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ORIGINAL ARTICLE

# Influence of operator experience on apical debris extrusion after endodontic instrumentation with different single-file systems


## ABSTRACT

***Aim:*** *This study evaluated whether operator experience interferes with the amount of apically extruded debris and actual instrumentation time.*
***Methodology:*** *Seventy-five mesial roots of extracted mandibular first molars were randomly allocated to 6 groups (n=15 each) according to operator experience and instrumentation system used (HyFlex EDM, WaveOne Gold, or Reciproc Blue). Each root was secured in a preweighed Eppendorf tube for collection of debris extruded during instrumentation. Actual instrumentation time (the timer was started when the instrument was set in motion within the root canal and stopped when the instrument was removed) and the total amount of extruded debris were recorded. The Shapiro-Wilk test was used to assess data distribution normality, followed by descriptive analysis and the Kruskal-Wallis test with Dunn's post hoc test. Spearman's correlation analysis was done too.*
***Results:*** *There was no significant difference in the amount of apically extruded debris between experienced and inexperienced operators or between the instrumentation systems used. Regarding instrumentation time, a significant difference was observed: HyFlex EDM-inexperienced > WaveOne Gold-experienced. No correlation between extruded debris, instrumentation time, and operator's experience was found.*
***Conclusions:*** *All instrumentation systems produced extrusion, with no difference between them or between operator's experience. Instrumentation time differed only between 2 groups.*



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## Introduction

Pain is an unpleasant experience associated with actual or potential tissue damage and one of the main reasons why a patient seeks endodontic treatment. Undeniably, a more significant amount of debris extruded apically during endodontic treatment increases the likelihood of postoperative pain, flare-ups, and even treatment failure (1).
Factors such as working length (WL), kinematics, apical diameter, amount and/or type of irrigant, and instrumentation systems have been evaluated in several studies investigating the amount of apically extruded debris (2-4).
The HyFlex EDM system uses continuous rotation kinematics and is manufactured by electric discharge machining, which, according to the manufacturer, provides flexibility and fracture resistance to the instruments. The system consists of a 25/.12 orifice opener (optional), a 10/.05 glide path file, and a 25/~ modeling instrument called HyFlex OneFile (https://www.coltene.com/fileadmin/Data/EN/Products/Endodontics/Root_Canal_Shaping/HyFlex_EDM/31328A_HyFlexEDM_Brochure_US.pdf).
The WaveOne Gold and Reciproc Blue systems use reciprocating kinematics and are manufactured by a "gold" and "blue" heat treatment process, respectively, which provides high flexibility and fatigue resistance to the instruments (5). The WaveOne Gold system consists of 20.07 (Small), 25.07 (Primary), 35.06 (Medium), and 45.05 (Large) files. They have a parallelogram-shaped cross-section with an 85° cutting angle and a semi-active tip (Dentsply Tulsa Dental Specialties. Wave One Gold. Available at: https://www.dentsply-sirona.com/content/dam/dentsply/pim/en_GB/Endodontics/Obturation/Paper_Points/WaveOne_Gold_Absorbent_Points/WaveOne%20GOLD%20Brochure%202015.pdf). The Reciproc Blue system consists of 25.08 (R25), 40.06 (R40), and 50.05 (R50) files with an S-shaped cross-section and a non-cutting tip. Both should be used in reciprocating motion with a three in-and-out movements (pecks) with a stroke amplitude of 3 mm and performed in each third of the canal (cervical, middle, and apical) until the WL is reached (2, 6).
It is known that all instruments available on the market promote apical extrusion of debris (7). However, to our knowledge, no study has investigated to date whether the amount of apically extruded debris varies according to operator experience, considering the importance of teaching mechanical instrumentation to dental undergraduates without generating risk for patients (8).
This ex vivo study's primary objective was to evaluate whether operator experience interferes with the amount of apically extruded debris. As a secondary objective, we evaluated actual instrumentation time to evaluate difficulties encountered in reaching the WL. The null hypothesis tested was that there would be no significant differences in the amount of apically extruded debris or time required for instrumentation between different instrumentation systems, whether used by experienced or inexperienced operators.

## Materials and Methods

*Tooth selection and specimen preparation*
After approval by the local Research Ethics Committee (approval number 2,379,268), 75 extracted human mandibular first molars, indicated for extraction for periodontal or ortodontic reasons, were selected for this study. Only teeth with fully formed apices showing independent foramina, curvature angles of 10-15° (9), no calcifications, no resorption, and no prior endodontic treatment were included in the study. Specimens were immersed in 0.5% chloramine-T trihydrate solution for one week for disinfection.
The sample size was calculated using G*Power statistical software, version 3.1.9.4. To detect a difference of 0.0024 (standard error of 0.0025) between the experimental groups, which is in agreement with the study of Uslu et al. (10), with a 5% significance level and a power of 80%, a sample size of 15 specimens per group was necessary.
Standard access cavities were made by

sectioning the crowns at the cementoenamel junction with a round diamond bur (Horico Dental Hpf; Ringleb, Berlin, Germany) mounted on a low-speed handpiece powered by a micromotor under water cooling, thus generating specimens of 13 mm in length, as confirmed by a digital caliper (500 series, DIN 862; Mitutoyo, São Paulo, SP, Brazil). The initial diameter of the mesiobuccal canal was determined by introducing a #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal until it fits snugly within the canal and its tip was visible at the apical foramen under a dental operating microscope at 12.5x magnification (Stemi 508; Carl Zeiss, Jena, Germany). The same procedure was used to determine the WL, set 1 mm short than this measurement. Canals that did not meet these criteria were discarded and replaced with new specimens.

*Randomization*

The specimens were randomly allocated using the Random Allocation Software, version 1.0.0, to 6 experimental groups (n=15 each) according to the instrumentation system used (HyFlex EDM, WaveOne Gold, or Reciproc Blue) and operator experience (experienced or inexperienced). The mesiolingual canals did not undergo any instrumentation or irrigation throughout the experiment.

*Instrumentation*

In the EDM-E group, 15 experienced operators used the OneFile instrument (25/~, variable taper) of the HyFlex EDM system (Coltène, Altstätten, Switzerland) in rotary motion (500 rpm, 2.5 Ncm), with 3 in-and-out movements (pecks) and a stroke amplitude of 3 mm in the cervical, middle, and apical thirds of the canal until the WL was reached. In the EDM-I group, 15 inexperienced operators used the same instrument and performed instrumentation in the same manner as described for the EDM-E group.
In the WOG-E group, 15 experienced operators used the Primary file (25.07) of the WaveOne Gold system (Dentsply Maillefer, Ballaigues, Switzerland) in reciprocating motion, with 3 in-and-out movements (pecks) and a stroke amplitude of 3 mm in the cervical, middle, and apical thirds of the canal until the WL was reached. In the WOG-I group, 15 inexperienced operators used the same instrument and performed instrumentation in the same manner as described for the WOG-E group.
In both the RCB-E (15 experienced operators) and RCB-I (15 inexperienced operators) groups, the R25 instrument (25.08) of the Reciproc Blue system (VDW GmbH, Munich, Germany) was used in the same manner as previously described for the WOG-E group.
In all experimental groups, the instruments were driven by an X-Smart Plus motor (Dentsply Maillefer, Ballaigues, Switzerland) adjusted for each system. Regardless of the system used, each instrument was used to prepare 1 root canal only and then discarded.
Inexperienced operators received a brief training using simulated root canals in clear resin blocks (three blocks per operator), with root curvature similar to that of the human teeth used in the study. This prior contact helped to establish a standardized technique protocol.
Throughout instrumentation, the specimens were irrigated with 3 mL of double-distilled water using a side-vented needle (30G NaviTip; Ultradent Products Inc, South Jordan, UT) at each three in-and-out movements or one-third of root instrumented. After each movement and irrigation cycle, foramen patency was confirmed with a #15 K-file extending 1 mm beyond the foramen in all groups. After completion of instrumentation, final irrigation was performed with 1 mL of double-distilled water, not exceeding the total amount of 10 mL of irrigant standardized for all specimens. Canals were aspirated with a capillary tip (Ultradent, South Jordan, UT) and then dried with paper points provided by the respective system's manufacturer. The canals were considered prepared when the working length was reached with the instrument, and to confirm the instrumentation's quality, the master gutta-percha point compatible with the instrument used was selected. For this, a periapical radiograph was taken.

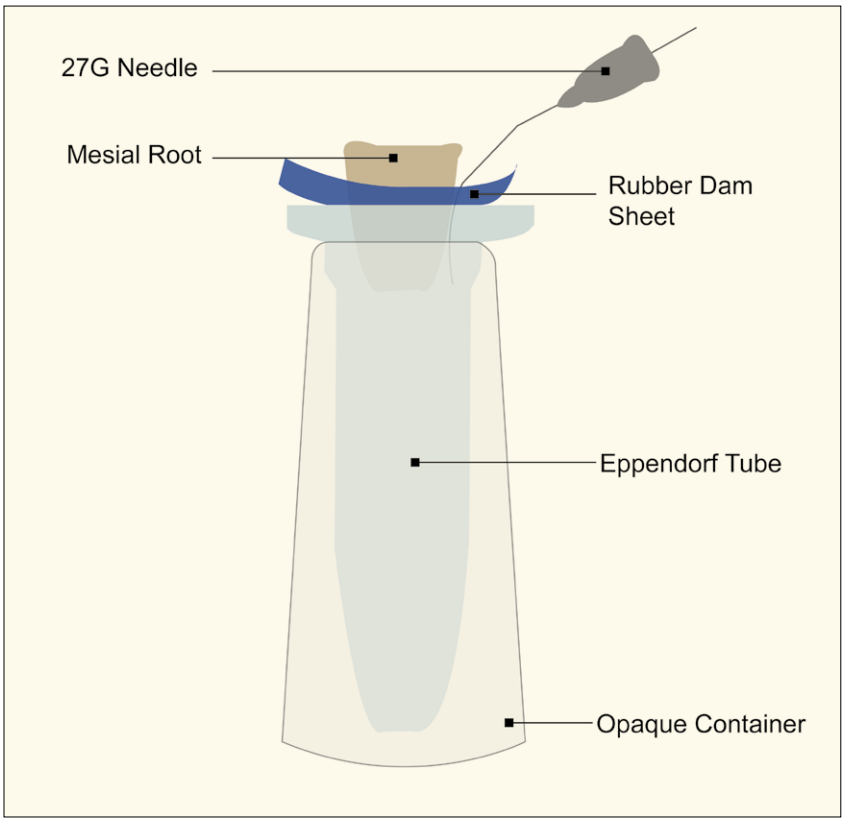


**Figure 1**
Root canal instrumentation apparatus inside an opaque container, preventing the visualization of the inside of the Eppendorf tube.

*Manufacture of the apparatus for collecting and weighing extruded debris*
The amount of apically extruded debris after instrumentation was quantified according to the method proposed by Myers & Montgomery (11) and modified by other authors (12, 13) (Figure 1).
In all experimental groups, each Eppendorf tube was weighed 3 times on the same precision balance initially used, and the average of three measurements was recorded as the final weight of the Eppendorf tube containing extruded debris. The dry weight of extruded debris (in grams) was calculated by subtracting the initial weight (empty tube) from the final weight (tube containing debris).

*Evaluation of actual instrumentation time*
The instrumentation procedure was timed for each specimen with a digital stopwatch (Seiko, Japan). For each instrument, the timer started when the instrument was set in motion within the root canal and stopped when the instrument was removed, resulting in the actual instrumentation time.

*Statistical analysis*
The results obtained for debris weight and instrumentation time were statistically analyzed using BioEstat 5.0. The Shapiro-Wilk test rejected the assumption of normality of data for both the amount of extruded debris and actual instrumentation time.
First, descriptive analyses were performed, and the Kruskal-Wallis test followed by Dunn's post hoc test was used, with the level of significance at 5%. A second analysis was performed using Spearman's correlation to determine the relationships between the operator's experience with the amount of extruded debris and the instrumentation time. The correlation of the amount of extruded debris with the instrumentation time was analyzed too. For the second analysis, all 90 samples were used, divided into two groups based only on the operator's experience (Table 1 and Figure 2).

## Results

There was no significant difference in the

**Table 1**
**Descriptive analysis of all samples grouped based only on the operator experience**

| Operator experience | Extruded Debris | | Instrumentation Time | |
|---|---|---|---|---|
| | Median±IQD | Mean±SD | Median±IQD | Mean±SD |
| Inexperienced (45) | 0.0018100±0.0016 | 0.00231840.0020755 | 26.130±10.3100 | 29.103±9.5855 |
| Experienced (45) | 0.0019000±0.0016 | 0.0018760± 0.0010776 | 25.550±10.0000 | 25.624±6.1516 |

*IQD: interquartile deviation; SD: standard deviation.*

**Table 2**

**Differences between instrumentation systems regarding apical debris extrusion and time required for root canal instrumentation**

| Group | Extruded Debris | | Instrumentation Time | |
|---|---|---|---|---|
| | Median ± IQD | Mean ± SD | Median ± IQD | Mean ± SD |
| EDM-E (15) | 0.0019±0.0015$^{AB}$ | 0.0020±0.0009 | 28.5600±6.1900$^{AB}$ | 29.1547±4.4305 |
| EDM-I (15) | 0.0021±0.0012$^{AB}$ | 0.0025±0.0012 | 30.2800±20.2550$^{A}$ | 35.3267±11.3072 |
| WOG-E (15) | 0.0020±0.0010$^{AB}$ | 0.0017±0.0007 | 20.3500±7.5150$^{B}$ | 22.5600±5.1632 |
| WOG-I (15) | 0.0019±0.0014$^{AB}$ | 0.0020±0.0008 | 22.5600±8.0150$^{AB}$ | 24.9227±7.0142 |
| RCB-E (15) | 0.0011±0.0020$^{AB}$ | 0.0019±0.0015 | 23.5700±9.4700$^{AB}$ | 25.1567±6.9997 |
| RCB-I (15) | 0.0013±0.0004$^{AB}$ | 0.0025±0.0034 | 26.1300±10.9900$^{AB}$ | 27.0587±6.8567 |
| P-value* | 0.2236 | | <0.05 | |

*EDM: HyFlex EDM system; WOG: WaveOne Gold system; RCB: Reciproc Blue system; E: experienced operator; I: inexperienced operator; IQD: interquartile deviation; SD: standard deviation.*
*Same superscript letters indicate no statistical difference between the groups, whereas different superscript letters indicate statistical difference.*
**Kruskal-Wallis test.*

amount of apically extruded debris between experienced and inexperienced operators or between the instrumentation systems used (Table 2) (p>0.05). Regarding instrumentation time, a significant difference was observed only between the EDM-I and WOG-E groups (p<0.05), with the latter requiring shorter instrumentation time (Table 2).
Regarding Spearman's correlation (Table 3), no significant correlation was found between the operator experience and extruded debris (p=0.545) neither between the operator experience and instrumentation time (p=0.173). The instrumentation time and the amount of extruded debris showed no correlation too (p=0.081).

## Discussion

The null hypothesis was accepted regarding the amount of extruded debris but rejected regarding instrumentation time. Extracted mandibular first molars with moderately curved roots were used in the present study, which approximates the study conditions to the difficulties routinely encountered in clinical practice

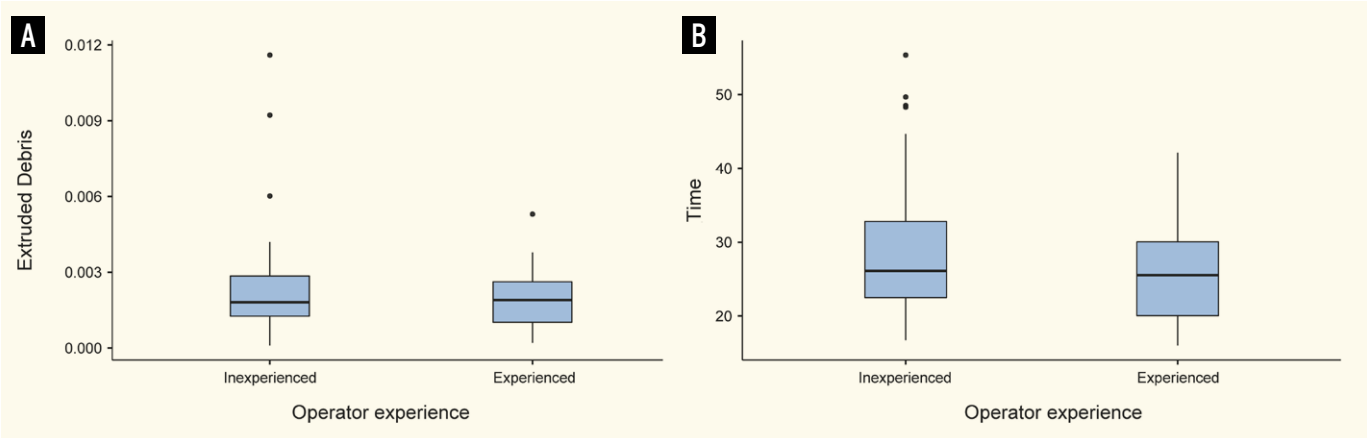


**Figure 2**
**A)** Box-plot distribution of the amount of extruded debris regarding the operator's experience. **B)** Box-plot distribution of the instrumentation time regarding the operator's experience.

**Table 3**
**Spearman's correlation of all samples grouped based only on the operator experience**

| | | Operator experience | Extruded Debris | Instrumentation Time |
|---|---|---|---|---|
| Operator experience | Spearman's rho | | | |
| | p-value | | | |
| Extruded Debris | Spearman's rho | -0.06459 | | |
| | p-value | 0.545 | | |
| Time | Spearman's rho | -0.14499 | 0.18494 | |
| | p-value | 0.173 | 0.081 | |

compared to similar studies that used clear resin blocks (14-16). The crowns were sectioned, and all root lengths were standardized at 13 mm to avoid canal length interference with the results. Despite standardization efforts, it is known that mandibular molars' mesial roots have anatomic variations (17, 18). For this reason, the initial foramen diameters were also standardized by introducing a #15 K-file into the canal, thus avoiding the use of calcified or very wide canals.

We decided to recruit 15 inexperienced operators to avoid the fact that when only one operator performs all procedures, he/she can begin to develop skills in the activity that will lead to improved performance (15). It is essential to highlight that final-year dental undergraduate, who had already performed endodontic treatments on patients but were skilled only in the use of manual files, participated in the study – this differs from previous studies in which operators were considered inexperienced if they had never had any contact with endodontics (15).

As shown in similar studies, double distilled water was used to irrigate the canals because it would not influence the final extruded debris weighing results after evaporation. The use of sodium hypochlorite could lead to the deposition of salts or the formation of crystals after the drying process, thereby increasing the mass of the extruded material (2, 6, 19). We chose the modified Myers & Montgomery weighing method (11-13) because it has been widely used in many studies (2, 13, 20).

In the present study, regardless of operator experience, there was no difference or correlation in the amount of apically extruded debris with the instrumentation system, whether reciprocating or rotary. However, the literature is controversial in this respect. While some studies report more significant debris extrusion with reciprocating instruments (10, 21), other studies show more significant extrusion with rotary instruments (12, 22). We believe that the absence of such difference in our study results from the fact that the HyFlex EDM system, despite having different kinematics than that of the WaveOne Gold and Reciproc Blue systems, also uses only one instrument to prepare the root canal, thus reducing the possibility of debris extrusion compared with multiple-file systems (12). Despite using instruments with different kinematics, instrumentation was set to be performed by root thirds, alternating with glide path maneuvers, which have been shown to produce less debris (7). Thus, all systems followed the instrumentation protocol using sequential files in the cervical, middle, and apical thirds, with a sequence of three in-and-out movements and a stroke amplitude of 3 mm under abundant irrigation until the WL was reached.

Regarding operator experience, there was also no correlation with the amount of apically extruded debris. Given the lack of *ex vivo* studies for comparison, clinically, our results are consistent with those of previous studies that demonstrated, as a secondary endpoint, no difference in postoperative pain (a factor that may be related to the amount of extruded debris) concerning operator experience (23, 24). However, it is essential to note that such

studies did not follow the same methodological standards used in the present study since their inexperienced operators were graduated dental surgeons.
The actual instrumentation time of root canals was statistically longer in the EDM-I group than in the WOG-E group. Although this may reflect inexperienced operators' difficulty in reaching the WL with continuous rotation kinematics, we believe that this finding is clinically insignificant because there were only 13 seconds of difference between the two groups. All other instrumentation time comparisons showed no difference between the groups, and there was no correlation between the instrumentation time with the operator's experience, which can be explained by previous training in three clear resin blocks, since it has been demonstrated that, regarding instrumentation time, little practice is required for inexperienced operators to reach the WL (15). In the present study, although inexperienced operators attended a very brief training session, the use of single-file systems allowed them to safely prepare the canals, without loss of length, deviation, or any other iatrogenic factors, in a time similar to that of experienced operators.
Since the crown was removed, direct access to the canal is a limitation of this study, as it prevented us from fully simulating the difficulties encountered in clinical practice. This has already been reported as a determinant of iatrogenic events in endodontic treatment performed by inexperienced operators (25).
Siqueira (26) has pointed out that endodontic treatment is technically demanding, and general dentists are not prepared to provide adequate endodontic care, explaining that a possible solution to the problem would be a paradigm shift in education in dental schools. It is known that a more significant amount of debris extruded apically during endodontic treatment can lead to flare-ups, pain, and even treatment failure (27). Since there was no correlation of the amount of extruded debris with the operator's experience in this study and that mechanized instrumentation is easy to learn (15), the introduction of mechanized instrumentation can be a safe way in an attempt to improve the endodontic treatment success and reduction of postoperative pain incidence (28).

## Conclusions

Within this study's limitations, it can be concluded that all instrumentation systems produced debris extrusion, with no difference between them or between experienced and inexperienced operators. Also, in most comparisons, the actual instrumentation time of root canals did not differ between the groups – only the EDM-I group required longer instrumentation time than the WOG-E group. No significant correlation was found between extruded debris, instrumentation time and operator's experience. All instrumentation systems tested can be safely used even by inexperienced operators regarding the amount of apically extruded debris, thus paving the way for further research to replicate these findings in clinical settings.

## Clinical Relevance

The knowledge about the influence of the operator's experience on extruded debris is an important factor considering the importance of teaching mechanical instrumentation to dental undergraduates without generating risk for patients.

## Conflict of Interest

The authors deny any conflicts of interest related to this study.

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