a more acute blade cutting angle against the dentin. The main consequence of the different blade angle of the reamers with regard to the K-Files is their poor efficiency at cutting with a push and pull movement (filing); to be used correctly the reamers should be rotated in the canal so that the blades have a 90 degrees angle contact with the dentin. The correct action of these instruments is passive insertion to a depth permitted by the canal diameter, and a quarter clock-wise rotation with simultaneous extraction of a few millimeters. The cutting action takes place during the withdrawal phase. This movement is repeated a number of times without ever forcing the instruments during their insertion but engaging the dentin during rotation and removal from the canal. A rotation exceeding half a turn is not recommended as it could cause engagement and fracture inside the canal (5). The reamer must be in contact with the walls of the canal in order to be effective, but it must not bind or it may break. They tend to remain self-centered in root canal resulting in less chances of canal transportation (4).

4.5. HEDSTROEM FILES

The Hedstroem Files, or H Files, are obtained by microgrinding a conical steel or NiTi wire with a round cross-section. The cutting angle of the blades (helical angle) against the dentin is, for the Hedstroem, close to 90 degrees making this instrument particularly aggressive when using the push and pull (filing) action. The design of the blades is however also responsible for the structural weakness of the Hedstroem files when used in a rotational manner. This is due to the fact that the deep grinding of the surface has reduced the central mass of metal which determines the torsional strength of the instrument. The efficient cutting action of the H-Files seems to be superior to that of K-Files and this explains the popularity of this instrument, especially for circumferential filing of canals with oval or elliptical cross-section. The Hedstroem files are distributed by most manufacturers of endodontic instruments, with diameters and lengths regulated by the ISO standard (5).

The uniqueness of the design and the method of fabrication of the barbed broaches and rasps separates them from other intracanal hand instruments. They also differ from H-type and K-type instruments because of taper and length of the operating length of the shaft (10 mm). Barbed broaches are used primarily for the removal of intact pulp tissue. The instrument is introduced slowly into the root canal until gentle contact with the canal walls is made. It is rotated 360 degrees either clockwise or counterclockwise, to entangle the pulpal tissue in the protruding barbs. It is then withdrawn directly from the root canal. If the maneuver is successful, the entire pulp comes out. If the vital pulp is so inflamed that the gel-sol state of the ground substance has been altered by edema or the collagen fibrous network has been destroyed, it probably cannot be removed intact by a barbed broach. The instrument will only lacerate the already hemorrhagic tissues. Unless a necrotic pulp maintains a high degree of cellular or fibrous integrity, it will not lend itself to removal by the barbed broach. Because of these biological realities and the design of the broach, this instrument has minimal clinical practice use. Rasps, being similar in design to barbed broaches, but having shallower and more rounded barbs, produce rougher walled canal preparations than other instruments for canal enlargement and shaping. For this reason they have been superceded by H-type files (4).

4.6. ENGINE DRIVEN INSTRUMENTS

Traditional engine driven instruments are Gates-Glidden burs. The Gates-Glidden drills are steel instruments for the contra-angled hand-piece characterized by a long shank and an elliptical extremity which is flame-shaped with a “guiding” non-cutting tip. The Gates-Glidden drills are available in six sizes marked with circular notches on the part that attaches to the contra angled hand-piece; the Gates no. 1 has one notch, the no. 2 has two notches, and so on. The calibration of the Gates Burs is measured at the widest part of their elliptical portion; no. # 1 has a maximum diameter of 0.50 mm, which increases by 0.20 mm for each successive size, until no. 6 which has a maximum diameter of 1.50 mm. Burs which have flame shaped cutting point mounted on long thin shaft attached to a latch type shank (5). If its cutting tip jams against the canal wall, the fracture should occur at the junction of the shank and the shaft but not at the tip of the instrument. They can be used both in crown down as well as step back fashion (4).

Peeso reamers are rotary instruments used mainly for post space preparations. Disadvantages for using Peeso reamers are:

- They do not follow the canal curvature and may cause perforation by cutting laterally.
- They are stiff instruments.
- They have to be used very carefully to avoid iatrogenic errors.

When using stainless steel files, the occurrence of procedural errors cannot be avoided, especially in case of curved canal. Deviation from the original shape, ledge formation, zipping, stripping and perforation are common problems which are seen in such cases. But the superelasticity of NiTi alloy allows these instruments to flex more then stainless steel instruments before exceeding their elastic limit, thereby allowing canal preparation with minimal procedural errors. NiTi was developed by Buchler 40 years ago. NiTi is also known as NiTinol (NiTi Navol Ordinance laboratory in USA). In endodontics, the commonly used Niti alloys are called 55 NiTi nol (55% weight of Ni and 45% Ti) and 60 NiTi nol (60% weight of Ni and 40% of Ti). The first use of NiTi in endodontics was reported in 1988 by Walia et al. when a 15 No. NiTi was made from orthodontic wire and it showed superior flexibility and resistance to torsional fractures (4).

Properties of Niti Alloys:

- ✓ Shape Memory
- ✓ Superelasticity
- ✓ Low modules of elasticity

- ✓ Good resilience
- ✓ Corrosion resistance
- ✓ Softer then stainless steel

Superelasticity and shape memory of NiTi alloys is present because of phase transformation in their crystal structures when cooled from a stronger, high temperature form (Austenite) to a weaker, low temperature form (Martensite). This phase transformation is chiefly responsible for the above mentioned qualities.

Over the last few years great amount of rotary nickel titanium system (RTN) have been made available. Although no system is perfect, if used in a proper way, it can result in desired canal shape. Various rotary nickel titanium systems available in the market are ProFile, ProTaper, Greater Taper Files, Quantec, Light Speed System, K3 system, HERo 642, RaCe and Real World Endo Sequence file system (4).

4.7. PROFILE

ProFile instruments made by Tulsa Dental were one of the first NiTi instruments available commercially. This system was introduced by Dr. Johnsson in 1944. The instrument set consists of orifice shapers (19mm long files with 5–8% conicity), the conical ProFile 06 with a 6% conicity in sizes 15–40, as well as the ProFile 04 with a conicity of 4% in sizes 15–90. Orifice shapers are used for the instrumentation of the coronal third of the root canal. The ProFile 06 instrument with a length 21 or 25mm is used for instrumentation of the middle third. Instrumentation of the apical segment is accomplished with the ProFile 04 files (21, 25, and 31 mm).

The instruments have a U-shaped cross-sectional profile and “radial lands”. These keep the instruments centered within the canal and enable easy smoothing of the canal walls. They prevent any binding or catching/sticking in dentin. The smooth, non-cutting tip serves to guide the file within the canal without scratching or gouging. The ProFile instruments must always be coated with a lubricant and between each change of instruments the canal must be copiously rinsed with 5% NaOCl solution. The ProFile instruments are used with a slight in-and-out movement, with a hub motion of no more than 2 mm and with only a slight application of force. ProFile instruments can only be used in combination with a motor that has a torsion limiter (e.g., ATR Technica)with low rpm (250–350). This will prevent over-twisting of the instrument and resultant fracture. No ProFile instrument should not be used more than 10 times (4).

4.8. PROTAPER

ProTaper instruments have a very unconventional shape. They combine several (ascending) conicities in a single file. There are three shaping files for coronal expansion and three finishing files for shaping the apical region. The diameter of the instruments at the tip of the working portion is between 0.17/0.19 and 0.20 mm for the shaping files, with 0.20/0.25/0.30 mm for the finishing files. In contrast to other types of instruments, the ProTaper files exhibit conicities between 2 and 19% in a single file. In the shaping files, the gradient toward the instrument tip is descending, and with the finishing files ascending. Up to finishing file 3, all instruments exhibit a triangular cross-sectional profile with convex cutting edges. The cross-section of file F3 is characterized by a modified triangular form with concave surfaces, but does not otherwise differ significantly from the other files. All instruments exhibit a rounded, non-cutting tip; the cutting edges of the working area extend almost to the tip. Because of the changing conicities, the tangent angle varies considerably, between 20 and 30 degrees. However, it increases in all instruments from the instrument tip to the coronal end of the working portion. In contrast to the other two nitinol instrument types, ProTaper instruments have the important advantage that even during initial instrumentation of the coronal root canal segments, widening up to the size of the corresponding Gates-Glidden drills 4–5 (sizes 110– 130) can be achieved; this significantly simplifies further apical instrumentation, as well as the subsequent filling of the canal via gutta percha condensation. The files are inserted into the canal using gentle in-and-out movements with the amplitude of about 1 mm; the files must be cleaned frequently, because large amounts of dentin are removed during initial instrumentation. The removed dentin can accumulate between the cutting edges and may lead to wedging of the file within the canal. Cleaning with sterile gauze and frequent rinsing of the canal with NaOCl are necessary. Cleansing of the root canal surface by instruments with a U-shaped cross-section and "radial lands" (ProFile, GT-Rotary) provides better results when compared to the FlexMaster and ProTaper systems with the conventional triangular cross-section. The U-shaped cross-section evacuates dentin chips more effectively and, in addition, the improved centering of the instruments provides efficient cleansing, without creating a pouch-like expansion at the critical apical region (6).

5. IRRIGATION

According to an old and famous endodontic axiom, what is removed from the root canal is more important than what is placed inside. Without minimizing the importance of the obturation phase, it is nonetheless true that the phase of preparing or emptying the root canal is undoubtedly the most important, the most complex, and the most delicate procedure. It is difficult to imagine how one can completely obturate a canal that has not been adequately cleaned and disinfected. On the other hand, minor deficiencies in the filling of a root canal that has been totally debrided and disinfected can be biologically tolerated, and they can also become contributing causes of periapical inflammation in a root canal that remains infected (5).

The complexity of the root canal system, presence of numerous dentinal tubules in the roots, invasion of the tubules by microorganism, formation of smear layer during instrumentation, and presence of dentin as a tissue are the major obstacles in achieving the primary objectives of complete cleaning and shaping of root canal system.

Two terms - cleaning and shaping - encompass and characterize clearly the most basic requirements for canal instrumentation, which were established by the "old master" of endodontics, Professor Schilder, more than 30 years ago: cleansing and giving the canal a proper form to receive the filling. Cleaning signifies the removal of all materials from the root canal, including infiltrated tissues, antigenic material, all organic components, bacteria and their products, but also caries, tissue debris as well as denticles and other hard tissue accumulations, contaminated canal filling material and other inflammation-inducing agents. Cleaning also means the instrumentation and mechanical removal of canal constituents, chemical dissolution of tissue debris, and rinsing them out of the canal.

Canal rinsing should:

• float dentin chips out of the canal, therefore preventing blockage

• dissolve vital and also necrotic tissue debris in those areas not accessible for manual instrumentation

• provide a lubrication effect for the instruments

• have an antibacterial effect

• have some bleaching effect.

To effectively clean and disinfect the root canal system, an irrigant should be able to disinfect and penetrate dentin and its tubules, offer long-term antibacterial effect (substantivity), remove the smear layer, and be nonantigenic, nontoxic and noncarcinogenic. In addition, it should have no adverse effect on dentin or the sealing ability of filling materials. Furthermore, it should be relatively inexpensive, convenient for application and not cause tooth discoloration. Other desirable properties for an ideal irrigant include the ability to dissolve pulp tissue and inactive endotoxins. The irrigants that are currently used during cleaning and shaping can be divided into antibacterial and decalcifying agents or their combinations. They include sodium hypochlorite (NaOCl), chlorhexidine (CHX), ethylenediaminetetraacetic acid (EDTA), and a mixture of tetracycline, an acid and a detergent (MTAD) (7).

5.1. SODIUM HYPOCHLORITE (NaOCl)

Potassium hypochlorite was first produced chemically in France by Claude Louis Berthollet as an aqueous chlorine solution. This solution was produced industrially by Percy in Javel near Paris, hence the name ‘Eau de Javel’. Hypochlorite solutions were first used as bleaching agents. Subsequently, sodium hypochlorite was recommended by Labarraque to prevent childbed fever and other infectious diseases. After the controlled laboratory studies by Koch and Pasteur, hypochlorite gained wide acceptance as a disinfectant by the end of the 19thcentury. In World War I, chemist Henry Drysdale Dakin and the surgeon Alexis Carrel extended the use of a buffered 0.5% NaOCl solution to the irrigation of infected wounds, based on Dakin’s meticulous studies on the efficacy of different solutions on infected necrotic tissue. Beside their wide spectrum, non-specific killing effects on all microbes, hypochlorite preparations are sporicidal, viricidal and show far greater tissue dissolving effects on necrotic than on vital tissues. These features prompted the use of aqueous NaOCl in endodontics as the main irrigant as early as 1919, as recommended by Coolidge. (8)

NaOCl (household bleach) is the most commonly used root canal irrigant. NaOCl solution varies from colorless to green/yellow and has a mild odor of chlorine; the pH value is between 10.7 and 12.2. It is an antiseptic and inexpensive lubricant that has been used in dilutions ranging 0.5% to 5.25%. When compared to a 0.5% solution, the antibacterial activity of a 2.5% solution was 3.5× higher, and that of a 5.25% solution 5.5× higher. In a test of cleansing effectiveness, instrumented root canals exhibited a cleaner surface after rinsing with a 2% NaOCl solution. Even in the first 15 minutes after rinsing with a 2% NaOCl solution, 15% of the pulpal soft tissues was dissolved; after 60 minutes, 45% and after two hours all pulpal tissue was dissolved. The free chlorine in NaOCl dissolves vital and necrotic tissue by breaking down proteins into amino acids. Decreasing the concentrations of the solution reduces its toxicity, antibacterial effect and ability to dissolve tissues. Increasing its volume or warming it increases its effectiveness as a root canal irrigant. The advantages of NaOCl include its ability to dissolve organic substances present in the root canal system and its affordability. The major disadvantages of this irrigant are its cytotoxicity when injected into periradicular tissues, foul smell and taste, and the ability to bleach clothes and cause corrosion of metal objects. In addition, it does not kill all bacteria, nor does it remove all of the smear layer. It also alters the properties of dentin. The results of a recent in vitro study show that the most effective irrigation regimen is 5.25% at 40 minutes, whereas irrigation with 1.3% and 2.5% NaOCl for this same time interval is ineffective in removing Enterococcus faecalis from infected dentin cylinders. Enterococcus faecalis is a persistent organism that, despite making up a small proportion of the flora in untreated canals, plays a major role in the etiology of persistent periradicular lesions after root canal treatment. It is commonly found in a high percentage of root canal failures and it is able to survive in the root canal as a single organism or as a major component of the flora (9). It is recommended to use other irrigants to increase the antibacterial effects during cleaning and shaping of root canals. NaOCl is generally not utilized in its most active form in a clinical setting. For proper antimicrobial activity, it must be prepared freshly just before its use in the majority of cases. However, it is purchased in large containers and stored at room temperature while being exposed to oxygen for extended period of time. Exposure of the solution to oxygen, room temperature and light can inactivate it significantly. The extrusion of NaOCl into periapical tissues can cause severe injury to the patient. When NaOCl is extruded beyond the root canal into the periradicular tissues, the effect is one of a chemical burn leading to a localized or extensive tissue necrosis. Given the widespread use of hypochlorite, this complication is fortunately very rare indeed. A severe acute inflammatory reaction of the tissues develops. This leads to rapid tissue swelling both intraorally within the surrounding mucosa and extra orally within the skin, and subcutaneous tissues. The swelling may be oedematous, haemorrhagic or both, and may extend beyond the region that might be expected with an acute infection of the affected tooth. A sudden onset of pain is a hallmark of tissue damage, and may occur immediately or be delayed for several minutes or hours. Involvement of the maxillary sinus will lead to acute sinusitis. Associated bleeding into the interstitial tissues results in bruising and ecchymosis of the surrounding mucosa and possibly the facial skin and may include the formation of a haematoma. A necrotic ulceration of the mucosa adjacent to the tooth may occur as a direct result of the chemical burn. This reaction of the tissues may occur within minutes or may be delayed and appear some hours or days later. If these symptoms develop, urgent telephone referral should be made to the nearest maxillofacial unit. Patients will be assessed by the on call maxillofacial team. A treatment is determined by the extent and rapidity of the soft tissue swelling but may necessitate urgent hospitalization and administration of intravenous steroids and antibiotics. Although the evidence for the use of antibiotics in these patients is anecdotal, secondary bacterial infection is a distinct possibility in areas of necrotic tissue and therefore they are often prescribed as part of the overall patient management. Surgical drainage or debridement may also be required depending on the extent and character of the tissue swelling and necrosis. (10) To minimize NaOCl accidents, the irrigating needle should be placed short of the working length, fit loosely in the canal and the solution must be injected using a gentle flow rate. Constantly moving the needle up and down during irrigation prevents wedging of the needle in the canal and provides better irrigation. The use of irrigation tips with side-venting reduces the possibility of forcing solutions into the periapical tissues (7).

The **smear layer** is created upon the canal wall surfaces as a result of instrumentation, and leads to closure of the dentinal tubuli orifices. Even canal instrumentation using sonic and ultrasonic devices cannot prevent the formation of a smear layer. One differentiates between the dentin debris forced into the dentinal tubuli and the smear layer that accumulates on the root canal walls. The smear layer creates a diffusion barrier that reduces the permeability of dentin by 25–30%. If the smear layer is removed, root canal dressings containing medicaments can better diffuse into the dentin of the canal walls, and the antibacterial effect increases.

Chelators have the capacity to limit the formation of smear layer on the canal wall surfaces during root canal instrumentation. The effectiveness is more related to the duration of application than to the choice of any particular preparation, and decreases significantly from coronal toward apical. Only five minutes after application there exists a 30 μm thick demineralization zone, which achieves 40 μm after 30 minutes, and up to 50 µm after 48 hours. The interface between this layer and the subjacent dentin is a clear line of demarcation (7).

5.2. EDTA

EDTA is ethylenediaminetetraacetic acid used as a chelator. It has a pH value of 7.3, but a relatively low antibacterial effect. At a 10–15% concentration, however, it is very effective in dissolving tissue debris and the smear layer. Therefore, like citric-acid rinsing, EDTA solution is recommended before the placement of calcium hydroxide. An EDTA solution does not penetrate diffusely into dentin, its effect is rather selflimiting. Following complex formation with calcium, certain equilibrium is established so that no further dissociation occurs. Even after five days, the maximum penetration is only 0.28 mm. In combination with instrumentation, chelators can significantly enhance dentin removal and therefore simplify the root canal instrumentation process. However, the demineralization effect is limited. It appears to be dependent upon the width of the root canal because, especially in narrow canals, insufficient demineralizing substance can be applied. During instrumentation, on the internal canal wall surfaces there is a 5 µm thick smear layer. The depth of the densely packed dentinal tubuli extends up to an additional 40 µm. Constituents of the smear layer include ground dentin and pulpal tissue residues, as well as bacteria in some cases. EDTA dissolves the inorganic component of the smear layer. In combination with NaOCl, the cleansing effect is significantly increased. The use of ultrasonics does not further improve cleaning efficiency. Following the dissolution of the smear layer with EDTA, dentin permeability increases because of enlargement of the orifices of the dentinal tubuli. This results in enhancement of the efficacy of medicament dressings in the root canal. Especially before placing calcium hydroxide dressings, the canal should be rinsed for three minutes with EDTA. Following the EDTA treatment, calcium phosphate crystals form in the depth of dentinal tubuli; these effectively close the tubuli and reduce permeability. EDTA also possesses a slight antibacterial potential. The antibacterial effect is enhanced by a combination of EDTA and 5% NaOCl. The antibacterial effect of gel-type chelators, such as RC Prep, Glyde, or File-Care, is primarily due to the addition of 10% urea or carbamide peroxide, and depends on the length of time the preparation is actually in contact with canal wall dentin. The instrumentation of the root canal should always be performed using a gel-type chelator. Because of the improved cleaning efficiency and the additional antibacterial effects, a 10% peroxide additive is recommended. The paste-type chelators also serve simultaneously as a lubricant for the files and reduce the risk of instrument fracture. A final rinsing with 17% EDTA removes the smear layer and dramatically increases the antibacterial effect of interim dressings. Rinsing with a chelator is also highly recommended before removal of broken instruments or silver points from the root canal (11).

6. PULP ANATOMY

The result of successful endodontics revolves around knowledge, respect, and appreciation for root canal anatomy and careful, thoughtful, and meticulously performed cleaning and shaping procedures. A clinician is required to have an insight of the morphology of tooth related to its shape, form and structure before commencing treatment. This can be achieved by routine periapical radiographs to assess the number, length, curvature and aberrations of the canal system of the tooth (12). Variations in morphology have become very common. Successful endodontic treatment is one where canal variations are detected, cleaned, shaped and obturated (13). Several anatomical and histological studies have demonstrated the complexity of the anatomy of the root canal system, including wide variations in the number, length, curvature and diameter of root canals; the complexity of the apical anatomy with accessory canals and ramifications; communications between the canal space and the lateral periodontium and the furcation area; the anatomy of the peripheral root dentin (3,14). As a cause of treatment failures, the lack of a working knowledge of pulp anatomy ranks second only to errors in diagnosis and treatment planning. Knowledge of the pulp must be three-dimensional. The pulp cavity must be mentally visualized both longitudinally and in cross-section. In addition to general morphologic features, irregularities and "hidden" regions of pulp are present within each canal (Figure 1) (15). To clean and shape the pulp system maximally, intracanal instruments must reach as many of these regions as possible to plain the wall in order to loosen tissue and tissue remnants. The internal anatomy of teeth, i.e. pulp cavity reflects the tooth form, yet various environmental factor s,whether physiological or pathological, affect its shape and size because of pulpal and dentinal reaction to them (4).

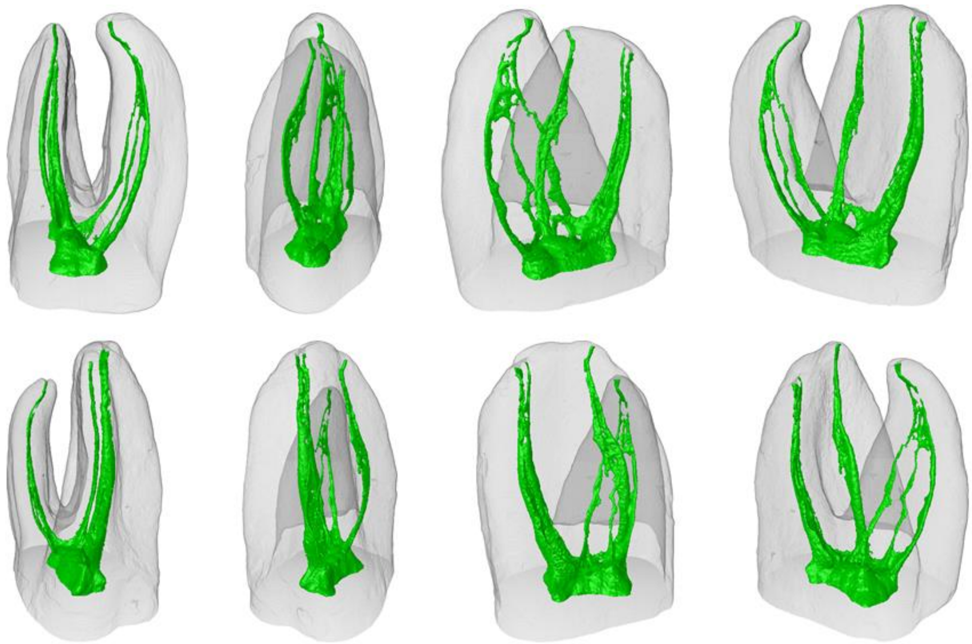

Figure 2. Illustration of complexity of the root canal system. Taken from: (16)

7. THE SELF-ADJUSTING FILE

The 3D cleaning, shaping and obturation of root canals have always been a desired goal in endodontic treatment. However, most root canals are not round in cross-section, which makes 3D preparation with rotary files a difficult and challenging procedure (17).

The Self-Adjusting File (SAF) is a hollow file, without any internal core, designed as an elastically compressible, thin-walled pointed cylinder, composed of a unique nickel-titanium mesh. The SAF's patented lattice-like design makes the instrument extremely flexible in all three dimensions, to fit the cross-section of the canal at any vertical location. The file does not impose its shape to the canal, instead, it will custom-fit itself to any root canal anatomy and shape it in a minimal invasive way by removing more contaminated dentin while conserving healthy tooth structure. The gentle scrubbing effect with its abrasive surface allows it to use minimal instrumentation and preserve the original form of the root canal. It acts as sandpaper to scrape dentin and promote root canal enlargement both circumferentially and longitudinally (Figure 2 and 3). The long axis of the canal is kept in its original place. The SAF is available in three standard lengths (21 mm, 25 mm and 31 mm) and two diameters (1.5 mm and 2.0 mm). The 1.5 mm SAF is designed for canals with an initial apical size of ISO 20-35. The 2.0 mm SAF is designed for use in wider canals with an initial apical size of ISO 35-60 commonly found in retreatments or younger patients. The 2.0 mm SAF may also be used in wider canals (≥#70), but would then require the dentist to pay attention to the possible rotation of the file inside the canal. Unlike rotary files, the SAF's lattice-like design allows it to partially tear without separating completely (Figure 4).

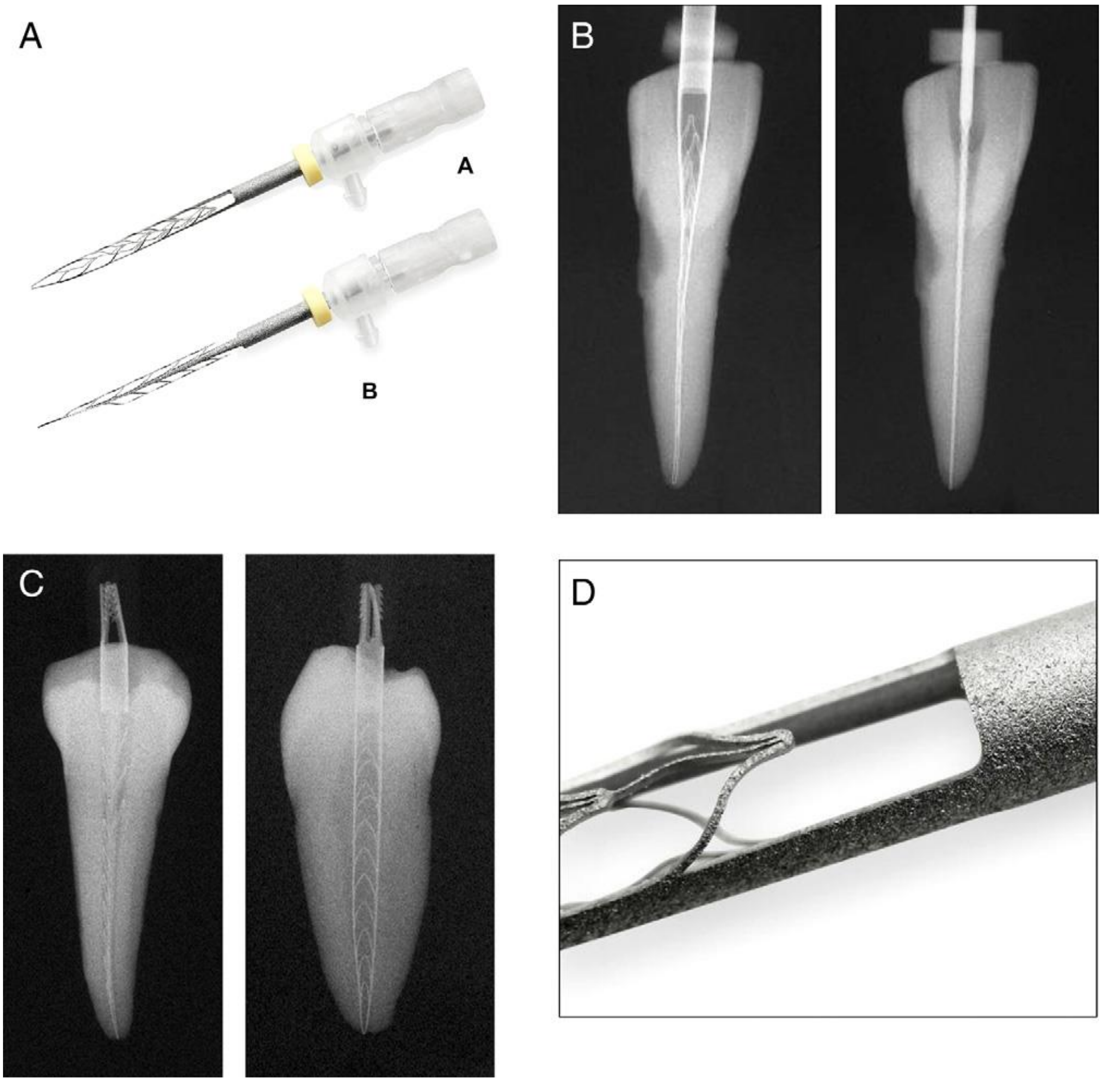

Figure 2. Self-adjusting instrument. Taken from: (18)

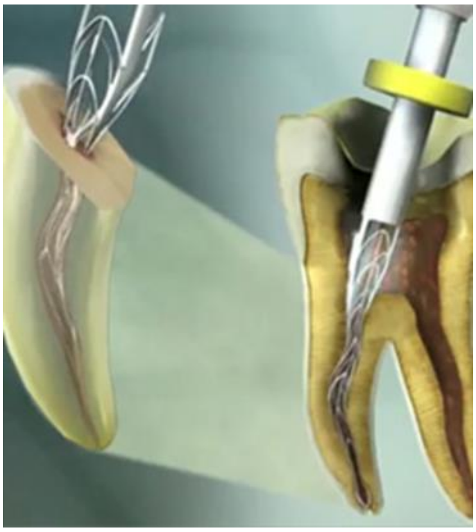

Figure 3. The ability of SAF to adapt to the root canal walls. Taken from: (19)

Excessive pressure and rotation speed increase the torsional stress on the file. In the rare case of complete file separation (chance of 0.6% or less according to a recent study), use a Hedström file or a barbed broach to bypass and remove the separated segment.

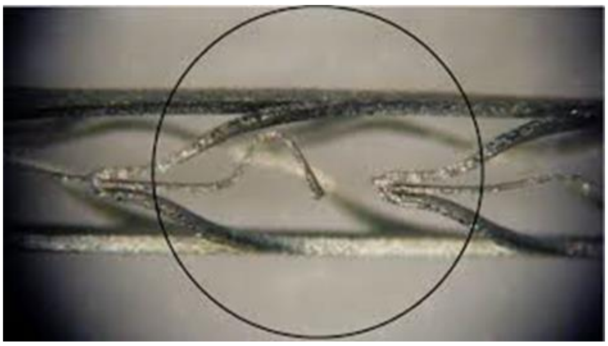

Figure 4. Lattice breakage. Taken from: (19)

The RDT3 hand-piece head operates the SAF with a 0.4 mm amplitude vertical vibration and is designed to be operated at 5,000 rpm. The patented RDT3 / RDT3-NX hand-piece heads are the only existing hand-piece heads that provide the combined motion of vertical vibration and rotation required for proper operation of the SAF. The RDT3 hand-piece head is designed to sustain prolonged exposure to sodium hypochlorite and is available in two models that fit a wide variety of low-speed endodontic motors hand-pieces. The file's main mode of operation is vertical vibration. These vibrations serve to circumferentially remove dentin from the canal walls while also providing a gentle scrubbing motion and agitation of the irrigant. The added rotation motion is very slow and almost torque-less. It only serves to repeatedly change the file's circular position in the root canal during treatment. The rotation motion is not meant to remove any dentin, and it only occurs when the file is not engaged with the canal walls. Continuous in-and-out hand pecking motions are recommended during operation of the SAF and are essential for the circular repositioning of the file to take place. Each out-bound stroke motion should reach far enough coronally to disengage the file and allow it to rotate. When inserted into the canal with the in-bound motion, the file should stop rotating but keep vibrating. The head contains a clutch mechanism that inactivates the rotation when the file is engaged in the canal.

The SAF may be operated with any of the two systems:

1. SAF System: includes the VATEA peristaltic irrigation device and the RDT3/RDT3-NX hand-piece head (Figure 5). The SAF system enables the user to work with various endodontic motors (which are not supplied with the system). The VATEA system is a self-contained fluid delivery unit intended to deliver irrigant solution during endodontic procedures. The irrigant is delivered via a disposable silicone tube. The flow of irrigant is toggled using a foot pedal and the operator can

adjust the flow rate by using the -/+ push buttons located on the control panel. A large LCD screen and audio notifications are used to indicate flow rate, working time and battery status.

Figure 5. RDT3/RDT3-NX hand-piece head and KaVo KaVo GENTLEpower hand-piece. Taken from: (15)

2. <u>SAF proSystem</u>: includes the EndoStationTM endodontic motor, the RDT3/RDT3-NX hand-piece head and a 1:1 E-type contra-angle hand-piece (Figure 6). The SAF System includes its own endodontic motor and does not require any additional endodontic motor. The EndoStationTM is a multi-functional endodontic motor that enables the user to operate various motored endodontic systems, including, alongside the Self-Adjusting File (SAF), all major brands of rotary and reciprocating files. The EndoStationTM includes an integrated peristaltic pump and irrigation system for work with the SAF System. The irrigation system and the endodontic motor of the EndoStationTM are simultaneously operated by a foot pedal. The irrigation system is at the back side of the device and includes a

detachable glass bottle, a peristaltic cassette that streams the irrigation fluid through a silicone tube that is disposable at its distal end (19).

The SAF system is different from any other available file system in two major aspects. First, the SAF system is a hollow, flexible instrument that was designed to adapt itself to the cross-sectional shape of the root canal. Second, this hollow file allows for continues irrigation of the root canal throughout a wide procedure, with additional activation of the irrigant by its vibrating motion that creates turbulence in the root canal (20).

Figure 6. EndoStationTM endodontic motor, the RDT3/RDT3-NX hand-piece head and a 1:1 E-type contra-angle hand-piece. Taken from: (21)

8. DISCUSSION

Many researches have compared NiTi rotary system with SAF and all results have been in favor of SAF (19). Here are some conclusions that were made in various different studies with several topics and their main focuses.

Some studies reported that canal preparation can cause dentinal defects like fractures, craze lines, incomplete crack and dentinal detachment. Over-instrumentation might weaken the root and create apical root cracks. With NiTi rotary system there is a possibility to go over the apical foramen and/or to make craze lines, and microcracks resulted from the active cutting edges and continuing rotation. The SAF system does not have the structure of a flute helix, cutting blades or the internal core. This system does not have screw-in force and no pressure from a metal shaft. Because of its ability to adapt to the canal's original anatomy and shape, the result is a noninvasive root canal preparation. The unique SAF mesh structure and cross sectional configuration minimizes the reaction forces against the root canal. When the file moves in-and-out of the canal, the contacts between the instrument and the root canal walls create many momentary stress concentrations in dentin. Higher stresses in root during instrumentation can be generated by stiffer instruments with bigger cross-sectional area, which may increase the risk of vertical root fractures. SAF, with its minimal cross-sectional area, may pose minimal risk of VRFS and maximum potential to preserve root canal integrity (22). Higher root stress concentrations may cause more canal deviations and result in thinner dentin areas. Thinner dentin weakens the root structure and increases the risk of apical cracking. On the other hand, the SAF generated a minimal reaction force and resulted in minimal dentin removal. This could contribute to the reduction of the fracture risk and dentinal defects (Figure 7) (23).

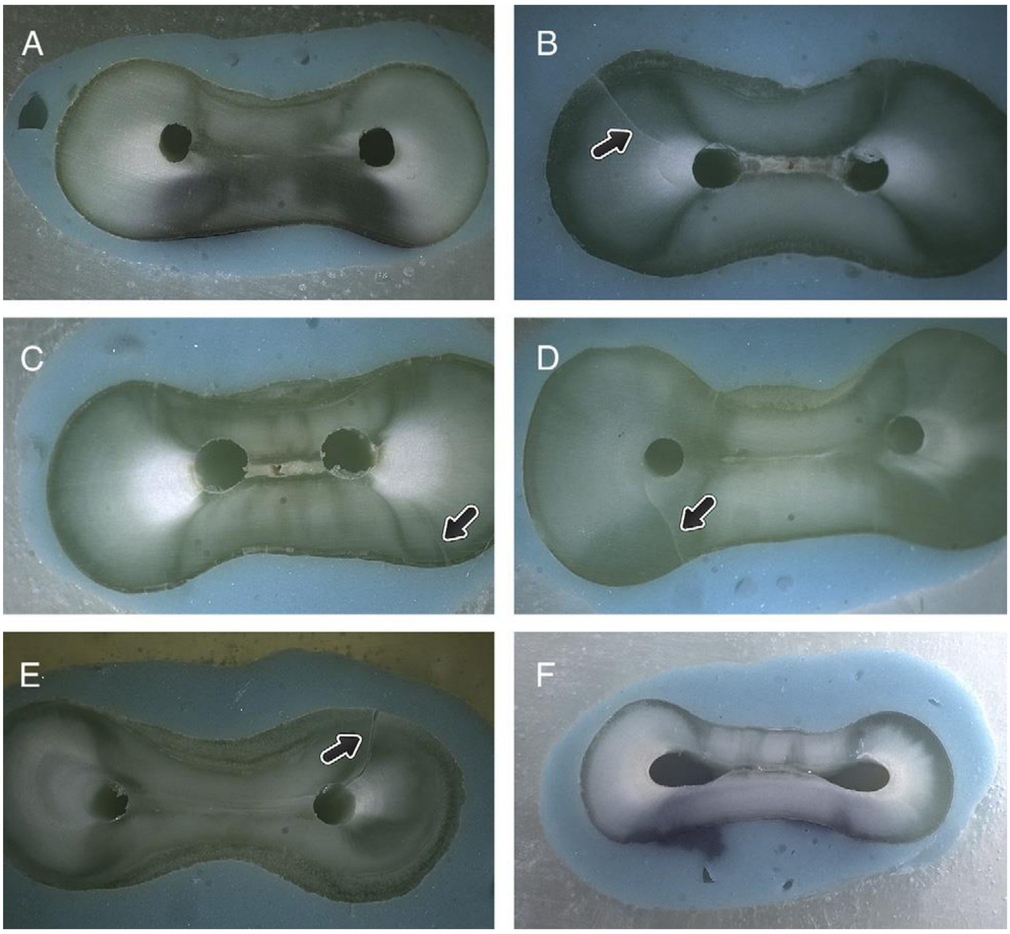

Figure 7. Microcracks in dentinal walls (B,C,D and E) as a consequence of root canal instrumentation with Hero Shaper (B), Revo-S (C), Twisted file (D) and ProTaper €. Hand (A) and SAF (F) instrumentation did not produce microcracks. Taken from: (23)

The shaping of the root canal is one of the most important steps in endodontics. For many years it has been common practice to enlarge a root canal to at least three ISO sizes larger than the first file, so as to bind at the apical part of the canal. It was assumed that such preparation will remove the inner layers of dentin while allowing the irrigant to reach the canal space. This goal is easier to achieve today with NiTi rotary system but the downside is its disability to make a 3D preparation where the third dimension was continuously ignored. The goal of cleaning and shaping may be achieved with rotary systems as far as relatively straight and narrow root canal with round cross-section is concerned. Nevertheless, in flat-oval shaped root canals and in curved ones, this goal is not easily attainable. The buccal and lingual areas of this kind on root canals and the area facing the isthmus in tear-shaped ones cannot be adequately prepared by current rotary files. Substantial untouched areas may be left and current technology may mislead the operator to believe that the canal is adequately prepared when there is a significant amount of infected tissue and debris left. Such canals may never be well obturated or sealed due to remaining of tissue and debris that provide a potential bacterial growth or future recontamination. Thinner instruments will maintain the apical part of the curved canal in place, and as for the stiffer ones, they have a tendency to remove more dentin on the outer side of the curvature, leading to canal transportation. Transportation of the canal can have two major deficiencies. First, the apical part of the canal on the inner side of the curvature remains untouched and full of debris and, second, it may lead to ledging or even subsequent perforation. To this day, most if not all file systems have the inherent problem to one extent or another. Another closely related problem is straightening of the root canal at the midroot section of curved root canals. Most files system will straighten a part of the curvature to one extent or another, by removing more dentin on the inner side of the curvature. This may reduce the thickness of the remaining dentin on the inner side of the curvature to such measure that it increases the risk of vertical fracture or even results in a strip perforation. The SAF file is different from any current NiTi rotary system. Most of them will find the widest part of the canal and gradually machine it, using several files of increasing diameter, to a wider canal with round cross section, if the canal happens to be relatively narrow; the whole original canal may be included in the preparation. However, if the canal is flat, tear shaped or simply large, this preparation may result in untreated recesses. The SAF file is used as a single file that starts as narrow and compressed shape and gradually expands in the canal while removing a uniform layer of dentin from its walls. Because the file adapts itself to the cross section of a given canal, a canal with a round cross-section is enlarged as a round, whereas an oval canal is enlarged as an oval canal of larger diameter. After preparation with SAF file, thickness of remaining dentin wall is uniform and it is predisposing factor for vertical fractures. When rotary files accidentally pass the apical foramen of an apically curved canal, due to misleading length measurements or failure to maintain the marker in place, they may soon ”zip” the apical foramen and form an oval opening. The SAF on the other hand may be operated in such conditions even for few minutes with no zipping whatsoever (20).

According to the present data and earlier pilot trials, the SAF is most effective during the first two minutes of use, and hence under the present experimental conditions, the bulk dentin removal was accomplished during the first two minutes of preparation. However, there was about 40 % unprepared canal area with the SAF 2.0 mm at that time. Regression analysis indicated that the optimum of prepared canal surface is more than 90 % on average, reached after five minutes of activation.

A recent micro-computed tomography (micro CT) study has shown that the percentage of root canal area affected by the SAF method is larger than that affected by popular rotary instruments. Consequently, less unprepared areas that might potentially harbor bacterial biofilms remnants are observed. Other study reported that SAF operation with continued irrigation resulted in root canal walls that were free of debris in all specimens and almost completely free of smear layer. The SAF system has a potential to be particularly advantageous in promoting disinfection of oval shaped canals (25, 26).

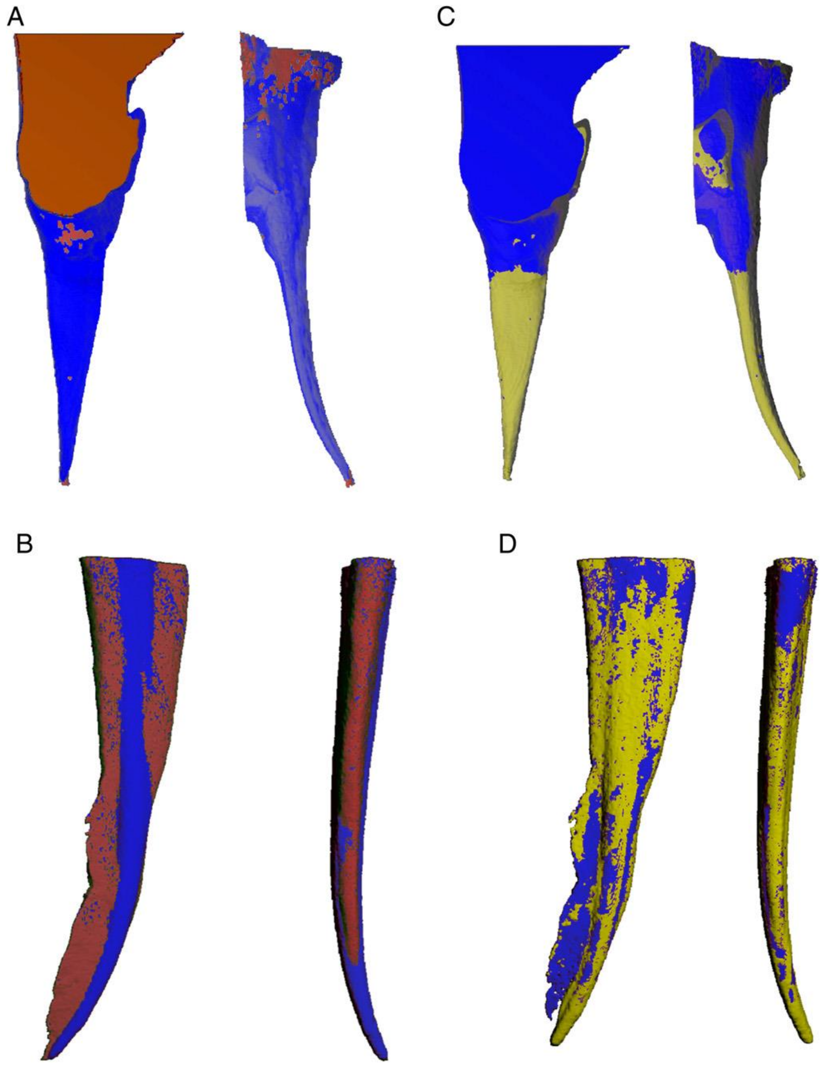

Figure 8. Micro-CT of root canals prepared with SAF (A) and rotary system (B). A good root canal filling adaptation with 98.1% of the canal wall in contact with the root canal filling (C) and a poor root canal filling adaptation with only 68.9% of the root canal wall in contact with the root canal filling material (D). Taken from: (27)

A recent study compared the prepared surfaces areas and revealed that the mean in unaffected areas ranged from about 60-80% from the total canal length. All the apical portion of the canal, the mean of untouched areas ranged from 65-75 % (28). Another recent study comparing the cleaning effects of three instrumentation techniques in oval-shaped canals reported that none of the techniques resulted in completely prepared and cleaned canals (29).

C-shaped canals presented a challenge to both file systems which resulted in a percentage of canal area unaffected by the procedures that was higher than previously reported in normal canals. The SAF was more effective than the ProTaper file system in shaping the walls of C-shaped root canals. In the SAF treated group, a mean 41% ± 14% of the canal walls was unaffected by the procedure, with a range of 21% to 70%. In the ProTaper group, a mean of 66% ± 6% of the canal walls were unaffected by the procedure with a range of 54 % to 75 % (30).

During root canal preparation procedures, dentin chips, pulp tissue, microorganisms, and/or irrigants can be extruded into the periradicular tissue. The extrusion of these elements may cause undesired consequences, such as the induction of inflammation and postoperative pain, and delay of periapical healing. Currently, all preparation techniques and instruments are associated with extrusion of debris; however, there are notable differences among the techniques. Based on a statistical data, the hand instrumentation group extruded significantly more debris than both of the other tested groups. The SAF system extruded less than the ProTaper file. According to the current results, apical debris extrusion occurred regardless of the instrumentation technique used (28).

The present results may be explained by differences in the instrument design and movement kinematics between SAF and ProTaper system. The metal mesh in the SAF system is closely adapted to the canal walls and removes dentin with a back-and-forth grinding motion, providing a scrubbing action on the canal walls. Moreover, the SAF allows continues the irrigation of the root canal throughout the procedures with additional activation of the irrigant by its vibrating motion, which creates turbulence in the root canals. The irrigation fluid enters the file through a free-rotating hub continuously replaced throughout the procedure, providing s fully active supply of irrigant. No positive pressure can be developed in root canal space because the solution easily escapes through openings in the file lattice. Under the condition of this study, it can be concluded that all systems caused apical debris extrusion. The SAF instrumentation was associated with significantly less debris extrusion compared with the use of hand and rotary files (25, 27).

The SAF system substantially reduced the amount of the remaining pulp tissue by 57% as compared with the conventional full sequence of ProTaper NiTi files. In other words, the SAF system improved the debridement standard produced by the conventional NiTi rotary preparation approach. In the ProTaper system group, substantial amounts of pulp tissue remained in the canals, 21% of the root canal cross-section contained pulp tissue remnants. This presents the inability of most rotary systems to access buccal and/or lingual recesses of oval canals. Furthermore, it represents the limited ability of sodium hypochlorite irrigant applied with a syringe needle to compensate for the inadequacy of the file itself. The current study results indicate that, in addition to its previously reported better efficiency for circumferentially removing dentin from all canal walls, as shown by microCT studies, the SAF system has also improved debridement and cleaning efficiency in the oval-shaped canals. This may, in turn, also aid in explaining the recently reported improved disinfection that the SAF system has in oval canals (25, 27, 31).

The SAF is extremely durable and may go through rather severe use before a mechanical failure occurs. It does not have a core like the others. Any strain applied to it is distributed along many of its delicate parts and the total endurance is a function of the accumulated endurance of each individual part (32).

The irrigation of the root canal with sodium hypochlorite during root canal treatment is widely recommended. It has been well documented that when exposed to its target of bacteria and tissue debris, sodium hypochlorite loses its activity rather quickly. Taking into account the extremely small volume of the root canal, the amount of sodium hypochlorite contained in the canal loses its activity within a very short time. Therefore, replacement of the irrigant as frequently as possible is mandatory for maintaining its optimal potency and effect. The SAF operates with a continuous flow of the irrigant, thus allowing continuously fresh irrigant to be present in the canal at all times. The vibration of the file's metal lattice within the irrigant facilitates its cleaning and debridement effects. It is evident that syringe and needle irrigation was ineffective in replacing the liquid in the apical part of a narrow curved canal. The SAF, which was used with continuous irrigation, combined with the vibrating action of the metal lattice, was affective in replacing the liquid in the apical part of the narrow curved canal. No pressure builds up in the canal during the SAF operation because the metal mesh allows free escape of the irrigant at all times. No irrigant passes the apical foramen during SAF operation (32, 33).

The SAF instrumentation system was highly effective in reducing bacterial population from infected root canals. Quantitative and qualitative results were significantly superior to those attained by a hand instrumentation protocol. Some bacterial species were identified in post-treatment samples and the excellent antibacterial effectiveness of SAF, the fact that almost half of the teeth still had detectable bacteria by molecular method, suggest that a supplementary step after chemomechanical procedures with SAF is also required to improve disinfection (34).

The SAF has proven to be more effective in areas of the root canals that are inaccessible to most other instruments. The SAF is expected to remove the remaining gutta percha after conventional retreatment because of its scraping motion with simultaneous irrigation and its ability to touch a higher percentage or root canal walls than rotary instruments. Removing gutta-percha is an essential and difficult step during root canal retreatment. Hand files, rotary files, and a solvent were not able to remove all gutta-percha from root canals in previous studies. The SAF makes more root canal-wall contact compared with other rotary files, resulting in a significantly lower percentage of untouched canal areas on oval canals. Moreover, a SAF operation with continuous irrigation, using alternating irrigants, resulted in root canal walls that were free of debris. Therefore, it was hypothesized that the SAF might scrape gutta-percha remnants of the root canal wall, resulting in cleaner canals after retreatment under the experimental conditions. The SAF increased the amount of gutta-percha removed from curved root canals when compared with ProTaper retreatment instruments alone. However, the removal of gutta-percha from the apical area of curved root canals still remains difficult (32).

A significantly higher PGFA (gutta-percha filled area) was found in oval shaped canals prepared using SAF system with continuous irrigation compared with similar canals prepared using a conventional NiTi rotary system with syringe and needle irrigation. Recent reports have indicated that the SAF cleaning and shaping irrigation system may improve both shaping and cleaning of oval shaped root canals compared with traditional NiTi rotary system. A higher percentage of the canal wall was affected by instrumentation with this method than with the rotary system, whereas less tissue debris is left after instrumentation and almost no packing of hard tissue particles occurs. Both instrumentation systems failed to achieve the desirable goal of 100% PGFA in all cases (32).

9. CONCLUSION

As mentioned previously, cleaning and shaping of the root canal is the most important step in every endodontic treatment. Currently, endodontic procedures are performed with hand and rotary instruments that do not adapt to the canal walls. The irrigation steps are intermittent and deliver limited amounts of irrigant to the apical third of the root. Unfortunately, the literature is loaded with examples of instrument breakage, poor results with chemomechanical preparation, canal transportation, and over-thinning of the canal walls. Since hand and rotary files are round in cross section, they leave more than half of the canal walls untouched and require multiple sequences of filling and irrigation.

The new SAF instrument actively adapts to the shape of each canal, moves in a new oscillating up-and-down motion, and allows simultaneous irrigation. After the proper glide path is established, only one SAF instrument is required to finish the entire 3-D instrumentation of the canal. This revolutionary technology has been proven in numerous peer-reviewed, published articles to contact more canal surfaces, improve canal disinfection, and provide better results. SAF technology provides a virtually unbreakable instrument and is changing the way we perform endodontics.

10. SUMMARY

Since the beginning of modern day endodontics, there have been numerous concepts, strategies, and techniques for preparing canals. Throughout decades, a staggering array of files has emerged for negotiating and shaping canals. In spite of the design of the file, the number of instruments required, and the surprising multitude of techniques advocated, endodontic treatment has been typically approached with optimism for probable success. The common misconception today is that dentists tend to relate to all root canals as if they had a uniform round cross section. This is true for the upper incisors, but wrong for every other tooth in maxilla and mandible. The Self-adjusting file (SAF) brings a new concept to the table in terms of root canal treatment. First of all, it is a system that combines irrigation and instrumentation at the same time. The special design of the instrument allows its compression inside the canals and three dimensional adjustment, no matter how complicated the configuration of root canal is, without fear of breakage. In addition, this instrument has the ability of circumferential removal of dentin to give better adhesion of the future filling and the canal wall. Surface of the SAF has a roughness of 2.8 μm ± 10 % which gives a file scraping feature and a possibility to smoothen walls of the root canal. It generates a vibration of 5000 rpm. With the SAF, goals like minimal reduction and uniformity of the remaining wall thickness become achievable. The prevention of canal transportation, continuous irrigation with sodium hypochlorite and high durability are just a few specifications that make this system a step towards a whole new era in modern endodontics.

11. SAŽETAK

Od početka modernog doba endodoncije, javljali su se brojni koncepti, strategije i tehnike za obradu kanala, te je do danas razvijen veliki broj različitih instrumenata. Zajednička zabluda većine stomatologa u današnje vrijeme jest tendencija da se odnose prema svim korijenskim kanalima kao da imaju jednak okrugli poprečni presjek. To se možda odnosi na pojedine dijelove korijenskih kanala nekih zubi (npr. gornjih sjekutića), no većina korijenskih kanala je izuzetno nepravilna. Samoadaptirajući instrument je primjer potpuno novog koncepta u obradi korijenskih kanala. Prije svega, to je sustav koji ujedinjuje irigaciju i instrumentaciju istovremeno. Poseban dizajn instrumenta za obradu kanala omogućuje njegovo komprimiranje unutar kanala i prilagodbu trodimenzionalnoj konfiguraciji korijenskog kanala, ma koliko ona bila komplicirana, bez straha od pucanja. Pored toga, taj instrument ima sposobnost cirkumferencijalnog uklanjanja dentina što omogućuje bolju adheziju budućeg punjenja uz stjenke kanala. Površina samoadaptirajućeg instrumenta ima hrapavost 2,8 μm ± 10%, što mu daje strugajuća svojstva i zaglađuje stjenke kanala. Ostvaruje vibraciju od 5000 rpm. Sa samoadaptirajućim instrumentom se postiže cilj minimalne redukcije i jednolikost preostale debljine stjenke kanala. Prevencija preko instrumentacije, izvan granice apikalnog foramena, kontinuirana irigacija korijenskog kanala natrijevim hipokloritom i visoka izdržljivost, samo su neke karakteristike koje čine ovaj instrument začetnikom nove moderne ere u endodonciji.

12. LITERATURE

1. Peters OA, Paqué F. Current developments in rotary root canal instrument technology and clinical use: A review. Quintessence Int, 2010;41(6):479–88.
2. Castellucci A. Endodontics: Volume 1. 1st ed. California: Il Tridente; c2004. Chapter 1, A brief history of endodontics; p. 2-6.
3. Hülsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. Endod Topics. 2005;10(1):30-76.
4. Garg N, Garg A. Textbook of Endodontics. 1st ed. New Delhi: Jaypee Brothers Medical Publisher Ltd; 2007. 504 p.
5. Castellucci A. Endodontics: Volume 2. 1st ed. California: Il Tridente; 2005. 750 p.
6. Messing JJ, Stock CJR. A Colour Atlas of Endodontics. 1st ed. London: Wolfe Medical Publications Ltd; c1988. Chapter 5, Basic instruments and materials; p. 54-84.
7. Kandaswamy D, Venkateshbabu N. Root canal irrigants. J Conserv Dent. 2010;13(4):256–64.
8. Spencer HR, Ike V, Brennan PA. Review: the use of sodium hypochlorite in endodontics — potential complications and their management. Brit Dent J. 2007;202(9):555-9.

9. Stuart CH, Schwartz SA, Beeson TJ, Owatz CB. Enterococcus faecalis: its role in root canal treatment failure and current concepts in retreatment. J Endod. 2006;32(2):93-8.
10. Spencer HR, Ike V, Brennan A. Review: the use of sodium hypochlorite in endodontics — potential complications and their management. Brit Dent J. 2007;202(9):555-9.
11. Hülsmann M, Heckendorff M, Lennon A. Chelating agents in root canal treatment: mode of action and indications for their use. Int Endod J. 2003;36(12):810-30.
12. Carrotte P. Endodontics: Part 4 Morphology of the root canal system. Br Dent J. 2004;197(7):379-83.
13. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endod Topics. 2005;10(1):3-29.
14. Maniglia-Ferreira C, de Almeida-Gomes F, Carvalho de Sousa B, Cabral dos Santos Acioli Lins C, Alves dos Santosc R. A Case of Unusual Anatomy in Second Mandibular Molar with Four Canals. Eur J Dent. 2008;2(1):217-9.
15. Torabinejad M, Walton RE. Endodontics: Principles and practice. 4th ed. St.Louis: Elsevier Health Sciences; c2009. Chapter 13, Internal Anatomy; p. 216-30.
16. Versiani MA, Pécora JD, Sousa Neto MD. Middle mesial canal: Maxillary first molar [Internet]. Sao Paolo: Marco Versiani; 2013 Mar [cited 2015 Sep 1] Available from: http://rootcanalanatomy.blogspot.hr/2013_03_01_archive.html.

17. Metzger, Z. From files to SAF: 3D endodontic treatment is possible at last. Alpha Omegan. 2011;104(1-2):36-44.

18. Metzger Z, Teperovich E, Zary R, Cohen R, Hof R. The Self-adjusting file (SAF): Respecting the root, canal anatomy - A new concept of endodontic files and its implementation. J Endod. 2010;36(4 Pt 2):679-90.

19. ReDentNova.com [Internet]. Israel: ReDent Nova; c2015 [cited 2015 Sep 13]. Available from: http://www.redentnova.com/.

20. Metzger Z, Teperovich E, Cohen R, Zary R, Paqué F, Hülsmann M. The Self-adjusting file (SAF): Removal of debris and smear layer - A scanning electron microscope study. J Endod. 2010;36(4 Pt 3):697-702.

21. Metzger Z. The Self-adjusting file (SAF) system: An evidence-based update. J Conserv Dent. 2014;17(5):401-19.

22. Kim HC, Sung SY, Ha JH, Solomonov M, Lee JM, Lee CJ et al. Stress generation during Self-Adjusting file movement: minimally invasive instrumentation. J Endod. 2013;39(12):1572-5.

23. Yoldas O, Yilmaz S, Atakan G, Kuden C, Kasan Z. Dentinal microcrack formation during root canal preparations by different NiTi rotary instruments and the Self-adjusting file. J Endod. 2012;38(2):232-5.

24. Hof R, Perevalov V, Eltanani M, Zary R, Metzger Z. The Self-adjusting file (SAF): Mechanical analysis, J Endod. 2010;36(4 Pt 2):691-6.

25. Peters OA, Paqué F. Root canal preparation of maxillary molars with the Self-adjusting file: A micro-computed tomography study. J Endod. 2011;37(1):53-7.

26. Peters OA, Boessler C, Paqué F. Root canal preparation with a novel nickel-titanium instrument evaluated with micro-computed tomography: Canal surface preparation over time. J Endod. 2010;36(6):1068-72.
27. Metzger Z, Zary R, Cohen R, Teperovich E, Paqué F. The quality of root canal preparation and root canal obturation in canals treated with rotary versus Self-adjusting files: A three-dimensional micro-computed tomographic study. J Endod. 2010;36(9):1569-73.
28. De-Deus GA, Nogueira Leal Silva EJ, Moreira EJ, de Almeida Neves A, Belladonna FG, Tameirão M. Assessment of apically extruded debris produced by the Self-adjusting file system. J Endod. 2014;40(4):526-9.
29. Taha NA, Ozawa T, Messer HH. Comparison of three techniques for preparing oval-shaped root canals. J Endod. 2010;36(3):532-5.
30. Solomonov M, Paqué F, Fan B, Eilat Y, Berman LH. The challenge of C-shaped canal systems: A comparative study of the Self-adjusting file and ProTaper. J Endod. 2012;38(2):209-14.
31. De-Deus G, Souza EM, Barino B, Maia J, Zamolyi RQ, Reis C et al. The Self-adjusting file optimizes debridement quality in oval-shaped root canals. J Endod. 2011;37(5):701-5.
32. De-Deus G, Barino B, Marins J, Magalhães K, Thuanne E, Kfir A. Self-adjusting file cleaning - shaping - irrigation system optimizes the filling of oval-shaped canals with thermoplasticized gutta-percha. J Endod. 2012;38(6):846-9.

33. Yoldas O, Yilmaz S, Atakan G, Kuden C, Kasan Z. Dentinal microcrack formation during root canal preparations by different NiTi rotary instruments and the Self-adjusting file. J Endod. 2012;38(2):232-5.

34. Neves MA, Rôças IN, Siqueira JF Jr. Clinical antibacterial effectiveness of the Self-adjusting file system. Int Endod J. 2014;47(4):356-65.

13. CURRICULUM VITAE

Kim Hulenić was born on 11th of October 1990 in Zagreb, where she finished primary school. In 2006 she enrolled in general high school in Zagreb, where she graduated in 2009. The same year she entered in University of Dental Medicine in Zagreb. During her studies she worked as an assistant in a private dental practice, published an article in the student newspaper, did one semester Erasmus exchange in Portugal and participated in several dental congresses in Croatia and abroad. She speaks English, German and Portuguese.