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Does a Conservative Access Cavity Design Combined with Minimally Invasive Rotary Files Decrease Apical Debris Extrusion?

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ABSTRACT

Objectives: To evaluate the influence of access cavity designs and minimally invasive NiTi rotary files on apical debris extrusion and preparation time.

Materials and Methods: Eighty extracted maxillary first molars with curved mesio-buccal canals were randomly allocated into four groups: conservative or standard access combined with ProTaper Gold (PTG) or TruNatomy (TN) rotary systems. Debris extrusion was quantified, and preparation time was recorded. Data underwent two-way ANOVA and Tukey's tests.

Results: Both cavity design and file type significantly impacted debris extrusion and preparation time ($p < 0.05$). The conservative cavity combined with TN showed minimal debris extrusion at (245.6 ± 63.6 mg) which was significant compared to other groups ($P < 0.05$). However, the standard cavity with TN had the shortest preparation time at (3.355 minutes).

Conclusions: Conservative cavities combined with minimally invasive rotary files minimize apical debris extrusion and reduce canal preparation time, supporting conservative endodontic approaches. However, when conservative cavities are combined with larger-taper rotary files, they do not significantly reduce apical debris extrusion.

Keywords: Apical debris extrusion, Conservative access cavity, NiTi rotary files, ProTaper Gold, TruNatomy.

1. Introduction

Root canal treatment (RCT) is an essential endodontic procedure aimed at eradicating infection and preserving natural dentition. Successful clinical outcomes in endodontics typically involve the absence of postoperative symptoms, especially pain, a critical concern among patients (1,2).

Despite technological advancements in instrumentation and techniques, postoperative complications, such as pain, remain common (3,4). Apical extrusion of debris, including dentin chips, pulp tissue remnants, microorganisms, and irrigants,

significantly contributes to these complications by triggering periapical inflammation, flare-ups, and delayed healing (5,6).

Access cavity preparation is the initial and pivotal step in RCT (7). Recently, conservative access cavity designs have gained popularity due to their potential in preserving coronal tooth structure and enhancing fracture resistance (8). However, these conservative approaches may compromise canal detection, cleaning effectiveness, and visibility, increasing risks, such as missed canals, ledge formation, instrument fracture, or inadequate debridement (9,10). Additionally, restricted

access may facilitate debris accumulation.

Standard access cavity (ST), known also as conventional or traditional access cavity, includes complete deroofing of the pulpal chamber and achieving straight-line access to the first curvature or the apical part of the canal. It has been shown that ST design has more dentine removal and more stress in the pre-cervical dentine; however, it did not show more favorable fracture resistance (11).

Concurrently, the evolution of rotary nickel-titanium (NiTi) file systems, distinguished by diverse designs, metallurgy, and kinematics, has led to considerable variations in shaping efficiency and debris extrusion (12-14). These differences are often attributed to instrument cross-section, taper, flexibility, and cutting action.

TruNatomy (TN; Dentsply Sirona), a recently developed heat-treated NiTi system, incorporates a slender wire design with a diameter of 1 mm, regressive taper, and off-centered rectangular cross-section, designed to conserve dentin and optimize debris removal (15,16). ProTaper Gold (PTG; Dentsply Maillefer), on the other hand, is a well-established rotary system characterized by progressive tapering and enhanced flexibility through proprietary heat treatment; it has a wire diameter of 1.2mm at D 16 (17).

Although prior studies have explored debris extrusion associated with various rotary systems (13,16-18), limited research exists on the combined effects of access cavity design and rotary file systems, particularly conservative NiTi systems, like TruNatomy (19,20). This study thus aimed to assess the influence of access cavity design and rotary file systems (TN and PTG) on apical debris extrusion and canal preparation time.

The null hypothesis tested was that there would be no significant difference in apical debris extrusion or preparation time among groups, regardless of access cavity design or file system employed.

2. Materials and Methods

This in vitro study utilized extracted human teeth procured under an existing institutional review board protocol and complied with the Declaration of Helsinki

guidelines (21).

2.1 Sample Size Determination

The sample size was calculated using G*Power 3.1 software (Heinrich Heine University, Düsseldorf, Germany). Based on a previous study by Al Omari et al. (16), that attempted to detect both debris extrusion and preparation time, with an effect size of 0.59, $\alpha = 0.05$, and a power of 0.80, the required minimum sample size was determined to be 20 specimens per group.

2.2 Tooth Selection and Group Allocation

Eighty freshly extracted human maxillary first molars were selected for this study. The teeth were cleaned using an ultrasonic scaler to remove soft tissues and calculus and were then inspected under a dental operating microscope (Zeiss Opmi Pico, Carl Zeiss Meditec AG, Germany) to identify and exclude those with cracks, resorption, calcifications, restorations, or caries. Only teeth with fully formed apices and Vertucci type I mesiobuccal (MB1) canals exhibiting moderate-to-severe curvature (25° - 40°), radiographically confirmed using Schneider's method, were included (22).

Teeth were randomly divided into four groups ($n = 20$ per group) using a random sequence generator (www.random.org), based on access cavity design and rotary file system:

- Cons/PTG: Conservative access cavity + ProTaper Gold;
- Cons/TN: Conservative access cavity + TruNatomy;
- ST/PTG: Standard access cavity + ProTaper Gold;
- ST/TN: Standard access cavity + TruNatomy.

2.3 Access Cavity Preparation

Access cavities were prepared with Endo Access burs (Dentsply Maillefer, Switzerland) under copious water irrigation. Periodontal probe (UNC 15) (Hu-Fridy, USA) calibrated in mm was used to assess the access cavity parameters. Conservative access cavities measured 2.0 ± 0.5 mm in mesiodistal and buccolingual dimensions, while standard access cavities measured 4.0 ± 0.5 mm and 5.0 ± 0.5 mm (Fig. 1), respectively, according to Shabbir et al. (11).

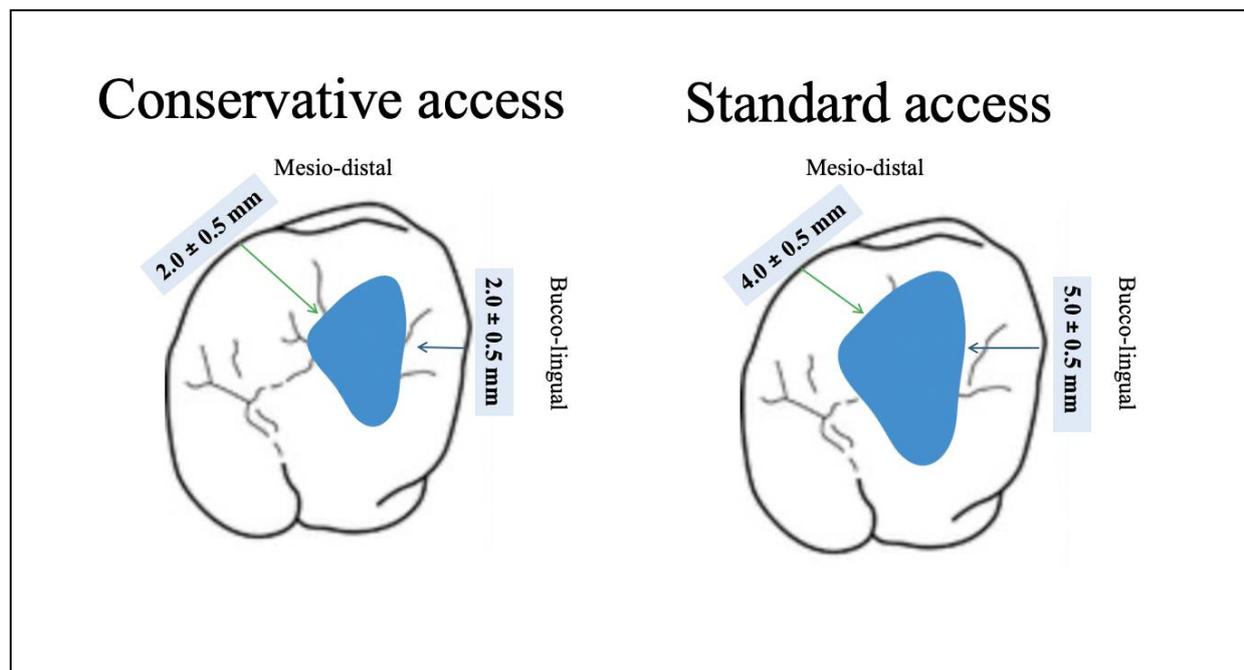


Figure 1: A schematic artwork for the access cavities type and dimensions, Conservative access measure 2.0 ± 0.5 mm in mesiodistal and buccolingual dimensions, Standard access measure 4.0 ± 0.5 mm and 5.0 ± 0.5 mm in mesiodistal and buccolingual dimensions

Canals were located using a DG-16 explorer and irrigated with 2.5% sodium hypochlorite. All canal orifices except the MB1 canal (palatal, distobuccal, and MB2 if present) were sealed with resin-modified glass ionomer cement (Vitrebond™, 3M, Germany). MB1 canals were negotiated using #10 and #15 K-files, with working length (WL) set 1 mm short of the apical foramen where a #10 file tip was visible. Canal patency was verified, and a manual glide path was established with a #15 K-file.

2.4 Apical Debris Collection

The apical debris collection method was adapted from Myers and Montgomery (23). Each tooth was mounted in a pre-weighed 10-mL glass vial sealed with a silicone stopper, exposing only the root apex. A 27-gauge needle was inserted into the stopper to equalize internal pressure and external pressure. The assembly was wrapped in aluminum foil to blind the operator and submerged in a 37°C water bath, simulating clinical conditions.

Glass vials were weighed five times before and after instrumentation using an analytical balance (Citizen CX 220, USA), and mean values were recorded. The weight of extruded debris was determined as the difference between pre- and post-instrumentation measurements.

Root Canal Instrumentation: Instrumentation was carried out by an experienced endodontist under 5× magnification:

- ProTaper Gold (PTG): Coronal flaring was conducted with an SX file, followed sequentially by S1, S2, F1, and F2 files to the full working length (WL) using a VDW Silver motor (VDW, Munich, Germany) at 350-400 rpm and torque settings of 2.5-3.5 Ncm, employing a slow pecking motion of approximately 3-mm increments.
- TruNatomy (TN): Coronal shaping was carried out using an Orifice Modifier (20/.08), followed by TruGlider (17/.02) and Prime (26/.04) instruments to the full WL at 500 rpm and 1.5-Ncm torque, applying gentle 2-stroke motions.

During instrumentation, canals were irrigated with 10 mL of 2.5% sodium hypochlorite delivered through a side-vented needle (Endo-Eze; Ultradent, South Jordan, UT, USA) positioned 2 mm short of WL. High-volume suction was utilized to minimize backflow. Preparation time was recorded using a digital stopwatch.

Upon instrumentation completion, each canal was flushed with 1 mL distilled water to collect residual debris. Vials were subsequently incubated at 70°C for 7 days to evaporate moisture before the final debris weighing.

2.5 Statistical Analysis

Data normality was verified using the Shapiro–Wilk test. Two-way ANOVA was conducted to evaluate the impact of access cavity design and rotary file system on debris extrusion and preparation time. Tukey’s HSD test was applied for *post hoc* comparisons, with statistical significance set at $p < 0.05$. All analyses were performed using IBM SPSS Statistics (Version 23, IBM Corp., Armonk, NY, USA).

3. Results

3.1 Apically Extruded Debris

Two-way ANOVA revealed that both access cavity

design ($F = 6.15$, $p = 0.02$) and rotary file system ($F = 4.995$, $p = 0.03$) had statistically significant effects on the amount of apically extruded debris. A significant interaction effect was also observed between the two variables ($F = 6.07$, $p = 0.02$), indicating that the influence of one factor depended on the other.

Among all groups, the Cons/TN group demonstrated the lowest mean debris extrusion (245.6 ± 63.6 mg), significantly lower than the other three groups ($P < 0.05$). No significant differences in debris extrusion were found among the Cons/PTG (340.6 ± 87.6 mg), ST/PTG (340.9 ± 77.9 mg), and ST/TN (345.5 ± 81.8 mg) groups ($P > 0.05$) (Fig. 2).

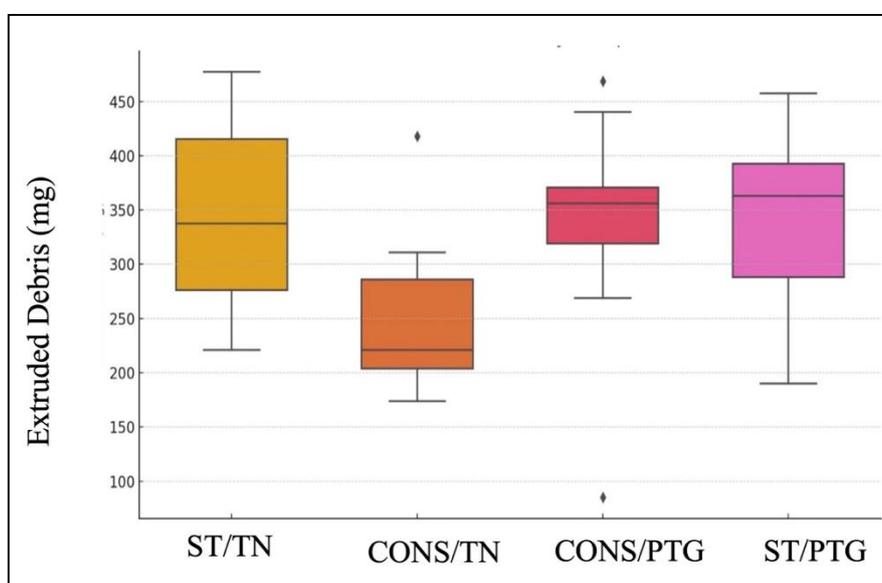


Figure 2: The average weight of extruded debris (mg) for different experimental groups based on the access cavity design and the rotary file system used. (Cons=Conservative access cavity), (ST= standard access cavity), (PTG=ProTaper Gold), (TN=TruNatomy)

3.2 Root Canal Preparation Time

Preparation time was significantly affected by both access cavity design ($F = 14.36$, $P < 0.001$) and rotary file type ($F = 77.45$, $P < 0.05$). However, the interaction between these variables was not statistically significant ($F = 2.28$, $P > 0.05$).

The ST/TN group exhibited the shortest mean

preparation time (3.36 ± 0.18 min), which was significantly faster than the Cons/PTG (5.02 ± 0.53 min) and ST/PTG (4.32 ± 0.72 min) groups ($P < 0.05$). No significant difference was noted between ST/TN (3.36 ± 0.18 min) and Cons/TN (3.65 ± 0.23 min) groups ($P > 0.05$) (Fig 3).

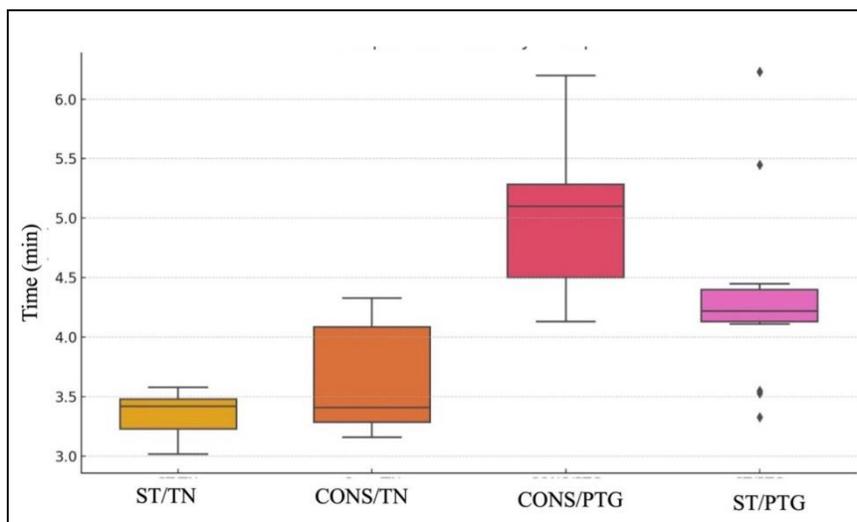


Figure 3: The average preparation time (minutes) for different experimental groups based on the access cavity design and the rotary file system used. (Cons=Conservative access cavity), (ST= standard access cavity), (PTG=ProTaper Gold), (TN=TruNatomy).

4. Discussion

The present study demonstrated that all rotary NiTi systems tested resulted in apical debris extrusion, consistent with findings reported previously in the literature. Both access cavity design and the type of rotary file significantly affected the amount of extruded debris. The conservative access cavity combined with the TruNatomy (TN) rotary file system resulted in the lowest debris extrusion. Moreover, TN files demonstrated significantly less debris extrusion than the ProTaper Gold (PTG) system ($p < 0.05$). This highlights the critical role of instrument geometry and access cavity design in root canal shaping outcomes. This could be justified as minimally invasive systems have less potential to remove dentine from pre-cervical dentine and more potential to evacuate debris coronally due to smaller size.

Preparation time was significantly influenced by both the access cavity design and file system independently, although their interaction did not achieve statistical significance ($p > 0.05$). PTG system has a longer sequence with more files than TN, which should be considered when evaluating the preparation time. This could justify why TN has a shorter preparation time.

Conservative access cavities aim to preserve coronal tooth structure and have gained popularity due to their potential biomechanical benefits (24-26). Finite element analyses suggest that conservative cavity designs can

improve tooth resistance to vertical fractures; however, conflicting evidence exists regarding stress distribution (27). Despite their structural benefits, conservative cavities may limit canal visualization, which could theoretically increase debris accumulation (10). Interestingly, our findings revealed that conservative cavities combined with TN files actually reduced debris extrusion, indicating that TN's file geometry and motion may effectively compensate for visibility limitations by facilitating better debris evacuation. This is in line with previous work by Al Omari et al. (16) and Mustafa et al. (28). However, both studies used different tooth types and different anatomies and canal curvature.

The significant reduction in debris extrusion observed with TN files is likely attributable to specific design elements, including regressive taper, reduced central core diameter, and off-centered rectangular cross-section (28). Collectively, these features enhance file flexibility and reduce canal wall engagement, thereby promoting better irrigant circulation and improved coronal debris evacuation.

In terms of preparation time, the TN system consistently demonstrated shorter durations compared with PTG, notably in both conservative and standard cavity designs. These findings align with those of Vorster et al. (29), who similarly reported shorter preparation times with TN files regardless of cavity type. In contrast, Marchesan et al. observed longer preparation times with conservative cavities, possibly

due to their utilization of narrower access openings in mandibular molars, suggesting that variations related to tooth type and anatomical complexities may impact preparation time outcomes.

Micro-CT analyses support our results, demonstrating superior dentin preservation by the TN system, particularly in the critical peri-cervical dentin region (29). Enhanced dentin preservation, coupled with reduced debris extrusion (30), underlines the clinical advantages of employing TN files, potentially leading to improved shaping efficiency and clinical outcomes.

Comparative studies evaluating PTG relative to other rotary systems present varied outcomes. While some studies suggest that PTG extrudes less debris compared to earlier ProTaper iterations (31,32), others indicate that newer systems surpass PTG regarding debris reduction (33,34). Although the ProTaper family is designed with a larger progressive taper intended to enhance debridement and debris evacuation, it conversely removes more dentine and generates a greater amount of debris. The present study corroborates the superior performance of the TN system in minimizing debris extrusion under the conditions tested.

In summary, this investigation supports the use of conservative access cavities in conjunction with advanced NiTi rotary systems, such as TruNatomy, to minimize apical debris extrusion and reduce preparation time. This combination may subsequently reduce post-operative complications and enhance patient outcomes. However, the current findings are based on an in vitro model using extracted teeth, which does not entirely

replicate clinical conditions, such as periodontal ligament responses and immune system involvement. Furthermore, this study was limited to maxillary first molars with MB1 canal morphology. Future studies employing micro-CT imaging, diverse tooth morphologies, and clinical outcome assessments, including post-operative pain and healing rates, are recommended for comprehensive validation of these findings.

5. Conclusions

Within the limitations of this in vitro study, both access cavity design and rotary file system significantly affected apical debris extrusion and root canal preparation time. The conservative access cavity combined with the TruNatomy system produced the lowest amount of apically extruded debris and the shortest preparation time under the tested conditions. These results indicate that, for the file systems and access designs evaluated, a conservative access approach used with TruNatomy may improve procedural efficiency and reduce debris extrusion without extrapolating beyond the scope of this study.

Conflict of interests

All authors deny any conflict of interests related to this study.

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