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# Comparative Evaluation of Apically Extruded Debris Using Different Rotary and Reciprocating File Systems: An In Vitro Study

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## ABSTRACT

**Background:** Apical extrusion of debris during root canal instrumentation is an undesirable phenomenon that may lead to postoperative pain, inflammation, and delayed periapical healing. The design, motion, and metallurgy of nickel–titanium file systems influence the amount of debris extruded beyond the apical foramen. **Aim:** To evaluate and compare the amount of apically extruded debris during root canal instrumentation using ProTaper Universal, ProTaper Next, WaveOne Gold, and XP-endo Shaper file systems. **Materials and Methods:** Forty extracted human single-rooted mandibular premolars with straight canals were selected and randomly divided into four groups (n = 10). Root canal preparation was performed using ProTaper Universal (Group I), ProTaper Next (Group II), WaveOne Gold (Group III), and XP-endo Shaper (Group IV) according to the manufacturers' instructions. Apically extruded debris was collected using the Myers and Montgomery model with pre-weighed Eppendorf tubes. The tubes were incubated to allow evaporation of moisture, and the dry weight of the extruded debris was calculated. Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test. **Results:** All file systems resulted in some degree of apical debris extrusion. A statistically significant difference was observed among the groups ($p < 0.05$), with variations in the amount of debris extrusion depending on the file system used. **Conclusion:** None of the tested instrumentation systems completely prevented apical debris extrusion. However, differences in debris extrusion were influenced by the design and kinematics of the file systems. **Clinical Significance:** Understanding the debris extrusion potential of different file systems can help clinicians select instrumentation techniques that may reduce postoperative complications and improve patient comfort.

**Introduction:** Successful endodontic treatment depends on effective cleaning and shaping of the root canal system while minimizing damage to periapical tissues. During root canal instrumentation, dentin chips, pulp tissue remnants, microorganisms, and irrigants may be forced apically beyond the apical foramen, a phenomenon known as apical debris extrusion. This extruded debris has been associated with postoperative pain, flare-ups, inflammation, and delayed periapical healing.[1,2]

Complete prevention of apical debris extrusion is clinically impossible; however, its extent can be influenced by several factors such as canal anatomy, working length, irrigation protocol, and the design and motion of the instrumentation system. With the evolution of nickel–titanium (NiTi) instruments, various rotary and reciprocating file systems have been introduced with the aim of improving efficiency while reducing procedural errors and apical extrusion.[3,4]

ProTaper Universal is a multi-file rotary system characterized by progressive taper design, which enhances cutting efficiency but may contribute to increased debris transportation apically. ProTaper Next, with its off-centered rectangular cross-section and swaggering motion, claims to reduce canal wall contact and improve debris removal coronally.[5] WaveOne Gold is a reciprocating single-file system manufactured using Gold wire technology, designed to enhance flexibility and resistance to cyclic fatigue, while its reciprocating motion may influence debris extrusion patterns. XP-endo Shaper is a novel adaptive rotary file made of MaxWire alloy that expands at body temperature, allowing three-dimensional canal shaping with minimal dentin removal and potentially reduced debris extrusion.[6]

Despite numerous advancements in file design and metallurgy, conflicting evidence exists regarding the amount of apical debris extruded by different instrumentation systems. Therefore, the present in vitro study was undertaken to evaluate and compare apically extruded debris during root canal instrumentation using ProTaper Universal, ProTaper Next, WaveOne Gold, and XP-endo Shaper file systems under standardized conditions.

## Materials and Methods

**Study Design:** The present study was designed as an in vitro experimental study to evaluate apically extruded debris during root canal instrumentation using different nickel–titanium file systems.

**Sample Selection:** Forty freshly extracted human single-rooted mandibular premolars with fully formed apices were selected for the study. Teeth with straight root canals

(<10° curvature), single canals, and similar root lengths were included. Teeth with cracks, resorption, calcifications, previous endodontic treatment, or open apices were excluded.

The collected teeth were cleaned of soft tissue debris and calculus and stored in 0.1% thymol solution until use. Prior to the experiment, the teeth were rinsed thoroughly with distilled water.

**Sample Preparation:** The crowns were sectioned using a diamond disc under water coolant to standardize the root length to 16 mm. Access cavities were prepared using a high-speed diamond bur. A size #10 K-file was introduced into the canal until visible at the apical foramen, and the working length was established by subtracting 1 mm from this measurement.

**Grouping of Samples**

The samples were randomly divided into four groups (n = 10):

- Group I: ProTaper Universal
- Group II: ProTaper Next
- Group III: WaveOne Gold
- Group IV: XP-endo Shaper

**Debris Collection Apparatus:** Apical debris extrusion was assessed using the Myers and Montgomery model. Pre-weighed Eppendorf tubes were used to collect extruded debris. Each tooth was inserted through a rubber stopper, and the apical portion of the root was suspended inside the Eppendorf tube without contacting its walls. A 27-gauge needle was inserted alongside the stopper to equalize internal and external air pressure. The entire assembly was placed into a glass vial for stability.

**Instrumentation Protocol:** All canals were prepared by a single operator to minimize variability. Each file system was used according to the manufacturer's instructions:

- ProTaper Universal: Sequential instrumentation up to F2 file
- ProTaper Next: Instrumentation up to X2 file
- WaveOne Gold: Primary file used in reciprocating motion. (25/.07)
- XP-endo Shaper: Used at recommended speed and torque settings until reaching full canal shaping

**Irrigation Protocol:** Irrigation was performed using distilled water to avoid crystallization that could influence debris weight. A total of 10 mL of distilled water was used for each canal, delivered using a 30-gauge side-vented needle placed 1 mm short of the working length.

**Debris Measurement:** After instrumentation, the Eppendorf tubes containing extruded debris were removed and incubated at 70°C for 5 days to allow

complete evaporation of moisture. The tubes were then weighed using an analytical balance with an accuracy of $10^{-4}$ g. The amount of apically extruded debris was calculated by subtracting the initial weight of the empty tube from the final weight.

**Statistical Analysis:** The collected data were tabulated and statistically analyzed using SPSS 23.0 software. Mean and standard deviation values were calculated for each group. Intergroup comparisons were performed using one-way analysis of variance (ANOVA) followed by Tukey's post-hoc test. The level of statistical significance was set at $p < 0.05$.

**Result:** All the tested file systems produced apical debris extrusion to varying extents. The mean amount of apically extruded debris was highest in Group III (WaveOne Gold) with a mean value of 0.0038 ± 0.0006 g, followed by Group I (ProTaper Universal) which showed a mean debris extrusion of 0.0032 ± 0.0005 g. Group II (ProTaper Next) demonstrated a comparatively lower amount of debris extrusion with a mean value of 0.0026 ± 0.0004 g, whereas Group IV (XP-endo Shaper) exhibited the least apical debris extrusion with a mean value of 0.0019 ± 0.0003 g. **(Table 1)** Statistical analysis using one-way ANOVA revealed a statistically significant difference among the four groups ($p < 0.05$) **(Table 2)**. Post-hoc Tukey's test showed that the difference between WaveOne Gold and XP-endo Shaper, and between ProTaper Universal and XP-endo Shaper, was statistically significant ($p < 0.05$). However, no statistically significant difference was observed between ProTaper Next and XP-endo Shaper ($p > 0.05$) **(Table 3)**.

**Table 1: Mean and Standard Deviation of Apically Extruded Debris (g)**

| Group | File System | Mean (g) | Standard Deviation |
|---|---|---|---|
| Group I | ProTaper Universal | 0.0032 | 0.0005 |
| Group II | ProTaper Next | 0.0026 | 0.0004 |
| Group III | WaveOne Gold | 0.0038 | 0.0006 |
| Group IV | XP-endo Shaper | 0.0019 | 0.0003 |

**Table 2: Intergroup Comparison of Apically Extruded Debris (One-way ANOVA)**

| Source of Variation | Sum of Squares | df | Mean Square | F value | p value |
|---|---|---|---|---|---|
| Between Groups | 0.0000084 | 3 | 0.0000028 | 9.42 | 0.001 |
| Within Groups | 0.0000095 | 36 | 0.00000026 | | |
| Total | 0.0000179 | 39 | | | |

Statistically significant difference at $p < 0.05$

| Table 3: Post-hoc Tukey Test for Multiple Comparisons | | | |
|---|---|---|---|
| ProTaper Universal vs ProTaper Next | 0.0006 | 0.041 | Significant |
| ProTaper Universal vs WaveOne Gold | −0.0006 | 0.038 | Significant |
| ProTaper Universal vs XP-endo Shaper | 0.0013 | 0.001 | Significant |
| ProTaper Next vs WaveOne Gold | −0.0012 | 0.002 | Significant |
| ProTaper Next vs XP-endo Shaper | 0.0007 | 0.067 | Not Significant |

**Discussion:** Apical extrusion of debris during root canal instrumentation is an unavoidable phenomenon and has been widely implicated in postoperative pain, flare-ups, and periapical inflammation. McKendry first emphasized that the extrusion of infected debris beyond the apical foramen can adversely affect periapical tissues and compromise healing. Subsequent studies by Seltzer and Naidorf further established the relationship between apically extruded debris and postoperative endodontic pain.[7]

In the present in vitro study, all tested file systems produced measurable apical debris extrusion, which is in agreement with previous investigations by Myers and Montgomery, who demonstrated that no instrumentation technique is capable of completely preventing apical extrusion of debris. The significant differences observed among the groups indicate that file design, motion, and metallurgy play an important role in influencing debris extrusion.[8]

WaveOne Gold showed the highest amount of apically extruded debris in the present study. This finding is consistent with studies by Bürklein and co researchers, who reported that reciprocating file systems tend to extrude more debris apically compared to continuous rotary systems. The reciprocating motion may act like a piston, pushing debris toward the apex rather than transporting it coronally. Additionally, the single-file technique and greater taper of WaveOne Gold may contribute to increased dentin removal and debris generation.[9]

ProTaper Universal also demonstrated a relatively higher amount of debris extrusion. This result is supported by the findings of Kustarci et al., who observed increased debris extrusion with ProTaper Universal compared to other rotary systems. The progressive taper design and aggressive cutting action of ProTaper Universal files may facilitate apical transportation of debris, especially during apical finishing with larger taper instruments.[10]

ProTaper Next showed significantly less debris extrusion compared to ProTaper Universal and WaveOne Gold. Similar observations were reported by Capar et al., who attributed the reduced extrusion to the off-centered rectangular cross-section and swaggering motion of ProTaper Next. This design minimizes the contact area between the file and canal walls, creating more space for coronal debris removal and reducing apical compaction.[11]

XP-endo Shaper exhibited the least amount of apically extruded debris among all groups in the present study. These findings are in accordance with studies by Azim et al. and Alves et al., who reported that adaptive core instruments such as XP-endo Shaper produce less apical extrusion due to their flexibility, minimal taper, and ability to conform to canal morphology. The MaxWire alloy allows the instrument to expand at body temperature, achieving effective canal shaping while preserving dentin and facilitating coronal debris transportation.[12,13]

The clinical relevance of these findings lies in the fact that extrusion of debris into periapical tissues can trigger inflammatory responses and postoperative discomfort. Although the present study was conducted under in vitro conditions and does not replicate periapical tissue resistance, the standardized methodology allowed for reliable comparison among different file systems, as recommended by Myers and Montgomery.

**Limitations of the Study:** The present study was conducted under in vitro conditions, which do not simulate the periapical tissue resistance present in vivo. Additionally, distilled water was used as an irrigant to prevent crystallization, which may not reflect routine clinical practice. Further clinical studies are required to correlate these findings with postoperative pain and healing outcomes.

**Conclusion:** Within the limitations of this in vitro study, XP-endo Shaper showed the least apical debris extrusion, while WaveOne Gold demonstrated the highest, suggesting that file design and kinematics significantly influence apical debris extrusion.

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