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# COMPARATIVE EVALUATION OF APICALLY EXTRUDED DEBRIS AMONG TRUNATOMY, PROTAPER GOLD, AND GENENDO ROTARY NICKEL-TITANIUM FILE SYSTEMS: AN IN VITRO STUDY

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## ABSTRACT
**Background:** Debris pushed beyond the apical terminus during canal shaping has long been implicated in postoperative discomfort, interappointment flare-ups, and delayed periradicular healing. Contemporary nickel-titanium (NiTi) rotary systems differ in taper, cross-sectional geometry, and kinematics — variables that can influence how much material is forced past the apex.
**Aim:** To compare, in vitro, the quantity of apically extruded debris generated by TruNatomy, ProTaper Gold, and GenEndo rotary NiTi systems while shaping mandibular premolars, using the Myers and Montgomery apparatus.
**Materials and Methods:** Thirty extracted single-rooted mandibular premolars of comparable canal anatomy were randomly divided into three equal groups ($n = 10$) and instrumented with TruNatomy, ProTaper Gold, or GenEndo within a Myers and Montgomery double-chamber setup. Debris forced past the apex was captured in pre-weighed Eppendorf tubes, desiccated, and re-weighed on an electronic analytical balance, with the weight gain representing extruded debris per specimen. Normality was checked with the Kolmogorov-Smirnov and Shapiro-Wilk tests; intergroup differences were analyzed by one-way analysis of variance (ANOVA), with pairwise comparisons via Tukey's Honestly Significant Difference (HSD) test, using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).
**Results:** Debris weights were normally distributed in all groups ($p > 0.05$). TruNatomy produced the smallest mean debris weight ($1.13 \pm 0.022$ g), followed by GenEndo ($1.24 \pm 0.019$ g) and ProTaper Gold ($1.39 \pm 0.022$ g). One-way ANOVA showed a highly significant intergroup difference ($F = 376.73$, $p < 0.001$), and Tukey's HSD confirmed that every pairwise comparison reached significance ($p < 0.001$).
**Conclusion:** Within the limits of this in vitro model, TruNatomy extruded significantly less apical debris than either GenEndo or ProTaper Gold, while ProTaper Gold extruded the most. File-design variables — particularly taper and cross-sectional geometry — appear to be meaningful contributors to the tendency for apical extrusion.

**KEYWORDS:** Apical debris extrusion; TruNatomy; ProTaper Gold; GenEndo; nickel-titanium rotary instruments; root canal preparation; Myers and Montgomery model

## INTRODUCTION
Mechanical instrumentation lies at the core of contemporary root canal therapy, aiming to remove necrotic pulp tissue, microorganisms, and dentinal debris while preserving the structural integrity of the root. Yet despite advances in rotary-instrument metallurgy and design, neither hand nor rotary techniques have been able to fully prevent debris, irrigant, and microbial content from being forced beyond the apical foramen.1,2 This extruded material, sometimes described as the "zone of injury," has repeatedly been linked to postoperative pain, flare-ups between appointments, and slower periapical healing.3

The advent of nickel-titanium (NiTi) alloys transformed endodontic instrumentation by combining superelastic behaviour with improved resistance to cyclic fatigue, allowing files with steeper tapers and more intricate cross-sectional geometries than stainless steel could support.4 The very design features that make these instruments cut and shape efficiently — taper, pitch, helical angle, and cross-sectional form — also govern how much canal content is pushed apically during preparation.5,6 This has driven a substantial body of in vitro research aimed at quantifying and comparing apical extrusion across the many rotary systems introduced over the past two decades.7–9

TruNatomy (Dentsply Sirona, Ballaigues, Switzerland) departs from conventional rotary-file design through a reduced core mass, a 0.03 taper at its finishing file, and a "parallelogram" cross-section intended to maximize flexibility and limit dentinal-wall engagement while preserving canal anatomy.10 ProTaper Gold (Dentsply Sirona), a heat-treated evolution of the original ProTaper Universal system, retains a multiple variable-taper design while gaining flexibility and cyclic-fatigue resistance through advanced thermomechanical processing.11 GenEndo (Gen Endo, India) is a single-file rotary system increasingly adopted in general and specialist practice across South Asia, built around continuous rotary motion with a distinct rake angle and taper progression; comparative data on its apical-extrusion behaviour, however, remain limited.12

Given the widespread clinical use of all three systems and the scarcity of direct comparative data — particularly involving GenEndo — this study was undertaken to evaluate and compare the quantity of apically extruded debris generated by TruNatomy, ProTaper Gold, and GenEndo during instrumentation of mandibular premolars, using the well-validated Myers and Montgomery experimental model.13

## MATERIALS AND METHODS

### Study Design and Sample Selection

This single-blinded, comparative in vitro study was carried out following institutional ethical clearance. Thirty freshly extracted, single-rooted human mandibular premolars — removed for periodontal or orthodontic reasons — were collected and stored in 0.1% thymol solution until use. Teeth were included on the basis of mature apical development, a single canal confirmed radiographically in two angulations, and the absence of root caries, resorption, fracture, previous endodontic treatment, or canal calcification, with root lengths matched within ±1 mm. Specimens were allocated using a computer-generated randomization sequence into three groups of ten teeth each ($n = 10$ per group): Group I (TruNatomy), Group II (ProTaper Gold), and Group III (GenEndo).

### The Myers and Montgomery Apparatus

First described in 1991, the Myers and Montgomery model enables direct collection and quantification of debris extruded through the apical foramen during canal instrumentation.13 Each crown was sectioned to standardize working length, and access cavities were prepared conventionally. Apical patency was confirmed with a size 10 K-file, and working length was set 1 mm short of the apical foramen. The root surface was coated with two layers of nail varnish, excluding the apex, to prevent lateral leakage of irrigant or debris. Each tooth was then mounted, via a rubber stopper, into the cap of a pre-weighed Eppendorf microcentrifuge tube so that the apex projected into the tube while the access cavity remained exposed coronally — isolating the apical exit so that all extruded material stayed confined within the collecting tube.

Before use, each Eppendorf tube was desiccated and weighed three times on a calibrated electronic analytical balance (sensitivity 0.0001 g), with the mean of the three readings recorded as the baseline weight.

### Instrumentation Protocol

All canals were shaped by a single calibrated operator to remove inter-operator variability. A uniform irrigation protocol was followed across groups: 2 mL of 3% sodium hypochlorite delivered through a 27-gauge side-vented needle positioned 2 mm short of working length between instrument changes, followed by a final rinse of 2 mL normal saline. The needle was never advanced beyond 2 mm short of working length, keeping the hydrodynamic contribution to extrusion consistent across groups.

Group I canals were instrumented with the TruNatomy sequence (Orifice Opener, Glider, and the Small/Prime finishing file) to working length per manufacturer instructions, using an endodontic motor at the recommended speed and torque. Group II canals received the full ProTaper Gold sequence (SX, S1, S2, F1, F2) to working length, again at manufacturer-recommended motor settings. Group III canals were shaped with the GenEndo single-file sequence to working length, using the manufacturer's recommended speed and torque. Each instrument was used with a slow in-and-out pecking motion and discarded after a single use to keep cutting efficiency uniform across specimens.

### Debris Collection and Quantification

On completion of shaping, the canal and pulp chamber were rinsed with 1 mL of distilled water to flush any residual debris adhering to the canal walls into the collecting tube, after which the tooth-stopper assembly was carefully removed. Tubes containing the collected debris and irrigant were incubated at 70°C for five days to allow complete evaporation of the fluid phase, then re-weighed under conditions identical to the baseline measurement. The difference between the post-instrumentation and baseline weights of each tube represented the mass, in grams, of apically extruded debris for that specimen.

### Statistical Analysis

Data were tabulated and analyzed using SPSS software (Version 26.0; IBM Corp., Armonk, NY, USA). Descriptive statistics — mean, standard deviation, minimum, and maximum — were computed for each group. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess normality. As the data met the assumption of normal distribution, parametric analysis was applied: one-way ANOVA for the overall intergroup comparison, and Tukey's HSD test for pairwise comparisons. A p-value below 0.05 was considered statistically significant, and below 0.01 was considered highly significant.

## RESULTS

Normality testing with the Kolmogorov-Smirnov and Shapiro-Wilk tests confirmed that debris-weight data in all three groups followed a normal (Gaussian) distribution ($p > 0.05$ for every group; Table 1), supporting the use of parametric statistical tests for the analyses that followed.

**Table 1. Tests of Normality for Debris Weight Across Experimental Groups**

| Group | K-S Statistic | df | K-S p-value | S-W Statistic | S-W p-value |
|---|---|---|---|---|---|
| TruNatomy | 0.136 | 10 | 0.200* | 0.978 | 0.953 |
| ProTaper Gold | 0.154 | 10 | 0.200* | 0.973 | 0.915 |
| GenEndo | 0.140 | 10 | 0.200* | 0.969 | 0.883 |

**Lower bound of the true significance (Lilliefors correction).*

On descriptive analysis, the TruNatomy group recorded the lowest mean weight of apically extruded debris (1.13 ± 0.022 g; range 1.10–1.17 g), followed by GenEndo (1.24 ± 0.019 g; range 1.21–1.27 g), with ProTaper Gold recording the highest mean extruded debris weight (1.39 ± 0.022 g; range 1.36–1.43 g) (Table 2). One-way ANOVA demonstrated a statistically highly significant difference among the three groups ($F = 376.73$, $p < 0.001$), leading to rejection of the null hypothesis of equal apical extrusion among the three file systems.

**Table 2. Descriptive Statistics and One-Way ANOVA for Mean Debris Weight (g)**

| Group | N | Mean (g) | SD | Min (g) | Max (g) | F / p value |
|---|---|---|---|---|---|---|
| TruNatomy | 10 | 1.13 | 0.022 | 1.10 | 1.17 | F = 376.73 |
| GenEndo | 10 | 1.24 | 0.019 | 1.21 | 1.27 | p < 0.001** |
| ProTaper Gold | 10 | 1.39 | 0.022 | 1.36 | 1.43 | |

***Highly significant (one-way ANOVA).*

Tukey's HSD post-hoc comparisons confirmed that all three pairwise comparisons were statistically highly significant ($p < 0.001$ in every case; Table 3). TruNatomy extruded significantly less debris than both ProTaper Gold (mean difference = –0.259 g) and GenEndo (mean difference = –0.107 g), while ProTaper Gold extruded significantly more debris than GenEndo (mean difference = +0.152 g).

**Table 3. Tukey HSD Pairwise Comparisons of Mean Debris Weight**

| Group (I) | Group (J) | Mean Diff. (I–J) | p value | Significance |
|---|---|---|---|---|
| TruNatomy | ProTaper Gold | −0.259 | < 0.001 | HS** |
| TruNatomy | GenEndo | −0.107 | < 0.001 | HS** |
| GenEndo | ProTaper Gold | −0.152 | < 0.001 | HS** |

***HS = highly significant.*

The hierarchical ranking of mean debris extrusion, from lowest to highest, was therefore: TruNatomy < GenEndo < ProTaper Gold — a pattern that held consistently across all ten specimens within each group, as reflected in the narrow standard deviations observed (0.019–0.022 g).

**DISCUSSION**

This study found highly significant differences in the amount of apically extruded debris among three contemporary NiTi rotary systems, with TruNatomy producing the least extrusion, GenEndo an intermediate quantity, and ProTaper Gold the greatest. This pattern is consistent with existing literature indicating that file taper, cross-sectional design, and the screw-conveyance effect are key determinants of apical extrusion during rotary instrumentation.14–16

TruNatomy's favourable performance in limiting apical extrusion may relate to its markedly reduced core mass and its comparatively gentle 0.03 taper at the finishing file, smaller than that of conventional systems. A shallower taper removes less dentin and therefore generates less debris overall, while also reducing the screw-in (auger) effect that drives material apically.10,17 TruNatomy's parallelogram cross-section is also reported to improve flexibility and reduce frictional engagement with canal walls compared with instruments carrying more cutting edges or a more aggressive rake angle, potentially allowing debris to be carried coronally along the flutes rather than pushed apically.18

The comparatively higher extrusion seen with ProTaper Gold echoes earlier reports that multiple variable-taper systems tend to extrude more debris than single, low-taper instruments.19,20 The progressively increasing taper along ProTaper Gold's active length produces greater wall engagement and a more pronounced auger effect, which may force a larger volume of dentinal debris, necrotic tissue remnants, and irrigant apically during shaping.21 This occurs despite ProTaper Gold's well-documented strengths in cyclic-fatigue resistance and cutting efficiency, underscoring that mechanical performance and biological outcome do not always align.22

GenEndo's intermediate result is notable given how little independent comparative data exist for this system. The present findings suggest that its taper progression and rake angle place its debris-extrusion profile between TruNatomy's conservative design and ProTaper Gold's more aggressive one. GenEndo's small standard deviation (0.019 g) further points to a high degree of reproducibility in its cutting and debris-displacement behaviour across specimens, a feature that may matter to clinicians seeking predictable outcomes.

Clinically, apically extruded material — infected dentin chips, necrotic pulp remnants, irrigant, and bacteria — has long been implicated as a major contributor to postoperative pain and interappointment flare-ups, particularly where periapical pathology already exists.23,24 The markedly lower debris extrusion seen with TruNatomy in this study may therefore translate into reduced postoperative morbidity, although this inference needs validation through well-designed clinical trials, since in vitro extrusion quantity does not necessarily correlate linearly with clinical symptoms.25

The Myers and Montgomery model used in this study remains among the most widely used and validated methods for quantifying apical extrusion, valued for its simplicity, reproducibility, and direct measurement of extruded material rather than reliance on indirect markers.13,26 Nonetheless, certain methodological limitations inherent to this and similar in vitro models must be acknowledged. The model cannot replicate the dynamic physiological environment of periapical tissue, including vascularity, immune response, and tissue compliance, all of which may shape the clinical consequences of extrusion in vivo.27 Likewise, the use of single-rooted mandibular premolars with relatively standardized canal anatomy, while necessary for methodological control, limits how far these results can be extrapolated to canals with greater curvature, complexity, or aberrant anatomy, where extrusion patterns may differ.28 Operator variables, although controlled here through use of a single calibrated operator, could still influence outcomes differently under typical multi-operator clinical conditions.

It is also worth noting that irrigation protocol and needle positioning — both standardized in this study — are themselves significant independent determinants of apical extrusion, and their interaction with file kinematics warrants dedicated further investigation.29 Future research should explore how these file systems perform in canals with greater curvature, in retreatment of previously obturated canals, and through ex vivo or clinical designs with larger sample sizes that directly correlate extrusion with postoperative symptom scores, in order to validate and extend the present in vitro observations.

## CONCLUSION

Within the limitations of this in vitro investigation, all three NiTi rotary systems evaluated produced measurable apical debris extrusion, though the magnitude differed significantly among them. TruNatomy was associated with the least apical debris extrusion ($1.13 \pm 0.022$ g), GenEndo with an intermediate quantity ($1.24 \pm 0.019$ g), and ProTaper Gold with the greatest extrusion ($1.39 \pm 0.022$ g), with every pairwise difference reaching high statistical significance ($p < 0.001$). These findings suggest that the reduced-taper, low-engagement design philosophy underlying TruNatomy may confer a clinically relevant advantage in minimizing periapical extrusion, and may be worth considering when clinicians select an instrumentation system — particularly where limiting apical extrusion is a priority. Further clinical and ex vivo studies are warranted to corroborate these in vitro findings.


## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Nil.


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