



## Research Article

# In Vitro Evaluation of Apical Debris Extrusion After the Root Canal Preparation with Gel Irrigants

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### Abstract

During root canal instrumentation, debris can extrude through the apical foramen, causing postoperative pain and periapical inflammation. To investigate the influence of different auxiliary solutions in gel on the extrusion of debris through the apical foramen during root canal instrumentation. Thirty extracted mandibular premolars were randomly divided into three groups (n=10) based on the irrigant used: CHXg group (chlorhexidine 2% gel), NaOClg group (NaOCl 3% gel) and control group (NG: Natrosol gel). The teeth were placed in Eppendorf tubes containing 1.5% agar gel, the tube-agar sets were weighed before and after root canal instrumentation. Debris extrusion was quantified by the weight difference. Data were analyzed using analysis of variance (ANOVA), with  $P < 0.05$  considered significant. Apical debris extrusion was significantly influenced by the irrigant ( $P = 0.009$ ), with lower extrusion in the CHXg and NG groups, which did not differ from each other, compared to the NaOClg group. All groups showed extrusion of debris through the apical foramen; however, the NaOClg group exhibited a greater amount of extruded material.

**Keywords:** Chlorhexidine; Debris; Extrusion; Hypochlorite Gel; Instrumentation

## Introduction

During root canal instrumentation, apical extrusion of debris such as pulp tissue, microorganisms, irrigant and dentin remnants can occur potentially leading to complications like postoperative pain and delayed periapical healing [1]. Debris extrusion is an inevitable phenomenon [2] and is influenced by several factors [3]. The use of effective irrigants for cleaning and neutralizing necrotic contents during root canal preparation is essential for successful endodontic treatment [4]. Sodium Hypochlorite (NaOCl) is widely used due to its antimicrobial efficacy and ability to dissolve organic material [5]. However, due to its cytotoxicity, it should be used cautiously, especially at high concentrations, as it can cause acute pain and edema if it contacts vital tissue [6]. NaOCl in gel form (NaOClg) has been proposed as an alternative to NaOCl solution, retaining its antimicrobial effect [7] but with a lower risk of apical extrusion, which may enhance procedural safety [8,9]. One study found significantly less extrusion of NaOCl in gel form compared to solution, especially in small-diameter apical foramina [10].

In this study, a 3% NaOCl gel (Chlorcid V, Ultradent, South Jordan, USA) with a pH between 11 and 13 was used, containing sodium hydroxide for stabilizing the NaOCl and polyacrylic acid as a thickening agent. Chlorhexidine Gel (CHXg) is another alternative to NaOCl and is characterized by broad antimicrobial activity, lower cytotoxicity, lubricating properties, and clinical efficacy [11]. The CHXg used in this study, with a pH between 6 and 7, contains Natrosol gel as a thickening agent. Additionally, CHXg has a rheological effect that keeps debris in suspension [11], reducing the risk of debris extrusion [12,13] and consequently minimizing postoperative complications. To date, no studies have compared CHXg and NaOClg regarding debris extrusion. Therefore, this study aims to evaluate the extrusion of debris and irrigants using these auxiliary chemicals in gel form during endodontic treatment, with NG serving as a control. The null hypothesis is that there will be no significant difference in debris extrusion between the tested substances.

## Methods

### Sample Selection and Preparation

This study was approved by the local ethics committee (CAAE: 42304521.9.0000.5374). The manuscript was written according to the Preferred Reporting Items For Laboratory Studies In Endodontology (PRILE) 2021 guidelines (Figure 1). Thirty single-rooted human mandibular premolars, recently extracted for periodontal or orthodontic reasons, were selected. Digital periapical radiographs (Spectro 70X X-ray unit, Dabi Atlante, Ribeirão Preto, Brazil) were taken to determine the degree of root

curvature and to observe the root canal's anatomy. Exclusion criteria included teeth with atresia, resorption, calcification, previous endodontic treatment and fractures or cracks. Teeth with single canals with a moderate curvature between 10-20° [14] and class I canals [15] were selected, ensuring a foraminal diameter compatible with any Kerr #15 file. Surgical access was achieved using 1014 HL spherical drills (KG Sorensen, Serra, Brazil), at high speed and cooled with an air/water spray. Subsequently, the tooth crowns were ground with a diamond disk (KG Sorensen) under an optical microscope at 40x magnification, standardizing the length of the roots to 17 mm (from apical to coronal), considering 4 mm apical, 4 mm middle, 4 mm cervical and 5 mm coronal rest (Figure 2). Root canal length determination was performed using the direct visual method, inserting a #10/.02 C-Pilot file (VDW, Munich, Germany) until its tip was visible at the apical foramen.

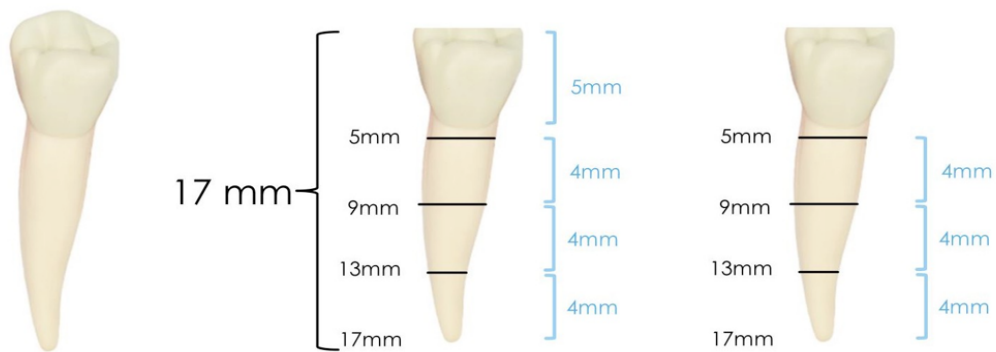
A surgical microscope (Alliance Microscopia, São Carlos, Brazil) with 20x magnification was used for this purpose. The working length (WL) was determined to be 17 mm. The teeth were placed in Eppendorf tubes (Eppendorf do Brasil, Sumarezinho, Brazil) containing 1.5% agar. Debris extrusion was measured using a modified method [16]. Tubes were drilled centrally to create a hole compatible with the cervical diameter of the root. Roots of the teeth were wrapped with Teflon tape, leaving 1 mm of the apical third exposed. They were then inserted into the caps of the Eppendorf tubes up to the level of the cervical, with 12 mm of the root positioned inside the tube and 5 mm of the coronal remnant outside the tube, as shown in Figure 3. The space between the tube cap and the tooth was sealed with Cyanoacrylate and the interface was protected with Top Dam Gingival Barrier (FGM, Joinville, Brazil) to prevent liquid ingress. Each cap/tooth set was numbered and weighed in triplicate on a high-precision electronic scale (NOVAK, São José do Rio Preto, Brazil), for initial weight (P1). Next, 2 mL of 1.5% agar gel (Kasvi, São José dos Pinhais, Brazil) was injected into the tubes, which were inverted to immerse the roots in the agar solution (Figure 2). After 24 hours, when the agar had completely gelled, the tubes were weighed again in triplicate and the weight obtained was designated as P2. The weight of agar alone (P3) was calculated as the difference between P2 and P1. Finally, the tubes were placed in an opaque glass container so that the operator could not see the samples during the endodontic procedure (Figure 4). Finally, once the endodontic preparation was complete, the samples were weighed. Extreme care was taken to remove the cap/tooth set from the Eppendorf tube so as not to dislodge the agar gel. The samples were weighed in triplicate on a high-precision electronic scale (NOVAK, São José do Rio Preto, Brazil), and the average of the three values was recorded as weight 4 (P4). The weight difference, representing debris and rinsing liquid extrusion, was calculated by subtracting P3 (weight of the tube with agar) from P4, resulting in value P5. The samples were

randomly divided into three groups (n=10) according to the chemical substance used in the canal preparation as follows

- Group CHXg: Chlorhexidine gel 2%
- NaOClg group: Sodium hypochlorite 3% gel (ChlorCid V)
- Group NG: Natrosol gel (control group)



**Figure 1:** PRILE flowchart.



**Figure 2:** Standardization of samples and division into thirds.



**Figure 3:** Sample preparation.



**Figure 4:** Eppendorf tubes placed in a dark bottle.

### Root Canal Preparation

Instrumentation was performed using the WaveOne® Gold Primary #25/.07 instrument (Dentsply Sirona, Charlotte, USA), driven by the X-Smart Plus endodontic motor (Dentsply Sirona) in the Wave One Gold reciprocating function. Three movements with an amplitude of 3 mm in pecking motion. After each sequence of three movements, the file was removed and disinfected with sterile gauze soaked in 70% alcohol. The Working Length (WL) was set to the WL. The entire process was performed by an endodontic specialist. A peristaltic pump (LAP-101-3 Tecnoyon, Piracicaba, Brazil) with a flow rate of 5 mL/minute was used for irrigation. The tubing was attached to a 1-mL injection syringe (BD Plastipak, Curitiba, Brazil) and an extra-short 29-G needle (21 mm) (Ultradent, Indaiatuba, Brazil). The preparation was carried out with the same protocol for all tested groups with the root canal preparation of the cervical and middle thirds.

It was started with a initial irrigation with 1 mL of CHXg 2% (Formula & Action, Brazil) in the canal until the needle reached 9 mm from the crown to the apex. Patency was then confirmed with the #10/.02 C-Pilot file (VDW, Munich, Germany) up to the apex. The cervical and middle third were instrumented with the #25/.07 WaveOne® Gold Primary, which penetrated 13 mm of the root length (end of the middle third). Subsequently, 1 mL of 0.9% saline solution (Formula & Action) was irrigated up to 13 mm into the canal. Patency was then confirmed with a #10/.02 C-Pilot file. After, a new irrigation with 1 mL of CHXg in the canal up to 13 mm. The apical third was instrumented until the WaveOne® Gold Primary #25/.07 reached 17 mm (end of apical third - WL). The canal was irrigated with 1 mL SF 0.9% until it reached 15 mm (2 mm below the apical third). Final patency was achieved with the #10/.02 C-Pilot file, followed by a final irrigation with 1 mL SF 0.9% inside the canal up to 15 mm. At the end of the preparation, 3 mL of SF was used as a irrigation solution and 2 mL of CHXg, 2 mL 3% NaOClg (ChlorCid V), and Natrosol gel was used as an auxiliary chemical solution. The distribution of the auxiliary substances per third of the canal is shown in Table 1.

**Table 1:** Volume of irrigant solution used per group.

	Cervical and middle	Apical	Total
CHXg	1 mL CHXg	1 mL CHXg	5mL
	1 mL SF	2 mL SF	
NaOClg	1 mL NaOClg	1 mL NaOClg	5 mL
	1 mL SF	2 mL SF	
NG	1 mL NG	1 mL NG	5 mL
	1 mL SF	2 mL SF	

CHXg: chlorhexidine gel; NaOClg: sodium hypochlorite gel; SF: saline solution; NG: natrosol gel

### Statistical Analysis

A one-way ANOVA was performed as the data conformed to normal distribution and homoscedasticity. Tukey’s test was used for multiple comparisons. Statistical calculations were performed using the SPSS 23 program (SPSS INC., Chicago, IL, USA) at a significance level of 5%.

### Results

Apical debris extrusion was significantly influenced by the irrigant ( $p = 0.009$ ), with high extrusion in the NaOClg group than in the CHXg and NG groups, which did not differ significantly (Table 2).

**Table 2:** Means and standard deviations of apical debris extrusion (in grams), according to irrigant substance.

Irrigant	Mean	Standard deviation
Clorexidine 2% gel	0.044 A	0.009
NaOCl 3% gel	0.059 B	0.017
Natrosol gel	0.040 A	0.012

Means followed by different letters indicate a significant difference between irrigants.

### Discussion

This study evaluated debris extrusion during endodontic instrumentation using CHXg and NaOClg, with NG as a control. Results showed that CHXg and NG had less debris extrusion compared to NaOClg, rejecting the null hypothesis. Teeth were selected based on type, size, canal curvature, number of canals, and working length to ensure the influence of irrigants rather than tooth morphology. The working length was defined by the actual length of the canal (0.0), based on a previous study that showed that instrumentation to the apical foramen or 1 mm below did not affect debris extrusion [17]. The size of the apical preparation was standardized with WaveOne Gold 25.07 after it was shown that the size of the preparation had no effect on debris extrusion [17]. The irrigants, CHX and NaOCl gel, are recognized in endodontics, while NG was used as a control [18]. NG, also known as hydroxyethyl cellulose, is a water-soluble non-ionic polymer that acts as a thickening agent and rheology modifier [19]. It was chosen as a control because it is the basis of CHXg and because it is similar to the gel used in NaOClg. Polyacrylic acid is used as a thickening agent in NaOCl gel because it can form stable and viscous gels that not only facilitate the precise application of irrigation, but also increase the antimicrobial efficacy of NaOCl, thus improving the cleaning and disinfection of root canals during endodontic treatment [20]. The use of NaOCl gel aims to reduce the risk of apical extrusion and avoid accidents related to NaOCl extrusion [8] Studies have shown that NaOClg has comparable

antibacterial efficacy to the solution [5,8].

The WaveOne Gold instrument was selected for canal preparation because it emits less debris [21]. To simulate the density of the periodontal ligament, a 1.5% agar gel was used [16] with a density of 1045 kg/m<sup>3</sup>, which is similar to that of periapical tissue (1000-1100 kg/m<sup>3</sup>) and allows the measurement of fluid and leaked debris [22]. In addition, there is no interaction between NaOCl and the agarose gel, making the system ideal for measuring extruded debris in the apical region [18]. Standardization of the experimental protocols is essential for the internal validity of the study. Irrigation was performed using a Tecnopon LAP-101-3 peristaltic pump with a flow rate of 5 mL/min to control the volume of irrigation fluid [23]. High irrigation flow and pressure is associated with greater debris [24] highlighting the importance of standardization. In this study, CHXg and Natrosol showed less extrusion of debris compared to NaOClg. The greater extrusion observed with NaOClg may be attributed to the effect of residual oxygen in the dentin, which can potentially reduce the cleaning capacity of NaOCl gel [25,26]. Another explanation could be due to the different surface tensions of the thickening agents, which may affect the stability of the products [25]. Polyacrylic acid has the same surface tension as water, while the hydroxyethyl cellulose solution has a lower surface tension than the values observed for water [24]. Due to the lower surface tension, the CHX gel can penetrate more anatomical irregularities and trap a greater amount of debris than the NaOCl gel, thereby removing a greater amount of debris from within the canal. The additives contained in commercial formulations of NaOCl may alter the physical properties of the gel, affecting penetration into the root canal and apical extrusion [26]. The lower extrusion observed with CHXg can be attributed to its higher viscosity compared to NaOClg, which keeps the debris in suspension during chemical-mechanical preparation [23] and to its thixotropic effect. This property allows the gel to liquefy under the endodontic instrumentation, enclosing more debris and keeping it in suspension [25], which facilitates debris removal. This can lead to less apical extrusion as the debris is contained in the gel and removed with it [24].

On the other hand, the increased viscosity limits the penetration of NaOClg into the dentinal tubules. This can be considered a limitation of the gel form of NaOCl, along with other problems such as questionable penetration into inaccessible areas and the inability to completely remove debris from the root canals [23]. The highly alkaline pH of NaOCl gel may affect the viscosity and thixotropic properties of the gel. Although NaOClg also has a thixotropic effect, its higher reactivity and lower viscosity compared to CHX can lead to greater extrusion of debris. The alkaline environment can also lead to greater dissolution of the organic content, potentially increasing the amount of debris extruded. At a more neutral pH (6-7), the CHX gel has a higher

viscosity, which can help keep debris in suspension. The difference in pH between chlorhexidine gel and NaOCl gel can significantly affect the extrusion of debris through the apical foramen, mainly due to its thixotropic properties, viscosity, interaction with dentin and effect on periapical tissues. The more neutral pH of CHXg appears to reduce debris extrusion and minimize postoperative complications, while the highly alkaline pH of NaOClg, although effective in disinfection, may increase the risk of extrusion and irritation of periapical tissues [22,23].

Another study concluded that PUI could not prevent debris extrusion. However, when 2% CHX gel was used, the amount of extruded debris was lower [12]. The reason for this result could be related to the higher viscosity of CHX gel, which helps to keep the debris suspended during irrigation [25]. CHXg showed less extruded debris than CHX solution and NaOCl solution [12] These results confirm the results of this study, in which there was minimal leakage of irrigation fluid when CHXg and NG were used. Micro-computed tomography could further quantify debris extrusion, offering an alternative to weight-based measurements, though it cannot specify irrigant amount [22,25]. Limitations of this study include not analyzing debris content or evaluating exact amounts required to trigger inflammatory responses. Further studies are needed to evaluate the extrusion conditions and to compare different formulations and viscosities of the auxiliary chemicals.

## Conclusion

In summary, the gel formulation did not prevent debris extrusion, but NaOClg showed a greater amount of extruded material.

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**Ethical Considerations:** The authors deny any conflict of interests.

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