Difference in the extent of debris extrusion between instrumentation with ProTaper® and ProTaper Next®: An experimental laboratory study

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Abstract. During chemomechanical preparation, debris extrusion could trigger an inflammatory response and delay periapical healing. Reportedly, while instrumentation with ProTaper® causes significant debris extrusion, no data are available for instrumentation with ProTaper Next®. This study aimed to determine and compare amounts of debris extruded in the instrumentation with ProTaper® and ProTaper Next®. In total, 60 premolars were evenly distributed into two groups as follows: ProTaper® group and ProTaper Next® group. Then, debris extruded during instrumentation was collected in a bottle and the difference between the weight of the bottle before and after instrumentation was considered as the amount of debris extruded. The amount of debris extruded with instrumentation with ProTaper® was significantly higher than that with ProTaper Next® (t-test, p < 0.005). Our experimental study demonstrates that the extent of debris extrusion with ProTaper Next® was less than that with ProTaper®.

1. Introduction
Initially, the success of endodontic treatment depends on the success of the endodontic triad, which includes the access preparation, root canal preparation (cleaning and shaping), and obturation (filling) [1,2]. Of these, the access preparation constitutes the simultaneous cleaning and shaping of the root canal assisted by irrigation and medicament administration for removing bacteria that cannot be otherwise removed by mechanical preparation [1-3].

Notably, cases of debris extrusion from the root canal into the periapical have been reported during chemomechanical preparation, which could trigger an inflammatory response, flare-up, post-obturation pain, and delay in periapical healing [4-6]. Flare-up is the occurrence of persistent or recurrent pain and/or a swelling during endodontic treatment [7]. Reportedly, the incidence of flare-up varies from 1.58%[8], 45%[9], 1.6%[10] to 48.5% [11].

At present, several instruments are available for root canal preparation with various tapering techniques, such as continuous and reciprocal rotations. Previously, studies have reported that all these instrumentation techniques may cause debris extrusion to the periapical. Ruiz-Hubard et al. have reported that the amount of debris extruded with the step-back technique was higher than that with the crown-down technique either in the straight or in the curved root canal [12]. In addition, Pramudita has demonstrated that debris extrusion by instrumentation with reciprocal rotation (Resiproc®) was less
than that with the continuous rotation instrumentation (Mtwo®) [13]. Givari and Kubasad have reported that debris extrusion with K3® instrument was higher than that with Mtwo® [14]. In fact, K3® file with an asymmetric cross-section and positive rake angle leads to higher debris extrusion [14]. Unlike Mtwo® file, which uses a single-length method, all other instruments enter the root canal until they reach their working length because the distance between the cutting blades increases from the end of the instrument to the shaft and has a progressive pitch but no radial land; thus, the Mtwo® file produces less debris.

Instruments with a continuous rotation, such as ProTaper® (Progressive Taper; Dentsply Maillefer, Ballaigues, Switzerland), comprise six instruments with various tapering techniques. In fact, ProTaper® is one of the most commonly used instruments, including at the Faculty of Dentistry, Universitas Indonesia, in Indonesia. However, Kustarcia et al. have reported that instrumentation with ProTaper® produced a higher amount of debris than that with K3® file [15]. In addition, Tanalp et al. have compared the ProTaper® technique with other continuous rotation instruments and have determined that debris extrusion with ProTaper® was significantly greater than that with others [16]. Despite using fewer instruments, ProTaper® leads to more excessive dentin removal in a short span owing to its higher cutting and tapering capacities [16]. Recently, a new instrument, ProTaper Next® (Dentsply Maillefer), has been introduced to enhance its predecessor, ProTaper®. Notably, ProTaper Next® uses the Ni–Ti M-wire file to enhance the flexibility of the file and comprises rectangular cross-section in the middle that causes a “snake-like” motion when it enters the root canal. In addition, ProTaper Next® induces a mechanical wave motion along the active part of the file. Besides, the “snake-like motion” lessens the contact between the dentin and the file compared to the file with constant tapering, resulting in maximizing the debris removal toward the corona. However, to date, no data are available regarding debris extrusion with ProTaper Next®. Hence, this study aims to investigate our hypothesis that ProTaper Next® produces lower debris extrusion than ProTaper®.

2. Methods
This study was an experimental laboratory study conducted at Oral Biology Laboratory and Conservative Dentistry Clinic, Teaching Hospital, Faculty of Dentistry, Universitas Indonesia, from July to September 2014. The study sample was the dentistry waste, including extracted lower premolar teeth. The number of sample in this study was 30 for each group.

In total, 60 single-rooted lower premolar teeth with perfectly closed apex and without any defect of the root surface were selected. The sample teeth were cleaned and soaked in saline solution prior to instrumentation. The access preparation for each tooth was performed using a diamond bur and a high-speed handpiece with water cooling system in order to facilitate instrumentation and irrigation. The teeth were irrigated with 2.5% NaOCl before changing every file and after instrumentation to dissolve the organic material inside the root canal. Finally, the samples were randomly numbered and divided into two groups as follows: ProTaper® group and ProTaper Next® group.

The apical foramen patency was standardized using a K-file #15 until the end point was visualized. Then, the working length of each tooth was recorded until 1 mm shorter than the working length of K-file #15 at this step. When the working length reaches the apical foramen, the extent of debris extrusion is higher. [15-17]. Next, each sample was sterilized to avoid bacterial contamination.

The sterilized tooth was inserted through a holed rubber marker cap. Before the root canal instrumentation, a collection tube for debris was weighed and then placed inside a 7ml tube. Then, the rubber marker with the tooth was placed inside the tube to close the tube. The debris tube acted as a container to collect the extruded debris and the irrigate that washed out of the apical foramen. Furthermore, the 7-ml tube was ventilated with a 23-gauge needle that penetrated the rubber marker to balance the air inside and outside the tube (figure 1).
Figure 1. The sample was prepared before the root canal instrumentation. (a) A tooth was inserted into a holed rubber marker cap; (b) rubber marker cap; (c) debris collection tube; (d) 7-ml tube; and (e) 23-gauge needle.

In this experiment, the samples were prepared with two different instruments, a Ni–Ti ProTaper® comprising the Sx, S1, S2, F1, F2, and F3 files and a ProTaper Next® comprising X1, X2, and X3. Of note, the experiment was conducted on a maximum of 10 teeth on each day to prevent operators’ fatigue.

After performing the access preparation of all teeth, the access was closed using temporary filling, and the debris tube was removed from the 7-ml tube. Then, the tooth was released from the debris tube, and the debris attached to the root surface was removed by rinsing the root surface with 1 ml distilled water. Before weighing the debris, the debris tube was placed in a dry oven at 70°C until the moisture evaporated. Next, the weighing process was performed in two steps. First, the debris tube was weighed before the root canal instrumentation, considered as the initial weight (A), and after the root canal instrumentation and drying process, considered as the final weight (B). The difference between the initial and final weights was considered the weight of extruded debris (B − A). Of note, the measurement was performed using an electronic balance, and each measurement was performed three times for each sample to calculate the average weight of extruded debris.

The results were statistically analyzed using the independent t-test with the significance value \( p < 0.05 \) to note the weight of debris extruded from the apical foramen. Of note, t-test was used when the data distribution was normal, while the Mann–Whitney test was used when the data distribution was not normal. The data distribution was tested using the Kolmogorov–Smirnov test (sample >50). The results obtained in the analyses are descriptively presented to elucidate the characteristics of each variable.

3. Results
The Kolmogorov–Smirnov test (sample >50) revealed a normal data distribution, with \( p = 0.086 \) for the ProTaper® group and \( p = 0.2 \) for the ProTaper Next® group. The results of independent t-test are summarized in table 1.

Table 1. Average value distribution and significance value of debris extrusion after the root canal instrumentation using ProTaper® and ProTaper Next®

| Group          | n  | Average±SD (mg) | Average Difference (IK95%) | \( P^* \) |
|----------------|----|-----------------|----------------------------|--------|
| ProTaper®      | 30 | 5.680±2.0002    | 4.21 (3.4169–5.0031)       | 0.000  |
| ProTaper Next®| 30 | 1.470±0.7742    |                            |        |

*Independent t-test.
Table 1 summarizes the average weight of debris extrusion after the root canal instrumentation with ProTaper® and ProTaper Next®. The ProTaper Next® group exhibited a lower extent debris extrusion than the ProTaper® group. The independent t-test revealed that the significance value was 0.000 (with $p<0.005$), confirming that the amount of debris extruded with ProTaper Next® was lower than ProTaper® thereby validating our hypothesis.

4. Discussion
This study assessed and compared the amount of debris extruded from teeth before and after the root canal instrumentation with ProTaper® and ProTaper Next®. Reportedly, during the chemomechanical preparation, some amount of debris can be pushed out of the root canal to the periapical; thus, dentists be aware of such a possibility considering that debris extrusion may trigger an inflammatory response, flare-up, post-obturation pain, and delayed periapical healing [4-6]. In this study, debris extrusion was after the root canal instrumentation with ProTaper® or ProTaper Next® was determined, which corroborates previous studies reporting that all instrumentations may cause debris extrusion to the periapical [4,12,16]. Thus, identifying the instrument that produces a minimal debris extrusion is imperative.

Irrigation is crucial in the root canal treatment, and a combination of 2.5% NaOCl and 17% EDTA is the most commonly used irrigation solution. In this study, we first irrigated teeth with 2.5% NaOCl before changing every file and after instrumentation to dissolve the organic material inside the root canal. Reportedly, NaOCl is the most effective irrigation solution and is used for the root canal treatment as an irrigation solution [18]. Another irrigation solution, 17% EDTA, is used to dissolve the inorganic smear layer, thereby increasing the retention of the sealer to the root canal surface. Owing to its acidic properties, EDTA can dissolve the inorganic material [19]. Of note, irrigation with NaCl is used for each irrigation with NaOCl and EDTA because EDTA might react with NaOCl, causing an adverse effect. Moreover, mixing EDTA with NaOCl can reduce the amount of chlorine in NaOCl and can reduce the efficacy of NaOCl in dissolving organic material, leading to the erosion of the dentin surface of the root canal [20]. However, NaOCl can affect the accuracy of debris extrusion weight measurement when the dried irrigation solution produces salt crystals that cannot be separated from the extruded debris, thereby affecting the accuracy of the final sample weight measurement [12,14-16]. In this study, distilled water was used to reduce the possibility of additional weight due to material contained in other types of irrigation solutions.

The sample preparation in this study was based on the weight measurement of debris extrusion to apical by Myers and Montgomery (1991) [21]. According this method, the difference in the weight between initial and final measurement is considered the weight of debris extruded. Thus, the higher the weight difference, the more the amount of debris that is extruded to periapical and vice versa [21].

Our results revealed a significant difference between debris extrusion to the periapical after instrumentation with ProTaper® and ProTaper Next®. The ProTaper Next® group produced lower debris extrusion than ProTaper®; which could be attributed to the fact that both instruments had different cross-sections: ProTaper® has a triangular three-edge convex with three points that connect with the root canal wall, while ProTaper Next® has a rectangular form in the middle and only two of four points that connect with the root canal wall, causing the file to exhibit a “snake-like” motion upon entering the root canal. The rectangular cross-sectional shape in ProTaper Next® would reduce the contact between the file and the dentin to maximize the debris removal toward the corona [22]. Apparently, the ProTaper Next® configuration has a larger and deeper flute than ProTaper® that can accommodate more debris, which is consistent with a report by Malagnino that the flute depth in Mtwo file increases the file capacity to lift the debris toward the corona [23].

In addition, the apical tapering of ProTaper® F1, F2, and F3 is 0.07, 0.08, and 0.09 respectively, whereas that of the ProTaper Next® file is 0.04, 0.06, and 0.07, respectively. A file with a larger tapering will remove more tissue than a file with a smaller tapering, resulting in a greater extent of debris extrusion in using the ProTaper® instrument, thereby explaining the increasing amount of extruded debris; this is in accordance with the findings of a study by Kustarcia et al. that instrumentation with ProTaper® produced a greater extent of debris extrusion than with the K3® file [15]. The final file in ProTaper®, F3, has a 0.09 tapering, which larger than the K3® file of 0.04. Thus,
F3 will remove more tissues than the K3® file, leading to higher debris extrusion; this is supported by a previous report [15].

The root canal instrumentation with ProTaper® uses five files for each sequence as opposed to only three with ProTaper Next®, which may result in a greater extent of debris extrusion with instruments using more number of files. An experiment conducted to investigate the root canal instrumentation of plastic block with ProTaper® and ProTaper Next® has revealed that ProTaper Next® saved 25% of the total time and 30% of times when evaluating extracted tooth. Meanwhile, Tanalp et al. have reported the contrasting results upon comparing the ProTaper® system with other continuous rotation instruments that the extent of debris extrusion was significantly higher with the ProTaper® technique [16]. Although ProTaper® used fewer instruments, it resulted in more dentin removal in lesser time because of its higher cutting capacity [16].

Notably, debris extrusion occurring during endodontic treatment can result in the entry of bacteria and their products into the periapical tissue, which can trigger acute inflammation. The intensity of the acute inflammatory response depends on the quantity (quantitative factor) and/or virulence (microbial species and qualitative factor) of the extruded microorganism. Highly virulent bacteria in the root canal when pushed into the periapical tissue during instrumentation could potentially cause periradicular inflammatory exacerbation, even with a small amount of infected debris.

5. Conclusion
The extent of debris extrusion into the periapical tissue after root canal instrumentation between ProTaper® and ProTaper Next® is significantly different. ProTaper Next® produces lower debris extrusion than ProTaper®. Hence, the use of instruments that minimize the occurrence of debris extrusion is recommended considering that the extrusion of infected debris can trigger an inflammatory response, pain, and delayed periapical healing.

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