

Comparison of Coronal Leakage in Tooth Preparation with Two Single File Systems and Three Obturation Techniques

Eshaghali Saberi¹, Shahram Shahraki Zahedani², Sediqe Ebrahimipour³, Neda Valian⁴

¹Department of Endodontics, Oral and Dental Diseases Research Center, Dental School, Zahedan University of Medical Sciences, Zahedan, ²Infectious Diseases and Tropical Medicine Research Center, Zahedan University of Medical Sciences, Zahedan, ³Department of Endodontics, Faculty of Dentistry and Dental Research Center, Birjand University of Medical Sciences, Birjand, ⁴Dentist, Khorasan Razavi, Mashhad, Iran

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INTRODUCTION

Success of endodontic treatment depends on the quality of root canal preparation and the ability of filling materials to establish a fluid tight seal and the proper coronal restoration.

Technological advancement in manufacturing of nickel-titanium (NI-TI) rotary instruments has led the new ideas in cleaning and obturation of root canal systems.

Studies have shown that preparation with single file rotary systems make the canal to be prepared faster and with fewer procedural errors.^[1-3]

ABSTRACT

Aims and Objectives: Root canal preparation and obturation are of great importance in endodontics. Its purpose is to eliminate pulpal and periradicular disease. The aim of this study was to compare coronal bacterial microleakage in prepared root canals using Neoniti A1 and Reciproc files that obturated with lateral compaction, single cone gutta-percha, and hybrid (tapered cone/lateral compaction) methods.

Materials and Methods: In this *ex vivo* study, a total of 110 single-rooted mandibular first premolars were choose and randomly divided into two study groups A and B (each 45) that one group was prepared with Reciproc and another with Neoniti A1 and negative and positive control groups (each 10). Each group divided into three subgroups of 15 each and obturated using a single cone, lateral compaction, and hybrid (tapered cone/lateral compaction) techniques. For evaluation of coronal leakage, “two-chamber setup” was used. The solution of enterococcus faecalis culture was injected in the upper chamber and incubated. If the bacteria pass through the canal and obturation materials, the lower chamber becomes turbid. TSB medium in the lower chamber (apex) were investigated every day in terms of occurrence of turbidity, and the duration of occurrence of leakage was recorded. The data were analyzed using Chi-square test.

Results: Data analysis showed that in each group the difference in percentages between subgroups was statistically significant ($P = 0.003$). So that the highest and the lowest amount of leakage in both groups were related to lateral compaction and hybrid techniques, respectively.

Conclusion: Under the conditions of this study, independent of the instrument used for canal preparation, hybrid method and then single-cone technique, however, were more effective in the prevention of coronal leakage than lateral condensation technique.

KEYWORDS: Dental leakage, single-cone obturation, tooth preparation

Neoniti A1 (NEOLIX, Châtres-la-Forêt, France), a newly introduced rotary file is made of M-Wire alloy that prepares the canal with continuous rotary motion^[4] and Reciproc file (VDW, Munich, Germany) with S-shaped cross section, a noncutting tip, and sharp cutting edges that shapes the canal by means of a reciprocal motion (30° clockwise and

Address for correspondence: Dr. Sediqe Ebrahimipour, Department of Endodontics, Faculty of Dentistry, Brjand University of Medical Sciences, Birjand, Iran. E-mail: sdent22@gmail.com

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150° counterclockwise) are two examples of single-file systems.^[1]

Studies that used these systems have shown that like other rotary systems, these files can maintain the original shape of the canal.^[5,6]

Obturation with warm gutta-percha systems is hard and time-consuming; so many dentists prefer to use the systems that obturate the root canal in less time.

Using the single-cone gutta-percha that matches the NiTi rotary instruments can fulfil three-dimensional filling in less time compared to conventional methods.^[7,8]

If the diameter and taper of gutta-percha exactly matches the shape of the prepared canals, the quality of root filling will be superior to conventional methods.^[9]

Several studies have emphasized the issue of standardization problems both in instruments and gutta-percha cones while others have pointed to dimensional variability of gutta-percha in two dimensions.^[9,10]

Amanda Rodrigues *et al.* concluded that single-cone technique provided greater percentage of gutta-percha area than the lateral compaction in the apical third of mesial root canals of mandibular molars.^[11]

Gordon *et al.* compared the percentage of gutta-percha, Sealer, and voids between the two single-cone and lateral condensation techniques. They found that at the 2.5 mm distance from the apex percentage of occupied area with single-cone gutta-percha was significantly more than the lateral condensation technique while no difference is seen in other levels.^[12]

Schäfer *et al.* reported that lateral compaction and single-cone techniques that used constant tapered gutta-percha produced higher percentage of gutta-percha area at the apical levels than variable tapered single-cone gutta-percha.^[13]

Given the lack of studies comparing the coronal leakage of the canals obturated with single cone prepared with single-file systems thus the aim of this *ex vivo* study was comparing the leakage of *E. faecalis* in three obturation methods: lateral compaction, single cone, and hybrid in root canal prepared with two single-file rotary systems Neoniti A1 and Reciproc.

MATERIALS AND METHODS

In this *ex vivo* study, a total of 110 single-rooted mandibular first premolars were studied which were extracted due to periodontal or orthodontic reason in surgical department of Zahedan dental school in 2014–2015.

This study was reviewed and approved by the Ethics Committee of Zahedan University of Medical Sciences with ethical approval letter No: 1690.

Inclusion criteria were single-rooted teeth with a round cross section and approximately the same length. All specimens were examined using a stereomicroscope ($\times 25$) to confirm the lack of cracks.

Radiographs of teeth in both buccolingual and mesiodistal directions were taken to exclude the samples with more than one canals, sever curved, internal or external root resorption, calcification, or apical size more than No. 15 K file. Teeth were cleaned of adhering soft tissue and debris and stored in physiologic saline solution at 4°C before the study.

The crowns of all teeth were cut at 16 mm distance from the apex with a high-speed handpiece and coolant. Patency was achieved with No. 15 k file, and the working length was determined 1 mm minus from the apical foramen.

To determine the sample size, similar studies were used.^[14,15] A total of 90 teeth were considered for the experimental groups then the teeth were randomly divided into two groups of 45 each based on the instrumentation technique.

In group N ($n = 45$), the root canals were prepared with NEONITI A1 single-file (25/0.08) (NEOLIX, Châtres-la-Forêt, France) along the working length according to the manufacturer's recommendations using an electric motor (RECIPROC silver, VDW, JAPAN) with torque control and full rotation and up and down motion. In group R ($n = 45$), the root canals were prepared along the working length with RECIPROC single file (25/0.08) (VDW, Munich, Germany) according to manufacturer's recommendations, and the electric motor with torque control (RECIPROC silver, VDW, JAPAN) and setting the device on Reciproc All button.

Ten teeth were considered as a negative control group in which 5 samples were prepared with Reciproc file and obturated by single-cone technique, and 5 samples were prepared with Neoniti A1 file and filled by lateral compaction technique. All tooth of this group were sealed entirely with two layers of nail varnish to prevent leakage. Of 10 samples of positive control group, 5 prepared with Reciproc file and 5 samples prepared with Neoniti A1 and no obturation.

In all groups, the files were cleaned from debris after each removal with clean gauze. During preparation, the canals were irrigated by physiologic saline with a 27-gauge needle. After completing the instrumentation, a #15 K file was passed 1 mm through the apex to the

foramen to control the patency. Final irrigation of all root canals was performed with 5 ml of 5.25% NaOCl, and then 5 ml of 17% EDTA (Biodinamica, ibipora, Brazil) for 1 min and 10 ml distilled water as final irrigation. Then the canals were dried with sterile paper points (Aria Dent, Tehran, Iran).

In both groups, the prepared canals were randomly divided into three subgroups ($n = 15$) according to root canal obturation techniques.

Subgroup SC (single-cone technique): The canals obturated using gutta-percha No. 25/0.08 (Gapadent, Republic of Korea) as single cone and AH plus sealer. Excess gutta-percha was removed by heated instrument.

Subgroup LC (Lateral compaction): The canals obturated by No. 25/0.02 gutta-percha as a master cone coated with AH plus sealer then accessory cones compacted alongside the master cone by finger sprider.

Subgroup H, hybrid (single cone/Lateral compaction): The canals obturated using gutta-percha No. 25/0.08 (Gapadent, Republic of Korea) as a master cone coated with AH plus sealer followed by lateral compaction technique by at least two 2% gutta-percha cones alongside the master cone.

The whole process of preparation and obturation was performed by an endodontist.

The obturated teeth were checked buccolingually and mesiodistally using X-ray to check the quality of obturation. The teeth were kept in 100% humidity at 37°C for 1 week to allow the sealer to set.

Double chamber set up; was used to evaluate the bacterial leakage. At first to prevent lateral leakage,^[16] two layers of nail varnish (Saviz Co., Tehran, Iran) were applied on the outer surface of the roots except the apical foramen and the orifice areas. To make the two chamber leakage set up, a hole was made at the end of the 2-ml syringes, and the tooth samples were placed into the hole so that the orifice area was within the

syringe and the apex was out of it. It forms the upper chamber that bacterial suspension was injected. For the lower chamber, the penicillin vial was used which would contain the cell culture medium. Silicone bonnets of the vials were punched proportion to the syringe end size. The syringes pressed into the vials. The gap between the roots, syringes, and the vials bonnets were sealed with adhesive and nail varnish.

Under the sterile conditions using a micropipette equivalent to 0.5 McFarland suspensions of 24-h growth of *Enterococcus faecalis* (ATCC = 29212) in BHI broth (Difco, Detroit, MI, USA) containing 1×10^8 bacteria was injected into the upper chamber (the coronal) and the set up incubated at 37°C.

Bacterial leakage to BHI broth in the lower chambers was checked daily for 8 weeks. The turbidity of BHI broth in the lower chambers was recorded daily. A new 24-h growth of *E. faecalis* was added each 3 days. The bacterial growth in the lower chambers was cultured to ensure that the reason of turbidity is just *E. faecalis*. Data were entered to SPSS 20 (IBM Corp., Armonk, NY, USA) and were analyzed using Chi-square test at 0.05 significance level.

RESULTS

The results of data analysis into two experimental groups: (Neoniti A1 and Reciproc) and six subgroups of 15 teeth (with three obturation technique: lateral compaction, single cone and hybrid) and both positive and negative control groups are listed in Table 1.

All samples of the positive control group were turbid within 24 h from the base line while all samples of negative control group showed no turbidity by the end of the project.

According to Table 1, during the study in both preparation groups, the highest percentage (100%) of leakage was pertinent to the lateral compaction and the lowest amount was pertinent to hybrid technique.

Table 1: Comparison of bacterial leakage of studied samples in different groups and subgroups

Group	Subgroup	n	Domain	Turbidity positive (%)	Turbidity negative (%)	Chi-square test*
Neoniti (N)	Single C	15	11-41	13 (86)	2 (14)	P=0.014
	Lateral C	15	3-51	15 (100)	0	
	Hybrid	15	12-43	9 (60)	6 (40)	
Reciproc (R)	Single C	14	8-43	12 (80)	3 (20)	0.009
	Lateral C	15	4-44	15 (100)	0	
	Hybrid	15	10-52	8 (53)	7 (47)	
Control positive		10	1≥	10 (100)	0	
Control negative		10	-	0	10 (100)	
Chi-square test**				P=0.003		

*Comparison of leakage between subgroups of each group, **Comparison of leakage between all subgroups

The Chi-square test showed that the difference in percentages between the 6 subgroups of the study is statistically significant ($P = 0.003$).

The test also showed that in each group the difference in percentages between subgroups was statistically significant ($P < 0.05$) So that in both groups, the highest leakage was associated with lateral compaction, and the lowest amount was related to hybrid subgroups.

In comparison of similar subgroups in both groups, Chi-square test showed that the percentage of turbidity between the two subgroups of SC ($P = 0.624$), two subgroups of LC (0.713) and between the two subgroups of H ($P = 1$) was not statistically significant. This finding means that the method of instrumentation had no effect on the coronal leakage.

DISCUSSION

Both *in vitro* and *in vivo* investigations show that postendodontic coronal leakage can allow bacterial penetration in the filled root canal system, causing recontamination and failure of treatment. A major concern for all clinicians is understanding the time required for bacteria to penetrate through root-canal obturation material and reinfect the entire canal length after preparation with two single rotary files: Neoniti A1 and Reciproc and obturation with these three techniques: Single cone, lateral condensation, and hybrid techniques.

Various methods have been proposed to assess coronal bacterial leakage, including dye penetration, bacterial leakage, bacterial metabolites, electrochemical techniques, radioisotope, and fluid filtration. In this study, coronal leakage of *Enterococcus faecalis* was chosen, because this method simulates the clinical conditions to some extent, moreover this bacterium is part of the normal oral flora of humans and is frequently found in dental infections with other aerobes and facultative anaerobes,^[17,18] and is the most commonly microbes isolated from canals with post treatment disease.^[19] Using single species in this study was to facilitate the setup and interpretation the results. Double-chamber technique models were used that it is also previously used by Saber *et al.*^[20]

The results showed that regardless of preparation technique, in both Group N and R, maximum leakage was observed in lateral condensation technique (Domain: Reciproc: 4–44 days, Neoniti A1: 3–51 days) then single cone (Domain: Reciproc: 8–43 days, Neoniti A1: 11–41 days) and at the end hybrid technique (Reciproc: 10–52 days, Neoniti A1: 12–43 days) due to the fact that 40%–47% of hybrid group and 14%–20% in single cone group remained free of leakage by the end of the study.

The differences between the various methods of obturation in both groups N and R were significant ($P < 0.003$), but there were no differences between the same subgroups, this finding indicates that preparation technique has no effect on bacterial leakage. Studies have shown that abturation following preparation with Ni-Ti rotary instruments had less microleakage than hand instruments, because the rotary files, making the smoother walls and these canals obturated more easily.^[21]

AH plus sealer was used in this study. One study reported that AH plus showed less apical microleakage along with all the ZOE formulations or calcium hydroxide base sealers because of less solubility and lower shrinkage. Results showed that AH Plus/gutta-percha and Epiphany/Resilon provided the same coronal seal,^[22] however, other studies indicating that gutta-percha and AH-plus do not offer resistance to coronal leakage and showing gross leakage increasing within the first 4 months following obturation when coronally challenged.^[23]

In the present study, 100% of the samples of in lateral compaction technique in two groups were infected within 3–51 days. Void formation in the body of the filling while using the spreader and the shrinkage of the sealer and gutta-percha are possible reasons for the relatively inferior results obtained with lateral compaction techniques.

The minimum time for occurrence of leakage in lateral compaction technique was less than a week. Two bacterial leakage studies by Saber *et al.* also showed that leakage occurs within a week in lateral condensation technique and in the lack of coronal seal.^[20,24] Kersten *et al.* stated that the efficiency of the cold lateral compaction of gutta-percha which frequently used in root canal therapy is differ depending on the different morphology of the canals.^[25]

In single-cone subgroups during the study period, 86% and 80% were infected in group N and R, respectively.

This noncompaction, single-cone filling of root canals has been introduced to minimize the sealer component with gutta-percha cones closely match to the geometry of NI-TI rotary instrument and ensure 3-dimensional obturation of the root canal without necessitating accessory cones and with less time spent.^[12] However, its success depends on the canal geometry and the ability of files to create a rounded tapered canals with a strict adaptation of gutta-percha cones to the prepared canals.

However, due to one gutta-percha cone and lack of compaction, the filling material does not be able to penetrate the canal wall irregularities and the will be accompanied by voids formation between sealer and gutta-percha and the coronal seal will not be established.

Robberecht *et al.* compared tapered single-cone method versus warm vertical condensation and injection system and concluded that a better apical adjustment of gutta-percha and a greater number of filled lateral or accessory root canals was perceived with the combined-system filling technique whereas low voids were observed in single-cone group in the coronal two-thirds.^[26] Yilmaz *et al.* reported that cold laterally compacted gutta-percha and the single-cone technique had similar sealing properties with the BeeFill system, which all were better than that of System B/Obtura II.^[15]

In several studies, both cold laterally compacted and single-cone gutta-percha have been compared with vertical compaction techniques, demonstrating better,^[27] similar,^[28] or inferior^[29] sealing properties. Such inconsistent results may be due to differences in tooth preparation, time, protocols of experiment, storage conditions, and the type of sealer used.

Another point that should not be ignored is adaptation of gutta-percha with the last file used in the canal.

Chesler *et al.* showed that all intramanufacturer diameters and tapers were significantly different from each other. For example, the diameter tolerance of #30 files is 0.02 mm and for gutta-percha cones is 0.07 mm. Discrepancy between files and cones can be 0.09 mm or nearly 2 ISO file sizes.^[30]

Obviously, a single technique is unable to establish a complete seal although the mass of gutta-percha used in this technique is more than lateral condensation.

In this study, the lowest leakage was observed in hybrid group where only 60% and 53% of the samples in N and R groups were infected, respectively, during the study. The use of accessory cones/tapered cone method reduced the coronal leakage significantly. Although in the present study, tapered cone/accessory cones method were significantly effective in reducing the coronal leakage, but the results also show that all three obturation techniques were unable to achieve an ideal seal.

CONCLUSIONS

Dentists should avoid oversimplification of treatment. Having sufficient knowledge about the anatomy of the root canal, adherence to the principles of preparation and three-dimensional filling are key issues, and it is recommended to including techniques that provide achieving these goals.

For example control of working length, using master cone fit to the apical size, using sealer and accessory cones and warm vertical compaction of gutta-percha to fill voids and irregularities can be mentioned.

Although the results of *in vitro* studies cannot fully extended to clinical condition, but, based on these studies, the weaknesses of different techniques could be realized and be solved.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Bane K, Faye B, Sarr M, Niang SO, Ndiaye D, Machtou P. Root canal shaping by single-file systems and rotary instruments: A laboratory study. *Iran Endod J* 2015;10:135-9.
2. Çapar ID, Arslan H. A review of instrumentation kinematics of engine-driven nickel-titanium instruments. *Int Endod J* 2016;49:119-35.
3. Alsilani R, Jadu F, Bogari DF, Jan AM, Alhazzazi TY. Single file reciprocating systems: A systematic review and meta-analysis of the literature: Comparison of reciproc and WaveOne. *J Int Soc Prev Community Dent* 2016;6:402-9.
4. Dhingra A, Gupta R, Yadav V, Aggarwal N. Endodontic retreatment using single file neoniti system. *Am J Oral Med Radiol* 2015;2:206-8.
5. Bürklein S, Hinschitzka K, Dammaschke T, Schäfer E. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. *Int Endod J* 2012;45:449-61.
6. Yilmaz A, Kucukay ES, Istektepe M, Sisli SN, Ersev H, Karagoz-Kucukay I. Comparison of the shaping ability of waveone reciprocating files with or without glide path in simulated curved S-shaped root canals. *J Int Soc Prev Community Dent* 2017;7 Suppl 1:S13-7.
7. Gound TG, Sather JP, Kong TS, Makkawy HA, Marx DB. Graduating dental students' ability to produce quality root canal fillings using single- or multiple-cone obturation techniques. *J Dent Educ* 2009;73:696-705.
8. Romania C, Beltes P, Boutsoukis C, Dandakis C. *Ex-vivo* area-metric analysis of root canal obturation using gutta-percha cones of different taper. *Int Endod J* 2009;42:491-8.
9. Darcey J, Roudsari RV, Jawad S, Taylor C, Hunter M. Modern endodontic principles. Part 5: Obturation. *Dent Update* 2016;43:114-6, 119-20, 123.
10. Capar ID, Ertas H, Ok E, Arslan H. Comparison of single cone obturation performance of different novel nickel-titanium rotary systems. *Acta Odontol Scand* 2014;72:537-42.
11. Rodrigues A, Bonetti-Filho I, Faria G, Andolfatto C, Camargo Vilella Berbert FL, Kuga MC. Percentage of gutta-percha in mesial canals of mandibular molars obturated by lateral compaction or single cone techniques. *Microsc Res Tech* 2012;75:1229-32.

12. Gordon MP, Love RM, Chandler NP. An evaluation of .06 tapered gutta-percha cones for filling of .06 taper prepared curved root canals. *Int Endod J* 2005;38:87-96.
13. Schäfer E, Köster M, Bürklein S. Percentage of gutta-percha-filled areas in canals instrumented with nickel-titanium systems and obturated with matching single cones. *J Endod* 2013;39:924-8.
14. Jacobson HL, Xia T, Baumgartner JC, Marshall JG, Beeler WJ. Microbial leakage evaluation of the continuous wave of condensation. *J Endod* 2002;28:269-71.
15. Yilmaz Z, Deniz D, Ozcelik B, Sahin C, Cimilli H, Cehreli ZC, *et al.* Sealing efficiency of BeeFill 2in1 and System B/Obtura II versus single-cone and cold lateral compaction techniques. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;108:e51-5.
16. Jafari F, Jafari S. Importance and methodologies of endodontic microleakage studies: A systematic review. *J Clin Exp Dent* 2017;9:812.
17. Savadkouhi ST, Bakhtiar H, Ardestani SE. *In vitro* and *ex vivo* microbial leakage assessment in endodontics: A literature review. *J Int Soc Prev Community Dent* 2016;6:509-16.
18. Antunes HS, Gominho LF, Andrade-Junior CV, Dessaune-Neto N, Alves FR, Rôças IN, *et al.* Sealing ability of two root-end filling materials in a bacterial nutrient leakage model. *Int Endod J* 2016;49:960-5.
19. Murad CF, Sassone LM, Faveri M, Hirata R Jr., Figueiredo L, Feres M. Microbial diversity in persistent root canal infections investigated by checkerboard DNA-DNA hybridization. *J Endod* 2014;40:899-906.
20. Saber E, Akbari N, Ebrahimipour S, Jalilpour H. *In-vitro* evaluation of coronal microbial leakage after post space tooth preparation. *Minerva Stomatol* 2016;65:127-33.
21. Zand V, Bidar M, Ghaziani P, Rahimi S, Shahi S. A comparative SEM investigation of the smear layer following preparation of root canals using nickel titanium rotary and hand instruments. *J Oral Sci* 2007;49:47-52.
22. Muliyar S, Shameem KA, Thankachan RP, Francis PG, Jayapalan CS, Hafiz KA. Microleakage in endodontics. *J Int Oral Health* 2014;6:99-104.
23. De Moor R, Hommez G. The long-term sealing ability of an epoxy resin root canal sealer used with five gutta percha obturation techniques. *Int Endod J* 2002;35:275-82.
24. Saber EA, Shahraki S, Ebrahimipour S, Rashed Mohassel A, Akbari N, Rezaei M. Comparison of bacterial leakage between 3 different root canal obturation techniques in oval shaped canals. *J Dent Mater Tech* 2014;3:112-7.
25. Kersten HW, Fransman R, VELZEN ST. Thermomechanical compaction of gutta-percha. II. A comparison with lateral condensation in curved root canals. *International Endodontic Journal*. 1986 May 1;19:134-40.
26. Robberecht L, Colard T, Claisse-Crinquette A. Qualitative evaluation of two endodontic obturation techniques: Tapered single-cone method versus warm vertical condensation and injection system an *in vitro* study. *J Oral Sci* 2012;54:99-104.
27. Hopkins JH, Remeikis NA, Van Cura JE. McSpadden versus lateral condensation: The extent of apical microleakage. *J Endod* 1986;12:198-201.
28. Kontakiotis E, Chaniotis A, Georgopoulou M. Fluid filtration evaluation of 3 obturation techniques. *Quintessence International*. 2007;38:407-416.
29. Yücel AÇ, Çiftçi A. Effects of different root canal obturation techniques on bacterial penetration. *Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol* 2006;102:e88-92.
30. Chesler MB, Tordik PA, Imamura GM, Goodell GG. Intramanufacturer diameter and taper variability of rotary instruments and their corresponding gutta-percha cones. *J Endod* 2013;39:538-41.