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THE CURRENT TRENDS AND USAGE OF NICKEL- TITANIUM ENGINE-DRIVEN ENDODONTIC INSTRUMENTS: A MULTICENTER SURVEY.

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ABSTRACT

The Current Trends and usage of Nickel-Titanium Engine-driven Endodontic Instruments: A multicenter Survey.

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Background: Due to their properties, Nickel-titanium (NiTi) alloys are used in manufacturing of endodontic instruments, especially rotaries. The first rotary 0.02 taper NiTi was designed by Dr. John MacSpadden and came to the market in 1992. Over the years, NiTi engine-driven instruments (NiTi-EIs) have evolved, and many changes are done to it from the first generation until the fifth generation. Heat-treated metal, different types of motion (rotation, reciprocating and adoptive), and different tapering with different rake angles.

Aim: This questionnaire-based study aimed to assess the extent of adoption, usage, and improvement associated with NiTi-EIs and techniques in endodontists and postgraduate endodontic residents in Kuwait and the United Arab Emirates (UAE), and it was an anonymous survey.

Materials and Methods: A cross-sectional survey of 75 endodontists from Kuwait and the UAE was conducted. Statistical analysis was carried out using Chi-square, t-test, ANOVA, and Pearson's correlation test. Questions related to the knowledge and practice of NiTi instruments usage and modalities were tabled and cross-tabulated against demographic variables. Statistical significance was set as $p < 0.05$.

Results: The 97% of Kuwait's participants are using NiTi-EIs in more than 90% of their cases, while in UAE, the percentage was 73%, with a significant difference ($p=0.006$). In Kuwait,

60.6% of the participants preferred NaOCl as a lubricant, while 16.2% in UAE did the same, with a significant difference ($p < 0.001$). Reciprocating motion is the predominant motion of 18.2% of Kuwait's participants, while no participant from UAE used it predominantly with a significant difference ($p = 0.006$). Dentsply Sirona was the most popular manufacturer in both regions and was chosen by 97.1% of all participants; among their products, ProTaper Universal Gold file was the most popular file in UAE with a significant difference ($p < 0.001$), and ProTaper Next file was the most popular file in Kuwait with a significant difference ($p = 0.003$). From FKG manufacturer iRace file was most popular in UAE than in Kuwait, with a significant difference ($p = 0.048$). Coltene ($p = 0.004$) and VDW® ($p = 0.002$) were familiar in Kuwait more than in UAE.

Conclusion: Within the limitations of the investigation, it can be stated that NiTi-EIs are widely used in the dental practice of both regions. Better education and lower costs, on the other hand, may enhance their use. Overall, endodontists demonstrated a high understanding of NiTi-EIs usage characteristics, which was reflected in usage modalities.

DEDICATION

This dissertation is dedicated to:

My beloved parents (Humoud and Fatemah) and my dear wife (Amal) for their endless love, sacrifices, prayers, support, and advice. You are my strength and refuge. Thank you for always believing in me. Without you, I would not be the person I am today.

My brothers (Mohammed, Abdullah, Hamad, Abdulrahman and Abdulaziz) and my sister (Nourah) for their continued encouragement, love, and support. They have never left my side and are very special to me.

My little angels (Humoud, Fatemah, Meshari and Mohammed) for bearing my neglect and the patience they showed throughout my master's degree journey.

DECLARATION

I declare that all of the contents of this thesis are my work. There are no conflicts of interest with any other entity or organization.

Name: Ahmad H A E KH Aljabilan

Signature:

A handwritten signature in black ink, consisting of a large, stylized initial 'A' followed by a series of loops and a final vertical stroke.

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TABLE OF CONTENTS

ABSTRACT	i
DEDICATION	iii
DECLARATION	iv
ACKNOWLEDGMENTS	v
TABLE OF CONTENTS	vii
LIST OF TABLES	ix
LIST OF FIGURES	x
1. INTRODUCTION	1
2. REVIEW OF THE LITERATURE	3
2.1. Objectives of cleaning and shaping root canal system	3
2.2. Development of instruments in endodontics	3
2.2.1. Techniques of root canal system preparation:	4
2.2.2. Irrigation of root canal system	4
2.3. Endodontic instruments	4
2.3.1. Basic metallurgy of nickel-titanium (NiTi)	4
2.3.2. Benefits of nickel-titanium instruments in endodontics	5
2.3.3.1 Different generations of NiTi instruments:.....	6
2.3.3.2 First-generation files	6
2.3.3.3 Second-generation files.....	7
2.3.3.4 Third-generation files.....	7
2.3.3.5 Fourth-generation files.....	7
2.3.3.6 Fifth-generation files.....	7
2.3.4 File fracture	8
2.3.4.5 Dynamics of instrument use:	10
2.3.4.5.1 Torque	10
2.3.4.5.1.1 Rotational speed.....	11
2.3.4.5.1.2 Electric versus air driven handpieces.....	11
2.3.4.5.2 Canal geometry and tooth type	11
2.3.4.5.3 Effect of cleaning and sterilization	12
2.3.4.5.4 Number of uses	13
2.3.4.5.5 Instruments design	14
2.3.4.5.5.1 Cross-sectional dimensions and design	14
2.3.4.5.5.2 Brands of rotary NiTi instruments	15
2.3.4.5.5.3 Instrument size	15
2.3.5 Files lubrication	16
3. AIM	17
4 MATERIALS AND METHODS	18

4.1	Study design, population, and location	18
4.2	Sample size.....	18
4.3	Data analysis.....	19
4.4	Inclusion criteria	19
4.5	Exclusion criteria	19
4.6	Reminders.....	20
4.7	Ethical considerations.....	20
4.8	Questionnaire and data collection	20
5	RESULTS.....	23
5.1	Study Sample characteristics.....	23
5.2	NiTi Instruments usage results.....	26
5.3	Modalities of NiTi instruments usage in root canal treatment.....	28
5.4	Future expectations of NiTi instruments and endodontics treatment development....	36
5.5	Association between NiTi instruments elements and country of practice	37
5.6	Association between brands and their products used in the country of practice	40
6	DISCUSSION	46
6.1	Study limitations.....	52
7	CONCLUSIONS	54
8	REFERENCES	55
9	APPENDICES	67
	Appendix I	68
	Appendix II.....	69
	Appendix III	70
	Appendix IV	76

LIST OF TABLES

Table 4.1: Demographic & General information questions

Table 4.2: Usage of NiTi instruments questions

Table 4.3: Modalities of NiTi instruments usage questions

Table 4.4: Current types of NiTi usage question

Table 5.1: Demographic characteristics

Table 5.2: Age's groups difference between Kuwait and UAE

Table 5.3: Usage of NiTi instruments

Table 5.4: Modalities of NiTi in root canal treatment

Table 5.5: Brands predominantly used in terms of NiTi instruments

Table 5.6: Association between NiTi instruments elements and country of practice

Table 5.7: Association between brand and its material used and country of practice

LIST OF FIGURES

Figure 5.1: Gender Distribution.

Figure 5.2: Country of practice.

Figure 5.3: Experience.

Figure 5.4: Type of practice.

Figure 5.5: Dentsply Sirona instruments.

Figure 5.6: FKG instruments.

Figure 5.7: MicroMega instruments.

Figure 5.8: Kerr™ instruments.

Figure 5.9: Coltene instruments.

Figure 5.10: VDW® instruments.

Figure 5.11: EdgeEndo® instruments.

Figure 5.12: Fanta® instruments.

Figure 5.13: Future expectations of NiTi instruments & Endodontics treatment development.

1. INTRODUCTION

The aim of root canal treatment (RCT) is to prevent/treat apical periodontitis, which is caused by microorganisms¹. Proper debridement of the root canal system by cleaning and shaping is essential for successful RCT². The cleaning and shaping of the root canal system can be carried out using different methods and techniques³. According to Schilder et al., the root-canal preparation should develop a continuously tapering funnel form and maintain the original form of the root canal, and the apical foramen in its original position are the main objectives for cleaning and shaping⁴. Therefore, knowing the instruments and materials used in RCT is essential for the practitioner. Historically, root canal instruments were manufactured from carbon steel. Stainless steel instruments (SSIs) were dominant for a few decades due to their higher ductility, allowing more significant resistance to fracture⁵. However, the previous instruments cannot maintain the original shape of the curved canal due to the lack of flexibility⁶. Moreover, the lack of flexibility of instruments causes errors during endodontic treatments⁷, which could decrease the success rate of the treatment⁸.

Nickel-titanium (NiTi) alloy was introduced in dentistry by WF Buehler in the early 1960s. The first rotary 0.02 taper NiTi was designed by Dr. John MacSpadden and came to the market in 1992⁹. The super-elasticity of NiTi allows deformations of as much as 8% strain to be fully recoverable, compared to a maximum of less than 1% with other alloys, such as stainless steel⁶.¹⁰ Due to its properties, NiTi alloys are used in endodontics instrument manufacturing, especially rotaries.

In different studies, NiTi engine-driven instruments (NiTi-EIs) have demonstrated better performance during cleaning and shaping of root canals when compared with SSIs^{11, 12}. The ability of the NiTi-EIs to maintain the canal curvature has been studied in different studies¹³⁻¹⁵. The chance of fracture is considered a significant disadvantage of these instruments³. Over the years, NiTi-EIs have evolved, and many changes have been made to them from the first

generation until the fifth generation, changes as heat-treated metal, different types of motion (rotation, reciprocating and adoptive), and different tapering with different rake angles⁹.

2. REVIEW OF THE LITERATURE

2.1. Objectives of cleaning and shaping root canal system

Proper debridement of the root canal system by cleaning and shaping is essential for a successful root canal treatment (RCT)². It entails enlarging and forming the intricate endodontic space, as well as disinfecting it¹⁶. The aim of RCT is to prevent/treat apical periodontitis caused by microorganisms¹, which is also the cause of endodontic treatment failure¹⁷. According to Herbert Schilder's mechanical objectives for cleaning and shaping of the RCT, the root-canal preparation should develop a continuously tapering funnel from the root apex to the coronal access cavity; in compliance with the previous principle, the cross-sectional diameter of the preparation should be narrower at every point apically, and wider at each point as the access cavity is approached, the root canal preparation should flow with the original form of the root canal, the apical foramen should remain in its original position, and the apical opening should be kept as small as practical in all cases⁴. Chemomechanical preparation of the root canal involves both mechanical instrumentation and antibacterial irrigation, and it is the most critical stage in disinfection of the pulp space¹⁸.

2.2. Development of instruments in endodontics

At the beginning of endodontics, the endodontists used manual files and reamers then progressed to rotary instruments. The root canal system's cleaning and shaping were achieved using the manual files and reamers in conjunction with root canal chemical debridement using irrigation disinfecting solutions¹⁹. Historically, root canal instruments were manufactured from carbon steel. Stainless steel instruments (SSIs) were dominant for a few decades due to their higher ductility, allowing more significant resistance to fracture⁵. A few decades later, Nickel-titanium (NiTi) alloy was introduced in dentistry by WF Buehler in the early 1960s. The first rotary 0.02 taper NiTi was designed by Dr. John MacSpadden and came to the market in 1992⁹.

2.2.1. Techniques of root canal system preparation:

Several root canal preparation techniques have been developed to overcome the iatrogenic damage caused by traditional steel instruments such as elbowing, zipping, ledge formation, and perforation of the canal^{20, 21}. The step-back technique is achieved after coronal flaring and determining the master apical file (the first file that binds slightly at the corrected working length), then the succeeding larger files are shortened by 0.5 or 1.0 mm increments from the previous length²². Crown-Down techniques are advocated for cleaning and shaping procedures as it removes coronal interferences and provide coronal taper by using Gates-Glidden to widen the orifices of the canals followed by manual files to remove organic canal tissue²². By using modified stainless-steel files, the balanced force technique allows for cleaning and shaping the curved canals²³.

2.2.2. Irrigation of root canal system

Irrigation is an essential part of successful root canal treatment²⁴. The optimal irrigant should have the following features: dissolution of organic and inorganic matter, killing of biofilm microbes, killing of planktonic microbes, detachment of biofilm, non-toxic to periapical tissue, non-allergenic, does not react with negative consequences with other dental materials, does not weaken the dentin, good penetration within the root canal system, temperature control, improving cutting of dentine by the instruments, reduction of friction, washing action and low cost²⁴. Many irrigant solutions available in the field include Sodium Hypochlorite (NaOCl), Ethylenediaminetetraacetic acid (EDTA), Chlorhexidine digluconate (CHX), Hydrogen peroxide, and Saline²⁴.

2.3. Endodontic instruments

2.3.1. Basic metallurgy of nickel-titanium (NiTi)

The nickel–titanium alloys utilized in root canal treatment include around 56% (wt) nickel and 44% (wt) titanium. However, in some alloys, a small percentage (<2% wt) of nickel can be

substituted by cobalt. The resulting mixture has a one-to-one atomic ratio (equiatomic) of the significant components, and the alloy will exist in different crystallographic forms¹⁰. A common name used for these alloys is 55-Nitinol. It exists in two temperature-dependent crystal structures. Nitinol is in an austenitic state at higher temperatures, and at lower temperatures, Nitinol has a martensitic crystalline structure. These two distinct features result from the transformation of austenite to martensite in the NiTi alloy. They are known as super-elasticity and shape memory effects. These are caused by temperature and stress^{7, 10}. Because of the super-elasticity of NiTi, deformations of up to 8% strain can be recovered. In contrast, stainless steel can only tolerate a maximum pressure of less than 1% before permanent deformation occurs.

Copper-zinc alloys, copper-aluminum alloys, gold-cadmium alloys, and nickel-niobium alloys are examples of super-elastic alloys. Nevertheless, none of these have the extent of strain or heat recovery, general corrosion resistance, human tissue compatibility, or the fluid body compatibility of nitinol^{7, 10, 25}.

2.3.2. Benefits of nickel-titanium instruments in endodontics

Nickel-titanium engine-driven instruments (NiTi-EIs) have become a pillar of clinical endodontics because they can quickly shape root canals with fewer procedural complications¹⁸. Many types of research have revealed that rotary NiTi-EIs maintain the original canal curvature better than stainless steel hand instruments when used on an extracted human tooth²⁶. In terms of NiTi-EIs' ability to shape, Short and Gluskin et al. reported that NiTi-EIs, especially in the apical area of the root canal, maintain the original canal curvature better than stainless-steel hand instruments^{27, 28}. Esposito and Cunningham found that NiTi files were much more effective than stainless steel hand files in saving the initial canal course when the apical preparation was extended beyond ISO size 30²⁹. According to in vitro research, NiTi instruments yield considerably less straightening and more oriented practices than stainless

steel hand files, reducing the likelihood of iatrogenic errors. Petiette et al. prepared 40 teeth with NiTi hand files or stainless steel K-files and discovered that NiTi instrumentation preserved the initial canal shape better. When the researchers compared the two groups one year after the endodontic surgery, they found that teeth prepared with NiTi files had a slightly higher healing rate (as assessed by changes in the densitometric ratio)¹¹. Tan and Messer discovered that using rotary NiTi instruments to instrument greater file sizes produced considerably cleaner canals in the apical 3 mm than hand instrumentation³⁰. When root canals of extracted teeth are prepared with NiTi-EIs, many procedural errors are minimized, including lack of working volume, instrument divergence, canal transportation, zip or elbow shape, strip perforation, and unnecessary root weakening^{31, 32}.

Moreover, when rotary nickel-titanium endodontic instruments are used, they have a higher success rate than when solely stainless-steel hand instruments are used³³. In two recent studies, undergraduate dental students at the University of Jordan used NiTi rotary files to improve the overall technical performance of root canal fillings in posterior molar teeth. Their initial experience was more reliable and successful than doing it by hand¹². Moreover, because of the high level of acceptance of the new technique, undergraduate students' knowledge and satisfaction were excellent, indicating the need for systematic incorporation of rotary NiTi instruments and methods for undergraduate teaching and future clinical practice³⁴.

2.3.3.1 Different generations of NiTi instruments:

2.3.3.2 First-generation files

This generation, in general, has passive cutting radial lands, which helped a file stay in the center of the canal curvature during work and fixed taper 0.04 mm & 0.06 mm over the length of their active blades³⁵. This generation has negative rake angles, which make the file passive, and these instruments perform a scarping than a real cutting action; it removes dentin slowly and has less of a tendency for canal straightening.

This generation system has the main disadvantage, which requires multiple files to complete the root canal preparation³⁶.

2.3.3.3 Second-generation files

In 2001 the second generation of NiTi-EIs became available in the dental markets⁶. The difference between this generation and the previous generation is the active cutting edges and thus require fewer instruments to prepare the root canal. The active cutting instruments are more effective, aggressive, and tend to straighten the canal curvature^{36, 37}.

2.3.3.4 Third-generation files

The NiTi metallurgy improvements helped to introduce the third generation of mechanical shaping files. In 2007, some manufacturers used heating and cooling methods to reduce cyclic fatigue and improve the safety with rotary NiTi instruments in the more curved canals²⁵.

2.3.3.5 Fourth-generation files

In the late 1950s, this technology was introduced by Dr. Blanc. A progression in canal preparation procedures was achieved with reciprocation, an operation that may be defined as any repetitive up-and-down or back-and-forth motion. Innovation in reciprocation technology led to the fourth generation of instruments for shaping canals. This movement allows a file to progress more readily, cut efficiently, and remove debris from the canal effectively³⁸.

2.3.3.6 Fifth-generation files

The latest generation of shaping files has been designed in such a way that the center of mass or the center of rotation, or both, are offset. During rotation, files that have offset design produce a mechanical wave of motion that travels along the active length of the file. Moreover, it promotes the removal of debris and improves flexibility along the active portion of the file—this generation adapts the advantages from both the second and the third generations³⁹.

2.3.4 File fracture

Even though root canal instruments can fracture at any stage of treatment, many studies have illustrated that smaller instruments are more likely to fracture⁴⁰⁻⁴³. That assigned to a smaller cross-section that is mechanically more susceptible to torsional fatigue and the clinical challenge of initial instrumentation, which enhance instrument stress. That may have implications for chemo-mechanical cleansing, suggesting that fracture would be more common earlier in the procedure. Other studies suggest that the larger stiffer files exhibited the most significant rate of fractures^{44, 45}. It suggests that fracture is more common in the later stages of treatment and more prevalent in the later stages of treatment. These reports may reflect different operator/instrumentation techniques or variations in canal morphology rather than the specific file dimensions. However, no study has answered the question of when root canal instruments are more prone to fracture.

2.3.4.1 Mode of fracture

NiTi is a flexible alloy with properties such as memory, super-elasticity, corrosion resistance, and biocompatibility⁶. NiTi files have two to three times more elastic flexibility and superior resistance to torsional fracture than SS files⁶. Nevertheless, the low output and tensile strength of NiTi compared to SS resulted in an increased susceptibility to fracture at lower loads⁴⁶. Fracture of SS files is mainly associated with overuse and is preceded by distortion⁴⁷. Visible alert signs of permanent distortion and the possibility of fracture are more often evident in manually SS files than NiTi-EIs⁴⁸. Because of that, NiTi-EIs have been associated with fractures without alerting^{49, 50}. The distortion of NiTi instruments often does not appear without magnification^{42, 51}, and this may be because of the shape-memory features of the alloy. NiTi-EIs are described as failing either due to cyclic flexural fatigue and torsional failure or both⁵².

2.3.4.2 Torsional fatigue

It occurs when the instrument (mostly the tip) becomes locked in the canal while the shank rotates. Subsequently, fracture of the file occurs when the elastic limit of the alloy is exceeded. Instruments that fracture because of torsional overload reveal evidence of plastic deformation such as unwinding, straightening, and twisting⁴².

2.3.4.3 Flexural fatigue

It occurs when the instrument continuously rotates loosely in a curved canal, creating tension/compression cycles at the point of maximum flexure, which ultimately results in a fracture. It is proposed that repeated tension-compression cycles caused by rotation within curved canals increase cyclic fatigue of the instrument over time^{42, 53}. Flexural fatigue fractures occur primarily due to overuse of the metal alloy. Other factors possibly adding to metal fatigue include corrosion and changes caused by thermal expansion and contraction.

2.3.4.4 Factors contributing to fracture

Multiple factors have been involved in the fracture of NiTi instruments, including operator experience/skill, instrumentation technique, dynamics of instrument use, number of uses, instrument design, an anatomic configuration of the canals, metallurgy, and number of sterilization cycles. Attempts have been made to achieve the relative importance of these factors with regards to their contribution to fracture^{33, 54}.

2.3.4.4.1 Operator experience

Operator expertise has been linked to the occurrence of clinical instrument fractures on numerous occasions^{40, 55}. When all other factors remained constant (instrument speed and sequence, canal morphology), the operator's ability was the most crucial factor in instrument failure⁵⁶. Other studies have proven the significance of the operator^{42, 57}. However, no significant difference in fracture rate was detected between experienced and inexperienced operators, a finding that was attributed to the more skilled operator being assigned complex

cases⁴⁴. Each rotary NiTi system has a ‘learning curve,’ emphasizing the importance of good training and initial monitoring in the use of NiTi endodontic systems, which can fracture if used improperly or aggressively^{58, 59}.

2.3.4.4.2 Significance of instrumentation technique

To reduce the incidence of instrument fracture, a crown-down instrumentation technique (enlarging the coronal aspect of the canal before apical preparation) and the establishment of a manual glide path (manually preparing the canals with an SS file to working length before rotary NiTi instrumentation) have been suggested^{60, 61}. Instrument ‘taper lock’ or ‘instrument jamming,’ which is linked to torsional fracture, can be reduced using these strategies. Crown-down instrumentation minimizes torsional stresses, which are especially common in smaller instruments⁶², and a glide path restricts the amount of torque applied to the instrument, preventing shear fracture⁶⁰.

2.3.4.5 Dynamics of instrument use:

2.3.4.5.1 Torque

Electric motors with torque control are usually recommended for use with rotary NiTi systems. Torque-controlled motors that perform below the elastic limit of the file reduce instrument fracture due to torsional loading, according to an in vitro study⁵⁹. Clinical trials, on the other hand, found no significant difference in instrument failure when Profile NiTi instruments were used with high or low torque motors^{40, 44}. Another clinical trial focused on three torque control levels (high, moderate, and low) during NiTi canal preparation and found that using a low torque-controlled motor reduced the number of fractures if the operator was inexperienced⁶³. However, when experienced operators used a high or moderate torque-controlled motor, no difference was detected in this investigation. One study questioned the use of torque control, claiming that rotary NiTi instruments perform better at higher torque and that frequent use of the auto-reverse function enhances the risk of torsional fatigue and failure⁶⁴.

2.3.4.5.1.1 Rotational speed

The impact of rotational speed on fracture incidence has yet to be determined, with some research claiming that rotational speed has no effect on fracture incidence^{40, 65} and others claiming the opposite^{66, 67}. When comparing these studies, there are difficulties because each one used various testing methods, instrument types, and operator skills. However, for the safe use of rotary NiTi instruments, manufacturers usually suggest a specified number of rotations per minute (rpm), usually in the range of 250-600 rpm.

2.3.4.5.1.2 Electric versus air driven handpieces

There was no difference in instrument fracture rate when air-driven and electric handpieces were compared⁶⁸. Clinical reasoning, on the other hand, indicates that an electric motor would provide a constant speed, whereas air-driven instruments would be subjected to pressure surges and a lack of speed and control, making the instrument more fracture-prone. It's worth mentioning that all NiTi instrument manufacturers currently suggest using the rotary files in a speed-controlled electric motor.

2.3.4.5.2 Canal geometry and tooth type

Cyclic fatigue testing of rotary NiTi files revealed that fracture occurs at the point of maximum flexure, which corresponds to the site of greatest curvature inside simulated root canals. These studies have demonstrated that when the angle of curvature increases and the radius of curvature decreases, the number of cycles required to file fracture decreases^{53, 65, 68, 69}. Clinical study demonstrates that most of the instrument's fracture at the apical third of the canal, which has the greatest curvature and smallest diameter⁴⁴. Iqbal et al. justified this by stating that the chance of separating a file was thirty-three times greater in the apical regions than in the coronal-third and six times more in the middle-third of the root⁴⁴. Other investigations verified the significant increase in file fracture in the apical third of root canals^{51, 70}. This is clinically

significant since the greater flexing a rotary NiTi instrument undergoes when used in curved canals, the shorter its expectancy.

Additionally, the more complicated the root canal morphology, the greater torsional failure occurs⁷¹. In general, the radius of canal curvature is decreased in molar teeth, decreasing the instrument's resistance to torsional forces⁷². This has been shown clinically, with instrument fracture being significantly greater (up to three times more) in molars than in premolars⁴⁴. The relative increase in file fractures in molar teeth has been previously noted^{43, 70}. Additionally, the probability of fracturing an instrument in the mesiobuccal canal of a maxillary molar was three times that of fracturing it in the distobuccal canal; similarly, the probability of fracturing a file in the mesiobuccal canal of a mandibular molar (known for their greater curvature) was three times that of fracturing it in the mesiolingual canal⁴⁴.

2.3.4.5.3 Effect of cleaning and sterilization

Concerning the effect of sterilizing on NiTi instruments, the literature looks inconsistent. Numerous investigations have shown that after multiple sterilization/autoclave cycles, NiTi instruments show fracture initiation and propagation, an increase in the depth of surface irregularities, and a decrease in cutting efficiency⁷³⁻⁷⁵. However, the detrimental effects of heat sterilization on the mechanical characteristics of NiTi files have been disproved, with other experiments determining that it has no discernible influence on the fracture incidence of NiTi instruments^{16, 51, 76}. However, the data seems to be clearer in respect to newly developed twisted files rather than machined files, with recent research revealing decreased cyclic fatigue resistance after multiple heat sterilization cycles⁷⁷. Interestingly, it has been found that the sterilizing procedure increases the fatigue life of NiTi files by reverting the stress-induced martensite phase to the parent austenite phase⁶⁵. However, the temperatures necessary to attain these favorable features are very unlikely in practice³³. The corrosive action of the root canal irrigant sodium hypochlorite (NaOCl) has been postulated to have a negative effect on the

mechanical properties of NiTi instruments⁷⁸. However, it has been stated that since NaOCl is unlikely to cause pitting or crevice corrosion in NiTi instruments⁷⁹, its use will not increase the prevalence of fracture or the number of revolutions necessary to cause flexural fatigue in NiTi instruments⁸⁰.

2.3.4.5.4 Number of uses

Since 2007, 'The Department of Health' in the United Kingdom has mandated that all endodontic files be single-use for cross-infection and possible prion transmission concerns⁸¹,⁸². In other European states, no such legislation exists, and the operator has complete discretion over the number of file uses. Recently, file manufacturers advocated for single-use files and included features into new files that deform during autoclaving, preventing reuse (WaveOne, Dentsply Maillefer, Ballaigues, Switzerland). The literature is ambiguous in guiding the problem of the number of uses, especially in the case of NiTi instruments, where file damage is often undetectable clinically prior to fracture⁵¹. Numerous studies indicate that the method in which NiTi instruments are used has a greater impact on their failure than the number of times they are used^{6, 16, 33, 43-45, 47-49, 54, 60, 83}. Regardless of the method of use, NiTi rotary files exhibit decreased flexural fatigue resistance with repeated use, and the force necessary to cause the failure of a previously used instrument is significantly less than that required for new instruments^{59, 84-86}. However, no clinical correlation between the number of uses and the frequency of file fracture has been found⁴². Advocates for single-use files argue that since even brand-new instruments fracture (0.9 percent) and files get more fatigued with frequent usage, recurrent use is unjustifiable⁴⁹. The cause for new file fracture has been hypothesized to be a combination of manufacturing errors, operator mistakes, and/or complicated canal anatomy⁴³. Others have advocated for the termination of SS or NiTi instruments after a predetermined number of clinical usages^{58, 87}. A considerable cohort research found that reusing ProTaper rotary NiTi files up to four times did not substantially increase fracture risk, although no details

were given about the prevalence of highly curved canals in the study⁴⁵. Similarly, another research showed that rotary instruments might be used clinically to accomplish endodontic treatment in up to four molars⁵¹, although this study excluded teeth with complicated root canal anatomy, such as sclerosed canals and/or canals with severe curvatures. The majority of deformations and fractures seemed to occur during repeated usage in complicated anatomical configurations, with almost 75% of NiTi deformations happening during molar tooth treatment⁴³. Even after a single usage, signs of deterioration in rotary NiTi instruments have been noted to be visible under SEM; however, this may not be clinically relevant⁸⁸. Given that visual examination is not a valid technique for assessing used NiTi instruments⁴⁵, it is sensible to take a cautious approach to instrument disposal. At the moment, there is no conclusive recommendation for the safe number of rotary NiTi file uses since use varies according to the tooth, operator, and root canal anatomy.

2.3.4.5.5 Instruments design

When instruments are exposed to flexural and torsional loads, it has been shown that their cross-sectional area and design may impact their resistance to fracture^{41, 89}.

2.3.4.5.5.1 Cross-sectional dimensions and design

Improving the diameter and cross-section of a file increases its resistance to torsional failure^{84, 90}, but reduces its resistance to flexural fatigue failure⁶⁵. Cross-sectional designs may also have a role in fracture incidence. Triangular ProTaper files were studied to U-fluted ProFile instruments, and it was determined that the ProTaper instruments had a more uniform distribution of stress⁴¹. This finding, however, may be muddled by taper variations between the files; the ProTaper file has a variable taper, while the ProFile file has a constant taper. Additionally, it was suggested that, although the U-flute design of ProFile and the resulting smaller cross-sectional area provided greater flexibility than the triangular form, it was weaker when subjected to torsional stress^{41, 90}. In terms of landed and unlanded instruments, it seems

as if the cutting flute does not affect the fatigue resistance of instruments of comparable size⁹¹,⁹². While it has been suggested that cross-sectional configuration has little effect on the fatigue resistance of NiTi instruments made from traditional wire⁹², one study found that a triangular and square design of NiTi instrument created from ‘controlled memory wire’ had significantly different fatigue lives⁹³.

2.3.4.5.5.2 Brands of rotary NiTi instruments

Perhaps more important than any system’s fracture resistance is the operator’s competency and knowledge with that system, experience that enables an understanding of the file’s limitations in clinical application. Ex vivo research comparing the ProFile, ProTaper, and K3™ instruments after usage on human extracted teeth found that the K3™ instruments had the lowest defect rate but found no difference in fracture frequency between the four instrument designs⁵⁰. This finding was reinforced by a clinical analysis of instrument fracture incidence in an endodontic graduate program⁴⁴, which showed that a higher incidence of instrument fracture could not be attributable to a specific rotary system.

2.3.4.5.5.3 Instrument size

Numerous in vitro studies have shown a greater fracture frequency and distortion in smaller NiTi instruments^{40, 94, 95}. Certain investigators found that smaller instruments are more prone to torsional failure than larger instruments and proposed that small files (e.g., 0.04 taper ProFile size 20) be regarded as single-use instruments due to the potential of distortion^{40, 41}. On the other hand, a large clinical cohort study⁴⁵ found that the most significant frequency of instrument failures came when larger diameter files were used, implying that larger stiffer files were subjected to more stress during usage^{65, 96}. Clinically, the reasoning would imply that smaller files are more prone to distortion since they are the principal files engaged in the root canal system’s negotiation and initial instrumentation.

2.3.5 Files lubrication

Lubrication is required throughout the root canal treatment process, from the placement of the dental dam until the obturation of the canal. Lubrication, which is often connected with instrumentation, is essential to ease the mechanical action of hand/rotary files and to aid in the emulsification and suspension of the debris generated^{16, 83}. While aqueous irrigation solutions such as sodium hypochlorite and ethylenediaminetetraacetic acid (EDTA) are lubricants, paste-type compounds are specially marketed for this function. Two types are often used: RC Prep (water-based) and Glyde (glycol-based). Both contain 10% carbamide peroxide, an antibacterial agent with a wide range of activity capable of disintegrating necrotic tissue. Before inserting the instrument into the root canal, gel-based lubricants may be applied to the instrument to minimize friction against the tight dentine walls. As more patients demand retention of teeth with narrow and curved root canals, the critical role of lubrication in all areas of root canal therapy must be recognized⁹⁷.

3. AIM

This questionnaire study aimed to assess the extent of adoption, usage, and improvement associated with NiTi rotary instruments and techniques in endodontists and postgraduate endodontic residents in Kuwait and United Arab Emirates (UAE), and it was an anonymous survey.

3.1 Specific objectives

- 1- The percentage of dentists who are using NiTi rotary instruments in Kuwait and UAE, and the difference in which brands trends in their region
- 2- Evaluate the NiTi usage modalities (lubrication methods, sterilization, & reuse) and the main concerns of NiTi usage.
- 3- Expectations for future developments in endodontic treatment

4 MATERIALS AND METHODS

4.1 Study design, population, and location

This cross-sectional survey-based study was conducted to assess the extent of adoption, usage, and improvement associated with NiTi rotary instruments and techniques in endodontists and postgraduate endodontics residents in Kuwait and UAE, disseminated through an online platform (Microsoft Forms). The survey period was among three months between 1st September 2021 and 1st December 2021. The research has proceeded in the form of a questionnaire that was e-mailed or sent by WhatsApp messages to Endodontists and Postgraduate endodontic residents through the endodontics association in UAE and Kuwait Dental Association, and the questionnaire was in English only because it is the primary language used in dental schools, journals, and dental community.

4.2 Sample size

Using size of 1673 dentist in Kuwait and base of the number of specialists according to report about dental service is 20%

Sample size calculation

The Cochran sample size for simple random sampling is given by the formula:

$$n = z_{\alpha/2}^2 \frac{p(1-p)}{d^2}$$

$$1.96 * 1.96 * 0.20 * (1 - 0.20) / (0.05 * 0.05) = 245 \text{ dentist}$$

If we expect the number of endodontists is 25% of this number of the whole specialist, then we expect to invite for this study number not less than 61 and not more than 245.

4.3 Data analysis

Data was entered in the computer using IBM-SPSS for Windows version 25.0 (SPSS Inc., Chicago, IL). Categorical variables were described by using proportion and continuous variables were described by a measure of tendency and measure of dispersion. Categorical variables were cross-tabulated to examine the independence between variables. For such variables, the χ^2 -square test or Fisher's exact test as appropriate was used. Kolmogorov-Smirnov was used to test the normality of continuous variables like age. The Mann-Whitney test was used to compare the means between the two groups. When comparing the means between more than two groups, the Kruskal-Wallis test was used. If the data fulfilled the condition of normality, t-test and ANOVA was used for the test. To test the effect of several variables on NiTi logistic regression was used. A P-value of less than 0.05 was considered significant in all statistical analyses.

4.4 Inclusion criteria

Practicing Endodontists and Postgraduate endodontic residents who are practicing in Kuwait and UAE.

4.5 Exclusion criteria

1. Endodontists who are not currently in practice.
2. Dental students
3. Dental nurses
4. Dental technicians
5. Any Endodontist who did not wish to take part in the study
6. Participants who are not practicing in Kuwait or UAE

4.6 Reminders

Two reminders were sent to the participants, the first reminder was sent one month after the survey starting date, and the second reminder was sent two months after the survey date.

(Appendix IV)

4.7 Ethical considerations

This study was conducted in full conformance with principles of the “Declaration of Helsinki”, Good Clinical Practice (GCP), and within the laws and regulations of the UAE/DHCC (Dubai Healthcare City). The ethical approval was obtained from the Research Ethics Review Committee at MBRU-IRB. (MBRU-IRB-2020-038).

Please check Appendix I for the approval and Appendix II for the consent form.

4.8 Questionnaire and data collection

The structured questionnaire used in this study had been built and reviewed by the endodontics department staff and Professor Amar Omer in the HBMCDM college of dentistry to ensure the questions were easily understood. The questionnaire did not include any identifying information and was completely anonymous.

After reading an information sheet about the survey, the participating dentist signed online informed consent before completing the questionnaire (Appendix II).

The questionnaire (see Appendix III) consisted of 17 questions to investigate the practitioner’s usage of the NiTi rotary system. The questions were divided into four main categories.

- A. Demographic & General Information:** Years of experience (for Endodontist or Postgraduate resident), Age, Gender, Type of practice (Government or Private), and Country of practice. Q1-Q5 in table 4.1.

Table 4.1: Demographic & General information questions

-
1. How many years has it been since you completed the Endodontic residency?
 2. What is your age? Open answer question
 3. What is your Gender?
 4. What is your type of practice?
 5. What is your country of practice?
-

B. Usage of NiTi instruments: Number of endodontics cases treated per week and the percentage of these cases treated by NiTi, methods of lubrication during instrumentation and concerns regarding the usage of NiTi instruments. Q6-Q10 in table 4.2.

Table 4.2: Usage of NiTi instruments questions

-
6. Do you use NiTi engine-driven instrument for preparing root canals?
 7. How many endodontic cases do you see per week on average? Open answer question
 8. What percentage of that cases do you use NiTi instruments?
 9. How Do You Lubricate NiTi Instruments in Root Canals?
 10. What is your main concern about the use of NiTi instruments in root canal treatment?
-

C. Modalities of NiTi instruments Usage: Adaptation of newer technology, type of motion, Reuse of the NiTi instruments, Number of cases prepared with each instruments, Sterilization methods (Before initial use and reuse) and the brands of NiTi instruments used. Q11-Q16 in table 4.3.

Table 4.3: Modalities of NiTi instruments usage questions

11. What is the motion that you predominantly use in your practice?
12. How many cases do you routinely shape with a rotary file before discarding it?
13. Do you sterilize NiTi rotary files before their first use?
14. Do you reuse NiTi rotary files?
15. How do you sterilize NiTi instruments for reuse?
16. Which brands do you predominantly use in terms of NiTi instruments? Lists of Manufacture with (Yes/No)

D. Future expectations in instruments development: expectations in the future for instrument's development. Q17 in table 4.4.

Table 4.4: Current types of NiTi usage question

17. What Are Your Expectations for Developments Regarding Canal Preparation in the Next 10 Years? Open answer question
--

All the questions in this questionnaire were mandatory to answer except question number 17. For question number 16, the participants faced a list of manufacturers; if the answer was yes, the participant would move to the list of files of the same manufacturer to choose between them then the participant will move to the following manufacturer; if no, the participant will move directly to the following manufacturer respectively.

5 RESULTS

5.1 Study Sample characteristics

An email and WhatsApp message were sent to 92 total number of Endodontists in Kuwait and UAE through the Kuwait Association of Endodontists (KAE) and Emirates Endodontic Society (EES); 75 participants responded to the questionnaire with an 81.5% response rate. The characteristics of the 75 endodontists who participated in the study are summarized in (Table 5.1.) the gender distribution (Figure 5.1) of the study population was: males were 65.3% (n=49), whereas females were 33.3% (n=25), and who preferred not to say was 1.4% (n=1). Country of practice (Figure 5.2) was UAE 49.3% (n=37), Kuwait 44% (n=33), and Others was 6.7% (n=5). Experience as an endodontist was 51.4% (n=38) for those who had experienced less than ten years, 20.3% (n=15) was for who had experience 10-25 years, 10.8% (n=8) was for who had experienced more than 25 years, and postgraduate residents was 17.6% (n=13) (Figure 5.3). For the type of practice (Figure 5.4), who were working in a public practice were 52% (n=39), the university-based practice was 24% (n=18), private practice was 20% (n=15), military practice was 4% (n=3). The mean age for all the participants (including others) was 39.35 years with a standard deviation (SD) of 7.98 years; there were 27 (73%) participants from UAE who were younger or equaled 45 years old and 10 (27%) participants who were older or equal to 46 years old while from Kuwait there were 30 (90.9%) participants who were younger or older than 45 years old and three (9.1%) participants who were older or equal to 46 years old with no significant difference between the participants of both regions (p=0.054)

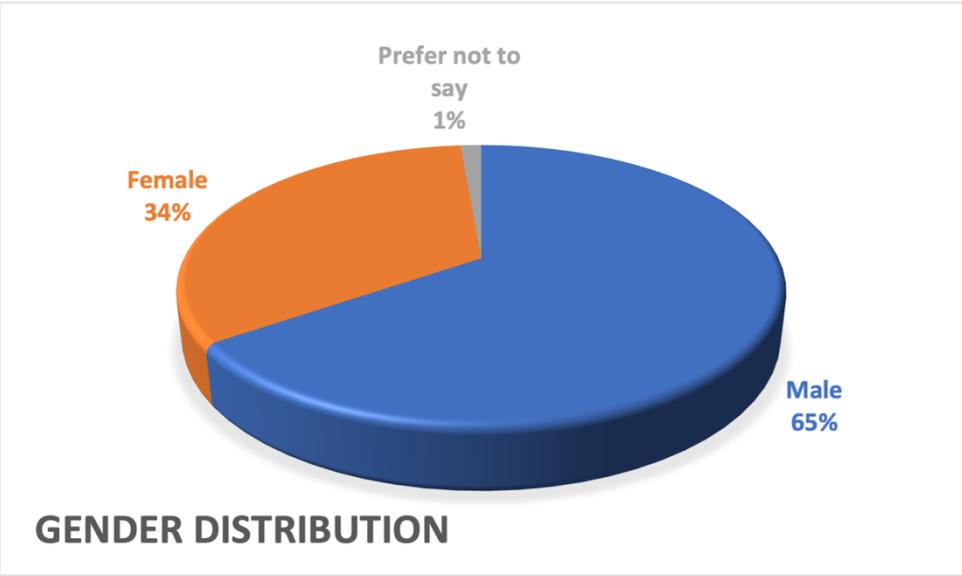


Figure 5.1



Figure 5.2

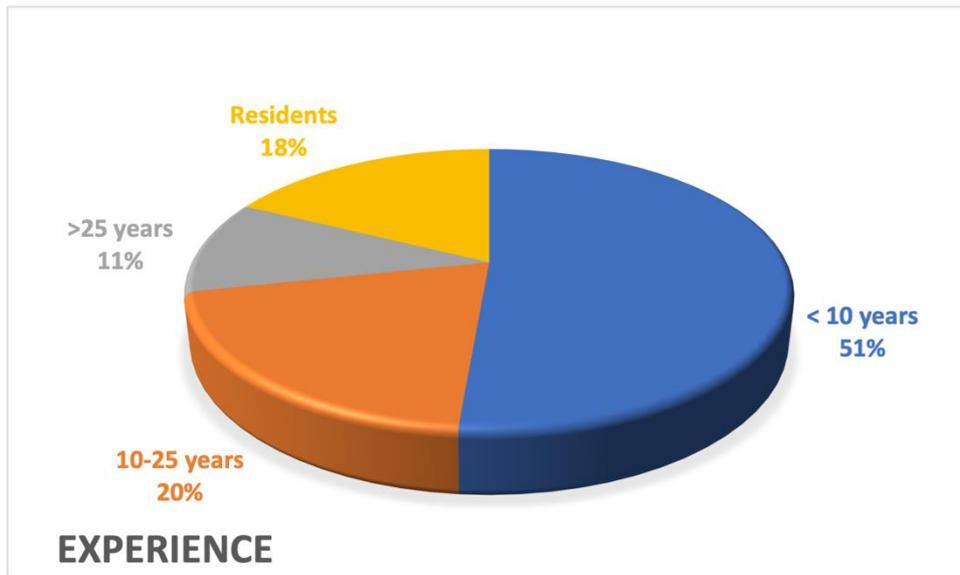


Figure 5.3

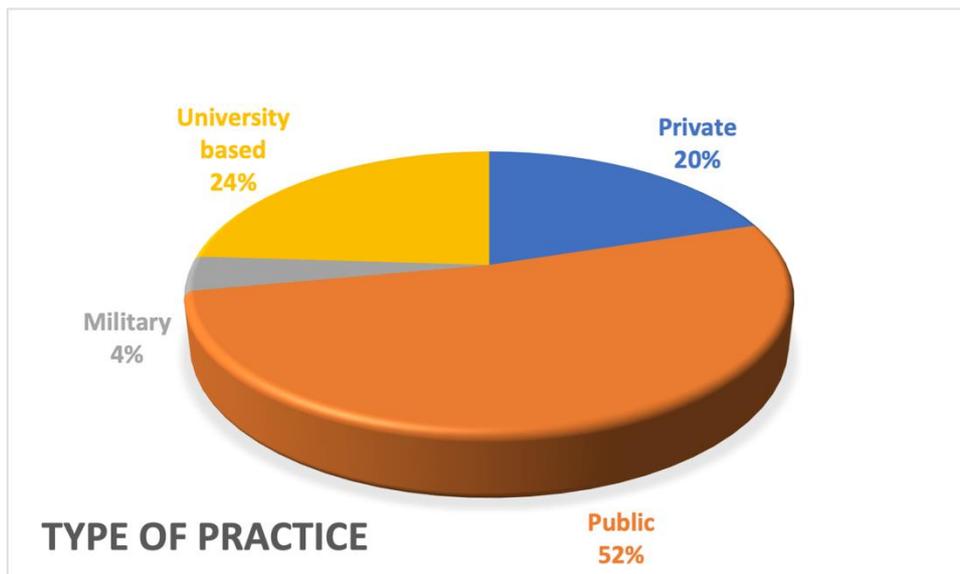


Figure 5.4

Table 5.1: Demographic characteristics

Item	No (%)
<i>Gender</i>	
Male	49 (65.3)
Female	25 (33.3)
Prefer not to say	1 (1.4)

Country of practice

UAE	37 (49.3)
Kuwait	33 (44)
Others	5 (6.7)

Experience as endodontist

< 10 years	38 (51.4)
10-25 years	15 (20.3)
>25 years	8 (10.8)
Residents	13 (17.6)

Type of practice

Private	15 (20)
Public	39 (52)
Military	3 (4)
University based	18 (24)

Age, Mean (SD) 39.35 (7.98)

Table 5.2: Age's groups difference between Kuwait and UAE

Age	UAE No (%)	Kuwait No (%)	P-value
<=45	27 (73)	30 (90.9)	0.054
>=46	10 (27)	3 (9.1)	

5.2 NiTi Instruments usage results

All the participants are using the NiTi instruments 100% (n=75), and 84% of the participants (n=63) used it in more than 90% of their cases, while those who used it in 70-90% of their cases was 13.3% (n=10), and those who used it in less than 70% of their cases was 2.7 percent (n=2). For the lubrication method during NiTi instruments usage, EDTA gel was the choice of

most of the participants 58.7% (n=44), NaOCl irrigant solution was 34.7% (n=26), water-based lubricant was 2.7% (n=2), and 4% (n=3) was not using any lubrication. The main concern about using NiTi instruments in root canal treatment was file fracture 66.7% (n=50), then Re-use of the instruments 16% (n=12), then preparation iatrogenic errors 14.7% (n=11), then flexibility & efficiency 1.3% (n=1) and cost of the instruments 1.3% (n=1). The mean of number of cases that were seen per week was 17.8 case with a standard deviation (SD) of 10.25 case.

Table 5.3: Usage of NiTi instruments

Item	No (%)
<i>Usage of NiTi instruments</i>	75 (100)
<i>Percentage of cases treated with NiTi instruments</i>	
50-70	2 (2.7)
70-90	10 (13.3)
>90	63 (84)
<i>Methods of lubrication of NiTi instruments in root canal treatment</i>	
No lubrication	3 (4)
EDTA gel	44 (58.7)
NaOCl irrigant	26 (34.7)
Water-based lubricant	2 (2.7)
<i>Main concern about NiTi instruments in root canal treatment</i>	
File fracture	50 (66.7)
Flexibility and efficiency	1 (1.3)
Preparation iatrogenic errors	11 (14.7)

Re-use of the instrument	12 (16)
Cost of the instrument	1 (1.3)
<i>Number of cases seen per week, mean (SD)</i>	17.8 (10.25)

5.3 Modalities of NiTi instruments usage in root canal treatment

The majority of the participants were using rotary motion 85.3% (n=64), then 8% (n=6) for the reciprocating motion, and 6.7% (n=5) for the adaptive motion. 50.7% (n=38) of the participants discarded the file after a single-use, 46.7% (n=35) used the files again from 2-3 cases, and 2.7% (n=2) used it for more than 3 cases. 57% (n=43) of the participants were not sterilizing the NiTi instruments before the first use, 37.3% (n=28) of them were buying pre-sterilized instruments, and 5.3% (n=4) do sterilize the instruments before the first use. When asked if they reuse the NiTi instruments, 62.7% (n=47) of them said yes, while 37.3% (n=28) do not. In the case of reuse of the NiTi instruments, 73.3% (n=55) of the participants were using steam autoclave for sterilization, 2.7% (n=2) chemiclave, 1.3% (n=1), and 22.7% (n=17) were using different methods.

Table 5.4: Modalities of NiTi instruments usage in root canal treatment

Item	No (%)
<i>Predominant type of motion</i>	
Adaptive motion	5 (6.7)
Reciprocating motion	6 (8)
Rotary motion	64 (85.3)
<i>Number of cases before discard the file</i>	
Single use	38 (50.7)
2-3 cases	35 (46.7)
>3 cases	2 (2.7)

Sterilization of NiTi instruments before the first used

No	43 (57)
Yes	4 (5.3)
Buy pre-sterilized instrument	28 (37.3)

Do you reuse the NiTi instruments?

No	28 (37.3)
Yes	47 (62.7)

Method of sterilization of NiTi instruments in case of reuse

Chemiclave	1 (1.3)
Dry heat	2 (2.7)
Steam autoclave	55 (73.3)
Others	17 (22.7)

For the brands predominantly used in terms of NITI instruments among all participants (Table 5.4), from Dentsply Sirona manufacturer ProTaper Next (PTN) was the most chosen file 76% (n=57), then Protaper Universal Gold (PTG) 48% (n=36), then ProTaper Universal (PTU) 36% (n=27), then WaveOne Gold (WOG) 33.3% (n=25), then TruNatomy 18.7% (n=14), then ProFile 14.7% (n=11), then WaveOne 12% (n=9). For FKG manufacturer XP-endo Shaper was the most used file with 28% (n=21), then iRace 21.3% (n=16), then BioRace 2.7% (n=2). For MicroMega manufacturer the most used file was One Curve with 12% (n=9), then REVO-S & One Shape were equal with 5.3% (n=4) for each, then 2Shape 4% (n=3). For Kerr™ manufacturer TF™ Adaptive file was most used file with 13.3% (n=10), then TF™ Twisted file 8% (n=6), then K3™ file 5.3% (n=4). For Coltene manufacturer HyFlex™ CM file was

the most predominant file to be used with 9.3% (n=7), then HyFlex™ EDM file 5.3% (n=4). For VDW® manufacturer the most predominant file was chosen by the participants was RECIPROC file with 24% (n=18), then RECIPROC blue file 16% (n=12), then Mtwo & FlexMaster files 1.3% (n=1) for each. For EdgeEndo® manufacturer EdgeFile™ was the most predominant file to be used with 12% (n=9), then EdgeTaper™ file 9.3% (n=7), then EdgeOne Fire™ 6.7% (n=5), then EdgeTaper Platinum™ & EdgeTaper Encore™ files with 4% (n=3) for each, then EdgeSequel Sapphire™ with 2.7% (n=2). For Fanta® manufacturer AF F EDM, AF F ONE, and AF BLUE ROTARY files were chosen 2.7% (n=2) for each, then AF BLUE S ONE, AF ROTARY, V-TAPER GOLD ROTARY, and V-TAPER BLUE ROTARY were chosen 1.3% (n=1) for each (table 5.4) (figure 5.5-5.12).

Table 5.5: Brands predominantly used in terms of NiTi instruments

Item	No (%)
<i>Dentsply Sirona</i>	
ProFile	11 (14.7)
ProTaper Universal (PTU)	27 (36)
ProTaper Universal Gold (PTG)	36 (48)
ProTaper Next (PTN)	57 (76)
WaveOne	9 (12)
WaveOne Gold (WOG)	25 (33.3)
TruNatomy	14 (18.7)
<i>FKG</i>	
iRace	16 (21.3)
BioRace	2 (2.7)
XP-endo Shaper	21 (28)
<i>MicroMega</i>	
REVO-S	4 (5.3)
2Shape	3 (4)

One Shape	4 (5.3)
One Curve	9 (12)
<i>Kerr™</i>	
K3™	4 (5.3)
TF™ Adaptive	10 (13.3)
TF™ Twisted file	6 (8)
<i>Coltene</i>	
HyFlex™ EDM	4 (5.3)
HyFlex™ CM	7 (9.3)
<i>VDW®</i>	
RECIPROC	18 (24)
RECIPROC blue	12 (16)
Mtwo	1 (1.3)
FlexMaster	1 (1.3)
<i>EdgeEndo®</i>	
EdgeFile™	9 (12)
EdgeOne Fire™	5 (6.7)
EdgeSequel Sapphire™	2 (2.7)
EdgeTaper™	7 (9.3)
EdgeTaper Platinum™	3 (4)
EdgeTaper Encore™	3 (4)
<i>Fanta®</i>	
AF F EDM	2 (2.7)
AF F ONE	2 (2.7)
AF BLUE S ONE	1 (1.3)
AF BLUE ROTARY	2 (2.7)
AF ROTARY	1 (1.3)

V-TAPER GOLD ROTARY

1 (1.3)

V-TAPER BLUE ROTARY

1 (1.3)

Figure 5.5: Dentsply Sirona instruments.

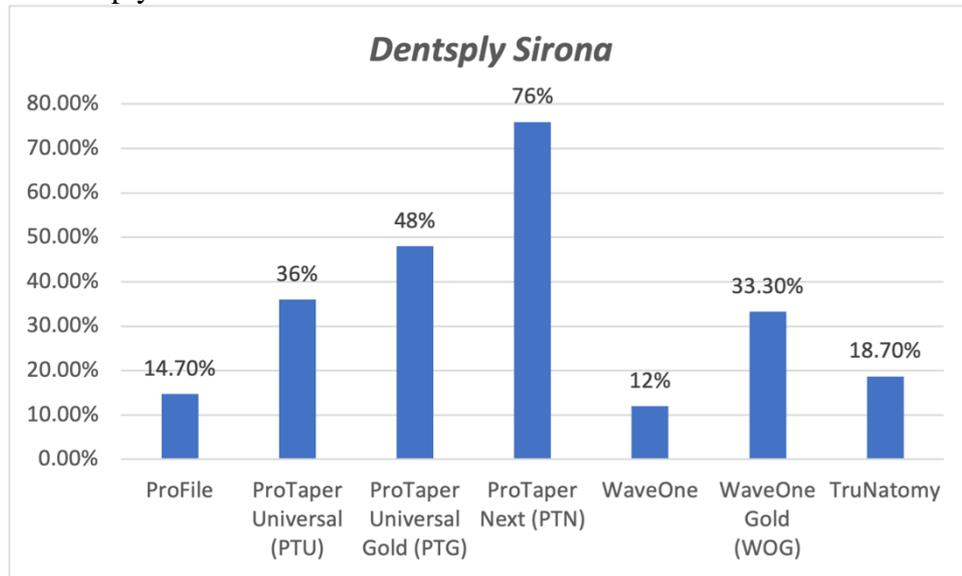


Figure 5.5

Figure 5.6: FKG instruments.

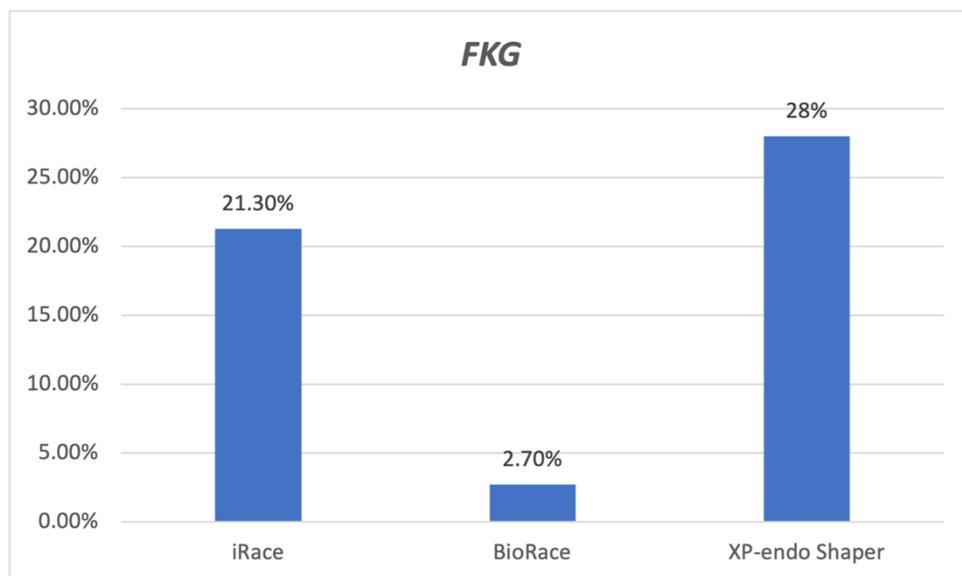


Figure 5.6

Figure 5.7: MicroMega instruments.

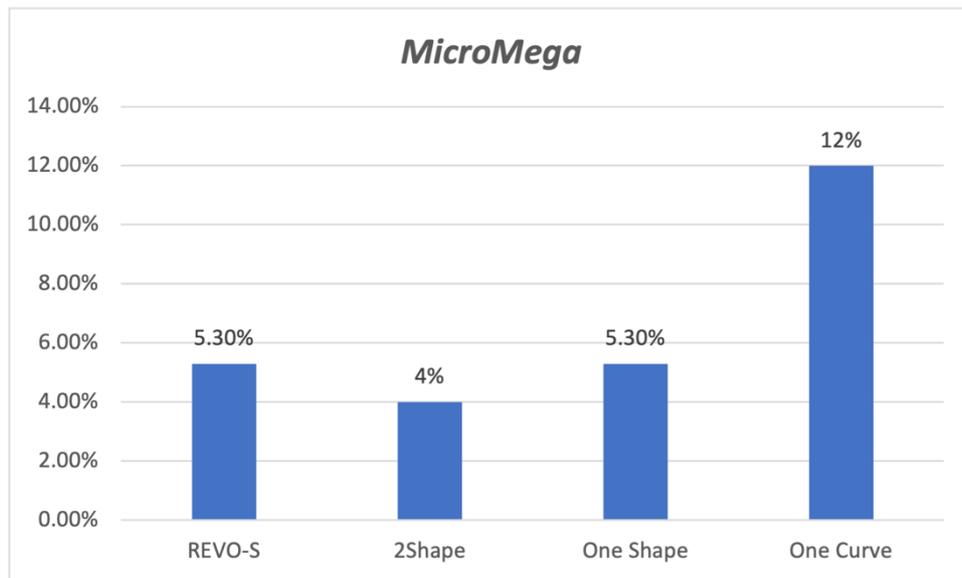


Figure 5.7

Figure 5.8: Kerr™ instruments.

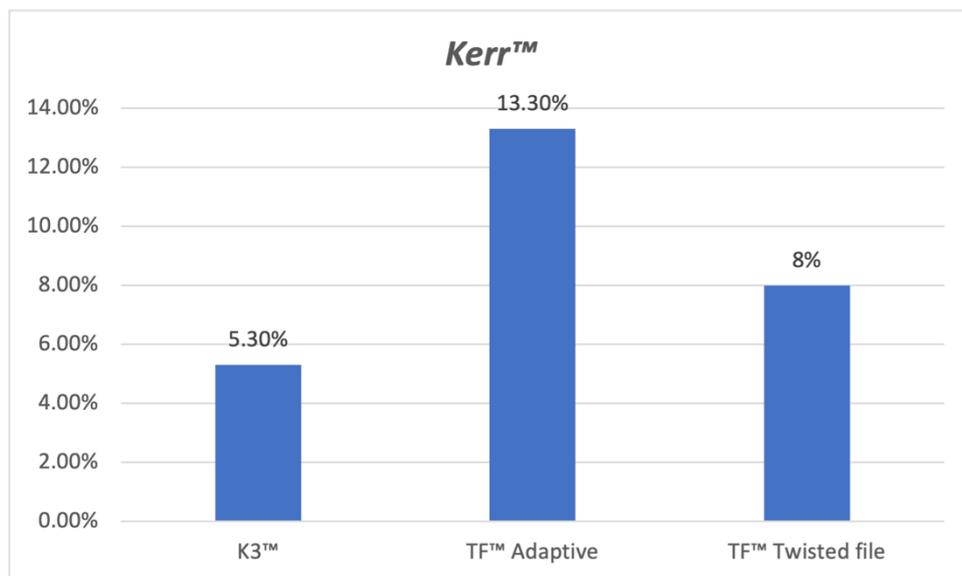


Figure 5.8

Figure 5.9: Coltene instruments.

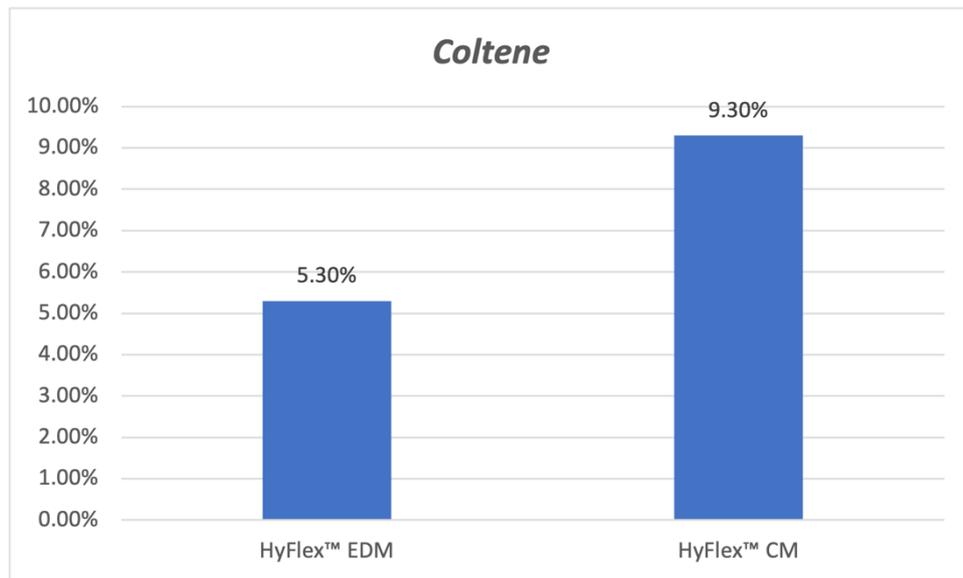


Figure 5.9

Figure 5.10: VDW® instruments.

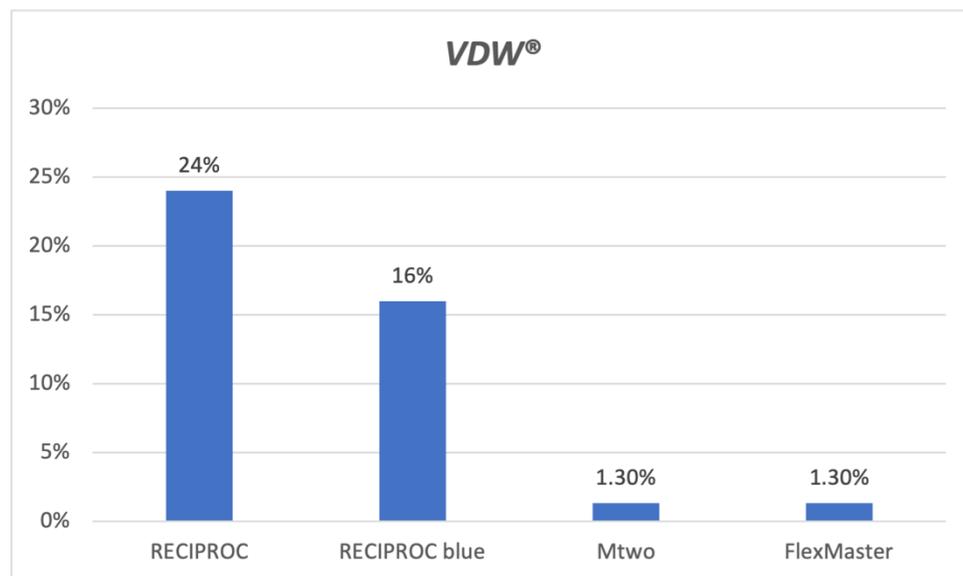


Figure 5.10

Figure 5.11: EdgeEndo® instruments.

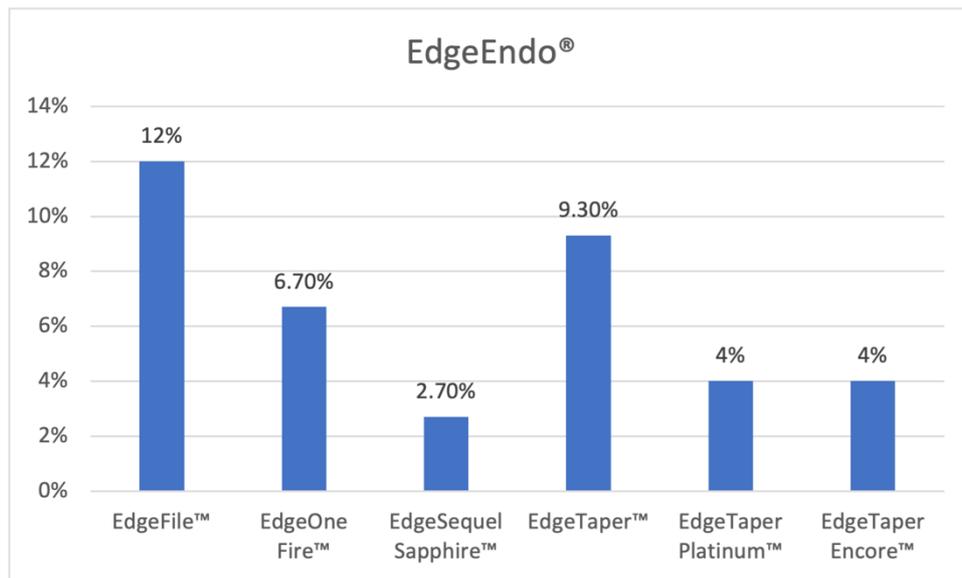


Figure 5.11

Figure 5.12: Fanta® instruments.

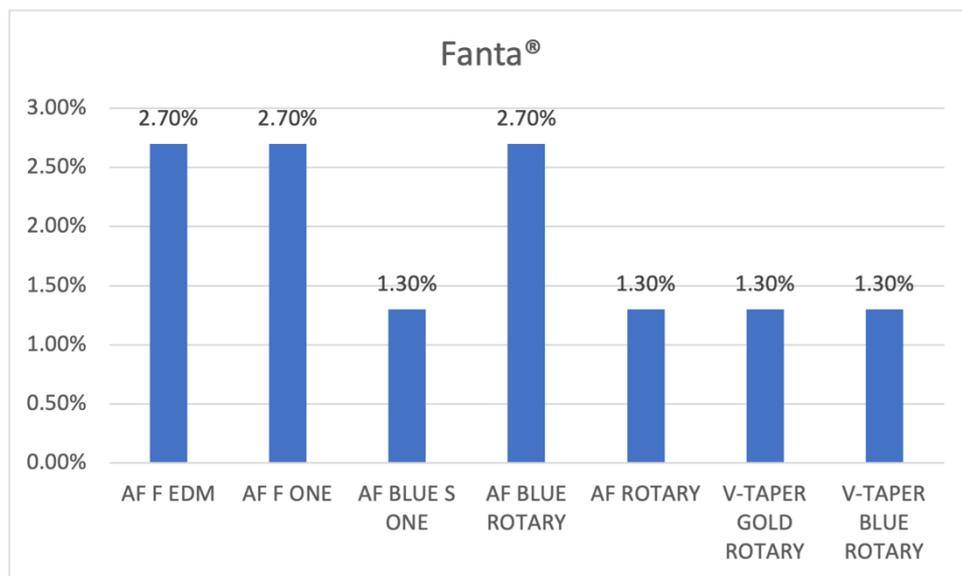


Figure 5.12

5.4 Future expectations of NiTi instruments and endodontics treatment development

The data from question number 17 is quantitative. The numbers do not replicate the number of the participants, but it represents their thoughts. Question number 17 was a non-mandatory open answer question; 72% (n=54) of participants answered the question. Three of them had a non-relevant answers, so they were excluded from this analysis. In contrast, the remaining 51 participants had at least one expectation or more about the future of NiTi instruments or the future of the endodontic treatment. The answers were distributed among six categories:

1. Design
2. Sequence & simplicity
3. Combined techniques
4. Non-instrumentation techniques
5. Advanced irrigation
6. Laser

Each participant answer which included cutting efficiency, less taper, development of heat treatment files, flexibility, conservative preparation, or fracture resistance, was categorized under the design section, and it was 24 answers, all the answers which included less number of files, single file, simple, easy or sequence was categorized under sequence & simplicity section, and it was 17 answers, all the answers which included combined cleaning, visualization, smart preparation (working length detection) or navigation were categorized under combined techniques, all the answers which included non-preparation/instrumentation or disinfection only were categorized under non-instrumentation techniques, and it was five answers, all answers which included irrigation & preparation at the same time or better irrigant delivery was categorized under advanced irrigation, and it was three answers, finally all the answers which mentioned laser or laser technique was categorized under the laser section and it was three answers (figure 5.13).

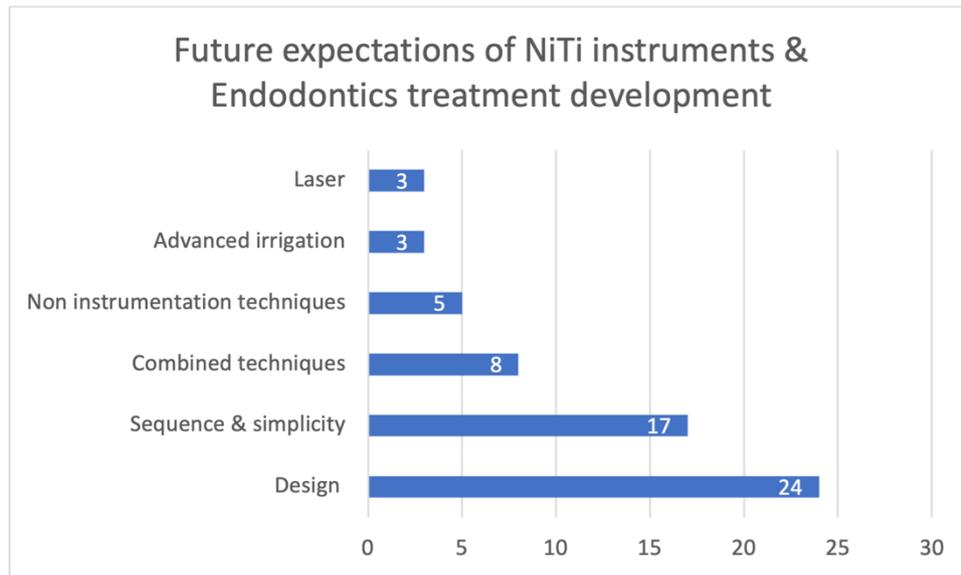


Figure 5.13

5.5 Association between NiTi instruments elements and country of practice

Five participants were excluded from this analysis because they answered question number five (country of practice) as other, and the comparison is between Kuwait and UAE; the total remaining number of participants is 70.

In terms of the percentage of those cases that use NiTi instruments to treat more or less than 90% of the cases, 97% (n=32) of the participants who works in Kuwait are using NiTi instruments with more than 90% of their cases, while in UAE 73% (n=27) of the participants who works in UAE are using NiTi instruments with more than 90% of their cases showing the significant difference with P-Value (p= 0.006).

There were no significant differences with no lubrication, EDTA gel, or water-based lubricant in terms of lubricating the NiTi instruments during the root canal treatment. While in NaOCl irrigant, 60.6% (n=20) of participants who work in Kuwait are using it while in UAE 16.2% (n=6) that shows a significant difference (p<0.001).

In terms of the main concern of the participant about using the NiTi instruments in root canal treatment, the main concern was file fracture in both Kuwait 72.7% (n=24) and UAE 56.8% (n=21), but there was no significant difference, and the same for the remaining concerns which

are flexibility & efficiency, preparation errors, re-use of the instrument, or the cost of the instrument.

When the participants were asked about the predominant motion, they were using in practice. There were no significant differences in rotary motion and adaptive motion. However, in Kuwait, 18.2% (n=6) of the participants are using reciprocating motion as a predominant motion; in contrast, no one is using it predominantly in UAE, which shows a significant difference (p=0.006).

The majority of the participants in both regions were not sterilizing the NiTi instruments before the first use (54.5% (n=18) in Kuwait and 56.8% (n=21) in UAE), there was no significant difference. For those who bought sterilized NiTi files or pre-sterilized the files before using them, there were no significant differences either.

When the participants were asked if they were re-using the rotary files, 60.6% (n=20) of participants in Kuwait and 64.9% (n=24) of participants in UAE said yes with no significant difference (p=0.452), and also when they were asked which sterilization method they will choose in case of re-use the instruments, the steam autoclave was the most chosen method in 81.8% (n=27) of Kuwait's participants and 70.3% (n=26) of UAE's participants with no significant difference (p=0.481).

Table 5.6: Association between NiTi instruments elements and country of practice

Items	UAE, No (%)	Kuwait, No (%)	P-Value
<i>Percentage of cases that treated with NiTi instruments</i>			
< 90	10 (27)	1 (3)	
>= 90	27 (73)	32 (97)	0.006

Method of lubrication of NiTi instruments in

Root canal treatment

No	3 (8.1)	0	
EDTA gel	27 (73)	12 (36.4)	
NAOCI irrigant	6 (16.2)	20 (60.6)	<0.001
Water-based lubricant	1 (2.7)	1 (3)	

Main concern about use NiTi instruments in root canal treatment

File fracture	21 (56.8)	24 (72.7)	
Flexibility, efficiency	0	1 (3)	
Preparation errors	9 (24.3)	2 (6.1)	0.168
Re-use of the instrument	6 (16.2)	6 (18.2)	
Cost of the instrument	1 (2.7)	0	

Predominant type of motion

Adaptive motion	4 (10.8)	0	
Reciprocating motion	0	6 (18.2)	0.006
Rotary motion	33 (89.2)	27 (81.8)	

Sterilization of NiTi instruments before the first used

No	21(56.8)	18 (54.5)	
Buy sterilize NITI files	13 (35.1)	14 (42.4)	0.594
Pre-sterilize new files before first use	3 (8.1)	1 (3)	

Do you reuse the NiTi instruments?

No	13 (35.1)	13 (39.4)	
Yes	24 (64.9)	20 (60.6)	0.452

Method of sterilization of NiTi instruments in case of reuse

Dry heat	1 (2.7)	1 (3)	
Steam autoclave	26 (70.3)	27 (81.8)	0.481
Others	10 (27)	5 (15.2)	

5.6 Association between brands and their products used in the country of practice

When we analyzed the questionnaire answers, we compared each manufacturer's differences in popularity and products in both regions.

We found that Dentsply Sirona was the most chosen manufacturer in both Kuwait (97%, n=32) and UAE (97.3%, n=36) with 97.1% (n=68) overall the 70 participants, there was no significant difference (p=0.467). For Dentsply Sirona files there was no significant differences between both regions for the following files ProFile (Kuwait (15.6%, n=5) & UAE (8.3%, n=3)) (p=0.290), ProTaper Universal (Kuwait (25%, n=8) & UAE (44.4%, n=16)) (p=0.077), WaveOne (Kuwait (12.5%, n=4) & UAE (11.1%, n=4)) (p=0.567), WaveOne Gold (Kuwait (34.4%, n=11) & UAE (33.3%, n=12)) (p=0.565), TruNatomy (Kuwait (18.8%, n=6) & UAE (19.4%, n=7)) (p=0.954). on the other hand, there was a significant difference (p<0.001) with ProTaper Univesal Gold which most preferred in UAE (69.4%, n=25) than Kuwait (21.9%, n=7); in contrast with ProTaper Next which was the most preferred in Kuwait (93.8%, n=30) than UAE (63.9%, n=23) which showed a significant difference (p=0.003).

FKG manufacturer was chosen by 43.2% (n=16) of UAE's participants and by 39.4% (n=13) of Kuwait's participants with no significant difference (p=0.467), for both BioRace file in Kuwait (7.7%, n=1) & UAE (6.3%, n=1) (p=0.704) and XP-endo Shaper file in Kuwait (84.6%, n=11) & UAE (56.3%, n=9) (p=0.107) there were no significant differences, while for iRace

file it was chosen by 68.8% (n=11) of UAE's participants and by 30.8% (n=4) of Kuwait's participants with a significant difference (p=0.048).

MicroMega manufacturer was chosen by 9.1% (n=3) of Kuwait's and by 18.9% (n=7) of UAE's participants with no significant difference (p=0.204). Both REVO-S file and 2Shape file were chosen by 42.9% (n=3) of UAE's participants, and none of Kuwait's participants chose it with no significant differences for both (p=0.292). The One Shape file was chosen by 42.9% (n=3) of UAE's participants and by 33.3% (n=1) of Kuwait's participants with no significant difference (p=0.667). For the One Curve file, it was chosen by 42.9% (n=3) of UAE's participants and by 100% (n=3) of Kuwait's participants with no significant difference.

Kerr™ manufacturer was chosen by 12.1% (n=4) of Kuwait's participants and by 21.6% (n=8) of UAE's participants with no significant difference (p=0.232). K3™ file was chosen by 25% (n=2) of UAE's participants, and none of Kuwait's participants chose it with no significant difference (p=0.424). None of the participants in both regions chose the K3™XF file. TF™ Adaptive file was chosen by 50% (n=4) of UAE's participants and by 100% (n=4) of Kuwait's participants with no significant difference (p=0.141). TF™ Twisted file was chosen by 37.5% (n=3) of UAE's participants and by 25% (n=1) of Kuwait's participants with no significant difference (p=0.594)

Coltene manufacturer was chosen by 27.3% (n=9) of Kuwait's participants and by 2.7% (n=1) of UAE's manufacturer with a significant difference (p=0.004). HyFlex™ EDM file was chosen by 100% (n=1) of UAE's participants and by 33.3% (n=3) of Kuwait's participants with no significant difference (p=0.400). HyFlex™ CM file was chosen by 100% (n=1) of UAE's participants and by 66.7% (n=6) of Kuwait's participants with no significant difference (p=0.700).

VDW® manufacturer was chosen by 51.5% (n=17) of Kuwait's participants and by 16.2% (n=6) of UAE's participants with a significant difference (p=0.002). RECIPROC file was

chosen by 64.7% (n=11) of Kuwait's participants and by 100% (n=6) of UAE's participants with no significant difference (p=0.123). RECIPROC blue file was chosen by 64.7% (n=11) of Kuwait's participants and by 16.7% (n=1) of UAE's participants with no significant difference (p=0.059). Any participant of both regions did not choose VDW.ROTATE file. The FlexMaster file was chosen by 5.9% (n=1) of Kuwait's participants and not by any participants from UAE with no significant difference (p=0.739). In contrast, the Mtwo file was chosen by 16.7% (n=1) of UAE's participants and not chosen by any participants from Kuwait with no significant difference (p=0.261).

EdgeEndo® manufacturer was chosen by 30.3% (n=10) of Kuwait's participants and by 16.2% (n=6) of UAE's participants with no significant difference (p=0.132). EdgeFile™ was chosen by 40% (n=4) of Kuwait's participants and by 66.7% (n=4) of UAE's participants with no significant difference (p=0.304). EdgeONE Fire™ file was chosen by 20% (n=2) of Kuwait's participants and 16.7% (n=1) of UAE's participants with no significant difference (p=0.696). EdgeTaper™ file was chosen by 50% (n=5) of Kuwait's participants and by 33.3% (n=2) of UAE's participants with no significant difference (p=0.451). EdgeSequel Sapphire™ file and EdgeTaper Platinum™ file were chosen by 20% (n=2) of Kuwait's participants, and none of UAE's participants chose it with no significant difference (p=0.375). EdgeTaper Encore™ file was chosen by 30% (n=3) of Kuwait's participants, and none of UAE's participants chose it with no significant difference (p=0.214).

Fanta® manufacturer was chosen by 3% (n=1) of Kuwait's participants and by 2.7% (n=1) of UAE's participants with no significant difference (p=0.724).

All the results are presented in (Table 5.6).

Table 5.7: Association between brands and their products used in the country of practice

Items	UAE	Kuwait	P-value
<i>Dentsply Sirona</i>	36 (97.3)	32 (97)	0.467
ProFile	3 (8.3)	5 (15.6)	0.290
ProTaper Universal (PTU)	16 (44.4)	8 (25)	0.077
ProTaper Universal Gold (PTG)	25 (69.4)	7 (21.9)	<0.001
ProTaper Next (PTN)	23 (63.9)	30 (93.8)	0.003
WaveOne	4 (11.1)	4 (12.5)	0.567
WaveOne Gold (WOG)	12 (33.3)	11 (34.4)	0.565
TruNatomy	7 (19.4)	6 (18.8)	0.954
<i>FKG</i>	16 (43.2)	13 (39.4)	0.467
iRace	11 (68.8)	4 (30.8)	0.048
BioRace	1 (6.3)	1 (7.7)	0.704
XP-endo Shaper	9 (56.3)	11 (84.6)	0.107
<i>MicroMega</i>	7 (18.9)	3 (9.1)	0.204
REVO-S	3 (42.9)	0	0.292
2Shape	3 (42.9)	0	0.292
One Shape	3 (42.9)	1 (33.3)	0.667
One Curve	3 (42.9)	3 (100)	0.167
<i>Kerr™</i>	8 (21.6)	4 (12.1)	0.232
K3™	2 (25)	0	0.424
K3™XF	0	0	NA
TF™ Adaptive	4 (50)	4 (100)	0.141
TF™ Twisted	3 (37.5)	1 (25)	0.594
<i>Coltene</i>	1 (2.7)	9 (27.3)	0.004

HyFlex™ EDM	1 (100)	3 (33.3)	0.400
HyFlex™ CM	1 (100)	6 (66.7)	0.700
VDW®	6 (16.2)	17 (51.5)	0.002
RECIPROC	6 (100)	11 (64.7)	0.123
RECIPROC blue	1 (16.7)	11 (64.7)	0.059
VDW.ROTATE	0	0	NA
FlexMaster	0	1 (5.9)	0.739
Mtwo	1 (16.7)	0	0.261
EdgeEndo®	6 (16.2)	10 (30.3)	0.132
EdgeFile™	4 (66.7)	4 (40)	0.304
EdgeOne Fire™	1 (16.7)	2 (20)	0.696
EdgeSequel Sapphire™	0	2 (20)	0.375
EdgeTaper™	2 (33.3)	5 (50)	0.451
EdgeTaper Platinum™	0	2 (20)	0.375
EdgeTaper Encore™	0	3 (30)	0.214
Fanta®	1 (2.7)	1 (3)	0.724
AF F EDM	1 (100)	0	0.500
AF F ONE	1 (100)	1 (100)	NA
AF Blue One	1 (100)	0	0.500
AF Blue R3	0	0	NA
AF Blue Rotary	1 (100)	0	0.500
AF Rotary	0	0	NA
V-Taper Rotary	0	0	NA
V-Taper Gold Rotary	1 (100)	0	0.500
V-Taper Blue Rotary	1 (100)	0	0.500

AF Max Rotary

0

0

NA

6 DISCUSSION

The response rate and representative sample size are essential in interpreting the results of questionnaire survey research. Low response rates may end up causing the data to be invalid (Tambor et al. 1993). Although a cursory assessment of nonresponse bias may appear to confirm low response rates, high response rates allow for more precise estimates and analysis of the data (Locker 2000). The proper sample size and sample selection are crucial (Dillman 2000). According to the literature, a minimum valid response rate of 75-80% is recommended (Gough & Hall 1977, Evans 1991). As a result, this study's 81.5 % overall response rate can represent all endodontists practicing in Kuwait and the United Arab Emirates. Furthermore, the data is further validated by the questions' extremely high item response rates. Nonetheless, any survey data interpretation must consider the possibility of incorrect responses due to factors such as questionnaire design, question phrasing, and respondent variables.

One of the most important steps in a successful RCT is cleaning and shaping the root canal system. In the last 30 years, there has been a significant development in the manufacturing of root-canal instruments, particularly NiTi-EIs, for safer and more predictable root-canal instrumentation⁹⁸. When compared to SSIs, NiTi-EIs have been found to be superior in cleaning and shaping the root-canal system^{11, 12}. A previous study found that teeth prepared with NiTi hand files had a significantly higher success rate than teeth prepared with SS K-files¹¹. When compared to SSIs, teeth instrumented with NiTi-EIs had a significantly superior outcome, according to a recent study⁹⁹. Furthermore, clinicians choose NiTi instruments for root-canal instrumentation because they are safer and faster. Despite the fact that various research has looked at the use of NiTi-EIs in dental practice in various countries, there is still a lack of data on usage modalities and factors influencing specialists' preferences. This is especially true given the unique characteristics and contributing elements that each dental community possesses.

The current study showed that 100% of the participants are using NiTi-EIs, 84% of them are using it with more than 90% of their cases, and 16% of them are using it with less than 90% of their cases, which agrees with a previous studies^{3, 100}.

The most used lubricant the participants chose was EDTA gel 58.7% (n=44) then NaOCl 34.7% (n=26), which may be because of the ability to improve fracture resistance that EDTA gel has when compared with NaOCl solution¹⁰¹.

According to different studies, among all the concerns of using NiTi-EIs, file fracture always presents in the first of the line^{100, 102}, and that was agreed with this study because the majority of the participants (66.7%, n=50) were concerned with the file fracture more than any other issue; furthermore, the second concern was about reuse the instrument (16%, n=12) after the first use which will reduce the treatment cost.

In a previous study, the percentage of the participants who used rotary motion as a predominant motion was between 83.5-94.7%, and the reciprocating motion percentage was between 5.7-16.5%, and the difference in the percentage was because they analyzed different groups depends on the years of experience¹⁰³. However, they did not add the adaptive motion in their answers option. In our study, we found that the most predominant motion in both regions was rotary motion (85.3%, n=64), followed by reciprocating motion (8% n=6), followed by adaptive motion (6.7%, n=5), which we added it in our questionnaire.

More than half of the participants (50.7% n=38) does not use the file again (single use), 46.7% (n=35) of them used the file in 2-3 cases before discarding it, and only 2.7% (n=2) of them use the file in more than 3 cases. However, this is not reflected in another study done in India. Only 0.9% of India's endodontists discard the files after the first use, 29% 3-5 cases, and the majority (63.9%) 5-10 cases¹⁰². It could be because of the strict rules on the healthcare providers in Kuwait and UAE or the difference in the population between India and our study regions. This

difference should decrease the incidence of file fracture or a sign of a good quality of treatment delivered to the population, and these two things needs further investigations.

When we asked the participants about sterilization of NiTi-EIs before first use, and the method of sterilization before the second use because the answers were, 43% (n=57) of the participants were not sterilizing the file before the first use in contrast 5.3% (n=4) of they do, and 37.3% (n=28) of them are buying pre-sterilized instruments. In another study regarding instrument sterilization, 22.9% of respondents reported using pre-sterilized files, 41.6% sterilized new files before use, and 35.5% used new files without pre-sterilizing¹⁰³. Here, we can see the variety of the results when compared with our study, we might agree to either buy pre-sterilized instruments or not sterilize the instruments before using them, but the difference was in sterilizing the instrument before using it.

We might have an issue with participants understanding the questions of instruments reuse. The issue was 62.7% (n=47) of the participants said they are reusing the instruments after the first use, and 37.3% (n=28) of them said they are not, which conflicts with a previous question (Number of cases before discarding the file) 50.7% (n=38) of the participants claimed that they are single using the file then they discard it. Another issue might happen with the last question in this section (Methods of sterilizing in case of reuse the instrument); the question was mandatory even if you said no to reuse the instrument, 73.3% (n=55) of the participants were chosen the steam autoclave as the preferred method of sterilizing the instruments, and 22.7% (n=17) of them were chosen other as their answer for the question, although the answer agreed with another study as the first choice but the percentage was different which is 92.6%¹⁰³

According to our data we found that 100% all participants were using the NiTi-EIs, but the difference was in the percentage of the cases which they are treat with NiTi-EIs, in Kuwait 97% (n=32) of the participants are using NiTi-EIs with more than 90% of their cases which agree with another study done in Iran¹⁰⁰. In UAE 73% (n=27) of the participants are using

NiTi-EIs to treat more than 90% of their cases, which agree with a study in Australia³. The difference here could be because of the age of the participants, the UAE group are older than Kuwait group, which made Kuwait's participants more updated or freshly graduated.

Regarding the type of lubrication used with NiTi instruments, EDTA gel was the choice of 36.4% (n=12) of Kuwait's participants and 73% (n=27) of UAE's participants. In contrast, 60.6% (n=20) of the participants from Kuwait preferred NaOCl solution as a lubricant, while in UAE, 16.2% (n=6) went with NaOCl; there was a significant difference ($p < 0.001$). Instruments are subjected to several strains during canal preparation. Torsion develops when the instrument's tip becomes lodged in the canal while the shank continues to revolve. When elements of the instrument are compressed and tensioned around a curve, flexural stress arises. When an instrument is subjected to continuous repeated stress, cyclic fatigue develops. Instruments must have adequate cycle fatigue resistance to handle stresses from operating in curved canals and enough shear strength to bear torsional stress; an increase in one usually means a decrease in the other. Instruments have the potential to break. A fractured instrument is removed to obtain a favorable treatment outcome if possible. When attempting to remove or bypass the blockage, issues like excessive tooth structure removal, ledges, canal transportation, and root perforation might occur¹⁰⁴. As a result, recommendations are made to prevent file fracture. Lubrication is not included as a prevention strategy in a recent publication on the subject¹⁰⁵. Although lubrications are not a prevention strategy of file fracture, in another questionnaire the found that 90.4% of their participants believed that irrigation protocol decreases the file fracture incidences¹⁰². In another study published in 2014, the researchers found that application of aqueous EDTA and/or sodium hypochlorite as intracanal lubricants caused less fracture of ProTaper instruments than canal lubrication with RC-Prep (gel type EDTA) but did not prevent it¹⁰¹. Our study did not find any significant difference regarding the

main concern about NiTi-EIs usage in root canal treatment ($p=0.168$), but file fracture was on the top of the concern's pyramid.

The most crucial phase in endodontic treatment is root canal shaping, making cleaning the root canal system easier. In nonsurgical retreatments, it comprises the removal of the pulp tissue, bacteria, diseased dentin, and root canal filling materials (RCFMs)¹⁶. The efficacy of irrigants and medicaments is improved by shaping the canal, as are subsequent filling^{16, 106}. In the last two decades, numerous advancements in endodontic instruments have been created to accomplish the excellent expansion of the main canal without procedural errors¹⁰⁶. In the early days of mechanical instrumentation in endodontics, reciprocating motion (RM) was widely utilized with stainless steel (SS) files. The RM used with nickel-titanium files differs significantly from SS files¹⁰⁷. RM is a relatively new technology that uses nickel-titanium instrumentation systems that promise to be more resistant to instrument fracture, allowing for easier treatment and a shorter learning curve for nickel-titanium file systems. In a recent systematic review, they found no difference in the clinical incidence of fracture of nickel-titanium instruments between reciprocating and rotary motions; however, other factors were identified¹⁰⁸. In our study, there was no difference in the number of the participants who preferred rotary motion as the predominant motion in both regions, while for the reciprocating motion, 18.2% ($n=6$) of Kuwait's participants preferred it as a predominant motion. In contrast, no participant from UAE does that, with a significant difference ($p=0.006$). The difference here could be because of the type of the file system used by these six participants; most of the file systems that use reciprocating motion are single-file systems, which are simple, easier, and faster.

The most popular manufacturer in both regions is Dentsply Sirona, and it was the choice of 97.1% ($n=68$) participants of both regions. That is because of the long history of this company producing NiTi-EIs, the quality of their products, and good marketing and education

(workshops) in the region. In 2001, ProTaper rotary file was developed by a group of endodontists: Dr. Cliff Ruddle, Dr. Pierre Machtou, and Dr. John West, in cooperation with Dentsply Maillefer (before merging with Sirona company). In 2006, ProTaper Universal was launched in the markets. In 2013, the ProTaper Next file was introduced as the first heat-treated file from Dentsply Maillefer, and in 2014 ProTaper Gold was launched as the heat-treated version of the ProTaper Universal file. This history can explain why ProTaper Universal Gold is the most file popular and chosen by the participants in UAE, and why there was a significant difference between Kuwait and UAE regarding the popularity of this file ($p < 0.001$), the age group of UAE participants is older than Kuwait's group, and that made them familiar with the first era of the ProTaper Universal file. In contrast, because the age group of Kuwait participants is younger than UAE's group, we found that ProTaper Next is the most popular file of this manufacturer in Kuwait than UAE with a significant difference ($p = 0.003$). This difference could be because of marketing, or the number of hands-on workshops done by the manufacturer in both regions.

In addition to the reasons mentioned earlier (why some files are more popular than other files in both regions), simplicity and file sequence to accomplish any treatment which decreases time-consuming are preferred by any clinician. All those reasons can also explain why the iRace file from FKG is popular in UAE more than in Kuwait ($p = 0.048$) or why Coltene ($p = 0.004$) and VDW® ($p = 0.002$) are prevalent in Kuwait more than in UAE.

File fracture is something the clinician does not want to happen to him during the treatment, and it was the primary concern in different studies, including our study^{100, 102}. The superelasticity of NiTi instruments facilitates the creation of a constant tapered root canal⁵³, although they are constantly at risk of fracture in clinical practice⁵⁸. Cyclic fatigue due to bending and shear stresses exceeding the alloy's resistance due to torque can induce fracture^{41, 54}. These stresses increase when the operator applies excessive pressure to the hand piece¹⁰⁹,

when the interface area between the dentin walls and the instrument edges expands, or when the canal diameter is less than the section of the file¹¹⁰: this is known as 'taper lock'⁹⁵. Enlarging the coronal third and creating an appropriate glide path before utilizing each NiTi rotary instrumentation will help decrease this risk^{61, 64, 111}. That might be the cause why the majority of the participants answered that their expectations of the future of endodontic treatment were about better file design, which has higher flexibility, less taper, and more fracture resistance. Root canal shaping is one of the essential aspects of endodontic therapy, and when done correctly, it can predict the treatment's outcome. It is crucial for appropriate disinfection, which is more effective once a correct shaping procedure is completed. NiTi-EIs in endodontics enhanced root canal shaping and reduced the time necessary for complete mechanical preparation. Several attempts have been made over the last two decades to optimize the procedure with various rotational NiTi endodontic file systems. All of these systems need several additional files. Recently, the concept of a single-file system became more popular and preferred by many clinicians because it is simple, faster, and requires less number of files to accomplish the root canal treatment. And in our study, the second expectation was about this concept.

Kuwait and the United Arab Emirates are both parts of the Gulf Cooperation Council (GCC); it's a political and economic union, and these union countries have the same healthcare rules and profile, which makes them like one nation. Further investigation is recommended to compare these countries with the other countries in the Middle East, East Asia, or Europe regarding manufacturers' popularity and treatment profile.

6.1 Study limitations

The limitations for this study would be as follows:

- The study looked into different aspects of the endodontic elements without focusing on a single thing, which made the study have multiple things to analyze and compare.
- The questionnaire was longer than expected, which made some participants bored, and maybe some of them left in the middle without completing the survey.
- The survey focused on endodontists in both regions because general dentists in Kuwait are not allowed to do RCT in government facilities; in contrast, UAE. Another study in UAE comparing endodontists and general dentists should be considered.

7 CONCLUSIONS

This study was found that:

- NiTi-EIs are popular in both regions and more used in Kuwait than in UAE due to the age group difference.
- NaOCl solution is the most popular mean of lubrication in Kuwait, with no difference between both regions regarding using EDTA gel.
- Reciprocating motion is a predominant motion of 18.2% of Kuwait's participants, with a significant difference when compared with UAE.
- Some manufacturers are more popular in a region than others, which can influence them to increase their marketing and workshops in the region they are not popular within.
- Both regions have the same treatment profile, and both of them are familiar with the recent technology, which can make anyone start the treatment in one region and finish it in the other.
- Within the limitations of the current investigation, it can be stated that NiTi-EIs are widely used in the dental practice of both regions. Better education and lower costs, on the other hand, may enhance their use. Overall, endodontists demonstrated a high understanding of NiTi-EIs usage characteristics, which was reflected in usage modalities.

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9 APPENDICES

Appendix I: Ethical approval from HBMCDM Research Ethics Committee.

Appendix II: Study Consent form.

Appendix III: The questions and their answers of this study.

Appendix IV: Reminder form.

Appendix I



31 March 2021

Ahmad Aljabilan
Resident – Endodontics
HBMCDM

RE: MBRU-IRB-2020-038

Dear Dr Ahmad,

Thank you for submitting the clarifications and the revised protocol on the study titled “The current trends and usage of Nickel-Titanium Engine-driven instruments: A multicenter survey of endodontics and postgraduate endodontic residents” to the IRB.

The Board had reviewed the same and has agreed to approve it. The approval is valid for a period of one year from the date of issue of this letter.

The study can now commence. Any change in protocol should be notified to the Board.

For any questions, please contact the Institutional Review Board irb@mbru.ac.ae.

Thank you for your interest in MBRU's IRB.

Sincerely,

Ahmed Ghoneima
Vice-Chair
MBRU-IRB



Appendix II

Consent-Form:

You are invited to take part in a research questionnaire about The Current Trends and usage of Nickel-Titanium Engine-driven Endodontic Instruments: A multicenter Survey.

Your participation in this research study is entirely voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time without any negative repercussions.

If you wish to participate, you will be asked to answer a series of questions which will take approximately 5 minutes. You will be asked questions regarding your demographic data. You will then be asked about the usage of NiTi instruments and the modalities in your practice. Your responses will be kept confidential and you will remain **anonymous** as the study does not collect any personal information such as name, student identification number or email address.

All information obtained from this study will be used strictly for research purposes only. If the study information is to use in any subsequent investigation, your consent will be taken.

If you have any questions about the research study, please contact ahmad.aljabilan@residents.mbru.ac.ae

Clicking “I agree” indicates that you have read the information, that you are an Endodontist or postgraduate endodontic resident in Kuwait or UAE and that you give your consent to participate in this survey.

I agree

Appendix III

1. How many years has it been since you completed the Endodontic residency?
 - I am post graduate endodontic resident
 - Less than 10
 - 10–25
 - More than 25
2. What is your age? Open answer question
3. What is your Gender?
 - Male
 - Female
 - Prefer not to say
4. What is your type of practice?
 - Own private practice
 - Full-time private
 - Part-time private in multiple clinics
 - Government based clinic
 - University-based clinic
 - Military
5. What is your country of practice?
 - Kuwait
 - UAE
 - Other
6. Do you use NiTi engine-driven instrument for preparing root canals?
 - Yes
 - No

7. How many endodontic cases do you see per week on average? Open answer question
8. What percentage of that cases do you use NiTi instruments?
 - Less than 50%
 - 50% - 70%
 - 70% - 90%
 - More than 90%
9. How Do You Lubricate NiTi Instruments in Root Canals?
 - EDTA gel
 - Water-based lubricant
 - NaOCl irrigant
 - I do not lubricate
10. What is your main concern about the use of NiTi instruments in root canal treatment?
 - File fracture
 - Preparation iatrogenic errors
 - Cost of the instrument
 - Reuse of the instrument
 - Others (please specify)
11. What is the motion that you predominantly use in your practice?
 - Rotary motion
 - reciprocating motion
 - adaptive motion
12. How many cases do you routinely shape with a rotary file before discarding it?
 - Single use
 - 2-3 cases
 - More than 3

- Until it fractures

13. Do you sterilize NiTi rotary files before their first use?

- Do not sterilize a new file before first use
- Pre-sterilize new files before first use
- Buy sterilized NiTi files

14. Do you reuse NiTi rotary files?

- Yes
- No

15. How do you sterilize NiTi instruments in case of reuse?

- Steam autoclave
- Chemiclave
- Dry heat
- Cold sterilization
- Other

16. Which brands do you predominantly use in terms of NiTi instruments?

Lists of Manufacture with (Yes/No)

Dentsply Yes/No

FKG Yes/No

MicroMega Yes/No

Coltene Yes/No

Kerr Yes/No

VDW Yes/No

EdgeEndo Yes/No

Fanta Yes/No

Please specify the File system that you are predominantly using

Dentsply Sirona

ProFile

ProTaper Universal (PTU)

ProTaper Universal Gold (PTG)

ProTaper Next (PTN)

WaveOne

WaveOneGold (WOG)

TruNatomy

FKG

IRace

BioRace

XpShaper

MicroMega

REVO-S

2Shape

One Shape

One Curve

Kerr™

K3™

K3™XF

TF™ adaptive

TF™ twisted file

Coltene

HyFlex™ EDM

HyFlex™ CM

VDW®

RECIPROC

RECIPROC blue

VDW.ROTATE

Mtwo

FlexMaster

EdgeEndo®

EdgeFile™

EdgeOne Fire™

EdgeSequel Sapphire™

EdgeTaper™

EdgeTaper Platinum™

EdgeTaper Encore™

Fanta®

AF F EDM

AF F ONE

AF BLUE S ONE

AF BLUE R3

AF BLUE ROTARY

AF ROTARY

V-TAPER ROTARY

V-TAPER GOLD ROTARY

V- TAPER BLUE ROTARY

AF MAX

AF MAX BLUE

17. What Are Your Expectations for Developments Regarding Canal Preparation in the Next 10 Years? Open answer question (not mandatory)

Appendix IV

Subject: **Reminder: A multicenter Survey of Endodontists and postgraduate endodontic residents.**

Dear participant,

You were recently invited to participate in The Current Trends and usage of Nickel-Titanium Engine-driven Endodontic Instruments: A multicenter Survey, to assess the extent of adoption, usage, and improvement associated with NiTi rotary instruments and techniques in endodontists and postgraduate endodontic residents in Kuwait and UAE and it will be an anonymous survey. Your feedback is critical as we strive to make the study as relevant as we can.

As always, your responses are confidential, and only aggregate data will be reported to the department. The link below is a Microsoft Forms page you do not need to log in or register.

Access the survey at:

[The_Link]

PLEASE NOTE: Surveys will CLOSE on **1st of December 2021** before midnight UAE Time.

Thank you very much for your help.

For any queries, you can always contact me ahmad.aljabilan@residents.mbru.ac.ae.

Ahmad Aljabilan,

Endodontic resident,

Mohammad Bin Rashed University – Hamdan Bin Mohammed College of Dental Medicine