EGYPTIAN DENTAL JOURNAL
VOL.67, 3711:3718, OCTOBER, 2021
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
CONSERVATIVE DENTISTRY AND ENDODONTICS
www.eda-egypt.org • Codex : 60/21.10 • DOI : 10.21608/edj.2021.81917.1686

IMPACT OF DIFFERENT INSTRUMENTS METALLURGY ON APICAL EXTRUSION OF DEBRIS AND FRACTURE RESISTANCE: A COMPARATIVE INVITRO STUDY

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ABSTRACT

The purpose of this research was to compare apical debris extrusion and fracture resistance of teeth prepared with OneCurve, WaveOne Gold, or ProTaper Universal.

Materials and Methods: Mandibular premolars were prepared with OneCurve, WaveOne Gold, or ProTaper Universal. In the experimental model, debris was recovered by apical section of the root washing with distilled water. The Eppendorf tubes were weighed after 15 days of storage to establish the overall weight of the tubes, including the extruded debris. The dry weight of the ejected material was then computed. After root canal obturation, the apical root ends were trapped in the acrylic up to 2 mm below the cementoenamel junction. The fracture force was calculated and given in Newtons. A one-way ANOVA test was used to compare more than two groups, followed by a Tukey post hoc test. The significance level was set at $P \leq 0.05$.

Results: The results revealed a statistically significant difference in extruded debris between OneCurve, WaveOne Gold, and ProTaper Universal ($P < 0.05$), as well as a statistically significant difference in the load required for vertical root fracture between the negative control and OneCurve, WaveOne Gold, and ProTaper Universal ($P < 0.05$).

Conclusion WaveOne Gold had the lowest weight value of debris extrusion, whereas ProTaper Universal had the most. Negative control had the highest load, followed by WaveOne gold and One Curve, and finally ProTaper Universal.

KEYWORDS: Apical extrusion; fracture resistance; OneCurve; ProTaper Universal; WaveOne Gold.

INTRODUCTION

In order to retain healthy periapical tissues, endodontic treatment focuses on removing irritating substances from the root canal system. During root canal instrumentation, microorganisms, pulp tissue residuals, dentin chips, and irrigation solutions may be extruded into the periapical tissues [1,2]. Discomfort following surgery, flare-ups, and an acute inflammatory reaction are all possibilities [3].

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The amount of apically extruded debris is influenced by the type of canal, apical diameter, working length, irrigation technique and solution used, instrumentation system, design, and kinematics [4,5]. The use of certain instrumentation techniques to decrease apical extrusion leads to improved periapical healing [6].

Many instrumentation tools have been created in recent years, but there appears to be no optimum strategy for preventing debris extrusion [7].

Rotary NiTi devices, according to various studies, produce less apical debris extrusion than manual instruments [8]. As a result of the development of single-file, full-sequence NiTi systems, manufacturers have created new single-file systems with flexible kinematics (rotary and reciprocating). A rotary instrumentation technique that shapes canals with a single file rather than a sequence of files was developed [9], and single-file systems were stated to have better shaping ability and less apical debris ejection[10].

Microcracks in the dentin may occur during the canal system preparation. This can spread, resulting in a vertical root fracture proportional to the remaining tooth structure. Because dentin is removed during canal preparation, the root's fracture strength may be decreased, increasing the likelihood of vertical root fracture [11]. In recent years, NiTi instruments have demonstrated a wide range of design, diameter, cross-section, angle, and depth of flutes. Dentin loss and fracture formation are affected by these changes [12]. When a single file is used for root canal preparation, canal dentin contact is reduced[13].

WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland), which replaced the original WaveOne with gold-wire thermal treatment and an offset parallelogram-shaped cross section to increase cycle fatigue resistance and hence flexibility [14], was released. It also eliminates the contaminated dentin in accordance with normal architecture, reducing tooth structural damage [15].

Endodontic files from OneCurve (OC; Micro Méga) were released in 2018. The file has shape-memory and the ability to be pre-curved due to the heat treatment of the NiTi alloy (C-wire). The diverse cross-sections with a triangular tip of the instrument and an S-shape near the shaft are assumed to be the cause of the effective cutting and centering ability [16].

To our knowledge, these files have not been compared in terms of apical extrusion of debris and fracture resistance of prepared teeth, which was the study's goal. There is no difference in apical extrusion of debris and fracture resistance of teeth treated using OneCurve, WaveOne Gold, or ProTaper Universal, according to the null hypothesis.

MATERIALS AND METHODS

The Ethical Committee, Faculty of Dentistry, Cairo University, (5/2/20) date 18/2/2020, examined and approved the current comparative in vitro designed trial in terms of scientific substance and conformity with applicable research and human subjects' rules.

Calculation of sample size

Using the results of Capar et al [17], a sample size of 17 participants per group was computed using an alpha (α) level of 0.05 (5%) and a beta (β) level of 0.20 (20%), i.e. power = 80% and the estimated difference in the experimental and control means of dentine debris is 0.007, using PS version 3.1.2.

A total of 51 freshly extracted human mandibular premolars were used to create the teeth. Pre-operative radiographs were utilised to rule out patients with multiple root canals and foramina, prior root canal therapy, root resorption, immature root apices, cavities, fissures, and root canal curvature more than 10 degrees. To detect any exterior flaws, the roots were examined with a stereomicroscope (Novex, Arnhem, The Netherlands) at X20 magnification. Teeth with these flaws were ruled out.

After properly cleaning the external tooth surfaces with running water, any soft tissue remnants or calculus were mechanically removed. The teeth were then kept at room temperature in physiological saline until they were needed.

Preparation of the specimens

Equal tooth lengths were manufactured to promote consistency (16 mm). The working length (WL) was established by putting a 15 K-file in the endodontic access cavity (Mani, Inc., Utsunomiya, Japan). Canals that are narrower than size 15 K-file or wider than size 20 K-file at the apex were not included to achieve uniformity.

Primary outcome

-Apical debris extrusion

Preparation of the experimental model

In a room with no windows, the initial weights of the tubes were measured with an analytical balance (Dhona 100 DS, Dhona Instruments (P) LTD., India) with an accuracy of 10^{-4} gram.The measurement was made three times, and the mean value was determined.

To equalise internal and external air pressure, each tooth was bonded to the stopper up to the cementoenamel junction, then attached to the eppendorf tube using a 27-gauge needle squeezed alongside the stopper. To prevent any bias during the chemomechanical preparation, a rubber dam sheet was placed over the eppendorf tube.

Root canal instrumentation

The teeth were divided into three groups (n = 17) based on the type of equipment employed.

The OneCurve, group I (OC; Micro Mega, Besancon, France) size 25 and taper 0.06 single file system was used in continuous rotation motion, with a rotational speed of 450 rpm and a torque of 2.50 Ncm, using an X-Smart endodontic motor (Dentsply, Maillefer, Switzerland).

The primary file (25, 0.07) from WaveOne Gold, group II (WOG; Dentsply Sirona, Baillagues, Switzerland) was used until the working length (WL) was reached, after which the file was used in a reciprocating slow in-and-out pecking motion.

Group III: In a mild in–and–out motion, Pro-Taper Universal files (PTU, Dentsply Maillefer, Ballaigues, Switzerland) were employed. The following was the order of events: Sx file (half of the working length), S1 and S2 files (2/3 of the working length), F1 file (size 20, 0.07 taper), then F2 (size 25, 0.08 taper) file to the full working length, at 300 rpm with torque of 5 Ncm for Sx and S1 instruments, 1.5 Ncm for S2 and F1 instruments, and 3 Ncm for F2.

Irrigation procedures

The root canals were irrigated with 2ml of distilled water between each filing using a 30-gauge side vented needle (NaviTip, Ultradent South Jordan, UT, US) put 2 mm short of the working length into the canal.

Quantification of the debris

The debris was removed by washing the apical section of the root surface with 0.5 ml of distilled water in the tube after the canals were dried with paper tips. The eppendorf tubes were incubated at 37°C for 15 days to evaporate the distilled water. The tubes were weighed to determine the total weight of the tubes, including the extruded debris. By removing the weight of the emplaced debris, the weight of the extruded debris was estimated.

Secondary outcome

Fracture Resistance

All of the roots were obturated with AH-26 sealer and a single-cone method (size 25, taper 6%). (Dentsply DeTrey, Konstanz, Germany). The master cone was inserted to its full working length into

the root canal system, the extra core was removed using a heated plugger, and the access cavities were sealed with Cavit provisional filling (3M ESPE, St Paul, MN, USA). The specimens were kept for two weeks to ensure that the set was complete. Group IV: no instrumentation or obturation was utilised as a negative control.

Fracture Measurement

The blocks were made with self-curing acrylic resin (Imicryl, Konya, Turkey) (25 mm in height and 10 mm in diameter). To recreate the periodontal ligament space, the apical root ends were immersed vertically in acrylic resin up to 2 mm below the cementoenamel junction, then uniformly covered with a thin coating of light body silicone impression material (Hereaus Kulzer, Hanau, Germany) before embedding.

Using Instron testing equipment, the roots were broken at a crosshead speed of 1 mm/min (Instron, Canton, MA). A steel conical tip was put into the machine, which was parallel to each specimen's long axis and aligned with the canal opening's centre (tip diameter = 0.5 mm, tapered at 60 degrees). Using computer software, the load necessary to fracture (in Newtons) was recorded and expressed in newtons (Nexygen-MT, Lloyd Instruments).

TABLE (1): The mean, standard deviation (SD) values of the weight of apically extruded debris of different groups.

Variables	Dentin debris in gram	
	Mean	SD
WaveOne gold	0.005112[b]	0.0006972
ProTaper Universal	0.017741[a]	0.0058625
OneCurve	0.005965[b]	0.0005098
p-value	**<0.001***	

Means with different letters in the same column indicate statistically significance difference.

****; significant (p<0.05) ns; non-significant (p>0.05)***

Statistical analysis

Normality was checked using the Kolmogrov-Smirnov and Shapiro-Wilk tests, and the data was analysed using IBM SPSS advanced statistics (Statistical Package for Social Sciences) version 21. (SPSS Inc., Chicago, IL). A one-way ANOVA test was used to compare more than two groups, followed by a Tukey post hoc test. The significance level was set at $P \leq 0.05$.

RESULTS

The mean and standard deviations (SD) of the weight of apically extruded debris (gm) and the load of vertical root fracture (N) of the three tested groups are shown (Table 1,2 and Figure 1, 2).

Debris Extrusion

The findings revealed a statistically significant difference in extruded debris between the OneCurve, WaveOne Gold, and ProTaper Universal groups (P=0.001, P<0.05), as well as a statistically significant difference between ProTaper Universal and each of OneCurve and WaveOne Gold (P=0.749, P>0.05) and no statistically significant difference between OneCurve and WaveOne Gold (P=0.749, P>0.05).

TABLE (2): The mean, standard deviation (SD) values of the load of vertical root fracture (N) of the different groups.

Variables	Fracture resistance (Newton)	
	Mean	SD
The uninstrumented	703.16[a]	95.41
ProTaper universal	433.85[c]	54.93
WaveOne gold	697.73[a]	80.93
OneCurve	585.68[b]	95.56
p-value	**<0.001***	

Means with different letters in the same column indicate statistically significance difference.

****; significant (p<0.05) ns; non-significant (p>0.05)***

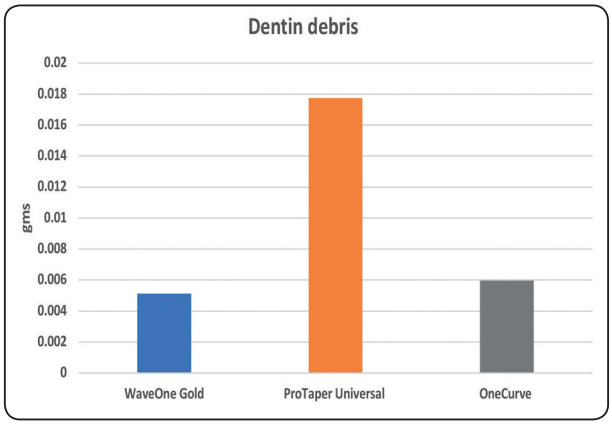

Fig. (1) Bar chart representing mean values of the weight of apically extruded debris of the three tested groups.

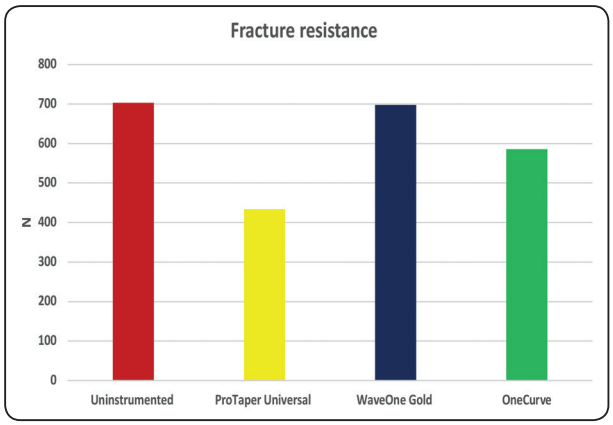

Fig. (2) Bar chart representing mean values of the load of vertical root fracture (N) of the different groups.

The highest weight value of debris extrusion was ProTaper Universal, followed by OneCurve, and the lowest was WaveOne Gold.

Fracture resistance

The load of vertical root fracture was statistically significant between the negative control and all other groups (P=0.001, P <0.05).

There was a statistically significant difference between the negative control group and each of the OneCurve and ProTaper Universal groups (P=0.001, P<0.05), but no statistically significant difference between the negative control group and the WaveOne gold group (P=0.998, P>0.05). The results demonstrated a statistically significant difference (P0.001) between the ProTaper Universal group and the WaveOne gold and OneCurve groups.

Furthermore, the WaveOne gold group and the OneCurve group had a statistically significant difference (P=0.001). The largest load was in the negative control group, followed by WaveOne gold and OneCurve, while the lowest load was in the ProTaper Universal group.

DISCUSSION

Extrusion of endodontic obturation materials, irrigation solutions, or medicaments into the periradicular tissues can cause delayed healing or trigger a periradicular acute reaction [19], so minimising debris extrusion while preparing root canals is desirable to reduce postoperative pain and improve healing potential.

Instrument size, type, canal preparation technique, canal length and size, apical stop and endpoint, irrigation solution, and irrigation delivery system are all factors that influence the amount of extruded debris [20]. Standard conditions were maintained for all of the research groups to minimise the impact of these concerns.

Because the amount of apical extrusion increased as the apical diameter patency increased, canals narrower than size 15 K-file or wider than size 20 K-file at the apex were ruled out [21].

According to studies, when the preparation is completed all the way to the canal length, there is more debris ejection. To ensure uniformity, equal tooth lengths (16 mm) were created, with the working length for all samples being 1 mm shorter than the tooth length. [22]. To preserve identical apical enlargement, all file systems with a same tip size (#25) were used.

According to a previous study [20], needles with side vents extruded less irrigant. All groups used side-vented needles that were inserted no more than 1 mm from the working length to avoid irrigation extrusion.

Because of its high antibacterial activity, sodium hypochlorite (NaOCl) is an extensively used irrigation solution. Because sodium hypochlorite has been shown to enhance the amount of extruded debris by forming sodium crystals, which compromises measurement reliability, distilled water was used in this study [7].

The debris was collected using an experimental model provided by Myers and Montgomery [23], however this system does not match the actual scenario. Furthermore, these methods provide the overall value of debris and irrigant weights.

In this investigation, the ProTaper Universal files generated more extruded debris than the OneCurve and WaveOne Gold files. As a result, the null hypothesis of the investigation was rejected. This was in line with previous studies, which revealed that the ProTaper systems extruded more debris than the WaveOne [24], WaveOne Gold [25], and OneShape [24] systems. This could be owing to the existence of progressive tapers, which lose a substantial quantity of dentin in a short period of time and thus become unable to coronally displace the debris effectively, increasing the probability of apical extrusion of debris[26]. Furthermore, Li et al[27] showed that prolonging the period of file insertion produces more debris, resulting in less effective canal flushing.

Reciprocal motions were associated with less debris extrusion than continuous rotation, according to Üstün et al. [28] and Arslan et al. [29], which could be explained by kinematics because reciprocating motion is a type of automatized balanced-force pressureless technique that is thought to have better control of apically extruded debris [30]. Furthermore, the properties of WOG minimise the bulk of the tip's centre and contribute to less debris extrusion [31], whereas Bürklein et al [32] and Küçükyilmaz et al [33] discovered that rotary instrumentation caused less debris extrusion than reciprocal instrumentation. This difference could be due to the method of debris collection used, the type of tooth used, and/or the instrumentation used.

Root canal therapy was hypothesised to influence the occurrence of vertical root fracture. Dentinal microcracks, which can lead to vertical root fracture, have been linked to NiTi systems [34]. The various preparation processes, manufacturing stages (R, austenite, and martensite), cutting edges, and operating motion of NiTi rotary instruments could all play a role in these issues.

The researchers wanted to explore how different NiTi systems affected vertical root fracture resistance in this investigation. The negative control group had the most load, followed by WaveOne gold and OneCurve, and the ProTaper Universal group had the least. As a result, the null hypothesis was rejected.

This was in agreement with Wilcox et al [35], who found that removing more root dentin resulted in more root fracture, Zandbiglari et al [36], who discovered that greater tapered instruments removed more root dentin, which was more susceptible to fracture than those with hand instruments, and Ashwinkumar et al [37], who discovered more microcracks with the rotary ProTaper Universal file than with reciprocating WaveOne files.

In this study, WaveOne gold and OneCurve had better fracture resistance than ProTaper Universal. Berruti et al[13], who discovered that single-file systems remove less dentin than ProTaper Universal, and Yusufoglu et al [38], who discovered that OneShape instruments have better fracture resistance than ProTaper instruments, could be explained by the higher flexibility of M-wire alloy and CM NiTi wire compared to those made from conventional NiTi wire.

It is also possible that a reciprocating motion reduces the strain on dentinal walls, resulting in reduced dentinal damage [13], which would explain WaveOne gold's exceptional fracture resistance when compared to OneCurve and ProTaper Universal.

Priya et al [39] and Lie et al [40] observed that the OneShape single file system, which rotated continuously, applied higher force on the dentinal

walls and caused more cracks than the Reciproc single file system.

Finally, within the study's constraints, WaveOne gold had a lower level of debris extrusion and a stronger resistance to vertical root fracture than OneCurve and ProTaper Universal. According to the findings, a single reciprocating file resulted in less debris ejection and tended to cause less dentinal injury during root canal therapy.

Conflicts of interest: The authors have stated that they have no conflicts of interest.

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