Comparison of the sealing ability of three filling techniques in canals shaped with two different rotary systems: A bacterial leakage study

Tamer Taşdemir, DDS, PhD,[a] Kürşat Er, DDS, PhD,[a] Tahsin Yildirim, DDS, PhD,[b] Kurtulus Buruk, DDS, PhD,[c] Davut Çelik, DDS,[a] Sabri Cora, DDS,[a] Erhan Tahan, DDS,[a] Behram Tuncel, DDS, PhD,[d] and Ahmet Serper, DDS, PhD,[d] Trabzon and Ankara, Turkey
KARADENIZ TECHNICAL UNIVERSITY AND HACETTEPE UNIVERSITY

Objective. This study compared the sealing ability of 3 current filling techniques in root canals shaped with 2 different rotary systems.
Study design. Eighty human extracted mandibular premolars were divided randomly into 2 similar groups of 40 each and instrumented with either ProTaper (Dentsply Maillefer, Tulsa, OK; group A) or Mtwo (VDW; Antaeos, Munich, Germany; group B) rotary systems. Each group was divided into 3 subgroups (n = 10) and 2 control groups (n = 5). Canals were filled either with the tapered single-cone technique (SC; subgroups A1 and B1), with lateral condensation (LC; subgroups A2 and B2), or warm vertical compaction (WVC; subgroups A3 and B3). AH Plus was used as a root canal sealer in all groups. Samples were sterilized in an ethylene oxide sterilizer for 12 hours. The apical 3-4 mm of the roots were immersed in brain-heart infusion culture medium with phenol red indicator within culture chambers. The coronal access of each specimen was inoculated every 48 hours with a suspension of *Enterococcus faecalis*. Bacterial leakage was monitored every 24 hours for 8 weeks. The data obtained were analyzed using a chi-squared test, and P was set at .05.
Results. In group A, 70% of the specimens filled with SC (subgroup A1), 50% of the specimens filled with LC (subgroup A2), and 20% of the specimens filled with WVC (subgroup A3) leaked. There was no statistically significant difference between the subgroups ($P > .05$). In group B, bacterial leakage was observed in 50% of SC samples (subgroup B1), 40% of LC samples (subgroup B2), and 50% of WVC samples (subgroup B3). There was no statistically significant difference between subgroups B1, B2, and B3 ($P > .05$). There was also no statistically significant difference between group A and group B ($P > .05$).
Conclusion. Filling with SC, LC, and WVC techniques in canals treated with ProTaper or Mtwo rotary instruments showed similar levels of sealing efficacy. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:e129-e134)**

The purpose of root canal filling is to seal the root canal system with the aim of preventing recurrence of bacterial infection. By hindering microleakage between the root canal and the periapical tissues, this procedure should also deprive any surviving microorganisms of nutrients and prevent toxic bacterial products from entering the periapical tissues.[1-4]

To date, many different materials and techniques have been developed for instrumentation and obturation of root canals. During the last 15 years, root canal preparation with rotary nickel-titanium (NiTi) instruments has become popular. It has been reported that rotary NiTi instruments shape the root canals easily, rapidly, and more predictably while reducing procedural errors and maintaining the original curvature of the root canals.[5] Additionally, preparation of the root canal with rotary instruments may improve the adaptation between the gutta-percha point and the canal wall, because the flexible NiTi instruments may result in less straightening and flaring of curved canals compared with the use of stainless steel instruments.[6,7] Furthermore, the use of rotary instruments may improve preparation of a uniformly round space compared with circumferential filling with hand instruments, although the cleaning efficacy may depend on canal morphology.[8,9]

Filling of root canals after cleaning and shaping is paramount in preventing reinfection of the root canal space.[10,11] Examples of commonly used techniques to reach this goal are cold lateral condensation (LC),

[a]Department of Endodontics, Faculty of Dentistry, Karadeniz Technical University.
[b]Department of Operative Dentistry, Faculty of Dentistry, Karadeniz Technical University.
[c]Department of Microbiology, Faculty of Medicine, Karadeniz Technical University.
[d]Department of Endodontics, Faculty of Dentistry, Hacettepe University.
Received for publication Mar 23, 2009; returned for revision Apr 30, 2009; accepted for publication May 5, 2009.
1079-2104/$ - see front matter
© 2009 Mosby, Inc. All rights reserved.
doi:10.1016/j.tripleo.2009.05.007

warm vertical compaction (WVC), and carrier systems. However, these techniques have some disadvantages, such as lack of homogeneity of the gutta-percha mass; a high percentage of sealer in the apical portion of the canal; poor adaptation to the root canal walls, and apical extrusion of the gutta-percha. To overcome these disadvantages, gutta-percha cones which match the exact size and taper of canals prepared with rotary instruments, have been introduced. The use of tapered cones with sealer may provide sealing of the root canal without the requirement for accessory cones and be quicker than LC when the root canal is enlarged with rotary instruments.[12,13] Although preparation of a root canal by using NiTi rotary instruments may result in a shape that does not match the corresponding gutta-percha point, resulting in gaps in the filling,[14] some manufacturers claim that matched tapered points can fill tapered canals effectively, because they correspond to canal shapes created by instruments similarly tapered. Limited information is available on the sealing quality of SC techniques compared with other filling techniques.

The purpose of the present investigation was to compare the sealing ability of single-cone (SC), LC, and WVC techniques with 2 different instrumentation systems (ProTaper [Dentsply Maillefer, Tulsa, OK] and Mtwo [VDW; Antaeos, Munich, Germany]), using a bacterial leakage model.

MATERIALS AND METHODS

Preparation of specimens

Eighty freshly extracted human single-rooted premolars with straight canals and mature apices were used. Preoperative radiographs and an operating microscope (Zeiss, Oberkochen, Germany) at ×20 magnification were used to ensure that the teeth did not have root caries, fractures, multiple canals, lateral radicular canals, calcifications, periradicular resorptive changes, or excessive curvatures. After removing extraneous tissue and calculus with a scaler, the teeth were stored in a saline solution at 4°C before use. The teeth were sectioned at the cementoenamel junction with a multipurpose bur in a high-speed handpiece with continuous water spray. The length of roots was adjusted to approximately 16 mm. Patency of the apical foramen was determined with a #15 K-file (Dentsply Maillefer). When the file tip appeared flush with the apical foramen, the length of the file was recorded; the working length was determined to be 1 mm short of the measured length.

Root canal instrumentation

All samples were then randomly divided into 2 groups (n = 40) according to the instrumentation techniques used (Fig. 1).

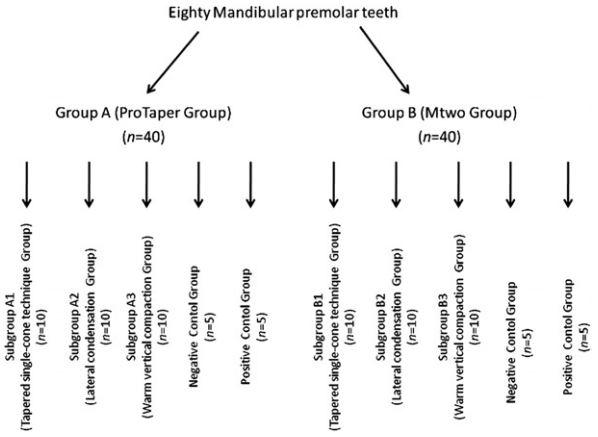


Fig. 1. Distribution of groups according to the instrumentation and filling techniques.

Group A (ProTaper). The root canals where prepared to the working length with ProTaper instruments according to the manufacturer's instructions. All of the instruments were used in a 16:1 gear reduction handpiece powered by a torque-controlled electric motor (X-Smart; Dentsply Maillefer) at a consistent rotation of 300 rpm. Shapers (S1, S2, and SX), were used in a brushing action. S1 was advanced to resistance, but no more than two-thirds of the canal depth. The SX file was then introduced until resistance was encountered. This was followed by the reintroduction of the S1 file to the full working length. The other files were then inserted to the full working length in the sequence S2, F1, F2, and F3 to achieve #30 for the apical preparation. The finishers (F1-F3) were used with in-and-out action.

Group B (Mtwo). The root canals where prepared to the working length with Mtwo instruments according to the manufacturer's instructions. The Mtwo instruments were set into permanent rotation, with the torque-limited rotation handpiece Mtwo direct (Sirona, Bensheim, Germany) at a maximum speed of 280 rpm. According to the manufacturer, the Mtwo instruments should be used in a single-length technique with a gentle in-and-out motion. Therefore, all files of the instrumentation sequence were used to the full working length of the root canal. Five rotary instruments were used: Mtwo 10/.04, Mtwo 15/.05, Mtwo 20/.06, Mtwo 25/.06, and Mtwo 30/.05.

Each canal was irrigated with 2 mL freshly prepared 5.25% NaOCl, using a syringe and a 27-gauge needle between each file. Apical patency was checked with a size 10 K-file between each instrument. After preparation, the canals were irrigated with 5.25 mL NaOCl followed by 5 mL 17% EDTA for 1 minute to remove the smear layer. Finally, the specimens were irrigated

with 10 mL distilled water to avoid the prolonged effect of the EDTA and NaOCl solutions. The canals were subsequently dried with paper points.

Root canal filling

After preparations, all root canals were then randomly divided into 3 experimental subgroups (n = 10) according to the filling techniques used and 2 control (positive and negative) groups (n = 5) for each instrumentaion technique (Fig. 1).

Subgroup A1 (tapered single-cone technique). The root canals were filled with gutta-percha and AH Plus sealer (De Trey/Dentsply, Konstanz, Germany) using an SC technique. An F3 ProTaper gutta-percha point (Dentsply Maillefer) was coated with AH Plus sealer and placed into the root canal with tweezer until fully seated. Excess gutta-percha was removed with a hot instrument, and a 3 mm coronal trough was created for each tooth.

Subgroup A2 (lateral compaction). The root canals were filled with gutta-percha and AH Plus sealer using an LC technique. The F3 ProTaper master cone's tip was dipped in sealer, and then seated apically. LC was accomplished using finger spreaders and fine-fine or fine-medium accessory cones dipped in the sealer. LC was continued until the spreader penetrated into the coronal third of the root canal space, and a 3 mm coronal trough was created for each tooth.

Subgroup A3 (warm vertical compaction). The root canals were filled with gutta-percha and AH Plus sealer using a continuous-wave WVC technique according to the manufacturer's instructions. A BeeFill Pack (VDW) was used for the initial down-pack to 3 mm from the working length followed by incremental backfill using the BeeFill (VDW), and the heated gutta-percha was condensed into the canal using a medium plugger. Following the manufacturer's instructions, the system was used at 180°C and 60% flow rate, and a 3 mm coronal trough was created for each tooth.

Subgroup B1 (tapered single-cone technique). The root canals were filled as in subgroup A1 using a 30/.05 Mtwo gutta-percha point.

Subgroup B2 (lateral compaction). The root canals were filled as in subgroup A2 using a 30/.05 Mtwo master and accessory gutta-percha cones.

Subgroup B3 (warm vertical compaction). Canals were filled as described in subgroup A3.

Radiographic documentation was performed to ensure the quality of the root filling. The filled roots were stored for 7 days at 37°C and 100% relative humidity to allow the sealer to set completely before leakage evaluation with a bacterial leakage model.

The 10 teeth that were instrumented but not filled were used as positive control samples to demonstrate bacterial leakage through the entire length of the canal. The negative control teeth (n = 10) were instrumented but not filled and sealed externally with 2 layers of nail polish except for coronal access.

Bacterial leakage test

The model used in this study was modified from a technique developed by Er et al.[15] The tapered ends of 1.5-mL polypropylene centrifuge tubes (Greiner, Mannheim, Germany) were cut, and the obturated roots were inserted into the tubes until the roots protruded through the end. The junction between each tube and root was sealed with cyanoacrylate to prevent leakage of the connection. Two coats of nail varnish were applied to all external root surfaces to the level of 3 mm from the apex. The entire apparatus was then gas sterilized using ethylene oxide for a 12-hour cycle using the Anprolene AN 74C Gas Sterilizer (Andersen Products, Haw River, NC). To ensure sterilization, the whole system was incubated at 37°C for 3 days. Any test apparatus that showed signs of turbidity in the brain-heart infusion (BHI) broth was discarded. A volume of 7-8 mL BHI broth (Difco, Detroit, MI) with 0.01% phenol red indicator was introduced into sterile 13 × 100 mm disposable culture tubes. The previously assembled portions of tooth and its container were then inserted in the culture tubes so that a minimum of 3-4 mm of the apical part of each root was immersed in BHI broth. Each assembled apparatus was then placed in a 16 × 125 mm sterile test tube and covered with a polypropylene cap. The bacterial suspension of the *Enterococcus faecalis* organism (American Type Culture Collection 29212; RSHSE, Ankara, Turkey) was used to contaminate root canals. Each access cavity was aseptically inoculated with 15 μL freshly prepared *E. faecalis* culture (10^6 cells/mL) once. All samples were incubated in a humid environment at 37°C for 8 weeks and examined daily for color change from red to orange-yellow each day. When the color of the broth had changed to orange-yellow, 10 μL of the culture broth was subcultured onto sheep blood agar to confirm purity. To assure sterility, all testing was performed in a class II laminar airflow cabinet.

To prevent bacterial leakage through the root surfaces, the roots of all teeth were coated with 2 coats of nail varnish, except over the apex. The apices of the negative control teeth were also sealed with nail varnish.

Statistical analysis

Statistical analysis of the data was accomplished using a chi-squared test. The level of significance was 5% ($P < .05$).

Table I. Samples that leaked in each subgroup at various time intervals

Group	*Subgroup*	*1 wk*	*2 wk*	*3 wk*	*4 wk*	*5 wk*	*6 wk*	*7 wk*	*8 wk*	*Total*
ProTaper	Tapered single cone	0	0	1	1	2	1	2	0	7/10
	Lateral compaction	0	0	2	2	1	0	0	0	5/10
	Warm vertical compaction	0	0	0	0	1	0	1	0	2/10
	Positive control	5	—	—	—	—	—	—	—	5/5
	Negative control	0	0	0	0	0	0	0	0	0/5
Mtwo	Tapered single cone	1	0	0	0	0	0	1	3	5/10
	Lateral compaction	0	0	0	3	0	1	0	0	4/10
	Warm vertical compaction	0	0	1	0	3	1	0	0	5/10
	Positive control	5	—	—	—	—	—	—	—	5/5
	Negative control	0	0	0	0	0	0	0	0	0/5

RESULTS

The numbers of samples with bacterial leakage at the end of each week are listed in Table I. No growth was observed when checking the sterilization of the whole apparatus. None of the negative controls showed any color change, indicating no leakage, and all of the positive controls demonstrated a color change, indicating leakage within the first 24 h. The broth cultures producing growth were then subcultured onto sheep blood agar to confirm that there was no contamination of the samples by bacteria other than *E. faecalis*. In the ProTaper group, leakage was observed in 70% of the specimens filled with SC (A1), 50% of the specimens filled with LC (A2), and 20% of the specimens filled with WVC (A3). There was no statistically significant difference between the subgroups ($P > .05$). In the Mtwo group, bacterial leakage was observed in 50% of SC (B1), 40% of samples of LC (B2), and 50% of samples of WVC (B3). There was no statistically significant difference between subgroups B1, B2 and B3 ($P > .05$) and there was no statistically significant difference between groups A and B ($P > .05$).

DISCUSSION

Leakage through a filled root canal may take place along the sealer-dentin and sealer-filling material interfaces or through voids within the sealer and is a possible cause of root treatment failure.[16] Pashley[17] stated that microleakage is a serious clinical problem because most dental materials exhibit varying degrees of microleakage. The most important prerequisites of endodontics are total debridement of the pulpal space, development of a fluid-tight seal at the apical foramen, and total filling of the root canal. Therefore leakage tests are a relevant way to evaluate the apical seal. Many in vitro methods have been used to evaluate the sealing ability of root canal filling materials by using dyes, scanning electron microscopy, fluid filtration techniques, electrochemical methods, radioisotopes, and bacteria.[12,15,18-20] Among these techniques, the bacterial leakage model is considered to be the most clinically relevant. *Enterococcus faecalis* has been identified as the bacterial species most commonly found in root canals of teeth presenting failure after endodontic treatment[21]and has been used in several studies on leakage.[15,22,23] Therefore, in the present bacterial leakage study, *E. faecalis* was used.

This study was designed to evaluate in vitro apical leakage in root canals prepared with 2 different NiTi rotary insruments (ProTaper and Mtwo) and filled with 3 different techniques (SC, LC, and WVC). A standardized tooth model was used to decrease the number of variables in this study. The teeth used were carefully selected according to tooth type, canal size at the working length, and canal curvature. The quality of sealer adaptation to dentin walls is a function of smear layer removal.[24] The presence of a residual smear layer after chemomechanical preparation is thought to be responsible for leakage between the root canal walls and the filling material.[24] In one study, Baumgartner and Mader[25] reported an effective smear layer removal with the use of NaOCl and EDTA as irrigation solutions during root canal instrumentation. It has also been reported that EDTA can remove the smear layer in 1 minute.[26] Based on this information we used solutions of 5.25% NaOCl and 17% EDTA to remove the smear layer.

Prepared root canals are usually filled with a solid core material and a sealer. The long-term seal provided by such root fillings has been considered to be essential to success. The sealer can fill in imperfections, thus improving the filling capacity of the gutta-percha.[27] However, sealers are subject to problems, such as shrinkage and solubility, that are incompatible with long-term sealing. If dissolution occurs, either at the interface between the gutta-percha and the dentin wall or between the gutta-percha points themselves, leakage may occur within the space originally taken up by sealer.[28] Consequently, the goal of various filling techniques is to maximize the amount of gutta-percha applied and minimize the amount of sealer. Gordon et

al.[29] reported a similar percentage of gutta-percha–filled areas when they filled curved canals using .06 tapered instruments with the SC and LC techniques. Hörsted-Bindslev et al.[30] reported that the LC technique did not differ from the SC technique regarding the radiographic quality of the root filling. Tasdemir et al.[13] found that the SC technique produced a significantly greater percentage of gutta-percha–filled area than the LC technique at 2 mm from the apex, but there was no significant difference between the techniques at 4 mm from the apex. In the present study, AH Plus sealer was chosen because of its low solubility. Schäfer and Zandbiglari,[31] who compared the solubility of resin-, silicone-, calcium hydroxide–, zinc oxide–eugenol–, and glass ionomer–based sealers in water and artificial saliva, reported that AH Plus lost the least amount of weight of all sealers tested in all liquids. Furthermore, Nagas et al.[12] suggested that AH Plus may be preferable to EndoRez and Ketac-Endo regarding improved sealing and bonding quality of filling material. Those studies indicated that the type of sealer can influence the quality of obturation.

Recently, single gutta-percha cones matching the geometry of the rotary instruments have been marketed for obturation of the prepared root canals. Use of a single cone can accelerate the obturation procedure while minimizing pressure applied to the root canal walls.[32] The single cone and sealer combination results in a uniform mass which avoids the gaps observed between multiple cones.[32] However, the geometry of the gutta-percha cone and the rotary instruments must be well matched for an optimum adaptation. Pommel and Camps[33] compared SC, LC, WVC, Thermafil, and System B techniques using a zinc oxide–eugenol–based sealer and reported that the SC technique had the highest leakage. Monticelli et al.[34] compared 2 contemporary SC techniques with the WVC technique and concluded that the latter provided a more durable apical seal. Yucel and Ciftci[35] concluded that the poor seal with SC may be related to the technique itself, because the gutta-percha is not compacted but is only inserted to the working length with a substantial amount of sealer. On the other hand, Wu et al.[36] studied the leakage of single-cone fillings using a silicone-based sealer for 1 year and concluded that single-cone fillings prevented fluid transport for 1 year. Antonopoulos et al.[37] and Yilmaz et al.[20] compared the apical leakage in root canals filled with the LC and SC techniques and reported no difference between the 2 techniques. Inan et al.[38] compared the apical sealing ability of SC, LC, and Thermafil techniques and found no difference between the techniques. Similarly, in the present study no difference regarding leakage was observed between the SC, LC, and WVC techniques over the 8-week period.

In the present study, the root canals were treated with ProTaper and Mtwo rotary instruments. ProTaper instruments have progressively increasing tapers, a convex triangular section, and a modified guiding tip. Mtwo instruments represent a new generation of NiTi rotary instruments; the transverse section of the Mtwo forms an italic "S" with 2 blade-cutting surfaces resembling that of the S-file. We also compared the effect of these 2 different instrumentation systems on the sealing ability of three different filling techniques. We found there was no difference between the instrumentation systems. The use of matched-taper master gutta-percha points in canals prepared with ProTaper and Mtwo rotary instrument systems may therefore provide similar sealing ability for all filling techniques.

In conclusion, our research found that filling with SC, LC, and WVC techniques in canals instrumented with ProTaper and Mtwo rotary instruments showed similar sealing effects.

REFERENCES

1. Cathro PR, Love RM. Comparison of Microseal and System B/Obtura II obturation techniques. Int Endod J 2003;36:876-82.
2. Bailey GC, Ng YL, Cunnington SA, Barber P, Gulabivala K, Setchell DJ. Root canal obturation by ultrasonic condensation of gutta-percha. Part II: an in vitro investigation of the quality of obturation. Int Endod J 2004;37:694-8.
3. Jarrett IS, Marx D, Covey D, Karmazin M, Lavin M, Gound T. Percentage of canals filled in apical cross sections—an in vitro study of seven obturation techniques. Int Endod J 2004;37:392-8.
4. Economides N, Kokorikos I, Kolokouris I, Panagiotis B, Gogos C. Comparative study of apical sealing ability of a new resin-based root canal sealer. J Endod 2004;30:403-5.
5. Tan BT, Messer HH. The quality of apical canal preparation using hand and rotary instruments with specific criteria for enlargement based on initial apical file size. J Endod 2002;28:658-64.
6. Kosa DA, Marshall G, Baumgartner JC. An analysis of canal centering using mechanical instrumentation techniques. J Endod 1999;25:441-5.
7. Tasdemir T, Aydemir H, Inan U, Unal O. Canal preparation with Hero 642 rotary Ni-Ti instruments compared with stainless steel hand K-file assessed using computed tomography. Int Endod J 2005;38:402-8.
8. Peters OA, Schönenberger K, Laib A. Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro computed tomography. Int Endod J 2001;34:221-30.
9. Hembrough MW, Steiman HR, Belanger KK. Lateral condensation in canals prepared with nickel titanium rotary instruments: an evaluation of the use of three different master cones. J Endod 2002;28:516-9.
10. Schilder H. Filling root canals in three dimensions. Dent Clin North Am 1967;11:723-44.
11. DuLac KA, Nielsen CJ, Tomazic TJ, Ferrillo PJ, Hatton JF. Comparison of the obturation of lateral canals by six techniques. J Endod 1999;25:376-80.
12. Nagas E, Altundasar E, Serper A. The effect of master point taper on bond strength and apical sealing ability of different root canal sealers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e61-4.
13. Tasdemir T, Yesilyurt C, Ceyhanli KT, Celik D, Er K. Evalua-

tion of apical filling after root canal filling by 2 different techniques. J Can Dent Assoc 2009;75:201-201d.
14. Ayar LR, Love RM. Shaping ability of Profile and K3 rotary Ni-Ti instruments when used in a variable tip sequence in simulated curved root canals. Int Endod J 2004;37:593-601.
15. Er K, Tasdemir T, Bayramoglu G, Herguner Siso S. Comparison of the sealing of different dentin bonding adhesives in root-end cavities: a bacterial leakage study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:976-82.
16. Monticelli F, Sword J, Marti RL, Schuster GS, Weller RN, Ferrari M, Pashley DH, Tay FR. Sealing properties of two contemporary single-cone obturation systems. Int Endod J 2007; 40:374-85.
17. Pashley DH. Clinical considerations of microleakage. J Endod 1990;16:70-7.
18. Wu MK, Wesselink PR. Endodontic leakage studies reconsidered. Part 1. Methodology, application and relevance. Int Endod J 1993;26:37-43.
19. Cobankara FK, Adanır N, Belli S, Pashley DH. A quantitative evaluation of apical leakage of four root-canal sealers. Int Endod J 2002;35:979-84.
20. Yilmaz Z, Tuncel B, Ozdemir HO, Serper A. Microleakage evaluation of roots filled with different obturation techniques and sealers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:124-8.
21. Pinheiro ET, Gomes BPFA, Ferraz CCR, Souza ELR, Teixeira FB. Microorganisms from canals of root-filled teeth with periapical lesions. Int Endod J 2003;36:1-11.
22. Fransen JN, He J, Glickman GN, Rios A, Shulman JD, Honeyman A. Comparative assessment of ActiV GP/glass ionomer sealer, Resilon/Epiphany, and gutta-percha/AH plus obturation: a bacterial leakage study. J Endod 2008;34:725-7.
23. Brosco VH, Bernardineli N, Torres SA, Consolaro A, Bramante CM, de Moraes IG, Garcia RB. Bacterial leakage in root canals obturated by different techniques. Part 1: microbiologic evaluation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 105:e48-53.
24. Saunders WP, Saunders EM, Herd D, Stephens E. The use of glass ionomer as a root canal sealer: a pilot study. Int Endod J 1992;25:238-44.
25. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod 1987; 13:147-57.
26. Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. J Endod 2002;28:17-9.
27. Wu MK, Fan B, Wesselink PR. Diminished leakage along root canals filled with gutta-percha without sealer over time: a laboratory study. Int Endod J 2000;33:121-5.
28. Kontakiotis EG, Wu MK, Wesselink PR. Effect of sealer thickness on long-term sealing ability: a 2-year-follow-up study. Int Endod J 1997;30:307-12.
29. Gordon MPJ, 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.
30. Hörsted-Bindslev P, Andersen MA, Jensen MF, Nilsson JH, Wenzel A. Quality of molar root canal fillings performed with the lateral compaction and the single-cone technique. J Endod 2007;33:468-71.
31. Schäfer E, Zandbiglari T. Solubility of root canal sealers in water and artificial saliva. Int Endod J 2003;36:660-9.
32. Gomes BP, Pinheiro ET, Sousa EL, Jacinto RC, Zaia AA, Ferraz CC, et al. Enterococcus faecalis in dental root canals detected by culture and by polymerase chain reaction analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102:247-53.
33. Pommel L, Camps J. In vitro apical leakage of System B compared with other filling techniques. J Endod 2001;27:449-51.
34. Monticelli F, Sadek FT, Schuster GS, Volkmann KR, Looney SW, Ferrari M, et al. Efficacy of two contemporary single-cone filling techniques in preventing bacterial leakage. J Endod 2007; 33:310-3.
35. Yucel AC, Ciftci A. Effects of different root canal obturation techniques on bacterial penetration. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102:e88-e92.
36. Wu MK, van der Sluis LW, Wesselink PR. A 1-year follow-up study on leakage of single-cone fillings with RoekoRSA sealer. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101: 662-7.
37. Antonopoulos KG, Attin T, Hellwig E. Evaluation of the apical seal of root canal fillings with different methods. J Endod 1998; 24:655-8.
38. Inan U, Aydin C, Tunca YM, Basak F. In vitro evaluation of matched-taper single-cone obturation with a fluid filtration method. J Can Dent Assoc 2009;75:123-6.

Reprint requests:

Dr. Tamer Taşdemir
Endodonti Anabilim Dali
Dis Hekimligi Fakultesi
Karadeniz Teknik Universitesi
61080 Trabzon
Turkey
tamertd72@yahoo.com