

Apical enlargement favors endodontic irrigation – an *in vivo* study

Marieli Navarin¹

Marina Canali Langaro²

Lauter Eston Pelepenko³

Ataís Bacchi⁴

Volmir Joao Fornari⁵

Jose Roberto Vanni⁶

Mateus Silveira Martins Hartmann⁷

Abstract

Aim: This study evaluated the irrigation penetration during root canal instrumentation and the clinical step in which the irrigation solution can be detected in the apical region. **Materials and Methods:** Twenty necrotic molars were divided according to the irrigation protocol, saline solution with manual active pressure, and 2.5% sodium hypochlorite with dripping delivery. Solution penetration assessment used a radiopaque component added to each irrigant solely before a periapical radiograph. Instrumentation sequence was: #10, and #15 K-files (step 1), cervical flaring using WaveOne Small (step 2), WaveOne Small at working length (step 3), Hero-642 #35/.02 (step 4), and Hero-642 #40/.02 (step 5). The step each contrasted-irrigant reached the 2-mm-apical region was registered. Shapiro-Wilk and Fisher's exact tests were used for comparisons. **Results:** In step 3, both contrasted-irrigants started to be detected in the apical region, and after step 5, contrasted-irrigants penetrated in 100% of the cases, without significant difference. **Conclusion:** Considering distal molar roots, the apical enlargement up to an instrument #40.02 favors the irrigation to reach the 2-mm apical region.

Keywords: Endodontics, instrumentation, irrigation, necrosis.

<http://dx.doi.org/10.5335/rfo.v28i1.15502>

¹ Specialist in Endodontics, CEOM, Passo Fundo, RS, Brazil

² M.Sc. in Endodontics, ULBRA, Porto Alegre, RS, Brazil

³ Post doctorate, FOP-Unicamp, Piracicaba, SP, Brazil

⁴ Post doctorate, USP, Sao Paulo, SP, Brazil

⁵ Ph.D. in Endodontics, FOP-Unicamp, Piracicaba, SP, Brazil

⁶ Ph.D. in Endodontics, FOP/UPE, Fortaleza, CE, Brazil

⁷ Ph.D. in Endodontics, FOP-Unicamp, Piracicaba, SP, Brazil

Introduction

Endodontic therapy consists of several steps initiating with diagnosis and followed by access, chemical-mechanical preparation, obturation, and coronal sealing. The chemical-mechanical preparation performed only by instrumentation is not complete once its mechanical action occurs mainly in the principal root canal ¹. The anatomic complexity present in the root canal system demands the use of auxiliary chemical substances along with instrumentation promoting an additional essential sanitization during the chemical-mechanical procedures ^{2,3}. The apical anatomy complexity includes deltas, accessory canals, curvatures, and irregular constrictions ^{4,5}.

This limited performance by instruments and auxiliary chemical substances, especially in the apical region, supposedly leaves instrumentation dentin debris, pulp remains, and bacteria inside the root canal, which may compromise the success of endodontic therapy ⁶. The involvement of the apical foramen in root canal chemical-mechanical preparation and keeping apical patency maintains the working length (WL) and provides tissue repair conditions ⁶⁻⁸.

There are several options, irrigation protocols, and irrigant concentrations available for use in Endodontics. The sodium hypochlorite and chlorhexidine are the most frequently studied endodontic antimicrobial agents ^{9,10}. Regardless of the solution choice, its delivery inside the root canal traditionally uses syringes and needles of different sizes and designs. Several techniques using sodium hypochlorite negative pressure are available ^{11,12}, aiming to avoid extrusion of this solution. Sodium hypochlorite accidents were extensively reported ¹³, and the delivery into the root canal must not use active pressure. Chlorhexidine gel can be associated in alternation with saline solution irrigation in order to remove debris produced during root canal instrumentation ⁹. The use of an inert saline solution allows pressure application once this solution is neutral for apical tissues ^{9,14,15}.

Several modifications in chemical substances and devices used for irrigation improved the penetration and effectiveness of endodontic solutions ¹⁶. These new irrigation systems are commonly used just as a final step in root canal chemical-mechanical preparation, making it essential to investigate when the contact of the irrigating solutions occurs in the apical region during instrumentation.

The objective of this preliminary study was to evaluate *in vivo* the irrigation apical progressive penetration during root canal preparation, and the instrumentation-step in which a contrasted-irrigant could be detected in the 2-mm apical region. Two substances and delivery methods used during endodontic treatment were evaluated. The tested hypothesis is that there is no difference between irrigants penetration ability.

Material and methods

This research project was conducted under the approval of an Institutional Review Board (Meridional School - IMED) under the number CAAE 56468415.6.0000.5319. Informed Consent Terms were obtained from all patients who participated in the study. All procedures were carried out under The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. All radiographs obtained for the analysis and endodontic therapy were obtained using patient suitable lead-coated protection for the neck and body. The exclusion criteria were: allergy to any of the components of the irrigation solution or the radiopaque contrast (barium sulfate), pregnancy, or the impossibility of signing the Informed Consent Term.

Sample selection

Twenty adult patients, aged between 18 and 49 years-old, with necrotic mandibular molars, presenting a negative response to cold tests were included. Distal roots with a single root canal that met the patient inclusion criteria were randomly divided into two groups according to the irrigation protocol. Group 1 (n = 10) 5 mL syringe with saline solution (LBS, Ultrafarma, SP, Brazil) using a 20 x 0.55 needle (Nipro, Sorocaba, SP, Brazil) under active-pressure. In this group, additionally to the saline solution, 2% chlorhexidine gel (Natupharma, Passo Fundo, RS, Brazil) was used as a chemical auxiliary substance during endodontic instrumentation. Group 2 (n = 10) 5 mL syringe with 2.5% sodium hypochlorite (Audax Butterfly, Sao Paulo, Brazil) with dripping-delivery using an Endo-Eze Irrigator 27G (Ultradent Products, USA).

Radiopaque irrigant solution preparation

A radiopaque substance, Bariogel™ (Cristália, Sao Paulo, Brazil), which is an inert barium sulfate-based component used in medical Radiology as a contrast medium during gastro-duodenal tube exams, was used for radiographic analysis. This substance was added to the saline solution, and the sodium hypochlorite immediately before use in a proportion of 50% Bariogel to each irrigation solution¹⁷, making it possible to detect the penetration level of the contrasted-irrigant using periapical radiographs.

Endodontic-stops were used for needle-calibration measured up to two-thirds short of the WL. Only for penetration analysis, 1 mL of the contrasted-irrigant was delivered inside the root canal, according to each delivery method, before the periapical radiograph. Complete endodontic instrumentation was performed solely with each irrigant, according to its group without the Bariogel.

Clinical procedures

For both groups, a diagnostic periapical radiograph (figure 1A) was obtained, and endodontic procedures started with access, root canal exploration, and apical patency using #10

and #15 hand K-files (step 1) (Dentsply Maillefer, Switzerland). Immediately after apical patency was obtained, the first periapical radiograph with the contrasted-irrigant was obtained to verify its presence in the 2-mm apical region¹⁸. The same periapical radiograph device ProDental (70 kVp Periapical, SP, Brazil), with an exposure time of 0,32 seconds, and a digital periapical radiographic sensor (Micro Imagem, SP, Brazil) were used during analysis.

In sequence, for cervical flaring (step 2), WaveOne Small (21/.06 Dentsply Maillefer, Switzerland) was used in the reciprocate-mode, according to manufacturer's instructions with the X-Smart Plus endodontic-motor (XSM, Dentsply Maillefer, Switzerland). The second periapical radiograph was obtained using the same prior parameters with the contrasted-irrigant (figure 1B).

After this procedure, the WL was determined using Propex II electronic apex locator (Dentsply Maillefer, Ballaigues, Switzerland) reading 'apex'. Instrumentation continued using WaveOne Small in the whole WL (step 3), and a third radiograph (figure 1C) with the contrasted-irrigant was obtained.

In sequence, the rotatory instrument Hero 642 #35 taper .02 (MicroMega, Besaçon, France) was used according to the manufacturer's instructions for instrumentation of the whole WL (step 4) and a fourth radiograph (figure 1D) with the contrasted-irrigant obtained. In conclusion, Hero 642 #40 taper .02 instrument completed the root canal instrumentation (step 5), and a final radiograph with the contrasted-irrigant was obtained (figure 1E). Between each instrument change, irrigation with conventional irrigant without Bariogel was performed.

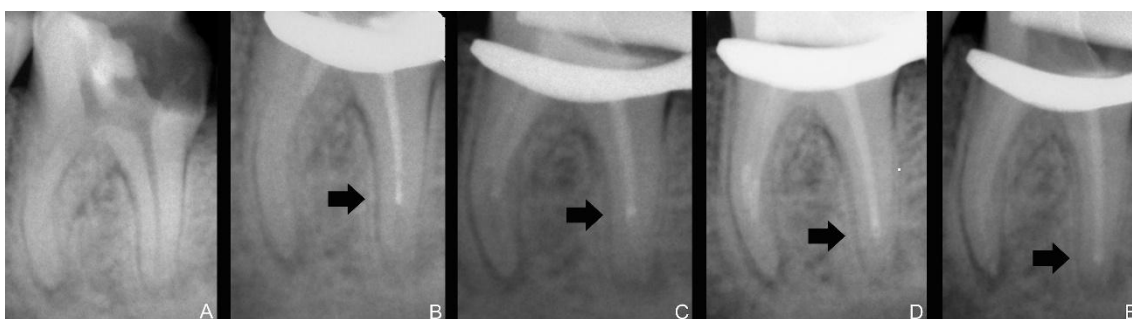


Figure 1. Representative images obtained for analysis. (A) Diagnostic periapical radiograph. (B) Image after cervical flaring with WaveOne Small and the contrasted-irrigant level detected (arrow) (step 2). (C) Periapical radiograph after WaveOne Small instrumented the whole WL and the contrasted-irrigant level detected (arrow) (step 3). (D) Periapical radiograph after Hero 642 #35 taper .02 at WL and the contrasted-irrigant level detected (arrow) (step 4). (E) Periapical radiograph after Hero 642 #40 taper .02 at WL and the contrasted-irrigant level detected (arrow) (step 5).

A single evaluator blinded for the irrigation method used, registered when the contrasted-irrigant reached the 2-mm-apical region in the radiographic image. Regardless of the instrumentation step observed, no additional radiograph exposure for the analysis purposes were taken. Only further radiographs necessary for the endodontic therapy conclusion were taken. Although experimental analysis finished in a #40.02 instrument, the final apical diameter was

determined according to the first apical instrument initially adapted, respecting the anatomical variability in the apical anatomy.

After instrumentation, passive ultrasonic irrigation used ultrasonic E1 Irrisonic tip (Helse Ultrasonic Br, SP, Brazil) for 15 seconds per root canal positioned 2 mm-short from WL, according to manufacturer's protocol. As a chelating agent, 3 mL ethylenediaminetetraacetic acid 17% solution (Natupharma, Passo Fundo, RS, Brazil) irrigation and a 5 mL final rinse saline solution before final obturation finished the root canal preparation for both groups. Endodontic final procedures were concluded according to each case. Pain control, if necessary, was managed using analgesic medication. No antibiotic medication was necessary.

Statistical analysis

The sample size was estimated based on a previous study ¹⁹. For the present study, was established a minimum of 10 specimens per group for an 80% power and α of 5% according to the Power and Sample Size Calculation software version 3.1.2 (Dupont & Plummer, Nashville, USA). Shapiro-Wilk assessed a normal data distribution, and Fisher's exact test was used for comparison between the groups.

Results

The percentage in which each contrasted-irrigant could be detected in 2-mm of the apical region is shown in table 1. Both contrasted-irrigants penetrated up to the apical region of the root canals during endodontic treatment only after WaveOne Small instrumentation at the whole WL (step 3) ($P = 0.303$).

Table 1 - Percentage of the correspondence between the step of instrumentation in which each contrasted-irrigant could be detected in 2-mm of the apical region. No significant difference could be observed between the solutions in each step ($P = 0,303$).

	Saline solution (active pressure)	2.5% Sodium hypochlorite (dripping delivery)
Step 1 - #10 and #15 hand K-files	-	-
Step 2 - WaveOne Small cervical flaring	-	-
Step 3 - WaveOne Small at working length	20%	10%
Step 4 - Hero-642 #35/.02	70%	50%
Step 5 - Hero-642 #40/.02	10%	40%
Total	100%	100%

The contrasted-irrigants penetrated in most of the cases after step 4 (Hero 642 #35 taper .02) and in all samples after step 5 (Hero 642 #40 taper .02). Therefore, the tested hypothesis that there is no difference between irrigants penetration ability could be accepted. Representative images obtained during the analysis are shown in figure 2.



Figure 2. Representative images after Hero 642 #40 taper .02 use as the final instrument. (A) Saline solution - diagnostic periapical radiograph. (B) Extruded irrigation solution in a distally oriented foramen (arrow). (C) Periapical radiograph after the endodontic filling. (D) Sodium hypochlorite - diagnostic periapical radiograph showing a periapical lesion (arrow). (E) Periapical radiograph showing the contrasted-irrigant in the apical region (arrow) after endodontic preparation. (F) Periapical radiograph after the endodontic filling with endodontic sealer extrusion (arrow).

Discussion

During endodontic treatment, most of the difficulties in root canal preparation are in the apical region due to the complex anatomy and the lower penetration of endodontic chemical substances to remove the microorganisms from this region, mandatory in cases of pulp necrosis^{16,20}. Penetration ability and the root canal preparation stage in which the irrigating solutions encounter the apical critical area was evaluated in this work. This preliminary study used *in vivo*, under clinical conditions, two different irrigation solutions, and a progressive enlargement. The reason for the selection of both: saline solution and sodium hypochlorite is a difference in fluid density and surface tension properties, as previously reported¹⁸. At step 2 and step 3, we used the WaveOne reciprocating system as instrumentation until its tip (#21) reached the WL. However, in step 4 and step 5, Hero 642 system was used to enlarge the apical area up to #35 and #40. Both substances reached the WL at a given time, but apical enlargement was necessary for this to occur.

The main reason for this system hybridization during instrumentation is the difference between its tapers. The use of a taper .02 (Hero 642) instrument used after a taper .06 (Wave One Small) enlarges more the apical area while preserving the cervical region. Our results showed that the sodium hypochlorite reached the apical region only after a #40 tip instrument apical enlargement in 40% of the cases. A similar result was obtained in a previous study¹⁸ varying the instruments used, and the authors also concluded that enlargement until at least diameter #40 is necessary for apical irrigation.

Establishing apical patency during endodontic therapy is an important issue, especially for foramen cleansing purposes⁸. This clinical step is usually performed with flexible and fine-caliber instruments, which move through the apical constriction and creates a glide path before NiTi instruments use²¹. According to the results of this study, it was not possible to observe the presence of the contrasted-irrigants in the apical third of root canals after this initial preparation stage (step 1) nor after cervical flaring using WaveOne Small (step 2). In both groups, the contrasted-irrigant was only detected in radiographs after the WaveOne Small reached WL (step 3), indicating that larger apical diameters are necessary to ensure irrigation in the apical region. An anterior study¹⁹ evaluated the final size of the instruments during the preparation of the root canal. The authors identified that the minimum instrumentation size required for irrigation penetration into the apical region and removal of debris is a #30-file, which is partially in agreement with the results observed in the present study where a #35 taper.02 instrument was used.

Another study¹⁸ also obtained similar results using another contrast substance (Claritrac 300), mixed with the irrigating solution used and also observed in 2-mm apical after instrumentation with an instrument #40. The authors considered this was probably due to the contact of the instrument with the root canal walls, along with the irrigation substance, that as it moves towards the apical region, irrigation would be facilitated. Besides, the insertion movement

and diameter of the instrument could better remove residual pulp and debris tissues and even burst air bubbles inherent to irrigation more easily than thinner endodontic files, as observed in the present study.

Mandibular molars distal canals usually are flattened and present proximal isthmus²². This shape may compromise pulp tissue removal and the mechanical action of endodontic instruments during instrumentation^{16,23}. The use of associated irrigating solutions is essential in the debridement of root canals in order to reach areas of irregularities. This anatomical variation justified the use of distal roots of lower molars in this *in vivo* study to observe the penetration of irrigation substance used in root canal instrumentation.

A factor not considered in the present study was the difference in the density of the substances used during irrigation. The density issue is a limitation in this analysis, but similar results were found accordingly to an anterior study^{18,24}, even with different needles and tip diameter. Contrasted-irrigants appeared in radiographs at similar moments in both groups, inferring that the delivery method (with pressure for the saline solution and dripping for the sodium hypochlorite) did not seem to influence in the results obtained. The radiographic evaluation used in a previous study²⁵ evidenced less irrigant penetration in lateral canals since the concentration of contrast material was not enough to be detected radiographically. Our results should be carefully interpreted once we state that apical enlargement provides optimized apical irrigation. Once our study was performed *in vivo*, a dynamic fluid evaluation using computational fluid dynamics analysis was not possible. A previous study stated that a vapor-lock was observed in 48% of the cases under *in vitro* conditions²⁶.

Iodized contrasts are potentially toxic to organic tissues and may cause inflammatory reactions²⁷. In this study, the contrast solution used does not contain iodine. Bariogel is a radiological contrast medium used in hospitals, administered orally, providing contrast in the detection of abnormalities in the esophagus, stomach, and small intestine¹⁷. Its main component is barium sulfate, associated with fewer risks of allergic or inflammatory reactions.

Conclusion

Irrigation solutions penetrated the root canal up to 2-mm from the apex in distal molar roots. The enlargement up to a #40 diameter using a taper .02 instrument ensured the detection of the contrasted-irrigant in the apical region during the progressive endodontic instrumentation regardless of the delivery method used.

Acknowledgments

No potential conflict of interest relevant to this article was reported. No funding was received for this project.

References

1. Siqueira Junior JF, Rôças I das N, Marceliano-Alves MF, Pérez AR, Ricucci D. Unprepared root canal surface areas: causes, clinical implications, and therapeutic strategies. *Braz Oral Res.* 2018;32(suppl 1). doi:10.1590/1807-3107bor-2018.vol32.0065
2. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. *J Endod.* 1987;13(4):147-157. <http://www.ncbi.nlm.nih.gov/pubmed/3106553>.
3. Nagendrababu V, Jayaraman J, Suresh A, Kalyanasundaram S, Neelakantan P. Effectiveness of ultrasonically activated irrigation on root canal disinfection: a systematic review of in vitro studies. *Clin Oral Investig.* 2018;22(2):655-670. doi:10.1007/s00784-018-2345-x
4. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. *Endod Top.* 2005;10(1):3-29. doi:10.1111/j.1601-1546.2005.00129.x
5. Thomas AR, Velmurugan N, Smita S, Jothilatha S. Comparative evaluation of canal isthmus debridement efficacy of modified endovac technique with different irrigation systems. *J Endod.* 2014;40(10):1676-1680. doi:10.1016/j.joen.2014.05.014
6. Vera J, Siqueira JF, Ricucci D, et al. One- versus two-visit endodontic treatment of teeth with apical periodontitis: A histobacteriologic study. *J Endod.* 2012;38(8):1040-1052. doi:10.1016/j.joen.2012.04.010
7. Souza RA. The importance of apical patency and cleaning of the apical foramen on root canal preparation. *Braz Dent J.* 2006;17(1):6-9. doi:10.1590/S0103-64402006000100002
8. Yaylali IE, Kurnaz S, Tunca YM. Maintaining Apical Patency Does Not Increase Postoperative Pain in Molars with Necrotic Pulp and Apical Periodontitis: A Randomized Controlled Trial. *J Endod.* 2018;44(3):335-340. doi:10.1016/j.joen.2017.11.013
9. Gomes BPFA, Vianna ME, Zaia AA, Almeida JFA, Souza-Filho FJ, Ferraz CCR. Chlorhexidine in endodontics. *Braz Dent J.* 2013;24(2):89-102. doi:10.1590/0103-6440201302188
10. Spratt DA, Pratten J, Wilson M, Gulabivala K. An in vitro evaluation of the antimicrobial efficacy of irrigants on biofilms of root canal isolates. *Int Endod J.* 2001;34(4):300-307. doi:10.1046/j.1365-2591.2001.00392.x
11. Arruda-Vasconcelos R, Barbosa-Ribeiro M, Louzada LM, Mantovani GD, Gomes BP. Apically Extruded Debris Using Passive Ultrasonic Irrigation Associated with Different Root Canal Irrigants. *Braz Dent J.* 2019;30(4):363-367. doi:10.1590/0103-6440201902674
12. Castelo-Baz P, Varela-Patiño P, Ruiz-Piñon M, Abella F, Miguens-Vila R, Martin-Biedma B. Continuous Apical Negative-Pressure Ultrasonic Irrigation (CANUI): A new concept for activating irrigants. *J Clin Exp Dent.* 2017;0-0. doi:10.4317/jced.53836
13. Farook SA, Shah V, Lenouvel D, Sheikh O, Sadiq Z, Cascarini L. Guidelines for management of sodium hypochlorite extrusion injuries. *Br Dent J.* 2014;217(12):679-684.

doi:10.1038/sj.bdj.2014.1099

14. Dioguardi M, Gioia G Di, Illuzzi G, Laneve E, Cocco A, Troiano G. Endodontic irrigants: Different methods to improve efficacy and related problems. *Eur J Dent.* 2018;12(03):459-466. doi:10.4103/ejd.ejd_56_18
15. Park E, Shen Y, Khakpour M, Haapasalo M. Apical Pressure and Extent of Irrigant Flow beyond the Needle Tip during Positive-pressure Irrigation in an In Vitro Root Canal Model. *J Endod.* 2013;39(4):511-515. doi:10.1016/j.joen.2012.12.004
16. Bao P, Shen Y, Lin J, Haapasalo M. In Vitro Efficacy of XP-endo Finisher with 2 Different Protocols on Biofilm Removal from Apical Root Canals. *J Endod.* 2017;43(2):321-325. doi:10.1016/j.joen.2016.09.021
17. Bariogel. Cristália Produtos Químicos e Farmacêuticos Ltda. *Bula.* 2016.
18. Vera J, Hernández EM, Romero M, Arias A, Van Der Sluis LWM. Effect of maintaining apical patency on irrigant penetration into the apical two millimeters of large root canals: An in vivo study. *J Endod.* 2012;38(10):1340-1343. doi:10.1016/j.joen.2012.06.005
19. Khademi A, Yazdizadeh M, Feizianfard M. Determination of the Minimum Instrumentation Size for Penetration of Irrigants to the Apical Third of Root Canal Systems. *J Endod.* 2006;32(5):417-420. doi:10.1016/j.joen.2005.11.008
20. Siqueira JF, Antunes HS, Pérez AR, et al. The Apical Root Canal System of Teeth with Posttreatment Apical Periodontitis: Correlating Microbiologic, Tomographic, and Histopathologic Findings. *J Endod.* 2020;46(9):1195-1203. doi:10.1016/j.joen.2020.05.020
21. Buchanan LS. The standardized-taper root canal preparation--Part 4. GT file technique in large root canals with large apical diameters. *Int Endod J.* 2001;34(2):157-164. doi:10.1046/j.1365-2591.2001.00387.x
22. Filpo-Perez C, Bramante CM, Villas-Boas MH, Húngaro Duarte MA, Versiani MA, Ordinola-Zapata R. Micro-computed tomographic analysis of the root canal morphology of the distal root of mandibular first molar. *J Endod.* 2015;41(2):231-236. doi:10.1016/j.joen.2014.09.024
23. Paqué F, Balmer M, Attin T, Peters OA. Preparation of Oval-shaped Root Canals in Mandibular Molars Using Nickel-Titanium Rotary Instruments: A Micro-computed Tomography Study. *J Endod.* 2010;36(4):703-707. doi:10.1016/j.joen.2009.12.020
24. Hsieh YD, Gau CH, Kung Wu SF, Shen EC, Hsu PW, Fu E. Dynamic recording of irrigating fluid distribution in root canals using thermal image analysis. *Int Endod J.* 2007;40(1):11-17. doi:10.1111/j.1365-2591.2006.01168.x
25. de Gregorio C, Estevez R, Cisneros R, Heilborn C, Cohenca N. Effect of EDTA, Sonic, and Ultrasonic Activation on the Penetration of Sodium Hypochlorite into Simulated Lateral Canals: An In Vitro Study. *J Endod.* 2009;35(6):891-895. doi:10.1016/j.joen.2009.03.015
26. Boutsoukis C, Kastrinakis E, Lambrianidis T, Verhaagen B, Versluis M, van der Sluis LWM. Formation and removal of apical vapor lock during syringe irrigation: a combined experimental and Computational Fluid Dynamics approach. *Int Endod J.*

2014;47(2):191-201. doi:10.1111/iej.12133

27. Brockow K, Sánchez-Borges M. Hypersensitivity to Contrast Media and Dyes. *Immunol Allergy Clin North Am*. 2014;34(3):547-564. doi:10.1016/j.iac.2014.04.002

Correspondent author:

Mateus M.S. Hartmann
R. Sen. Pinheiro, 224 - Vila Rodrigues, Passo Fundo - RS, Brazil, CEP 99070-220
E-mail: mateushartmann@gmail.com

Recebido em: 11/01/2024. Aceito: 21/01/2024.