

Clinical and Radiographic Evaluation of a Resin-based Root Canal Sealer: An Eight-year Update

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Abstract

Introduction: This retrospective clinical and radiographic study evaluated the 8-year outcome of one-visit endodontic treatment of root canals filled with gutta-percha and a methacrylate resin-based sealer (EndoREZ). **Methods:** From an initial sample size of 180 patients, subsequently 145 and 120 patients were evaluated after 14–18 months and 5 years, respectively. Of the remaining patient pool of 120 patients evaluated after 5 years, 112 patients with 212 root canals responded to the 8-year recall. The outcome of treatments was assessed on the basis of clinical and radiographic criteria. Endodontic success was rated on the basis of absence of clinical symptoms, the presence of a normal or slightly widened periodontal ligament space, and absence or substantial reduction in size of preexisting periradicular radiolucencies. Teeth that did not meet these criteria were considered endodontic failures. **Results:** The root canals had been adequately filled to the working length in 90 teeth (80.35%) and were short in 19 instances (16.96%). None of the roots showing apical extrusion of the sealer immediately postoperatively had radiographic evidence of the sealer in the periradicular tissues after 8 years. At recall, all patients were comfortable and free of clinical symptoms. A life table analysis showed a cumulative probability of success of 86.5% after 8 years, with a 95% confidence interval of 79.0–92.0. **Conclusions:** The results of this retrospective clinical and radiographic study suggest that the tested methacrylate resin-based sealer used in conjunction with gutta-percha cones performed similarly to conventional endodontic sealers during a period of up to 8 years. (*J Endod* 2010;36:1311–1314)

Key Words

Endodontic therapy, EndoREZ, methacrylate-based sealers, root canal filling

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Success or failure rates of treatment modalities are an important part of evidence-based practice of endodontics. Numerous studies have been published evaluating endodontic success and failure by using clinical and radiographic examination (1–5). Well-defined predetermined clinical and radiographic criteria offer a reliable method to evaluate the long-term results of endodontic therapy (2–4, 6–8). A preliminary retrospective study on 180 patients (9) evaluated the results of endodontic treatment of 295 root canals filled with laterally condensed gutta-percha cones in conjunction with EndoREZ (Ultradent Products Inc, South Jordan, UT), a methacrylate resin-based endodontic sealer. After 14–24 months, 145 patients were evaluated for a follow-up examination. An overall success rate of 91% was reported. In a second follow-up study performed 5 years after initial therapy, 120 of 180 patients were available for follow-up evaluation (10), and an overall success rate of 90% was reported. Because the outcome of endodontic treatment varies over time, the purpose of this retrospective study was to obtain 8-year postoperative data on the same patient pool that was previously evaluated.

Materials and Methods

Of the original patient pool (age range, 12–75 years) treated in private practice, 112 patients (44.64% male and 55.35% female) with 212 root canals were available for an 8-year follow-up examination during which they were clinically and radiographically evaluated. Subjects were contacted by mail or telephone or e-mails were sent requesting they come in for a follow-up examination. Preoperative radiographs were taken during the initial treatment, and the status of pulp and periradicular areas was recorded. All treatments had been completed in a single visit. After administration of local anesthesia, rubber dam was placed, and the pulp chamber was accessed. The canals were hand-instrumented with a crown-down technique for radicular access combined with a step-back technique for apical preparation. The coronal two thirds were first flared with #1-3 Gates Glidden drills (Dentsply/Maillefer, Ballaigues, Switzerland), and the working length was established with a #15 file, approximately 1 mm short of the radiographic apex. Canal preparation was made with K-type and Hedström files (Dentsply/Maillefer) at the apical third to a master apical #30-40 file and coronally to a #60 file. On occasion, the instrumentation sequence was modified because of difficulty in negotiating root canals with complex anatomy. Patency was confirmed with a #10 K-file. Irrigation was performed after every change of instrument by using 2.0 mL of 2.5% NaOCl followed by rinsing with 2.0 mL of sterile saline. After instrumentation, a final copious rinse with saline was performed. The irrigation solutions were administered with sterile plastic syringes and through 30-gauge endodontic irrigation needles. Excess irrigation solution was removed with sterile paper points; however, the canal walls were kept slightly moist to take maximum advantage of the hydrophilic properties of the resin sealer, thus allowing for deep penetration into the dentinal tubules and promoting a better seal. The canals were then filled with lateral condensation of gutta-percha cones and EndoREZ as the sealer. The access cavities were temporarily sealed with IRM (Dentsply/Caulk, Milford, DE), and the patients were instructed to see their referring dentist for definitive restorative care.

During the follow-up evaluation, a clinical examination was performed (percussion), and radiographs were made. Postoperative and recall radiographs were made by using the same x-ray unit with a film-holder attached to beam-guiding XCP instrument (Rinn Corp, Elgin, IL) and Kodak 32 × 43 mm ultraspeed films (Eastman Kodak

TABLE 1. Tooth Number and Location in the Maxillary or Mandibular Arch Evaluated 8 Years Postoperatively

	Maxillary	Mandibular	Total
Central incisor	18	2	20
Lateral incisor	9	1	10
Canine	12	5	17
First premolar	5	9	14
Second premolar	9	9	18
First molar	8	10	18
Second molar	4	8	12
Third molar	—	3	3
Total	65	47	112

Company, Rochester, NY). The immediate and 8-year postoperative radiographs were compared in a darkened room by using an illuminated x-ray viewer with a magnifying glass. All radiographs were analyzed by 2 independent and calibrated endodontists with more than 25 years of clinical experience. Calibration was carried out by having the evaluators analyze twice a standard set of 110 individual pairs of postoperative and recall radiographs of endodontic treatments that were randomly selected from the files of 2 private and 1 postgraduate endodontic services. To meet the inclusion criteria, the radiographs had to be of high quality and had to clearly exhibit periapical tissues, widened periodontal space, loss of cortical bone, changes in trabecular patterns, or easily discernible periapical radiolucencies. If there was a disagreement between the evaluators, the x-rays were assessed jointly until a consensus was reached. If necessary, additional radiographs were made at different horizontal angulations to improve visualization, thus improving the reliability of the evaluation. The level of the root canal fillings in relation to the working length was recorded, and the quality of the fillings was judged to be adequate when they were placed to the full working length and no voids were detected, while special attention was focused on the last 5 mm of the root canal. Canals that did not meet these conditions were categorized as filled short or inadequate. Failure of 1 canal in multirooted teeth was considered a complete failure, regardless whether other canals were rated successful. In cases with apical radiolucencies, the size of the lesions was estimated on the radiographs as being <2 or >2 mm. Success or failure of the endodontic treatment was determined on the basis of radiographic findings and clinical signs and symptoms according to the following criteria.

For success, (1) radiographically, the contours and width of the periodontal ligament (PDL) space were within normal limits or slightly widened around an accidental overfill, and the patient was free of symptoms. Slight tenderness to percussion for a brief postoperative period was considered acceptable. (2) The size of a preoperative radiolucent area decreased by at least 50% and the patient was free of symptoms, or the contours and width of the PDL space had returned to normal. (3) Absence of preoperative periapical radiolucency remained unchanged over time.

For failure, (1) periapical radiolucency was observed in the preoperative radiograph and remained unchanged or increased in size over time or (2) there was a root that, in absence of preoperative periapical pathosis, developed a radiolucency over time.

TABLE 2. Outcome of Treatment by Gender and Age in Root Canals Filled with Gutta-Percha and EndoREZ after 8 Years

Factor	No. of cases (%)	Success (%)	Failure (%)
Gender			
Male	50 (44.64)	48 (96.00)	4 (8.00)
Female	62 (55.35)	57 (91.93)	3 (4.83)
Age (y)			
12–30	19 (16.96)	17 (89.47)	2 (10.52)
31–55	61 (54.46)	58 (95.08)	3 (4.91)
56–75	32 (28.57)	30 (93.75)	2 (6.25)

The clinical and radiographic data recorded by the 2 examiners were analyzed for interexaminer agreement. The correlation of treatment outcomes with respect to age, gender, and specific preoperative and postoperative data were analyzed by the Fisher exact test ($P < .05$). Taking into consideration the censored data, ie, the total number of patients who did not respond to the previous 14- to 24-month and 5-year recalls (35 and 25, respectively) (9,10), a life table survival analysis was used to determine the cumulative probability of success of the 8-year recall. A corresponding 95% confidence interval was determined.

Results

The examiner calibration showed an interexaminer agreement ratio of 92%, revealing a strong interobserver agreement. Therefore, the radiographic interpretation of the results was considered reliable. The recall rate after 8 years was 62.22%. A total of 112 patients with 212 treated root canals presented for follow-up evaluation. All data collected from the 112 patients were tabulated, and the tooth locations were noted. The number and location of teeth that were evaluated are shown in Table 1. Distribution of patients by age and gender is presented in Table 2. Distribution by significant preoperative and postoperative factors related to treatment results is shown in Tables 3 and 4, respectively. Fig. 1 is representative of the successful treatment of a lower molar. A postoperative glass ionomer restoration was replaced sometimes after 5 years with a bonded resin composite filling because the general practitioner judged the glass ionomer restoration in need of replacement as a result of breakdown.

Ninety teeth (80.35%) were evaluated as adequately filled to the working length. In 19 cases (16.96%) the apical limit of the root filling material was found to be short of the working length. Fifteen (13.39%) of these, which were filled flush at the time of endodontic treatment, underwent slight resorption of the sealer within the lumen of the canals. These cases showed that the end of the root fill was located at ± 2 mm from the radiographic apex. Three cases in which extrusion of the sealer was radiographically established immediately after treatment showed no radiographic evidence of the sealer in the periradicular tissues. Forty-nine teeth (43.75%) with preoperative vital pulps were successful in 46 cases, whereas 63 (56.25%) with preoperative nonvital pulps were successful in 59 cases. Forty-six teeth (41.07%) with preoperative periapical radiolucencies revealed almost total or total healing in 43 cases, whereas 3 of them were evaluated a failure clinically and radiographically. Sixty-six teeth (58.92%) without preoperative periapical radiolucent areas were successful in 62 instances. In 7 of these, a slight widening of the PDL space was noted, but the teeth were asymptomatic and the radiographs showed the presence of well-defined cortical bone. The remaining 4 teeth were considered a failure clinically and radiographically. Overall, after 8 years, all patients were clinically

TABLE 3. Relation of Preoperative Factors to Treatment Results in Root Canals Filled with Gutta-Percha and EndoREZ

Factor	No. of cases (%)	Success (%)	Failure (%)
Pulp diagnosis			
Vital	49 (43.75)	46 (93.87)	3 (6.12)
Nonvital	63 (56.25)	59 (93.65)	4 (6.34)
Periapical radiolucency			
Present	46 (41.07)	43 (93.47)	3 (6.52)
Absent	66 (58.92)	62 (93.93)	4 (6.06)
Lesion size			
<2 mm	38 (82.60)	35 (92.10)	3 (7.89)
>2 mm	8 (17.39)	4 (50.00)	4 (50.0)

TABLE 4. Relation of Final Restoration to Treatment Results in Root Canals Filled with Gutta-Percha and EndoREZ

Restoration	No. of teeth (%)	Success (%)	Failure (%)
None	2 (1.78)		2 (100)
Post (with or without crown)	48 (42.85)	46 (95.83)	2 (4.16)
Coronal filling (amalgam, composite, glass ionomer, etc)	62 (55.35)	59 (95.16)	3 (4.83)

comfortable. The differences in the outcome of treatments related to age, gender, preoperative pulp or periapical status, the size of periapical lesions, and the type of permanent restorations were not statistically significant ($P > .05$). The life table analysis revealed a cumulative probability of success of 86.5% at the 8-year recall, with a 95% confidence interval of 79.0–92.0.

Discussion

This retrospective 8-year clinical and radiographic cohort study of a methacrylate-based endodontic sealer and gutta-percha was considered reliable and demonstrated a stable outcome of treatment as defined per parameters outlined by Ørstavik (11). Using a method of evaluating consenting patients following a predetermined clinical and radiographic protocol is considered a reliable procedure when evaluating the outcome of endodontic treatment (2–4, 6–8, 12), especially because the evaluation criteria are currently being used by clinicians. In this respect, 2 recent histologic investigations (7, 12) demonstrated a good correlation between radiographic success and the histologic status of the periapical tissues in humans.

In common with a previous report (10), the current study was designed to show whether EndoREZ can be recommended for routine use in clinical endodontics. The recall rate of 62.22% after 8 years was within the American Dental Association requirements for subject size in clinical trials as reported by Franco et al (13) and met the required standards for evidence levels (14). It was also comparable to that in previous endodontic follow-up studies (1–5, 11, 15) and is in agreement with the study by Ørstavik (11) in that the recall rates in follow-up studies were substantially reduced as the recall period increased. The influence of the recall rates on the results of the current study deserves some discussion. The 8 patients who were not evaluated either could not be located or did not respond to recall request. This might mean that these patients were without symptoms, they had relocated, or they had returned to the referring dentist when problems occurred. When a patient does not respond to a recall, there is always the possibility that one is dealing with an endodontic failure, and therefore, the data that were generated might not be totally representative of the actual results. It should be noted, however, that the results of endodontic treatments in patients who did not return for follow-up (censored data) are not considered representative of a particular treatment result category (5). It should also be pointed out that the 8 patients who could not be evaluated at this recall were seen at the 5-year follow-up evaluation and categorized as endodontically successful (10).

Data related to the type and location of teeth were pooled because it has been shown that these factors did not skew the outcome of endodontic treatment (3–6). Factors such as gender and age did not negatively affect the results of the study. These observations are in agreement with our previous findings (10) and with those of others (5, 6, 15, 16). Furthermore, no significant differences were found between teeth with vital and nonvital pulps, as has been previously reported by Barbakow et al (3) and Sjögren et al (6). The presence of a preoperative apical radiolucent area did not appear to adversely affect the outcome of endodontic treatment. This observation is in support of our previous findings (9, 10) but disagrees with others (1, 5, 17, 18) who found significantly lower success rates in teeth

with infected root canals and preexisting periapical pathosis. However, our results are in agreement with Sjögren et al (6) and Peak et al (19), who showed that the prognosis of teeth with nonvital pulps and preexisting periapical radiolucent areas was as good as that for vital teeth. We can hypothesize that factors such as early coronal flaring complemented with a careful instrumentation technique in which the incremental removal of the bulk of infected root dentin, thus allowing for a more effective penetration of irrigants, as well as the previously reported tight seal provided by EndoREZ (20), might have contributed to a more favorable condition for periapical healing.

Of further interest is that extrusion of EndoREZ, which accidentally occurred in 10 cases at the initiation of the study, did not show an adverse effect on the outcome of treatments. This is in contradiction with some authors who stated that extrusion of root filling material might interfere with the repair process (17, 21, 22). After 8 years,

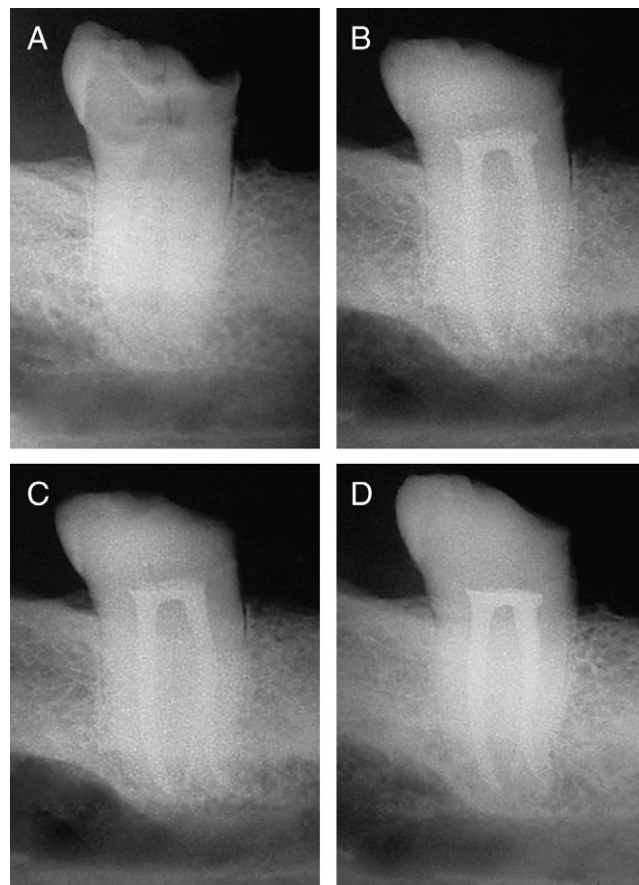


Figure 1. (A) Preoperative radiograph of mandibular left second molar. (B) Immediate postoperative view of root canal filling. Tooth was restored with glass ionomer cement. (C) Five-year follow-up radiograph showing no abnormalities. (D) Eight-year recall radiograph demonstrating normal periapical condition. Postoperative glass ionomer restoration was replaced sometime after 5 years with bonded resin composite filling because the general practitioner judged the glass ionomer restoration in need of replacement as a result of breakdown.

however, all these cases appeared radiographically normal without evidence of sealer in the periapical tissues. These findings suggest that the lack of adverse effects from the extruded EndoREZ can be attributed to the good tissue compatibility of the sealer, as has been demonstrated in previous animal studies (23, 24). In the current study, all patients were treated in a single visit. Our results tend to support previous evidence that the single-visit endodontic therapy constitutes a reliable procedure (25–29), even in cases with infected root canals and preexisting periradicular pathosis. In this respect, more recent evidence provided by Molander et al (30) and a Cochrane systematic review by Figini et al (31) showed that the outcome of treatment was not significantly influenced whether endodontic therapy was performed during a single or multiple visit protocol.

Previous studies (5, 6) reported that the type of coronal restoration (single coronal restoration, presence or absence of a post in the canal) did not significantly affect the outcome of endodontic treatment. In this study, 55.35% presented with single metal/ceramic, amalgam, and resin composite or glass ionomer coronal fillings, whereas in 42.85%, posts were present. Two cases were classified as failures. These cases did not show periapical radiolucencies at the time of the initial treatment, whereas at the 5-year follow-up (10) the patients were asymptomatic, with no radiographic changes in the periapical tissues and with teeth showing adequate coronal fillings. Therefore, they were evaluated as successful after 5 years, whereas at the 8-year recall these teeth presented without coronal restoration and radiographically detectable periapical radiolucent areas. Feedback from these patients revealed that the coronal fillings were lost, and the root canals were exposed to saliva for a prolonged period of time. This observation suggests that although EndoREZ offers a good adaptation to the root canal walls (32, 33–35), treatment failure might occur as a result of coronal bacterial penetration caused by the loss of coronal protection.

In conclusion and within the limitations of this clinical and radiographic study, the results suggest that EndoREZ used in conjunction with gutta-percha constitutes an acceptable root canal filling procedure. Patients recalled after 8 years reported being comfortable with the treated teeth, which continued to be functional. The sealer seems to be well-tolerated by periapical tissues even in cases of accidental extrusion beyond the apical foramen. Furthermore, the success rate was comparable to what had been reported previously (4, 5, 19, 36–38) with different endodontic sealers.

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References

- Grossman LI, Shepard LI, Pearson LA. Roentgenologic and clinical evaluation of endodontically treated teeth. *Oral Surg Oral Med Oral Pathol* 1964;17:368–74.
- Heling B, Tamshe A. Evaluation of the success of endodontically treated teeth. *Oral Surg Oral Med Oral Pathol* 1970;30:533–6.
- Barbakow FH, Cleaton-Jones P, Friedman D. An evaluation of 566 cases of root canal therapy in general dental practice: 2—postoperative observations. *J Endod* 1980;6:485–9.
- Swartz DB, Skidmore AE, Griffin JA. Twenty years of endodontic success and failure. *J Endod* 1983;9:198–202.
- Friedman S, Lost C, Zarrabian M, Trope M. Evaluation of success and failure after endodontic therapy using a glass ionomer cement sealer. *J Endod* 1995;21:384–90.
- Sjögren U, Haggglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. *J Endod* 1990;16:498–504.
- Green TL, Walton RE, Taylor JK, Merrel P. Radiographic and histologic periapical findings of root canal treated teeth in cadaver. *Oral Surg Oral Med Oral Pathol* 1997;83:707–11.
- Ørstavik D, Qvist V, Stolze K. A multivariate analysis of the outcome of endodontic treatment. *Eur J Oral Sci* 2004;112:224–30.
- Zmener O, Pameijer CH. Clinical and radiographic evaluation of a resin-based root canal sealer. *Am J Dent* 2004;17:19–22.
- Zmener O, Pameijer CH. Clinical and radiographic evaluation of a resin-based root canal sealer: a 5-year follow-up. *J Endod* 2007;33:676–9.
- Ørstavik D. Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. *Int Endod J* 1996;29:150–5.
- Ricucci D, Lin LM, Spångberg LSW. Wound healing of apical tissues after root canal therapy: a long-term clinical, radiographic and histopathologic observation study. *Oral Surg Oral Med Oral Pathol* 2009;108:609–21.
- Franco EB, Benetti AR, Ishikiriyama SK, et al. 5-year clinical performance of resin composite versus resin modified glass ionomer restorative system in non-carious cervical lesions. *Oper Dent* 2006;31:403–8.
- Friedman S. Expected outcomes in the prevention and treatment of apical periodontitis. In: Ørstavik D, Pitt Ford T, eds. *Essential endodontology: prevention and treatment of apical periodontitis*. 2nd ed. Frederiksberg, Denmark: Blackwell Munksgaard Ltd; 2008:408–69.
- Selden HS. Pulpoperiapical disease: diagnosis and healing—a clinical endodontic study. *Oral Surg Oral Med Oral Pathol* 1974;27:271–83.
- Kerekes K, Tronstad L. Long term results of endodontic treatment performed with a standardized technique. *J Endod* 1979;5:83–90.
- Seltzer S, Bender IB, Turkenkopf S. Factors affecting successful repair after root canal therapy. *J Am Dent Assoc* 1963;67:651–62.
- Seltzer S, Bender IB, Smith J, Freedman I, Nazimov H. Endodontic failures: an analysis based on clinical, roentgenographic, and histologic findings. *Oral Surg Oral Med Oral Pathol* 1967;23:517–30.
- Peak JD, Hayes SJ, Bryant ST, Dummer PMH. The outcome of root canal treatment: a retrospective study within the armed forces (Royal Air Force). *Br Dent J* 2001;190:140–4.
- Pameijer CH, Zmener O. Current status of methacrylate-based sealers and obturation techniques. *Pract Proced Aesthet Dent* 2006;18:674–6.
- Storms JL. Factors that influence the success of endodontic treatment. *J Can Dent Assoc* 1969;35:83–97.
- Seltzer S. Long term radiographic and histological observations of endodontically treated teeth. *J Endod* 1999;25:818–22.
- Louw NP, Pameijer CH, Norval G. Histopathological evaluation of a root canal sealer in subhuman primates (abstract). *J Dent Res* 2001;79:654.
- Zmener O, Banegas G, Pameijer CH. Bone tissue response to a methacrylate-based endodontic sealer: a histological and histometric study. *J Endod* 2005;31:457–9.
- Oliet S. Single-visit endodontics: a clinical study. *J Endod* 1983;9:147–52.
- Soltanoff W. A comparative study of the single-visit and the multiple-visit endodontic procedure. *J Endod* 1978;4:278–81.
- Pekruhn RB. The incidence of failure following single-visit endodontic therapy. *J Endod* 1986;12:68–72.
- Weiger R, Rosendahl R, Löst C. Influence of calcium hydroxide intracanal dressing on the prognosis of teeth with endodontically induced periapical lesions. *Int Endod J* 2000;33:219–26.
- Field JW, Gutmann JL, Solomon ES, Rauskin H. A clinical radiographic retrospective assessment of the success rate of single-visit root canal treatment. *Int Endod J* 2004;37:70–82.
- Molander A, Warfvinge J, Reit C, Kvist T. Clinical and radiographic evaluation of one-and-two visit endodontic treatment of asymptomatic necrotic teeth with apical periodontitis: a randomized clinical trial. *J Endod* 2007;33:1145–8.
- Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth: a Cochrane systematic review. *J Endod* 2008;34:1041–7.
- Zmener O, Pameijer CH, Macri E. Evaluation of the apical seal in root canals prepared with a new rotary system and obturated with a methacrylate-based endodontic sealer: an in vitro study. *J Endod* 2005;31:392–5.
- Gillespie WT, Loushine RJ, Weller RN, et al. Improving the performance of EndoRez root canal sealer with a dual-cured two-step self-etch adhesive. II—apical and coronal seal. *J Endod* 2006;32:771–5.
- Zmener O, Pameijer CH, Alvarez Serrano S, Vidueira M, Macchi RL. Significance of moist root canal dentin with the use of methacrylate-based endodontic sealers: an in vitro coronal dye leakage study. *J Endod* 2008;34:76–9.
- Herbert J, Bruder M, Braunsteiner J, Altenburger MJ, Wrbas K-T. Apical quality and adaptation of Resilon, EndoRez, and Guttaflow root canal fillings in combination with a noncompaction technique. *J Endod* 2009;35:261–4.
- Ørstavik D, Kerekes K, Eriksen HM. Clinical performance of three endodontic sealers. *Endod Dent Traumatol* 1987;3:178–86.
- Augsburger RA, Peters DD. Radiographic evaluation of extruded obturation materials. *J Endod* 1990;16:492–7.
- Huomonen S, Lenander-Lumikari M, Sigurdsson A, Ørstavik D. Healing of apical periodontitis after endodontic treatment: a comparison between a silicone-based and zinc oxide-eugenol-based sealer. *Int Endod J* 2003;36:296–301.