

Influence of Apical Enlargement in Cleaning and Extrusion in Canals with Mild and Moderate Curvatures

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Optical microscopy and morphometric analysis were used in this study to evaluate, *in vitro*, the cleaning of the apical region in root canals with mild or moderate curvatures subjected to biomechanical preparation with a rotary system, as well as to assess the amount of extruded material to the periapical area. Lateral incisors (n = 32), 16 with curvature angles smaller or equal to 10° (GI) and 16 between 11° and 25° angles (GII) were submitted to Hero 642 rotary instrumentation with different surgical diameters: (A) 30.02 and (B) 45.02. Irrigation was performed at each change of instrument with 5 mL of ultrapure Milli-Q water and the extruded material through the apical foramen was collected. Root cross-sections were subjected to histological analysis by optical microscopy ($\times 40$) and the images were evaluated morphometrically using the Image Tool software. Quantification of the extruded material was performed by weighing after liquid evaporation. ANOVA showed no statistically significant differences ($p > 0.05$) among the groups with respect to the procedures used to clean the apical region. Considering the amount of extruded material, the Tukey's HSD showed that canals with mild curvature prepared with the 45.02 surgical diameter showed significantly higher values ($p < 0.05$) than those of the other groups, which were similar between themselves ($p > 0.05$). In conclusion, the effect of cleaning the apical region did not differ in the groups, considering root curvature and the surgical diameter of instruments used for apical preparation. The amount of extruded material was greater in canals with mild curvature that were prepared with the 45.02 surgical instrument diameter.

Key Words: root canal cleaning, rotary instrumentation, apical extrusion.

INTRODUCTION

The mechanical action of endodontic instruments during biomechanical preparation combined with the physicochemical properties of irrigation solutions is aimed at cleaning and disinfecting root canals and favor periapical repair (1). During this procedure, rests of excised dentin not removed by the irrigation/aspiration processes are kept inside the root canal, adhered to the walls and forming an amorphous structure called smear layer or, at the canal lumen in areas not reached by the endodontic instruments and/or irrigation solution forming debris that remain together with pulp remnants.

Scientific advancements have improved the

development of new instruments, techniques and technologies, but complete removal of smear layer or debris has not yet been achieved (2,3). Anatomic variations are limiting factors in the biomechanical preparation of root canals, favoring the persistence of tissue remnants and bacterial debris in the isthmus, re-entrances and ramifications of the canals (3,4).

Cleaning of the apical canal third is obtained by correct shaping and irrigating procedures, but an accurate determination of the anatomic diameter and enlargement of the canal lumen are indispensable (5). According to Pasternak-Junior et al. (6), even greater enlargements could be done in curved canals due to the flexibility of nickel-titanium (NiTi) instruments,

which allow increased final diameters with less risks of transportation. In addition, Fornari et al. (7) have shown that greater instrument diameters allow better fitting to the canal walls and produces more efficient cleaning. However, excised material composed of dentin chips, vita/necrotic pulp tissue fragments, microorganisms and irrigation solution might be forced beyond the apex in direction of the periapical region causing inflammatory reactions and post-instrumentation pain (8). The amount of material extrusion to the periapex varies according to the instrumentation and irrigation techniques, the apical patency and root curvature (9,10).

Considering that extrusion of material to the periapical region during the biomechanical preparation of root canals may cause persistent inflammation and postoperative pain, it is relevant to reflect on the usefulness of increased instrument final diameter.

MATERIAL AND METHODS

Thirty-two human maxillary lateral incisors with completely formed roots, more than 19 mm of root length and no calcifications and internal resorptions were used.

Extruded material through the radicular foramen during biomechanical preparation was collected by a device constructed with 20 mL glass flasks with rubber covers and 0.5 mL Eppendorf tubes connected to the apical region of each tooth. Apical patency was gained by introducing a #15 K-file (Dentsply-Maillefer, Ballaigues, Switzerland) into the root canal of each tooth until its tip was visible at the apical foramen. The working length (WL) was set 1 mm short of this measurement.

The roots were randomly assigned to two groups; G1 (n=16) comprised roots with curvature angles equal or less 10° (mild curvature) and G2 including roots with curvature angles ranging from 11° to 25° (moderate curvature). Each group was divided in two subgroups (n=8) according to the final instrumentation diameter to be used: 30.02 and 45.02.

The root canals were prepared with rotary instruments (Hero 642; Micromega, Besançon, France) activated by an electric motor (Endo-Mate TC-NSK, Nakanishi Inc. Tokyo, Japan). In GI, half of the specimens was prepared with 30.06 instrument with 12 mm penetration, 30.04 instrument at 2 mm short of WL (16 mm penetration) and 30.02 instrument to the full WL. The other half of the specimens was prepared using the same sequence of instruments adding 35.02, 40.02 and 45.02 instruments to the full WL. In GII, half of the

specimens was prepared with 25.06 instrument with 12 mm penetration, 25.04 instrument at 2 mm short of WL, 25.02 instrument to the full WL, 30.04 instrument at 2 mm short of WL and 30.02 instrument to the full WL. The other half of the specimens was prepared using the same sequence of instruments adding 35.02, 40.02 and 45.02 instruments to the full WL. At each change of instrument, the canals were irrigated with 5 mL of ultrapure MiliQ water delivered by a plastic syringe (Ultradent, South Jordan, Utah, USA) with a 21-mm-long Navitip needle (Ultradent) with a rubber stop positioned at 12 mm from the tip. The prepared roots were stored in buffered 10% formalin in individual containers.

The apical root third was sectioned with an scalpel were subjected to histological processing by the Leica TP 1010 automatic tissue processor (Leica Instruments GmbH, Nussloch, Germany). A Leica RM 2145 microtome (Leica Instruments) was used for the serial section of each specimen producing 6-mm-wide sections, which were stained with hematoxylin-eosin. The apical 1 mm was discarded. Ten sections of each apical third were selected for morphometric analysis with an optical microscope (Eclipse E 600, Nikon, Tokyo, Japan) fitted with a 4X/0.13 ocular lens, an amplifying objective (10X/25) and a final magnification of $\times 40$. Images were captured by the software Adobe Photoshop 5.1 (Adobe Systems Inc., San Jose, CA, USA) and analyzed with the Image Tool, version 3 software (UTHSCSA, San Antonio, TX, USA). The total cross-section area of the root canals and the area containing debris were determined by a measuring device. Percentages of the cross-section area occupied by debris were calculated from the two measurements. To determine extrusion, the coverless (sectioned) Eppendorf tubes were dehumidified for 12 h in an calcium carbonate atmosphere and weighed in a precision balance (10^{-4} OHAUS Analytic Standard, Model AS 200 MFD; OHAUS Corporation Forham Dark, NJ, USA). The final weight was an average of five measurements.

Data were analyzed statistically by ANOVA and HSD Tukey test at 5% significance level (SPSS software, version 17.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Means and standard deviation of remaining debris in the apical third of different curvature root canals (percent values) and the amount of material extruded after different procedures are shown in Table 1.

There were no statistically significant differences between areas (%) occupied by debris either in root canals with mild and moderate curvatures curved roots or in those prepared with instruments of different diameters. Values of *p* were 0.90 for differences between mild and moderately curved roots, 0.31 for different instrument diameters (30.02 and 45.02) and 0.99 for the interaction curvature versus surgical diameters.

As to the weights of extruded material, the values for different surgical diameters were not statistically different (*p*=0.063). However, mildly and moderately curved root canals showed significant differences in the amount of extruded material (*p*=0.036) as well as in the interactions between different curvatures and surgical instruments, 30.03 and 45.02 diameters (*p*=0.017).

Root canals with mild curvature prepared with the 45.02 instrument to the full WL showed the highest values for extruded material to the periapical region (0.87±0.22). This result was significantly different (*p*<0.05) from the other combinations, which, in turn, were statistically similar among themselves (*p*>0.05).

Figures 1 and 2 show representative photomicrographs of representative cross-sections at the apical level from mildly and moderately curved roots, respectively, after preparation with instruments of different diameters. In both types of root canals (mild and moderate curvatures), preparation with 35.02 diameter did not touch all canal walls (Figs. 1 and 2A,B) while the use of the 45.02 diameter increased canal wall cleaning, although it is still possible to see pre-dentin in several sections.

Table 1. Means and standard deviation of remaining debris in the apical third of different curvature root canals and material extrusion after different procedures.

Final instrument diameter	Debris (%)	Extrusion (mg)
Mild curvature		
30.02	3.02 ± 2.88a	0.66 ± 0.07§
45.02	2.14 ± 2.07a	0.87 ± 0.22Δ
Moderate curvature		
30.02	2.92 ± 2.74a	0.68 ± 0.11§
45.02	2.09 ± 1.49a	0.65 ± 0.09§

Different letters and different symbols indicate statistically significant differences for debris and material extrusion, respectively. HSD Tukey test *p*<0.05.

DISCUSSION

Literature reports indicate that biomechanical preparation in curved root canals should be performed by Ni-Ti rotary instruments highly tapered and with a minimum final apical diameter (ISO size 20, 25 or 30), which produce compacted filling material and less extrusion (11). Khademi et al. (12) considered that removal of dentin from the apical region is not necessary when the coronal portion is adequately prepared, and that a size 30 instrument is able to produce the smallest enlargement necessary for adequate penetration of irrigants into the apical third.

Fornari et al. (7) reported that better cleaning is obtained in severely curved roots when final instruments of greater diameter are used, but this greater enlargement and apical patency may result in material extrusion to the periapical region causing persistent inflammation and postoperative pain (8). Thus, it is important to reach a balance between using final instruments with greater diameter of during root canal shaping and the amount of material extruded to the periapex.

The influence of final instrument diameter in apical cleaning in curved root canals was assessed in this study by using diameters 30.02 and 45.02. Diameter 30 was selected based on the reports of Kademi et al. (12) mentioned above. The choice for diameter 45 was based on the conclusions of Pasternak-Junior et al. (6) that Ni-Ti instruments are more indicated to increase canal enlargement even in roots with accentuated curvatures, as they can be maintained centered in the canal. Instrument manufacturers suggest that moderately curved canals should be prepared with instruments up to size 30.

In this study, apical cleaning was assessed by the morphometric analysis of root cross-sections to determine the percent canal areas occupied by debris, as reported elsewhere (7,13,14). The morphometric analysis was performed with Image Tool software, an image-analysis software that provides good acuity and accurate measurements of delineated areas (7,14).

Collection of excised material was performed by a reproducible, widely accepted method using a custom-made device, which was designed to collect all material extruded though the apex (10). After evaporation of the irrigation solution and drying, the material was weighed.

Criteria for root selection in this study were the curvature angle, measured by orthoradial radiography using Schneider's method, and the parameters described by Pruett et al. (16). According to Pruett et al. (16), two

canals may have the same curvature but different radius. The smaller the radius, the more abrupt the curvature, negatively influencing transport and making it difficult to touch root canal walls with the instrument. Thus, the root canals chosen in this study had mild ($\leq 10^\circ$) and moderate curvatures (11 to 25°).

The results of the present study suggest that removal of debris from the apical third does not depend on the root curvature or the final instrument diameter used in the biomechanical preparation, although Fornari et al. (7) claimed that instruments with greater diameters allow a better contact with canal walls and, thus, more effective cleaning.

The manufacturer's instructions and the findings of Kademi et al. (13), who reported that root canals with moderate curvatures should be prepared with instruments

up to size 30, which is the smallest enlargement necessary for adequate penetration of chemical solutions into the apical third. However, in the present study, the qualitative analysis of histological sections showed that canals shaped with size 30 instrument showed untouched dentin walls. This is in contrast with the results obtained with the size 45 instrument, which provided better contact with canal walls regardless of root curvature, corroborating the findings of Fornari et al. (7).

Ibelli et al. (17) demonstrated that clinical determination of the root anatomic diameters varied from size 30 to 45 after cervical preparation, implying inadequate action of instrument 30 in the apical region. Therefore, it seems more reasonable to establish final instrument diameters based on the anatomic diameter after cervical preparation instead, as the manufacturer

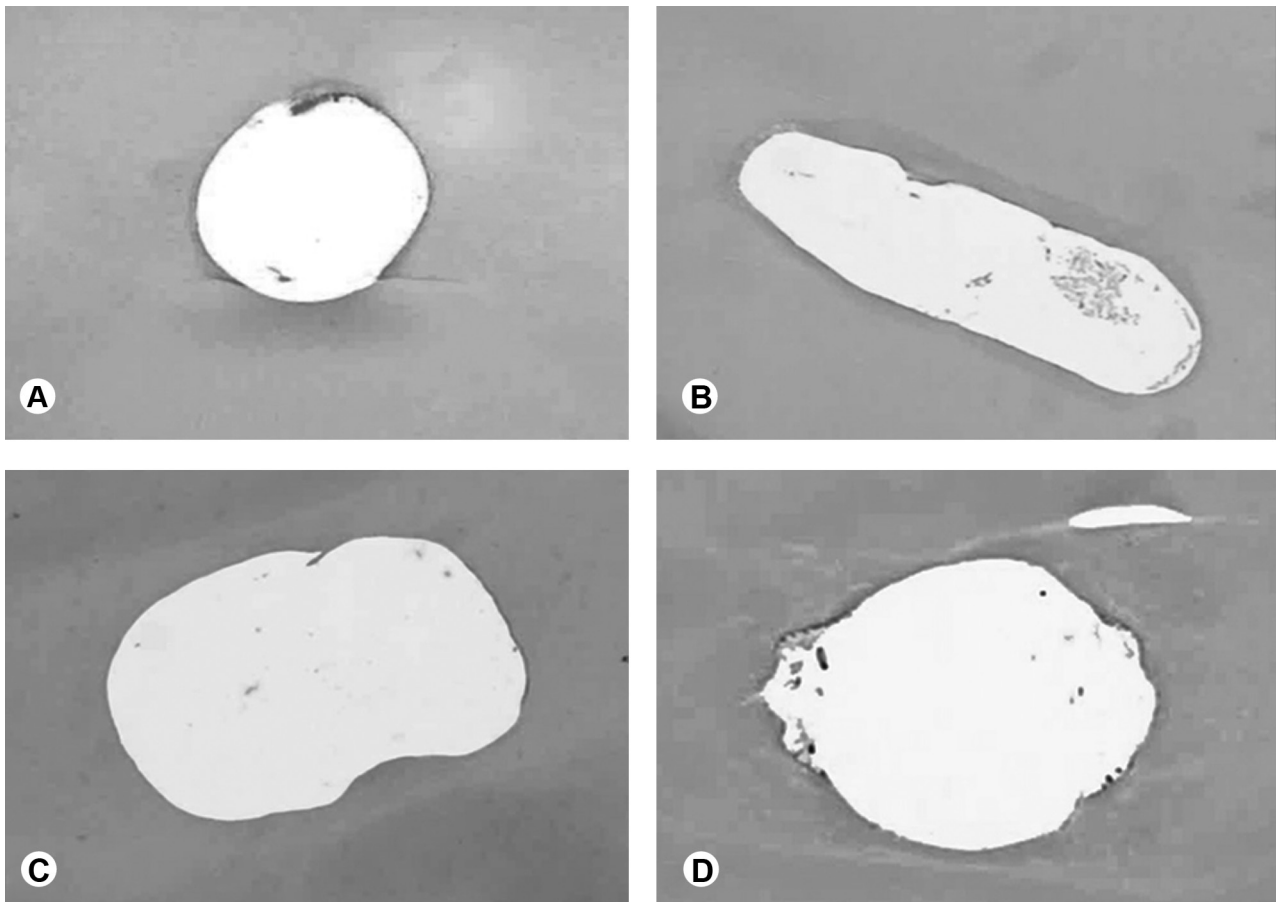


Figure 1. Photomicrographs of representative cross-sections at the apical level in mildly curved roots (original magnification $\times 40$). A. Cross-section of a root canal with mild curvature prepared with a final instrument diameter 30.02, showing pre-dentin. B. Cross-section of a root canal with mild curvature with elliptical configuration, prepared as in A, showing debris in the canal lumen. C. Cross-section of a root canal with mild curvature prepared with final instrument diameter 45.02, showing debris in the canal lumen. D. Cross-section of a root canal with mild curvature prepared as in C showing greater wall touching by instrumentation.

suggests, on the root curvature, as larger canal enlargements even in accentuated root curvatures are possible due to the flexibility of NiTi instruments (6).

In the present study, extrusion of material to the periapex was shown to be significantly different in canals with mild curvatures prepared with instrument 45 in comparison to all other combinations. Previous studies have shown that material extrusion may be related to root canal anatomy and instrumentation technique (10), although emphasizing that no technique is free from the risk of pushing material to the periapical region (19,20).

The greater extrusion values shown in the canals with mild curvature could be explained by the greater alignment of foramen and canal direction, although that rotary instrumentation tends to promote material

reflux (21). The same anatomic structure may also be involved in the higher pressure of irrigating solutions in comparison to moderate or accentuated root curvatures, thus increasing extrusion. According to Hinrichs et al. (22) and Ferraz et al. (21), the amount of extruded material is related to the volume of the irrigating solution.

The findings of this study confirmed those of Leonardi et al. (23), who found no significant differences in apical extrusion among canals with different curvatures prepared with size 30 instrument. The significant apical extrusion in canals with mild curvatures prepared with size 45 instrument is confirmed by previous reports (23,24). Lambrianidis et al. (25) observed greater amount of extrusion when the apical constriction was kept intact previously to enlargement.

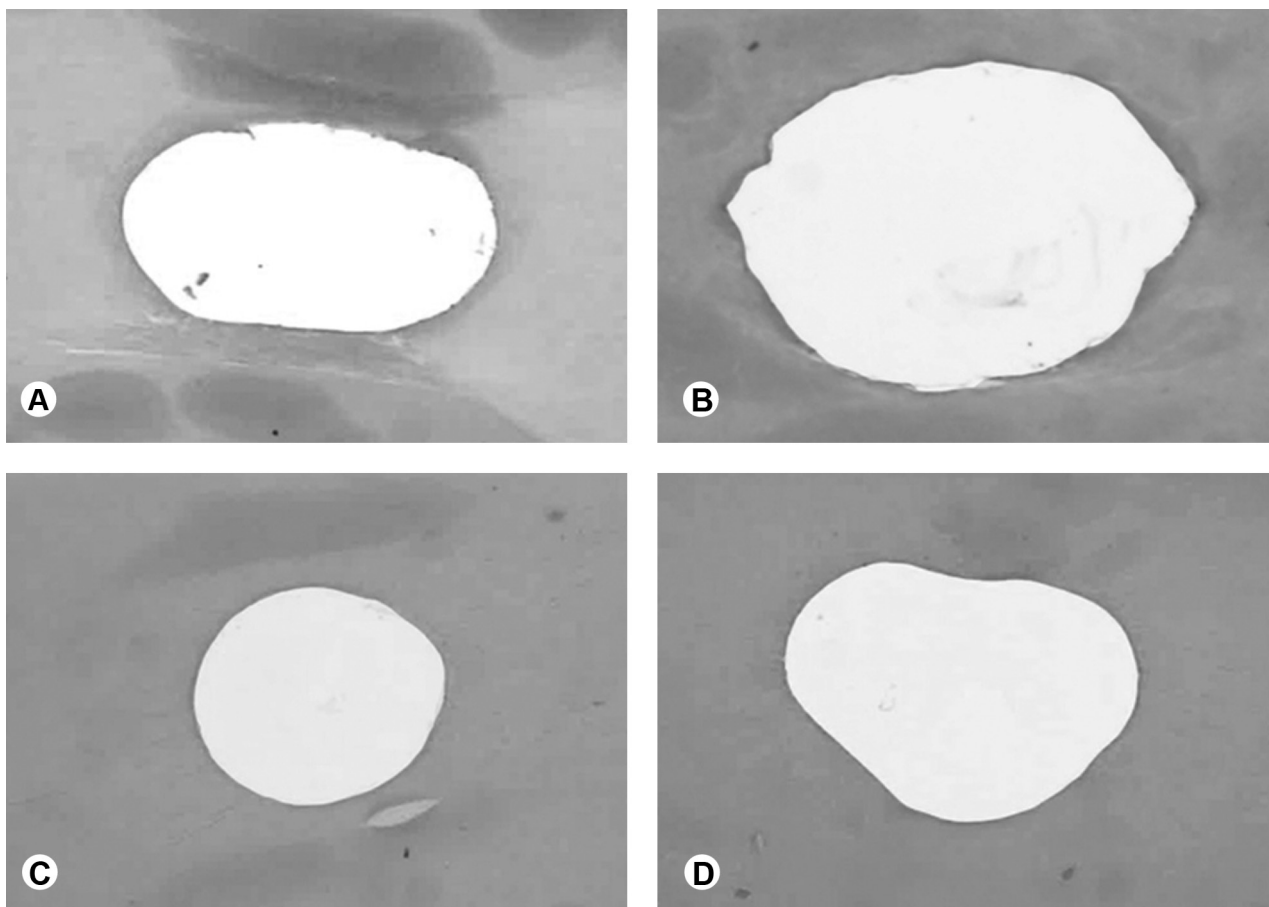


Figure 2. Photomicrographs of representative cross-sections at the apical level in moderately curved roots (original magnification $\times 40$). A. Cross-section of a root canal with moderate curvature prepared with a final instrument diameter, 30.02, showing debris in the canal lumen and pre-dentin. B. Cross-section of a root canal with moderate curvature, prepared as in A, showing circular configuration and few wall touching by instrumentation. C. Cross-section of a root canal with moderate curvature prepared with a final instrument diameter 45.02, showing a circular configuration and debris in the canal lumen. D. Cross-section of a root canal with moderate curvature, prepared as in C, showing improved dentin touching by instrumentation.

Concern with the biomechanical preparation is still a reality in endodontic practice. Further studies are needed to verify apical cleaning and extruded material in root canals prepared with NiTi instruments, by increasing the final instrument diameter after determination of the anatomic diameter.

RESUMO

Este estudo avaliou, *in vitro*, por meio de microscopia óptica e morfometria, a limpeza da região apical em canais radiculares com curvatura leve e moderada submetidos ao preparo biomecânico com sistema rotatório, bem como avaliou a quantidade de material extruído para a área apical. Incisivos laterais ($n = 32$), sendo 16 com ângulo de curvatura igual ou inferior a 10° (GI) e 16 entre 11° e 25° (GII), foram submetidos à instrumentação rotatória com o sistema Hero 642 com diferentes diâmetros cirúrgicos: (A) 30,02 e (B) 45,02. A irrigação, a cada troca de instrumento, foi realizada com água ultra-pura de Milli Q (5 mL), e o material extruído através do forame apical foi coletado. As raízes foram submetidas a análise histológica sob microscopia óptica ($40\times$) e as imagens foram submetidas à análise morfométrica utilizando o software Image Tool. A quantificação do material extruído foi realizada por pesagem, após a evaporação do líquido. A análise de variância não mostrou diferença estatística significativa em relação à limpeza da região apical nos diferentes grupos testados ($p > 0,05$). Considerando a quantidade de material extruído, o teste de Tukey mostrou que os canais com curvatura leve preparados com o diâmetro cirúrgico 45,02 apresentaram os maiores valores, sendo estatisticamente diferente dos demais grupos ($p < 0,05$) que foram semelhantes entre si ($p > 0,05$). Pode-se concluir que a limpeza da região apical não diferiu entre os diferentes grupos, considerando a curvatura radicular e o diâmetro cirúrgico. A quantidade de material extruído foi maior nos canais preparados com curvatura leve que foram preparados com diâmetro cirúrgico 45,02.

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