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AN *IN VITRO* STUDY ON THE CLEANING ABILITY OF VARIOUS IRRIGATION TECHNIQUES USING DIFFERENT ROTARY NITI SYSTEMS

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ABSTRACT

This study compared the cleaning efficacy of EndoVac and NaviTip FX irrigation needles using TF and RaCe, both are NiTi rotary systems. One hundred and seventy six extracted single-rooted human teeth were divided randomly into four groups of irrigation methods which are EndoVac, NaviTip FX, Conventional 25G and control. The samples were instrumented using TF and RaCe. Four-micron-thick serial sections were prepared at 1.5 and 3.5mm from the apical foramen, and the images were captured and analyzed using Mirax software. The results showed that while the cleaning ability of EndoVac was significantly better than conventional needle using both TF and RaCe at 3.5 and 1.5mm ($p < 0.008$), there is no significant difference between NaviTip FX and conventional needles. With the exception of the cleaning ability at 1.5mm using TF, there is no significant difference between EndoVac and NaviTip FX ($p > 0.008$). At both levels, the cleaning ability of TF and RaCe were not significantly different. In conclusion, we found that EndoVac has the better cleaning ability than NaviTip and conventional needle with both TF and RaCe rotary NiTi systems, especially at 1.5 mm from the apical foramen. TF and RaCe have similar cleaning ability with all irrigations methods.

KEYWORDS: Cleaning ability; Root canal irrigation; NiTi rotary files

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INTRODUCTION

Elimination of microorganisms and pathologic debris are the most important objective of root canal therapy. The process of chemo-mechanical debridement has been described as the removal of all the root canal system contents during the cleaning and shaping procedure[1]. Thorough instrumentation of the apical region has long been considered to be an essential component in the cleaning and shaping process[1]. In the early 1990s, NiTi endodontic files have been introduced as a viable treatment approach for curved canals[2]. The NiTi alloy proved to be more flexible and resistant to torsional fracture than stainless steel, allowing greater instrument control in small, curved canals[3]. These favorable characteristics led to the creation of countless file systems with various designs and shapes. The Twisted file (TF) (SybronEndo, USA) is a recently introduced nickel titanium (NiTi) rotary system with different manufacturing process aiming to improve the root canal preparation procedure. TF is made triangular in cross section by twisting the nickel titanium during the R phase, which is a different phase of crystalline structure. Once twisted, the file is heated and cooled again to maintain its new shape and also to convert it back into the super elastic austenite crystalline structure[4]. The reamer with alternating cutting edges (RaCe) (FKG Dentaire, Switzerland) rotary system has a triangular cross sectional design and alternating cutting edges, a design that is claimed to perform two functions: to eliminate screwing in and blocking in continuous rotation and to reduce the working torque. These characteristics may allow the instrument to rotate inside the canal without having continuous contact with the walls[5]. Owing to the complexity and irregular structure of the root canal system, it is not possible to ensure adequate elimination of all pulp tissue remnants and microbial irritants via mechanical instrumentation alone[6]. Accordingly, the method for irrigating the root canal system has been claimed to be the most critical step during root canal treatment[6]. Irrigation facilitates clean root canal systems by flushing debris and they serve as bactericidal agents, tissue solvents and lubricants. Debris is defined as dentin chips and residual vital and necrotic pulp tissues that are loosely attached to the root canal wall, which is infected in most cases. The presence of debris on prepared root canal surfaces prevents the efficient removal of microorganisms, which is one of the major goals of thorough debridement of a root canal system. The EndoVac apical negative pressure irrigation system (Discus Dental, Smart Endodontics, USA) has 3 components: Master Delivery Tip (MDT), the Macrocannula (MACRO) and the Microcannula (MICRO)[7]. One advantage of the EndoVac irrigation system seems to be the ability to deliver the irrigant safely into the working length. However, the possibility of blockage of its microcannula is considered as its main disadvantage[8]. Few years ago, a size 30 gauge irrigation needle covered with a brush (NaviTip FX, Ultradent, USA) was introduced into the market. Al-Hadlaq et al.[9] showed that this irrigation needle can exhibit cleaner instrumented root canal walls in the coronal third than the NaviTip needle without brush. However, the cleaning ability at the apical and middle thirds was not significantly different. In the contrary, Goel and Tewari[10] reported an adequate removal of all smear layer and debris at the apical third, when this irrigation technique is activated via a scrubbing motion. The chemo-mechanical preparation of any given root canal is influenced significantly by the type of mechanical instrumentation and the method of irrigation used. Therefore, this study aims to determine and compare the cleaning efficacy of EndoVac and NaviTip irrigation systems using TF and RaCe rotary NiTi systems.

MATERIALS AND METHODS

Teeth collection and preparation

One hundred and seventy six recently extracted single rooted human permanent teeth were collected and stored in 0.9% isotonic saline at room temperature[8]. All participants provide their written informed consent (One of the parents, either father and/or mother gave written consent for the adolescent subjects). This study was approved by the Ethical Committee of the Hospital Universiti Sains Malaysia (HUSM) (USMKK/PPP/JEPeM [248.4.(1.9)]).

Endodontic procedure

With the aid of a hard tissue cutter (Exakt, Germany) fitted with a water coolant, each study sample was cut at 17mm of the tooth length measured from the root apex[6]. Following this, a size 15 K-file (Dentsply Maillefer, Switzerland) was introduced into each canal until it was just visible from the apical foramen, and the working length was determined by withdrawing the instrument 1mm short of the root length. A shallow horizontal groove was prepared in the coronal one third of each root for mechanical retention, and the teeth were placed in paper molds filled with rubber impression material (Express XT Putty soft, 3M ESPE, Italy) to mimic periodontal support[6]. The groups of the study were shown in Table 1. In each group, the root canals were instrumented using two rotary systems (TF rotary system size 25 taper 0.10 - 0.08 - 0.06, RaCe rotary system size 40 taper 0.10, size 35 taper 0.08 and size 25 taper 0.06 – 0.04 – 0.02). In group A, after each file size, the root canals were thoroughly irrigated using EndoVac irrigation system with 2 ml freshly prepared 2.5% NaOCl solution. The needle (macro-cannula or micro-cannula) was positioned to the working length or binding point to the dentinal wall for irrigation. Final irrigation was performed by adding 5 ml 17% EDTA for one minute, then with 1 ml NaOCl[6]. In group B, the NaviTip FX irrigation needle size 30G was used passively after each file size. It was positioned to the working length or binding point to the dentinal wall and 2 ml freshly prepared 2.5% NaOCl solution was delivered into the canal. At the final irrigation, the needle was placed 1mm short of working length and intracanal push and pull strokes (active movement) was performed along the canal wall with concomitant delivery of irrigants, first with 5 ml 17% EDTA for 1 minute then with 1 ml NaOCl[10]. In group C, the conventional needle 25G was placed 1mm short of the working length and the root canal was irrigated by an up and down motion using 2 ml freshly prepared 2.5% NaOCl solution after each file size. The final irrigation was performed using 5 ml 17% EDTA for 1 minute then with 1ml NaOCl[6]. In group D (control), no irrigation was performed[6].

Preparation of serial sections

The samples were removed from the impression material, and marked at 1.5 and 3.5mm from the apical foramen with a water proof pen, which represents the most challenging areas for debris removal[6]. After that, the samples were immersed in formalin for 24 hours and 7% nitric acid solution for 7 days. Subsequently, a sharp scalpel was used to cut the roots at the marked areas, and the root fragments were introduced into a tissue processing machine (Thermo scientific, UK) for 14 hours and 14 minutes, and then they were immersed vertically in wax. Using a soft tissue microtome, serial sections of 4 µm thickness of the sample were cut, and placed on glass sample slides after their application onto a hot water bath. The samples were then dried on a hot plate. Subsequently, the samples were stained using hematoxylin and eosin (H&E). After that, the samples were examined by an optical microscopy at 100X magnification (Leica, China) (Figures 1, 2, 3 and 4) and using Mirax software (Zeiss, Germany)[6].

Quantification of remaining debris in the root canal

The Mirax software (Zeiss, Germany) was used to calculate the amount of debris remaining in the root canal space in pixels. The amount of debris remaining in each root canal was quantified as a percentage of the root canal lumen area. Finally, the values were calculated and compared[6].

Statistical analysis

Data from the completed results were introduced in the Statistical Package for the Social Sciences (SPSS) (version 18) software. The Median and interquartile range (IQR) was determined and the data were statistically analyzed using Kruskal-Wallis H Test ($p < 0.05$) and Mann-Whitney U Tests ($p < 0.008$).

RESULTS

I) Comparison of remaining root canal debris within TF rotary system group

There is a significant difference between all groups (A1, B1, C1, D1) at 3.5mm and 1.5mm from the apical foramen using Kruskal-Wallis Test ($p < 0.05$). Tables 2 and 3 show the intergroup comparisons using Mann -Whitney Test ($p < 0.008$)

II) Comparison of remaining root canal debris within RaCe rotary system group

There is a significant difference between all groups (A2, B2, C2, D2) at 3.5mm and 1.5mm from the apical foramen using Kruskal-Wallis Test ($p < 0.05$). Tables 4 and 5 show the intergroup comparisons using Mann-Whitney Test ($p < 0.008$)

III) Comparison of remaining root canal debris between TF and RaCe groups

Mann-Whitney test was applied to compare between 1) TF/EndoVac (Group A1) and RaCe/EndoVac (Group A2), 2) TF/NaviTip FX needle (Group B1) and RaCe/NaviTip FX needle (Group B2), 3) TF/conventional 25G needle (Group C1) and RaCe/conventional 25G needle (Group C2) at 3.5mm and 1.5mm from the apical foramen, and the results were not significant differences (p value > 0.05) (Tables 6 and 7).

DISCUSSION

The purpose of this experimental study was to determine the effectiveness of root canal debridement after irrigation and aspiration via EndoVac system compared to NaviTip FX needle and conventional 25G needle using two different NiTi rotary systems. Based on the results of this *in vitro* investigation, all test groups (A, B, C) EndoVac system, a NaviTip FX needle and conventional 25G needle demonstrated a statistically significant enhancement in the removal of root canal debris at 3.5mm from the apical foramen when compared to the control (Group D). Data analysis using Mann Whitney test showed that there is no significant difference between the cleaning ability of EndoVac system (Groups A1 and A2) and NaviTip FX needle (Groups B1 and B2) at 3.5mm from the apical foramen (Tables 2, 4). This finding indicates that the removal of debris via mechanical activation induced by scrubbing motion of the NaviTip FX was comparable to that of EndoVac negative pressure macro- and micro-irrigation system. The cleaning ability of EndoVac irrigation system (Groups A1 and A2) was significantly better than conventional 25G needle (Groups C1 and C2) (Tables 2, 4). One possible explanation could be attributed to the apical negative pressure of the EndoVac irrigation system which comprises the Master Delivery Tip (MDT) that simultaneously delivers and evacuates the irrigant. One of the greatest advantages of using EndoVac is that it is an apical negative pressure system, which does not cause extrusion of an irrigant into the periapical area making it safe to use in canals with open apices. It is worth noting that Nielsen and Baumgartner[8] reported that some of the holes of the microcannula may become blocked during the negative pressure procedure. However, a positive pressure rinse, or replacement of the cannula would obtain a good patency of the cannula, thus maintaining a good performance of the system. In agreement to these favorable findings and despite the difference in mechanical instrumentation procedures, a previous study by Shin et al.[6] which compared between the cleaning ability of EndoVac, conventional 24G and 30G needles using Profile NiTi rotary system on sixty-nine extracted, decoronated anterior teeth and found similar results in which EndoVac was significantly better than conventional 24G and 30G needles at 3.5mm. Interestingly, the results presented in our study regarding EndoVac system are contradicted with a previous study by Nielsen and Baumgartner[6] who showed that root canals irrigated using the EndoVac system exhibited no significant difference in debris removal, at 3mm from the apex, with those irrigated with standard syringe technique. This controversy could be explained by difference in methodological procedures in which Gates

Glidden burs and profile rotary system were used for mechanical instrumentation. In addition, the irrigation was performed using NaOCl at 5.25% concentration and conventional 30G needle. Siu and Baumgartner[11] compared the debridement efficacy of the EndoVac irrigation system versus 30G conventional needle irrigation system *in vivo*. Seven adult patients with a total of 22 matched pairs of single-canal vital teeth with fully formed apices were selected. At the 3mm level, there was no significant difference between the 2 methods of irrigation. The median amount of debris remaining at 3mm was 0.09% for the EndoVac group and 0.07% for the conventional irrigation group. These results are consistent to our study in which EndoVac and 25G conventional needle systems demonstrated median values of 0.00% and 0.02% at 3.5mm for TF rotary system, and median values of 0.00% and 0.03% at 3.5mm for RaCe rotary system, respectively. The cleaning ability of NaviTip FX and conventional 25G needles were significantly better than the control group (Group D1, D2) (Tables 2, 4). Despite that NaviTip FX needle (Groups B1 and B2) shows less debris compared to the conventional 25G needle (Groups C1 and C2), there is no significant difference between the two groups (Tables 2, 4). This would explain that the use of 2.5% sodium hypochlorite (NaOCl) and 17% EDTA for root canal irrigation using either the passive and final active motion of the NaviTip FX or conventional 25G needle has the ability to provide comparable cleaning ability of the root canals. The results of our study concerning the NaviTip FX needle are contradicted with a previous study by Goel and Tewari[10] who compared between the effect of continuous, intermittent passive ultrasonic irrigation (PUI), conventional 30G needle and NaviTip FX in removing the smear layer in forty single-rooted teeth. In that study, all groups were subjected to final irrigation with 17% EDTA followed by 2.5% NaOCl for 1 minute. With the aid of scanning electron microscope (SEM), the results showed that NaviTip FX showed a significantly lower smear score than conventional 30G needle at the 3mm level. This controversy could be explained by difference in methodological procedures in which Gates Glidden burs and K-files were selected for mechanical instrumentation. It is worth noting that the step-back technique was performed till K-file size 70. This massive enlargement might have enhanced the effect of scrubbing motion of the NaviTip FX accompanied with an enhanced irrigant flow in the root canal system. Similar to the results presented at 3.5mm, all test groups (A, B, C) EndoVac system, NaviTip FX needle and conventional 25G needle enhanced the removal of root canal debris at 1.5mm from the apical foramen when compared to the control (Group D). However, EndoVac system (Group A1) was significantly better than NaviTip FX (Group B1) and conventional 25G needle (Group C1) using TF rotary system (Table 3). Although EndoVac system (Group A2) also shows better cleaning ability than NaviTip FX (Group B2) and conventional 25G needle (Group C2), the results were not significant when the canals were mechanically instrumented by RaCe rotary system (Table 5). These desirable findings of EndoVac system could be explained by the unique design of the Macrocannula (MACRO) and Micrcannula (MICRO). The micro cannula allows the irrigant to reach the apical canal effectively, and has been reported to suction nearly 50% of the fluid delivered by the master delivery tip[12]. The conventional needle is still a widely accepted method of irrigant delivery by dental practitioners. It may be effective in cleaning the coronal third of the root canals, but may not clean the apical third, because the irrigant must have a direct contact with the internal canal surfaces for effective action. However, it is often found that the irrigant is difficult to reach the apical portion of the canal because of air entrapment (vapor-lock effect) that would prevent further flow of the sodium hypochlorite into the narrow root canal space[13]. Despite the methodological differences between our study and the study by Nielsen and Baumgartner[8], the results are consistent when the cleaning ability was examined at 1mm. Indeed, the presence of more debris at this level of the root canal system would obscure the cleaning ability of conventional needle techniques, regardless of the gauge size, type and concentration of the irrigation solution. The results of our study concerning the EndoVac system are consistent with that of previous studies. In the same study by Shin et al.[6], the authors also found that EndoVac system was significantly better than conventional 24G and 30G needles at 1.5mm. In an interesting clinical investigation by Munoz and Camacho-Cuadra[14], the authors compared the ability of conventional endodontic irrigation needle, passive ultrasonic irrigation (PUI), and EndoVac system to provide an adequate delivery of the irrigant to the full working length (WL) of mesial canals in thirty mandibular molars. By the aid of digital imaging, they found that EndoVac system was significantly more effective than conventional 27G needle in delivering the irrigant to the full working length. The results of this study are consistent to another investigation by Parente et al.[15] who examined the canal debridement efficacy of EndoVac system in both 'Closed' (similar to our study) and 'Open' system fixtures, in order to simulate the anatomy of closed and open root apices, and it was found that the EndoVac system was able to provide optimal cleaning ability in the presence of both open and closed canal systems. Siu and Baumgartner[11] compared between the cleaning ability of EndoVac irrigation system and 30G conventional needle irrigation system on 22 matched pairs of single-canal vital teeth with fully formed. At the 1mm level, the median amount of debris remaining at 1mm was 0.05% for the EndoVac group and 0.12% for the conventional irrigation group, and the different was significant. Although the difference was not significant in our study, the results presented by Siu and Baumgartner[11] are quite consistent to our study in which EndoVac showed a better cleaning ability than 25G conventional needle system, and the results demonstrated median values of 0.00% and 0.22% at 1.5mm for TF rotary system, and median values of 0.00% and 0.22% at 1.5mm for RaCe rotary system, respectively. NaviTip FX needle (Groups B1 and B2) is significantly less effective than EndoVac (Groups A1 and A2), and shows no significant difference when compared to conventional 25G (Groups C1 and C2) at 1.5mm from the apical foramen. This deficient cleaning ability of the NaviTip at 1.5mm probably is the fate of its design being without bristles at the apical 2mm of the needle. This would compromise the effect of mechanical activation of the needle during the scrubbing motion using TF and RaCe rotary systems (Tables 3, 5). Various studies have been done in regards to irrigation[7,11-14,16-18]. This study shows that when the canals are instrumented using RaCe rotary system, there is no significant difference between EndoVac system (Group A2), NaviTip FX needle (Group B2) and conventional 25G (Group C2) at 1.5mm from the apical foramen (Table 5). The means of cleaning ability presented by Groups B2 (0.83 %) and C2 (4.24 %) were better than Groups B1 (0.87 %) and C1 (5.36 %). This finding might be explained by the fact that RaCe instruments have a combined triangular cross section and alternating cutting edges that would ensure efficient evacuation of the root canal debris using the NaviTip and conventional irrigation needles[19-20]. Although the use of conventional 25G needle (Groups C1 and C2) shows less debris compared to the control (Groups D1 and D2), there is no significant difference between the two groups (Tables 3, 5). This emphasizes the crucial role of the needle design, regardless of the type and concentration of the irrigant used, in achieving desirable cleaning ability of the apical third of the root canal. Use of local anesthetics in irrigation of root canal can also be debated due to its astringent action and increased solubility [21].

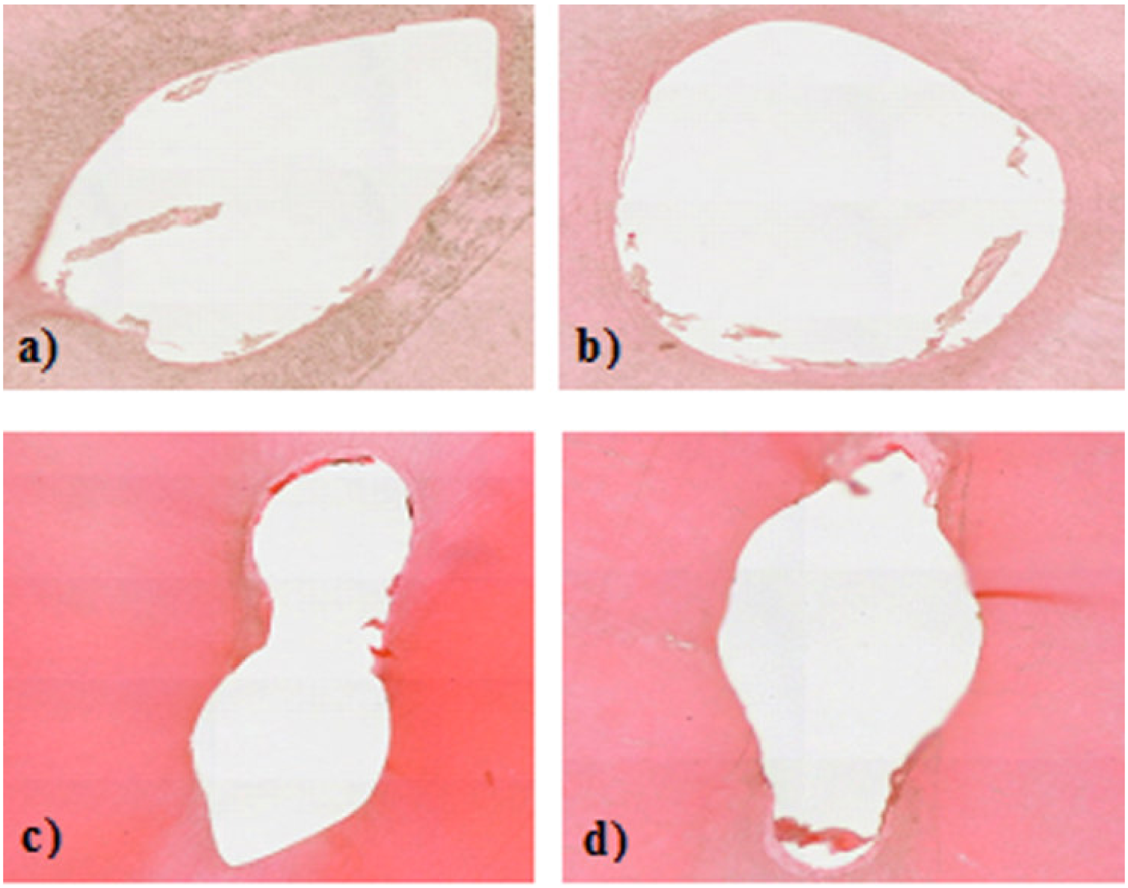

Figure 1

a) Maximum sample TF rotary system and EndoVac irrigation system at 3.5mm.
b) Maximum sample TF rotary system and EndoVac irrigation system at 1.5mm.
c) Maximum sample RaCe rotary system and EndoVac irrigation system at 3.5mm.
d) Maximum sample RaCe rotary system and EndoVac irrigation system at 1.5mm.

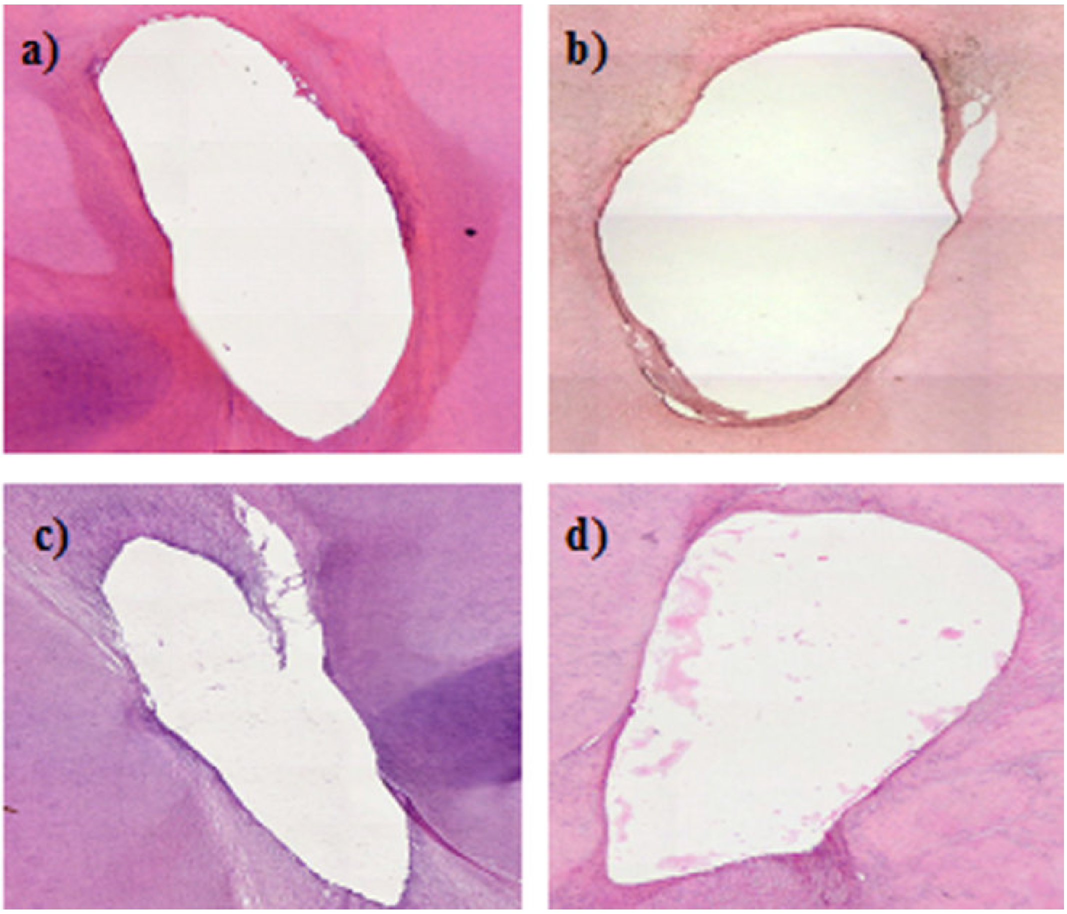

Figure 2

a) Maximum sample TF rotary system and NaviTip FX irrigation system at 3.5mm.
b) Maximum sample TF rotary system and NaviTip FX irrigation system at 1.5mm.
c) Maximum sample RaCe rotary system and NaviTip FX irrigation system at 3.5mm.
d) Maximum sample RaCe rotary system and NaviTip FX irrigation system at 1.5mm.

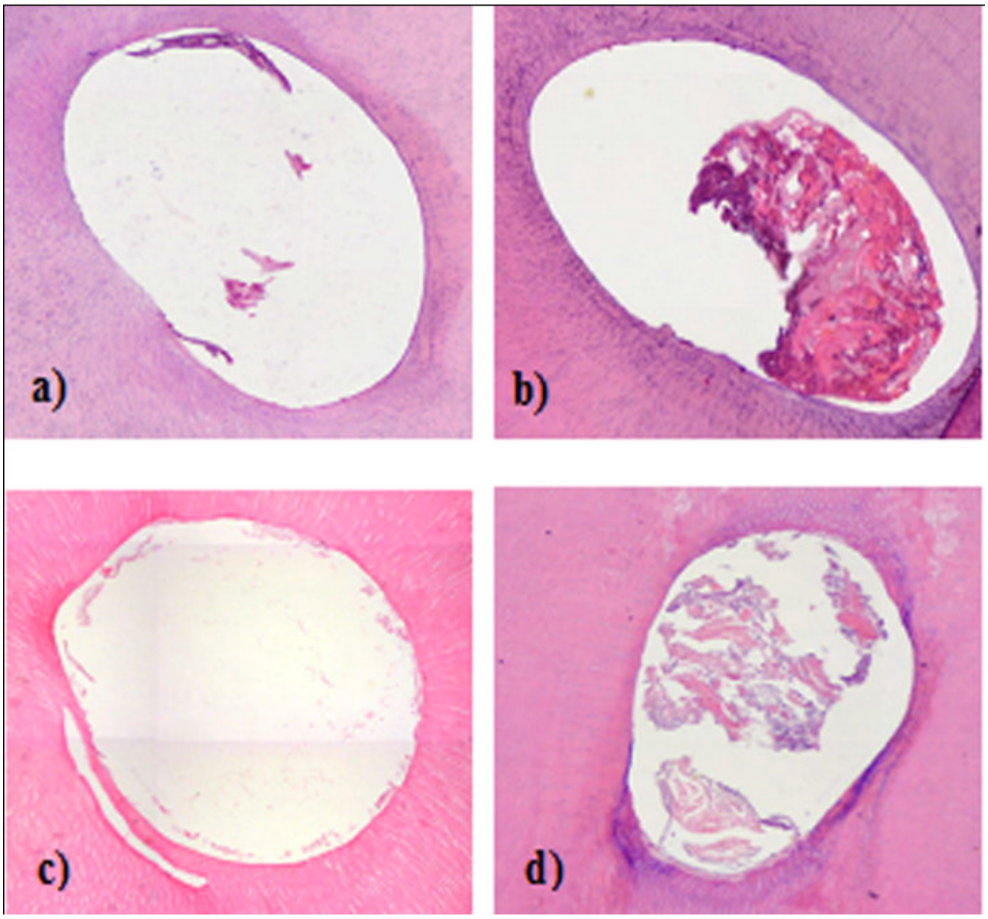

Figure 3

a) Maximum sample TF rotary system and conventional 25G needle system at 3.5mm.
b) Maximum sample TF rotary system and conventional 25G needle system at 1.5mm.
c) Maximum sample RaCe rotary system and conventional 25G needle system at 3.5mm.
d) Maximum sample RaCe rotary system and conventional 25G needle system at 1.5mm.

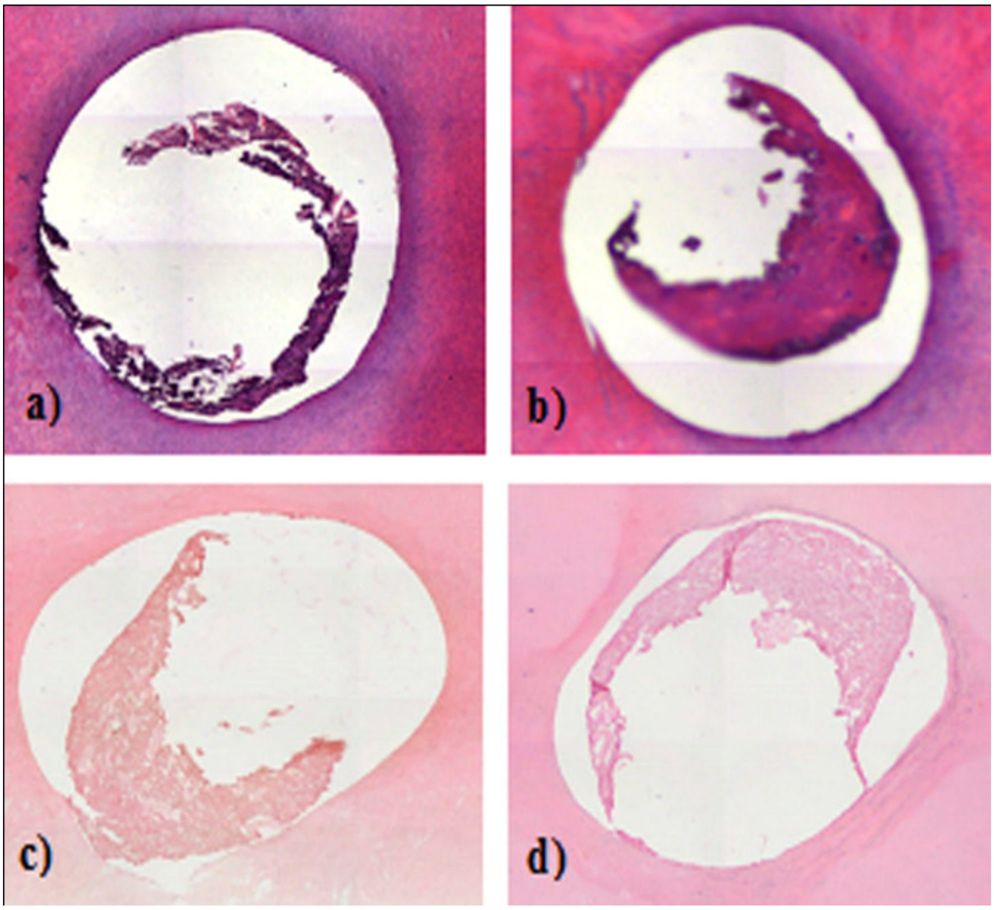

Figure 4

a)Maximum sample TF rotary system as control group at 3.5mm.
b)Maximum sample TF rotary system as control group at 1.5mm.
c)Maximum sample RaCe rotary system as control group at 3.5mm.
d)Maximum sample RaCe rotary system as control group at 1.5mm.

Table 1
The groups of the study was divided as the following

Rotary system / Irrigation system	TF	RaCe
EndoVac	Group A1	Group A2
NaviTip FX	Group B1	Group B2
Conventional	Group C1	Group C2
Control	Group D1	Group D2

Table 2

Correction by using Mann Whitney test for remaining root canal debris at 3.5mm from the apical foramen between EndoVac irrigation system, NaviTip FX needle irrigation system, conventional 25G needle systems and control by using TF rotary system

Irrigation systems	n	Median (IqR)	Z	*p* value
EndoVac (Group A1)	22	0.00 (0.00)	-2.59	0.010
NaviTip FX needle (Group B1)	22	0.00 (0.07)		
EndoVac (Group A1)	22	0.00 (0.00)	-3.11	**0.002**
Conventional 25G needle (Group C1)	22	0.02 (0.12)		
EndoVac (Group A1)	22	0.00 (0.00)	-4.35	**0.000**
Control (Group D1)	6	6.72 (13.52)		
NaviTip FX needle (Group B1)	22	0.00 (0.07)	-0.68	0.498
Conventional 25G needle (Group C1)	22	0.02 (0.12)		
NaviTip FX needle (Group B1)	22	0.00 (0.07)	-3.35	**0.001**
Control (Group D1)	6	6.72 (13.52)		
Conventional 25G needle (Group C1)	22	0.02 (0.12)	-3.13	**0.002**
Control (Group D1)	6	6.72 (13.52)		

Mann-Whitney Test p < 0.008

Table 3

Correction by using Mann Whitney test for remaining root canal debris at 1.5mm from the apical foramen between EndoVac irrigation system, NaviTip FX needle irrigation system, conventional 25G needle systems and control by using TF rotary system

Irrigation systems	n	Median (IqR)	Z	*p* value
EndoVac (Group A1)	22	0.00 (0.02)	-2.92	**0.003**
NaviTip FX needle (Group B1)	22	0.05 (1.46)		
EndoVac (Group A1)	22	0.00 (0.02)	-3.43	**0.001**
Conventional 25G needle (Group C1)	22	0.22 (3.35)		
EndoVac (Group A1)	22	0.00 (0.02)	-3.62	**0.000**
Control (Group D1)	6	4.48 (31.72)		
NaviTip FX needle (Group B1)	22	0.05 (1.46)	-1.21	0.225
Conventional 25G needle (Group C1)	22	0.22 (3.35)		
NaviTip FX needle (Group B1)	22	0.05 (1.46)	-2.81	**0.005**
Control (Group D1)	6	4.48 (31.72)		
Conventional 25G needle (Group C1)	22	0.22 (3.35)	-1.91	0.057
Control (Group D1)	6	4.48 (31.72)		

Mann-Whitney Test p < 0.008

Table 4

Correction by using Mann Whitney test for remaining root canal debris at 3.5mm from the apical foramen between EndoVac irrigation system, NaviTip FX needle irrigation system, conventional 25G needle systems and control by using RaCe rotary system

Irrigation systems	n	Median (IqR)	Z	*p* value
EndoVac (Group A2)	22	0.00 (0.00)	-1.14	0.256
NaviTip FX needle (Group B2)	22	0.00 (0.04)		
EndoVac (Group A2)	22	0.00 (0.00)	-3.10	**0.002**
Conventional 25G needle (Group C2)	22	0.03 (0.27)		
EndoVac (Group A2)	22	0.00 (0.00)	-4.19	**0.000**
Control (Group D2)	6	5.72 (18.25)		
NaviTip FX needle (Group B2)	22	0.00 (0.04)	-2.35	0.019
Conventional 25G needle (Group C2)	22	0.03 (0.27)		
NaviTip FX needle (Group B2)	22	0.00 (0.04)	-3.71	**0.000**
Control (Group D2)	6	5.72 (18.25)		
Conventional 25G needle (Group C2)	22	0.03 (0.27)	-2.93	**0.003**
Control (Group D2)	6	5.72 (18.25)		

Mann-Whitney Test p < 0.008

Table 5

Correction by using Mann Whitney test for remaining root canal debris at 1.5mm from the apical foramen between EndoVac irrigation system, NaviTip FX needle irrigation system, conventional 25G needle systems and control by using RaCe rotary system

Irrigation systems	n	Median (IqR)	Z	*p* value
EndoVac (Group A2)	22	0.00 (0.67)	-0.97	0.332
NaviTip FX needle (Group B2)	22	0.06 (0.62)		
EndoVac (Group A2)	22	0.00 (0.67)	-2.59	0.010
Conventional 25G needle (Group C2)	22	0.22 (4.55)		
EndoVac (Group A2)	22	0.00 (0.67)	-3.42	**0.001**
Control (Group D2)	6	9.06 (26.56)		
NaviTip FX needle (Group B2)	22	0.06 (0.62)	-1.68	0.092
Conventional 25G needle (Group C2)	22	0.22 (4.55)		
NaviTip FX needle (Group B2)	22	0.06 (0.62)	-3.23	**0.001**
Control (Group D2)	6	9.06 (26.56)		
Conventional 25G needle (Group C2)	22	0.22 (4.55)	-2.19	0.029
Control (Group D2)	6	9.06 (26.56)		

Mann-Whitney Test p < 0.008

Table 6

Comparison of median of remaining root canal debris at 3.5mm from the apical foramen between TF EndoVac and RaCe EndoVac, TF NaviTip FX needle and RaCe NaviTip FX needle finally TF conventional 25G needle systems and RaCe conventional 25G needle systems

Irrigation systems	n	Median (IqR) %	Z	*p* value
TF EndoVac (Group A1)	22	0.00 (0.00)	-0.38	0.701
RaCe EndoVac (Group A2)	22	0.00 (0.00)		
TF NaviTip FX needle (Group B1)	22	0.00 (0.07)	-1.07	0.286
RaCe NaviTip FX needle (Group B2)	22	0.00 (0.04)		
TF conventional 25G needle (Group C1)	22	0.02 (0.12)	-0.69	0.493
RaCe conventional 25G needle (Group C2)	22	0.03 (0.27)		

Mann-Whitney Test p < 0.05

Table 7

Comparison of median of remaining root canal debris at 1.5mm from the apical foramen between TF EndoVac and RaCe EndoVac, TF NaviTip FX needle and RaCe NaviTip FX needle finally TF conventional 25G needle systems and RaCe conventional 25G needle systems

Irrigation systems	n	Median (IqR) %	Z	*p* value
TF EndoVac (Group A1)	22	0.00 (0.02)	-1.12	0.262
RaCe EndoVac (Group A2)	22	0.00 (067)		
TF NaviTip FX needle (Group B1)	22	0.05 (1.46)	-0.54	0.593
RaCe NaviTip FX needle (Group B2)	22	0.06 (0.62)		
TF conventional 25G needle (Group C1)	22	0.22 (3.35)	-0.14	0.888
RaCe conventional 25G needle (Group C2)	22	0.22 (4.55)		

Mann-Whitney Test p < 0.05

CONCLUSION

Despite these considerable variations in mechanical properties, this study shows that the cleaning ability of TF and RaCe rotary systems has no significant difference when compared using a given irrigation technique (i.e. EndoVac, NaviTip FX and conventional 25G needle) at 3.5mm and 1.5mm from the apical foramen. One possible explanation could be attributed to the similar equilateral triangular cross sectional design of both TF and RaCe systems.

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