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Apical extrusion following different glide path instrumentation in curved canals of mandibular molars

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ABSTRACT

Endodontic failures are usually the result of technical errors compromising the proper endodontic procedures required to control and prevent periradicular infections. Among these errors, the extrusion of materials through the apical foramen has been associated with periapical inflammation, postoperative pain, tissue necrosis, delayed periapical healing and long-term failure. ***Aim:*** *To compare the debris extruded through the apical foramen when different glide path files are used prior to endodontic instrumentation with the WaveOne Gold Primary file.* ***Materials and Method:*** *Twenty-four mesial roots of extracted human mandibular first molars were divided into three groups (n=8): C-Pilot hand file (CPH) #15/.02; R-Pilot (RPL); WaveOne Gold Glider (WGG). The roots were placed in Eppendorf tubes containing 1.5% agar gel and weighed before and after instrumentation to calculate the weight of debris and irrigant solution extruded. Apical extrusion of debris was compared using one-way analysis of variance. The Games-Howell test was used for multiple comparisons due to heteroscedasticity, with a significance level of 5%.* ***Results:*** *Debris extrusion was significantly lower with the WaveOne Gold Glider file than with the R-Pilot file, which in turn produced less extrusion than the C-Pilot file.* ***Conclusion:*** *All glide path files caused apical extrusion, with the WaveOne Gold Glider causing the least.*

Keywords: *apical extrusion - automated instruments - debris - glide path*

Extrusão de debris após diferentes protocolos de glide path em canais curvos de molares inferiores

RESUMO

O fracasso do tratamento geralmente é resultado de erros técnicos que comprometem os procedimentos endodônticos adequados necessários para controlar e prevenir infecções perirradiculares. Entre esses erros, a extrusão de material obturador através do forame tem sido associada à inflamação periapical, dor pós-operatória, necrose tecidual, atraso na cicatrização periapical e falhas a longo prazo. ***Objetivo:*** *Comparar os detritos extruídos através do forame apical quando diferentes instrumentos para exploração do canal radicular são usados antes da instrumentação com o instrumento WaveOne Gold Primary.* ***Material e Métodos:*** *Vinte e quatro raízes mesiais de primeiros molares inferiores humanos extraídos foram divididas em três grupos (n=8): Lima manual C-Pilot (CPH) #15/.02; R-Pilot (RPL); WaveOne Gold Glider (WGG). As raízes foram colocadas em tubos Eppendorf contendo gel de ágar a 1,5% e pesadas antes e depois da instrumentação para calcular o peso dos detritos e da solução irrigante extruídos. A extrusão apical de detritos foi comparada usando análise de variância unidirecional. O teste de Games-Howell foi usado para múltiplas comparações devido à heterocedasticidade, com um nível de significância de 5%.* ***Resultados:*** *A extrusão de detritos foi significativamente menor com o instrumento WaveOne Gold Glider do que com o R-Pilot, que por sua vez produziu menos extrusão do que o C-Pilot.* ***Conclusão:*** *Todos os instrumentos de caminho de deslizamento causaram extrusão apical, sendo o WaveOne Gold Glider o que causou a menor extrusão.*

Palavras-chave: *extrusão apical - instrumentos automatizados - detritos - exploração do canal radicular*

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INTRODUCTION

Endodontic failures are usually the result of technical errors compromising the proper endodontic procedures required to control and prevent periradicular infections. Among these errors, the extrusion of materials through the apical foramen has been associated with periapical inflammation, postoperative pain[1], tissue necrosis, delayed periapical healing and long-term failure[2].

All instruments and techniques used in root canal preparation may transfer varying amounts of debris into the periradicular area. The debris may consist of hard tissue (dentin), pulp tissue, microorganisms and/or irrigants[3].

Rotary NiTi instruments have advantages over hand files in terms of faster preparation and better preservation of canal geometry[4], but they still pose a challenge in terms of debris extrusion[5]. The amount of extruded content can be influenced by endodontic file design and kinematics[6], technique (hand, reciprocating or rotary)[7,8], number of instruments used to prepare the canal, and file taper, cross-section and cutting capacity[9].

There is controversy in the literature about which instruments cause the most apical debris extrusion, though some studies have found that reciprocating instruments may produce more than rotary instruments do[10-13].

There are also contradictory results regarding the amount of debris extrusion caused by different types of irrigants[11]. One study found that 5.25% hypochlorite caused more debris extrusion than 2.5% hypochlorite or 2% chlorhexidine[12]. In another study, more debris was extruded with chlorhexidine gel than with 2.5% NaOCl[11]. EDTA gel, citric acid and peracetic acid in the root canals during preparation produced less apically extruded debris than other solutions did[13]. Irrigation, though essential to the success of endodontic treatment, may facilitate the extrusion of debris into the periapical region[14], causing inflammatory reactions such as pain, edema, and the possibility of delayed tissue repair[15].

Creating a path from the canal opening to the apical foramen, referred to as a "glide path," prior to canal preparation helps to improve file performance and may reduce the amount of apically extruded debris[15].

A glide path can be created using hand, rotary or reciprocating instruments[6].

The following are two of the reciprocating files available on the market that can be used to prepare glide paths:

- WaveOne Gold Glider (Dentsply Sirona, Charlotte, USA), which has thermomechanical treatment, parallelogram-shaped cross-section, tip diameter 15, and variable taper of 2-6%[1],
- R-Pilot (VDW, Munich, Germany), which has M-wire heat treatment, S-shaped cross-section, tip diameter 0.125 mm and constant taper of 4%[16].

Both these files have been previously evaluated for debris extrusion prior to instrumentation with the Reciproc Blue R25 reciprocating system[1].

The aim of this *ex vivo* study was to evaluate the apical extrusion of debris using different files when preparing the glide path prior to endodontic instrumentation with the WaveOne Gold file. The null hypothesis was that there would be no difference between the systems in terms of the amount of debris extruded.

MATERIALS AND METHOD

This study was approved by the local research ethics committee (approval number R002/2023).

Required sample size was calculated with the program G*Power 3.1.9.4, using the analysis of variance model. With an effect size of 0.734, which was determined in the study by Gunes[17], a significance level of 5 % and a power of 90 %, the calculation showed that a total sample of 24 mesial roots would be required to detect significant differences among groups.

Selection and preparation of the specimens

Forty-eight mesial canals from 24 type IV mesial roots from human mandibular first molars, extracted for reasons unrelated to this study, were selected. Teeth with previous endodontic treatment, incomplete rhizogenesis, root fractures, internal or external resorption and foramina larger than 0.10 mm were excluded. Mesial roots with moderate curvature (10º to 20º) according to Schneider's Classification[18] were included. To confirm the inclusion criteria, periapical radiographs were taken in the mesiobuccal and distolingual directions with a K #08/.02 hand file (Dentsply Maillefer, Ballaigues, Switzerland) in the canal, during the working length measurement, as explained below. The teeth were immersed in 5% sodium hypochlorite for 30 minutes, their outer surface was cleaned with a periodontal curette, and they were stored in saline solution and refrigerated at 4°C until use.

For sample selection, the teeth were fixed with utility wax (Lysanda, São Paulo, SP, Brazil) to the platform of a micro-CT scanner (SkyScan 1273; Bruker micro-CT, Kontich, Belgium) and scanned at 70 kV, 114 mA, 14 µm pixel size, 360° around the vertical axis, rotation step of 0.5, and 2 average frames using a 1.0-mm-thick aluminum filter. Images were reconstructed using N. Recon v.1.6.9.16 software (Bruker micro-CT), with ring artifact correction of 5, beam hardening correction of 50%, and smoothing of 8 to create axial slices of the internal structure of all root canals. Next, the 3-dimensional quantitative analysis (volume, major and minor apical diameter) was performed using CTAn v1.14.4.1 software (Bruker micro-CT), to pair samples and select groups considering similar morphological parameters ($p>0.05$) assessed by micro-CT. Finally, a total 24 teeth (48 mesial canals) were included in the study (Fig. 1).

Fig. 1: Representative CT images of the Vertucci's type IV mandibular molars used in the present study.

CTAn v1.14.4.1 software v.1.5.2 (Bruker microCT) was used to measure, the minor diameter of each canal at the apical foramen on the axial plane. Mean minor root canal diameter measured on the micro-CT scans was 0.26 ± 0.05 mm (median = 0.26 and range = 0.14-0.34).

Sample preparation

The teeth were prepared by an experienced specialist in Endodontics. The specimens were immersed in 2.5% sodium hypochlorite (NaOCl) solution for 30 minutes for surface disinfection and then in saline solution, and finally, placed in Eppendorf tubes (Eppendorfs do Brazil, São Paulo, SP, Brazil). To standardize the teeth to 17 mm, the crowns were worn with a carborundum diamond disk (KG Sorensen, Serra, Brazil). The working length (WL) was measured visually, using a K #08/.02 hand file (Dentsply Maillefer, Ballaigues, Switzerland) under microscope at 20x magnification until the tip of the file was visible through the apical foramen. The WL of the canal was set at 17 mm, i.e. the entire length of the tooth.

The caps of the Eppendorf tubes were removed with scissors. A hole was drilled at high speed into the center of each cap using a #1014 (KG Sorensen, Serra, Brazil) diamond ball drill. The roots were wrapped with Teflon tape and only the apical 1 mm was exposed[19]. The Teflon-wrapped root remnants were inserted into the holes in the caps up to the border of the cementum, leaving 12 mm of the root below the cap and 5 mm of the coronal remnant above. Then, the interface between the cap and the tooth was sealed with cyanoacrylate (Super Bonder, Loctite, Henkel Ltda., São Paulo, Brazil). Fluid resin (FGM, Joinville, Brazil) was applied over the cyanoacrylate to protect it and prevent irrigant solution from entering the tube during root canal preparation. All weights in the following experiment were measured three times on a high-precision electronic balance (RADWAG, Radom, Poland), and the mean values were calculated and recorded.

Each cap/tooth set was weighed. This weight was designated as P1. Then 1.5 mL of 1.5% agar gel (Kasvi, São José dos Pinhais, Brazil) was placed in each Eppendorf tube (uncovered) using a pipette. After the tubes had been filled with the liquid agar, they were covered with the cap/tooth, turned upside down, and placed in a plastic holder so that the roots were completely immersed in the agar solution. The gelled agar was used to simulate periapical tissues.

After the agar had fully gelled at room temperature for 24 hours, each tube/agar/cap/tooth set was weighed. This weight was designated as P2. Thus, P2 (tube/agar/cap/tooth) minus P1 (cap/tooth) provided the weight of the tube with agar, which was designated as P3 (tube/agar).

The Eppendorf tubes were positioned in a holder to prevent the operator from seeing the tooth root during endodontic preparation. The specimens were divided into three groups (n=8): CPH, WGG and RPL, and the glide paths of the mesio-buccal and mesio-lingual root canals prepared using one the following glide path instruments: *Group CPH* - C-Pilot hand file (Dentsply Maillefer, Ballaigues, Switzerland), *Group WGG* - WaveOne Gold Glider

(Dentsply Sirona, Charlotte, USA) or *Group RPL* - R-Pilot (VDW, Munich, Germany). After the glide paths had been prepared, the canals were instrumented with WaveOne Gold Primary files.
During the glide path and mechanical preparation of the canals, a peristaltic pump model EK1960 (Gikfun, China) and a NaviTip 30G 25mm needle (ULTRADENT, Indaiatuba, Brazil) were used to irrigate with double distilled water at a flow rate of 1mL/minute. A total 4 mL of double distilled water was used to prepare each root canal.

Glide path procedure in the tested groups

Group CPH: C-Pilot hand file #15/.02
The first rinse was performed with 1mL of double distilled water in the canal until the needle reached 13 mm (end of the middle third). Patency was achieved with a K#10/.02 (Dentsply Maillefer) file 1 mm beyond the foramen. The glide path was started with a C-Pilot #15/.02 hand file using gentle pushing and pulling movements with amplitudes of no more than 1 mm and a quarter turn to the left and a quarter turn to the right until the WL (17 mm) was reached. Then, the cervical and middle thirds were instrumented with a WaveOne Gold Primary file driven by the IQ motor (Dentsply Sirona) in reciprocating mode, followed by irrigation with 1 mL of double distilled water with a needle inserted into the canal 2 mm short the WL, followed by a K#10/.02 file until patency. Instrumentation was then performed with the WaveOne Gold Primary file until WL. Final irrigation was then performed with 1 mL of double distilled water in the canal, with the needle penetrating up to 15 mm intracanal.

Group RPL: R-pilot 12.5/.04
The roots were prepared in the same way as in group CPH, but with the glide path with the R-Pilot file (VDW) coupled to an X-Smart IQ contra-angle handpiece motor (Dentsply Sirona, Charlotte, USA) in the reciprocating function with smooth in-and-out movements of 3 mm amplitude to a depth of 17 mm.

Group WGG: WaveOne Gold Glider 15/.02
The roots were prepared in the same way as in group RLP, but with the glide path with the WaveOne Gold Glider (Dentsply Sirona).

Extruded material quantification
After completion of mechanical preparation, the Eppendorf tubes were removed from the holder, and the caps/teeth carefully detached from the tubes. The Eppendorf tubes containing the agar, debris and irrigant were weighed and labeled as P4 (tubes/agar/debris/irrigant). The amount of debris and irrigants extruded through the foramen and deposited in the agar gel was calculated as P4 - P3, i.e. tube/agar/debris/irrigants (after instrumentation) (P4) minus tube/agar (before instrumentation) (P3). This weight was designated as P8.
Any remaining debris that might have adhered to the root apex of the cap/tooth removed from the agar was washed with 2 mL of double distilled water, and collected in another Eppendorf tube, which was previously weighed and designated as P5. These tubes were placed in a stove at 37°C for 48 hours to evaporate the liquid, and then weighed again as P6: Weight of the Eppendorf tube with debris collected from the tooth apices of the cover/teeth set. P6 - P5 = P7 was the weight of the debris adhering to the outer surface of the tooth apex (Fig. 2).
Thus, the total amount of debris extruded through the foramen (both deposited on the agar and adhered to the tooth apex) was represented by P7 plus P8 and labeled as P9. Fig. 3 shows the sequence of weighing the extruded dentinal debris.

Statistical analysis
Given the normal distribution, comparison between the glide path files in terms of apical extrusion of debris was performed using one-way analysis of variance. For multiple comparisons, the Games-Howell test was used due to heteroscedasticity. Statistical calculations were performed using the SPSS 23 program (SPSS Inc., Chicago, IL, USA), assuming a significance level of 5%.

RESULTS
One-way analysis of variance showed that apical debris extrusion was significantly influenced by the type of glide path file ($p < 0.001$). Debris extrusion was significantly lower with the WaveOne Gold Glider file than with the R-Pilot file, which in turn produced less extrusion than the C-Pilot file (Table 1).

Discussion
The aim of this study was to investigate the apical extrusion of debris after the use of different glide

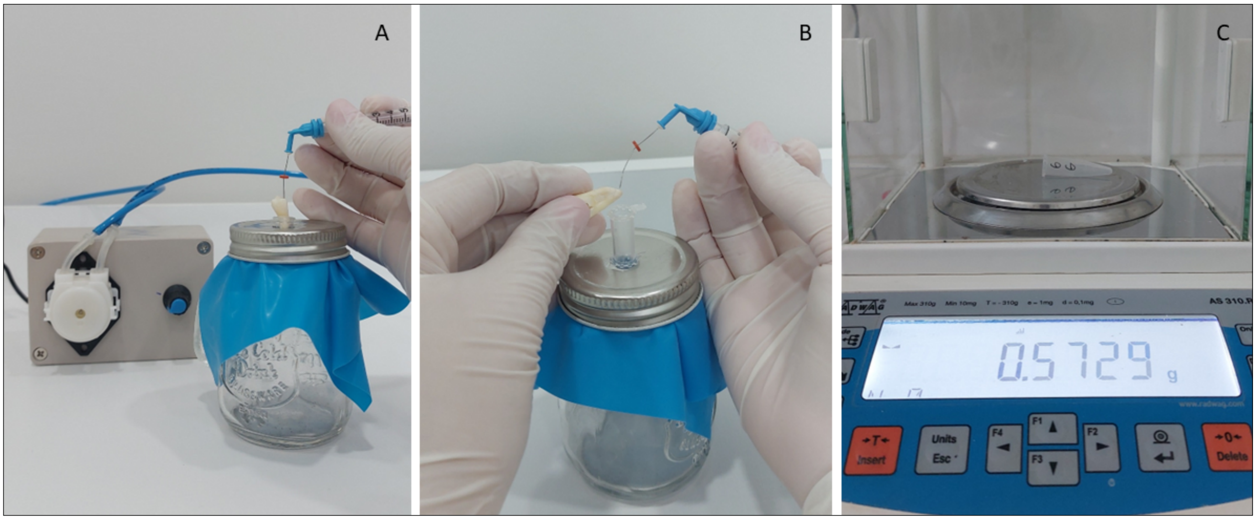

Fig. 2: Representative images of the extruded dentinal debris weighing procedure. A) Shaping and irrigating procedures. B) Washing any remaining debris that might have adhered to the root apex. C) Debris weighing procedure.

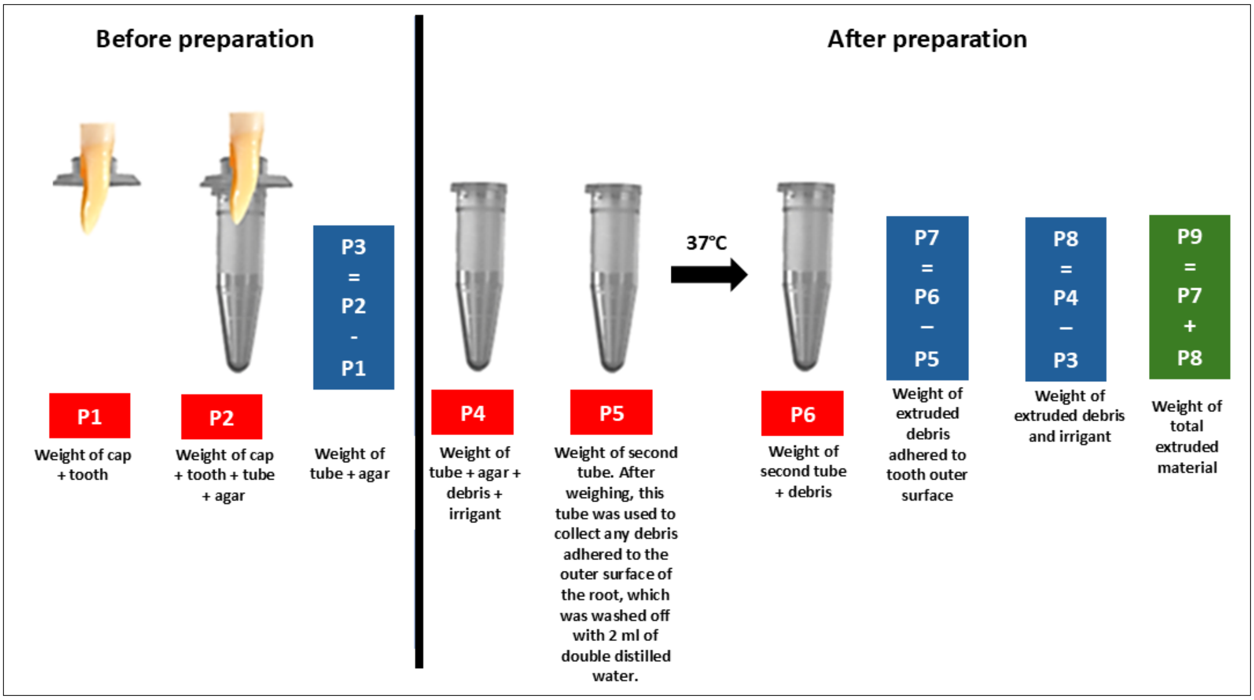

Fig. 3: Schematic figure showing the technical sequence of weighing the extruded dentinal debris.

Table 1. Mean and standard deviation of apical debris extrusion, according to the glide path instrument used.

File	Mean	Standard deviation
C-Pilot	0.137 C	0.037
R-Pilot	0.089 B	0.030
WaveOne Gold Glider	0.042 A	0.012

Different letters indicate significant difference between instruments.

path files – C-Pilot #15/.02, WGG and R-Pilot – were used prior to instrumentation with the WaveOne Gold primary file. Double distilled water was used to irrigate the canals, as reported in other studies[20,21], because using sodium hypochlorite may cause salt deposition or crystal formation after the evaporation process, which would lead to overestimation of the mass of extruded material[22]. A peristaltic pump was used in the present study to standardize the total volume and flow rate of the double distilled water to 1 mL/min to ensure controlled conditions, as the manually controlled flow rates of the rinsing agent may not be sufficiently standardized[23].

This study used agar gel to simulate periapical tissues because its density is similar to that of periapical tissues for apically extruded materials[19,24].

The glide path technique has been associated with a lower incidence and intensity of postoperative pain and less apical extrusion[25]. However, several factors may influence this outcome, including the taper, tip size, preparation technique and kinematics[26]. Tooth-related factors, including the curvature and size of the apical foramen, have been reported to contribute to debris extrusion[6,27,28]. The cross-section of the instrument and the volume of irrigation fluid used during preparation can also influence the extrusion of debris[29].

In this study, the amount of debris extruded using the three different glide path files differed significantly, therefore the null hypothesis was rejected. The hand C-Pilot file caused higher debris extrusion than the R-Pilot and WGG files ($p<0.05$). This may be related to the stiffness of stainless-steel C-Pilot hand files, which can push more debris apically than NiTi alloy files with M-wire[30]. Studies have shown that hand stainless-steel files cause higher extrusion of debris than rotary and reciprocating systems[17,31]. In this study, the C-Pilot hand file also caused higher extrusion of debris, while the WGG file caused lower extrusion than the R-Pilot file. The WGG file is a NiTi file with gold heat treatment, which is more flexible than the R-Pilot file. Flexible instruments may cause lower apical transportation and consequently lower extrusion of debris in curved canals[32]. This could explain the lower extrusion in the WGG group compared to the R-Pilot and C-Pilot groups. In the study by Kirici et al[33], less debris was extruded when WGG was applied before WOG compared to ProGlider, in agreement with the results of the current study.

The results of the present study differ from those of Keskin[1], who investigated the apical extrusion of debris and found that the use of the R-Pilot, WGG and ProGlider followed by the use of the Reciproc Blue R25 file caused a similar amount debris extrusion from the mesial roots of mandibular molars. The fact that debris extrusion with the R-Pilot, WGG and ProGlider files was evaluated after using the Reciproc Blue R25 file may have masked the difference in debris extrusion with the glide path files, as the Reciproc Blue file caused significantly more debris extrusion than the Wave One Gold file when shaping root canals[34,35].

CONCLUSION

Glide path preparation resulted in apical extrusion, regardless of the instrument used. However, since the best results were achieved with the WaveOne Gold Glider (lowest debris extrusion), it could be recommended for use before instrumentation with the WaveOne Gold primary file. It is important to note that, due to the ex vivo nature of the study, the results should be extrapolated with care to clinical situations.

DECLARATION OF CONFLICTING INTERESTS

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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