In vivo efficacy of various retrofills and of CO_2 laser in apical surgery

Friedman S, Rotstein I, Mahamid, A. *In vivo* efficacy of various retrofills and of CO_2 laser in apical surgery. Endod Dent Traumatol 1991; 7: 19–25.

S. Friedman, I. Rotstein, A. Mahamid

Department of Endodontics, Hebrew University – Hadassah School of Dental Medicine, Jerusalem, Israel

Abstract – The purpose of the present study was to radiographically assess the efficacy of various retrofilling materials and of the use of CO_2 laser in apical surgery. The mandibular premolars of six beagle dogs were infected, resulting in periapical lesions. Apical surgery was performed without root canal treatment. Amalgam with cavity varnish, glass ionomer cement and a light-cured composite resin were the retrofilling materials used. In half of the material CO_2 laser was used on the root surface and the bone, for occlusion of the dentinal tubuli and sterilization. The healing following surgery was observed radiographically for six months. The highest success rate (89%) was found in the roots retrofilled with amalgam and varnish, and the lowest (60%) in those retrofilled with the composite resin. The difference between these groups was statistically significant. The success rate following retrofilling with glass ionomer cement was 69%, and was not significantly different from both the other groups. Under the conditions of this study, the use of CO_2 laser during surgery did not affect the treatment results.

Key words: apical surgery; retrograde filling; glass ionomer cement; composite resin; amalgam; CO_2 laser.

Dr. Shimon Friedman, Department of Endodontics, School of Dentistry, P.O.B. 1172, Jerusalem 91 010, Israel

Accepted for publication July 6, 1990

Failures following apical surgery are associated with the leakage of irritants from the root canal, due to poorly sealing retrograde fillings (1). Consequently, the sealability of various suggested retrofilling materials has been extensively studied (2–12). Composite resins (2, 3) and glass ionomer cement (4) compared favourably with various retrofilling materials including amalgam. In those studies amalgam was used without cavity varnish, that significantly improves its seal (5, 6). Compared to amalgam with varnish, composite resins (6, 7) and glass ionomer cement (6–9) sealed equally well or better. The retrofilling in most of the sealability studies was performed in vitro, and their results are incomparable to retrofilling in vivo (10) which was performed infrequently (5, 10–12). Clinical comparison of retrofilling materials has been advocated (3, 5, 9), but such studies are scarce (1, 13, 14).

Apical leakage might occur also via dentinal tubuli that are exposed by bevelling the root surface, bypassing the retrofilling (15). This pathway of leakage may be eliminated by minimizing the bevel or by extending the retrofilling coronally (15). Technically, however, it is sometimes impossible to accomplish, and therefore sealing of the dentinal tubuli on the bevelled root surface is desirable (15).

Apart from the persistent bacterial apical leakage, bacteria may be harbored extraradicularly (16–18), by colonizing the apical root surface (17) and by invading the periapical tissues (18). The common modality for riddance of the infected tissue is the curettage performed in apical surgery, but it may be incomplete. Moreover, during the surgical procedure the periapical tissues may become further contaminated (19). However, conventional sterilization of the periapical environment during apical surgery cannot be employed in situ.

Melcer et al. (19) suggest the use of CO_2 laser to improve the prognosis of apical surgery. The surface fusion and recrystallization of CO_2-lased dentin (20) result in tubular occlusion (21, 22), which might seal the bevelled root surface (19). CO_2 laser effectively sterilizes infected dentin (23, 24), and has been utilized in apical surgery to sterilize both the root surface and the periapical alveolar bone (19, 22, 25). Soft tissue ablation and occlusion of minor blood vessels (26) are further advantages of applying CO_2 laser in apical surgery (25). The success rate of apical surgery using CO_2 laser is reported to be as high as 98% (19). In contrast, the use of CO_2 laser in animals on long bones (27) and alveolar bone (28, 29) slows down osseous healing (27, 28), and occasionally bone sequestration occurs (28, 29).

The purpose of the present investigation was to study the healing following apical surgery performed with the use of various retrofilling materials, with and without the use of CO_2 laser.

Material and methods

Experimental design

Six male 2-year-old beagle dogs were used in the present study. For every intervention the dogs were anesthetized by means of intravenous administration of 6% pentobarbital (30 mg/kg), after sedation by intramuscular injection of 2% Rompun (Bayer, Leverkusen, West Germany) (1 ml/kg). Apical periodontitis was induced in the mandibular premolars of the dogs (30) by coronally exposing the pulps and sealing cotton pellets with the dogs' plaque into the pulp chambers. Three weeks later the development of periapical lesions was confirmed radiographically (Fig. 1), whereupon apical surgery was performed. The composition of the experimental and control groups is presented in Table 1. The treated teeth were observed radiographically for six months, at which time the dogs were sacrificed by means of an overdose of 6% pentobarbital.

Surgical procedure

Buccal full thickness flaps were reflected after sulcular incision with a diagonal vertical release at the first molar region. Surgical access cavities were established individually for each root, except when adjacent roots were in close proximity to each other. The access cavities were prepared by means of tungsten carbide tapered fissure burs at high speed with water spray cooling. The roots were then apicected and bevelled with the same burs. The periapical granulation tissue was curetted out. Following the identification of the root canals retrograde cavities were prepared by means of small round steel burs at slow speed. After packing the access cavities with gauze, the retrograde cavities were dried by means of paper points and retrofilled with the test materials (Fig. 2). The flaps were replaced and secured tightly by means of interrupted 3.0 silk sutures, that were in place for two weeks before removal.

Fig. 1. Radiograph of dog's mandibular premolars three weeks after infection by sealing plaque in their root canals. Apical periodontitis developed in conjunction with all the roots.

Table 1. Design of the study in which apical surgery in dogs was performed with various retrofilling materials, with or without the use of CO_2 laser.

Retrofilling material	Experimental groups (roots)			Negative control	Positive control
	Unlased	Lased	Total		
Amalgam and varnish	14	14	28	3	4
Glass ionomer cement	14	12	26	4	4
Composite resin	12	13	25	2	2
Total no. of roots	40	39	79	9	10

Retrofilling materials and techniques

Each one of the test materials was used for retrofilling the roots in two dogs. The following materials were used according to the manufacturers' instructions.

Amalgam. Silmet non-gamma 2 amalgam (Silmet, Givatayim, Israel) was used. Prior to retrofilling

Fig. 2. Clinical view of a complete group of roots retrofilled with amalgam and varnish without the use of laser. All the roots were accessed individually, except the first premolar and the second premolar mesial root. The access and the retrograde cavities were sized as uniformly as clinically possible.

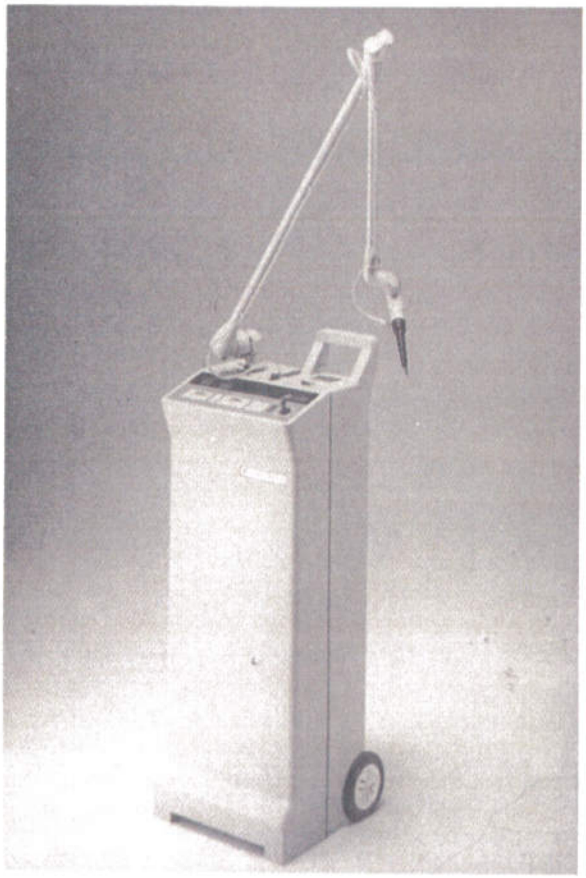

Fig. 3. Photograph of the CO_2 laser used in the present study. The transmittance of the laser beam is through an articulated arm, ending with a handpiece. Activation of the laser beam is by means of a foot switch, which is not shown.

with the amalgam, the retrograde cavity walls were coated with Copalite (Bosworth, Skokie, Illinois, USA), by means of reversed paper points. The amalgam was placed into the retrograde cavities and compacted by means of miniature carriers and pluggers.

Glass ionomer cement. Fuji II glass ionomer cement (G-C Dental Industrial Co., Tokyo, Japan) was used. The retrograde cavities were acid etched with Fuji Dentin Conditioner. An impression material syringe (Caulk, Milford, Delaware, USA) was used for placing the retrofillings. Immediately after their placement the retrofillings were coated with Fuji Varnish.

Composite resin. Estilux Posterior mixed with XR-1 radiopaquer light cured composite resin (Kulzer, Friedrichsdorf, West Germany) was used. Before retrofilling the retrograde cavities were acid etched with Esticid, rinsed and dried. Dentin Adhesive bonding agent was applied to the retrograde cavities by means of reversed paper points and light cured. The composite resin was then syringed into the retrograde cavities like the glass ionomer cement.

Use of CO_2 laser

Sharplan 1020 CO_2 laser (Laser Industries, Tel Aviv, Israel) was used in the experimental teeth on the left side. This laser delivers a maximum power of 20 W in continuous, single pulse or repeated pulse modes. The laser beam is transmitted through an articulated arm to a "handpiece", from which it is emitted at either straight, 90 degree or 120 degree angles (Fig. 3). The focal spot diameter is 0.22 mm. Based on the literature regarding the clinical use of CO_2 laser in apical surgery (19, 22, 25) it was used as the following.

Ablation of granultion tissue. 10–15 W defocused in 0.05 sec repeated pulse mode.

Hemostasis. 3–5 W defocused in continuous mode.

Treatment of dentin. 15 W at focus with 0.05 sec single pulses. The retrograde cavities were exposed before retrofilling and the bevelled root surfaces were exposed after retrofilling, by single adjoining exposures (Fig. 4).

Treatment of alveolar bone. 15 W at focus and defocused in 0.05 sec repeated pulse mode. The periapical bone was lased all around the surgical access cavity (Fig. 4) before replacing the flaps.

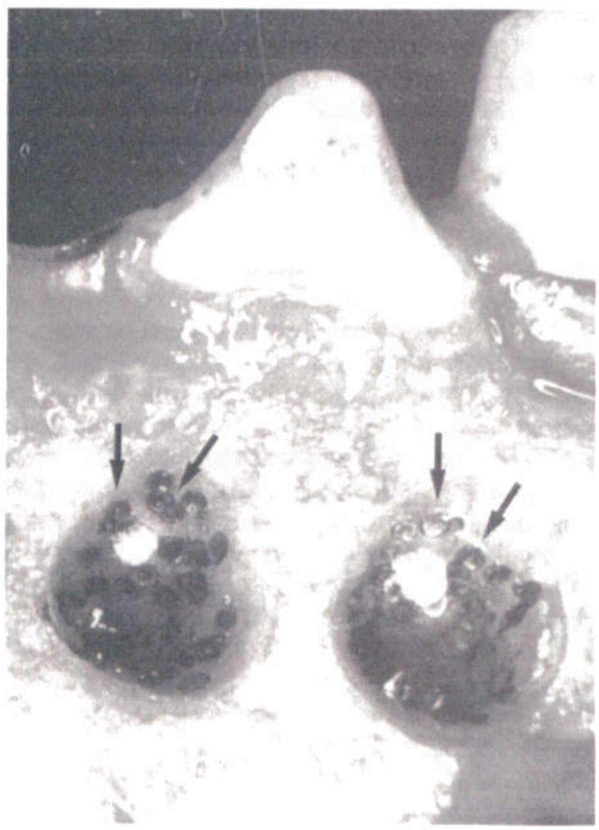

Fig. 4. Clinical view of the effect of CO_2 laser exposure resulting in charring of the dentin and bone. The root surfaces were exposed after retrofilling (arrows), followed by exposing the periapical bony cavities before repositioning the flap.

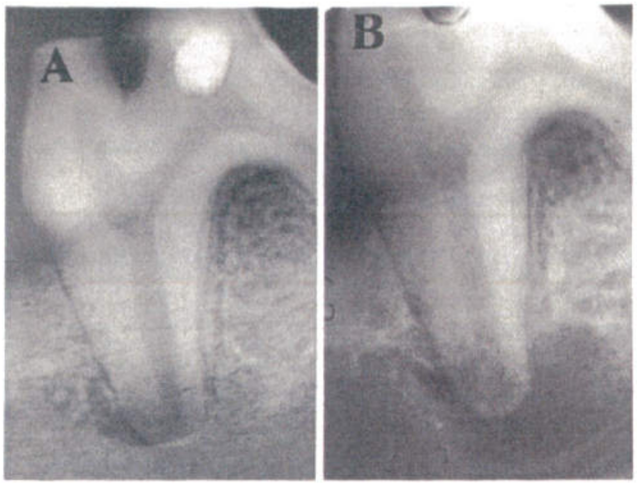

Fig. 5. Radiographs of the mesial root of a dog's left first mandibular molar serving as a positive control. The periapical lesion has increased in size in the absence of a retrofilling. A. Immediately after apicoectomy. B. Lack of periapical repair upon final follow up at six months.

Controls

The positive control consisted of the left first molars, that were infected and apicected like the experimental teeth, but were not retrofilled. The negative control consisted of the right first molars that were not infected but rather extirpated, root canal instrumented and obturated with gutta-percha and sealer. They were then apicected and retrofilled like the experimental teeth, with the same material as the experimental teeth in the same dog.

Assessment of results

Each group of treated teeth was radiographed immediately after surgery. The periapical healing was followed radiographically at two, four and eight weeks postoperatively, and continued at monthly intervals up to six months. The exposure of all the radiographs was the same (65 KV, 10 m amp, 0.4 sec), the angulations were controlled using a paralleling device, and the processing was done under standardized conditions. They were then viewed and compared independently by the three examiners, two of whom were unaware of the viewing sequence. The repair of the periapical surgical defects with bone was observed. Restoration of normal periapical appearance, allowing a remaining widening of the periodontal ligament space, was considered as "success". Lack of periapical repair was considered as "failure". The results were compared using the Kruskal-Wallis 1-way analysis of variance. Each two groups were compared using the Mann-Whitney U-test. Levels of $p=0.05$ were considered significant in both tests.

Results

Comparison of the radiographic interpretation by the three examiners revealed no interexaminer variation. All positive control roots exhibited persisting apical periodontitis (Fig. 5A, B). All the negative control roots demonstrated complete repair (Fig. 6A, B). The lased lesions appeared to be repairing slower than the unlased ones. However, this was only a subjective observation. An example of the radiographic appearance immediately after completion of apical surgery and after six months is demonstrated in Fig. 7A and B respectively.

The results of the study are presented in Fig. 8. The differences in the success rates obtained with the three retrofilling materials were statistically significant ($p<0.05$). Retrofilling with amalgam and varnish was significantly more successful than with the composite resin ($p<0.02$). The difference between glass ionomer cement and amalgam or glass ionomer cement and composite resin were not statistically significant ($p=0.07$ and 0.5 respectively).

With respect to the use of CO_2 laser the success rates obtained with or without the use of laser within each retrofilling material group were not significantly different. The average success rate was similar with and without the use of CO_2 laser.

CO_2 laser ablation of periapical granulation tissue was considerably lengthier than conventional curettage. Also, hemostasis with the laser was not predictably obtained. Repeated lasing after drying of the surgical cavities resulted in renewed hemorrhage.

Discussion

The present study was designed to evaluate the efficacy of the retrofilling materials and the use of

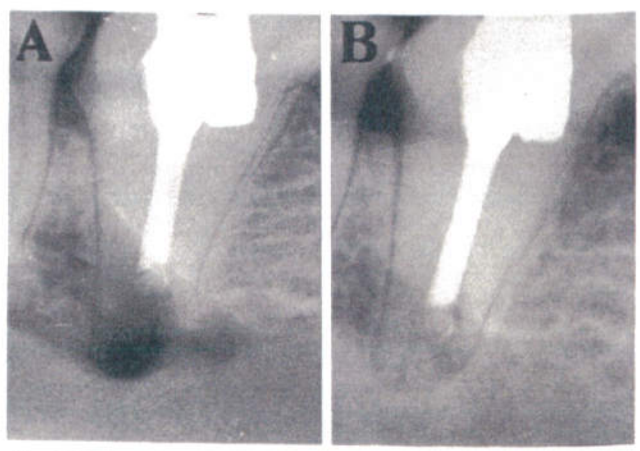

Fig. 6. Radiographs of the distal root of a dog's right first mandibular molar serving as a negative control. Complete periapical repair occurred in the absence of root canal infection.
A. Immediately after root canal obturation, apicoectomy and retrofilling with a composite resin. B. Complete periapical repair upon final follow up at six months.

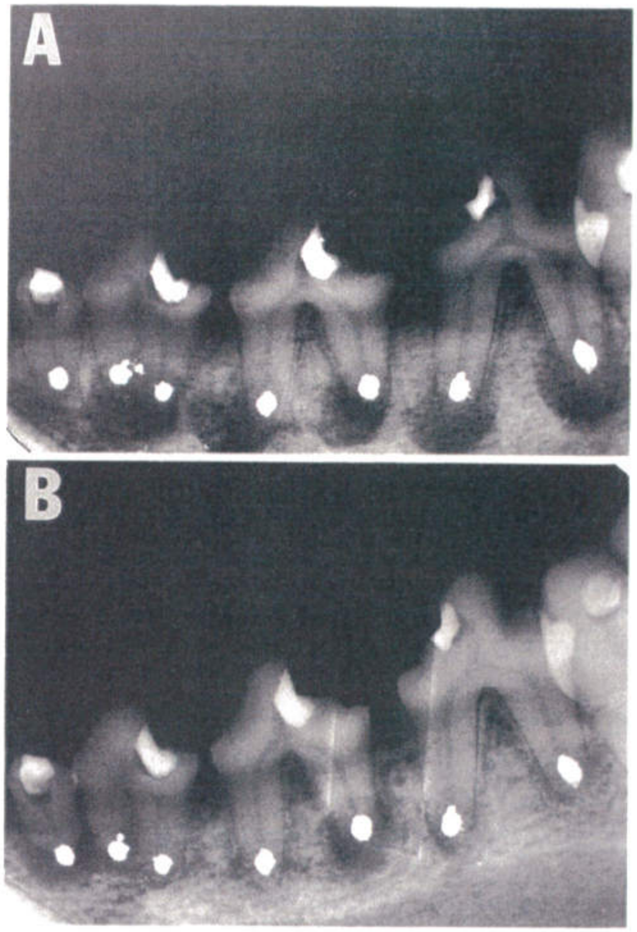

Fig. 7. Radiographs of dog's mandibular premolars which were retrofilled with amalgam and varnish with the use of CO_2 laser. A. Immediately after completion of surgery. B. Final follow up at six months, demonstrating "success" and "failure" of treatment.

CO_2 laser in apical surgery in vivo. In vitro sealability studies of retrofilling materials have only suggestive value (3, 5, 9). Implanting retrofilled roots (5) allows the materials to interact with tissue before leakage is compared. The same is achieved by performing the retrofilling in vivo (10–12), which better simulates the clinical limitations than if the retrofillings are inserted extraorally. However, the correlation of leakage of the commonly used tracers with clinical efficacy is questioned (31). Therefore, retrofilling materials should be compared in a clinical setting before they may be rated conclusively (5). Clinical studies are the most desirable model, but they require a long term observation of large populations. To avoid that, in the present study periapical repair was assessed in dogs.

The mandibular premolar teeth were chosen for this study. Their roots are usually well separated from each other making it possible to individually access each root and observe the healing of each periapical defect. Root canal fillings were not performed, so that the retrograde fillings alone sealed

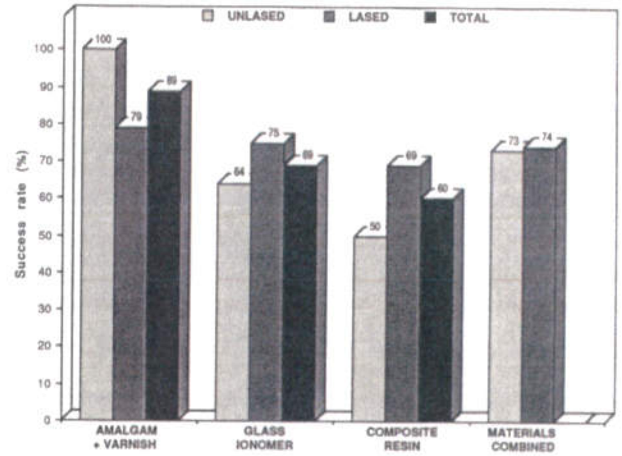

Fig. 8. Plotted representation of the study results. The success rate was assessed radiographically following apical surgery performed with various retrofilling materials, with or without the use of CO_2 laser.

the infected root canals. The negative and positive controls validated the experimental model by confirming that without infection periapical repair consistently occurred, while persistent infection prohibited repair.

Retrofilling with amalgam and varnish was significantly more successful than with composite resin, and somewhat better than with glass ionomer cement. In in vitro studies amalgam with varnish is found to be equal to (6) or inferior to (7) composite resin. In vitro it is also inferior to glass ionomer cement (7–9). Compared clinically, amalgam without varnish is more successful than glass ionomer cement (13), but less successful than a composite resin (14) when these materials are used for retrofilling. In vivo the seal of amalgam retrograde fillings is initially improved by the use of cavity varnish (5). With time it becomes gradually better (10), by accumulation of corrosion products in the marginal gaps (5). Conversely, the setting reaction of glass ionomer cement in vivo may be hindered by the humidity (32). Technically, in this study the condensation of amalgam retrofills could be well controlled, whereas the condensation of the composite resin and glass ionomer cement proved to be difficult, and may have resulted in voids. With respect to biocompatibility, the poor adaptation of fibroblasts to a composite resin in vitro (33) indicates that it may irritate the periapical tissues. The tissue compatibility as retrofillings has been confirmed histologically for both amalgan (34) and glass ionomer cement (35).

Melcer et al. (19) report a 98% success following apicoectomy with the use of CO_2 laser in a comparable manner to that used in the present study. With the exception of unpublished information (22) the authors are unaware of other such reports. In that respect the present study is the first comparison of the prognosis of apical surgery with and without the use of CO_2 laser. Under its conditions it failed to demonstrate clinical advantages with the use of laser. The well documented effect of tissue ablation and coagulation (26) did not facilitate the surgical procedure, which could be performed quicker by conventional means. The use of CO_2 laser as described did not improve the success rate after apical surgery. It remains a possibility that exposing the entire bevelled root surface, rather than performing intermittent exposures as demonstrated previously (19, 22), may seal the dentinal tubuli more effectively and result in a better prognosis. Nevertheless, this study confirmed that healing occurred after irradiation of the periapical bone with CO_2 laser with a power as high as 15 W. This finding appeared to contradict previous reports of impaired bone healing after CO_2 laser irradiation with comparable powers (27–29). However, the extent of thermal tissue damage from laser irradiation is proportional to the exposure time (36). In the present study the bone was exposed with 0.05 sec pulses, whereas in the previous studies the exposure time varied from 0.5 sec (28) to continuous mode (27, 29). In view of the theoretical advantages of using lasers in apical surgery it appears appropriate to suggest that their various effects on the apical and periapical tissues be studied in further detail.

In conclusion, amalgam and cavity varnish resulted in a significantly higher success rate than a composite resin when used as retrofilling materials in apical surgery. Glass ionomer cement was insignificantly poorer than amalgam and varnish, and better than the composite resin. Regarding the use of CO_2 laser in apical surgery, this study did not demonstrate differences in the treatment success obtained with or without its application.

We express our gratitude to Prof. Jashovam Shani, Department of Pharmacology, Hebrew University-Hadassah School of Medicine, Jerusalem, Israel, for his stimulation in designing this study. We also thank Mr. Milu Sadovnik, Department of Oral Biology, Hebrew University-Hadassah School of Dental Medicine, for his invaluable assistance in performing the study.

This project was sponsored in part by the Research Fund of the Hebrew University-Hadassah School of Dental Medicine, Jerusalem, Israel.

References

1. Persson G, Lennartson B, Lundström I. Results of retrograde root-filling with special reference to amalgam and Cavit as root-filling materials. *Svensk Tandlak T* 1974; *68:* 123–33.
2. Shani J, Friedman S, Stabholz A, Abed J. A radionuclidic model for evaluating sealability of retrograde filling materials. *Int J Nucl Med Biol* 1984; *11:* 46–52.
3. Smee G, Bolanos OR, Morse DR, Furst ML, Yesilsoy C. A comparative leakage study of P-30 resin bonded ceramic, Teflon, amalgam, and IRM as retrofilling seals. *J Endodon* 1987; *13:* 117–21.
4. Zetterqvist I, Anneroth G, Danin J, Roding K. Microleakage of retrograde fillings – a comparative investigation between amalgam and glass ionomer cement *in vitro*. *Int Endod J* 1988; *21:* 1–8.
5. Tronstad L, Trope M, Doering A, Hasselgren G. Sealing ability of dental amalgams as retrograde fillings in endodontic therapy. *J Endodon* 1983; *9:* 551–3.
6. Abdal AK, Retief DH, Jamison HC. The apical seal via the retrosurgical approach. II. An evaluation of retrofilling materials. *Oral Surg* 1982; *54:* 213–8.
7. Thirawat J, Edmunds DH. The sealing ability of materials used as retrograde root fillings in endodontic surgery. *Int Endod J* 1989; *22:* 295–8.
8. Schwartz SA, Alexander JB. A comparison of leakage between silver-glass ionomer cement and amalgam retrofillings. *J Endodon* 1988; *14:* 385–91.
9. Barkhordar RA, Pelzner RB, Stark MM. Use of glass ionomers as retrofilling materials. *Oral Surg* 1989; *67:* 734–9.
10. Delivanis P, Tabibi A. A comparative sealability study of different retrofilling materials. *Oral Surg* 1978; *45:* 273–81.
11. Kimura JT. A comparative analysis of zinc and non-zinc alloys used in retrograde endodontic surgery. Part 1: Apical seal and tissue reaction. *J Endodon* 1982; *8:* 359–63.
12. Bramwell JD, Hicks ML. Sealing ability of four retrofilling techniques. *J Endodon* 1986; *12:* 95–100.
13. Dalal MB, Gohil KS. Comparison of silver amalgam, glass ionomer cement and gutta-percha as retrofilling materials, an in vivo and an in vitro study. *J Indian Dent Assoc* 1983; *55:* 153–8.
14. Rud J, Andreasen JO, Rud V. Retrograd rodfyldning med plast og dentinbinder: helingsfrekvens sammenlignet med retrograd amalgam. *Tandlaegebladet* 1989; *93:* 267–73.
15. Tidmarsh BG, Arrowsmith MG. Dentinal tubules at the root ends of apicected teeth: a scanning electron microscopic study. *Int Endod J* 1989; *22:* 184–9.
16. Tronstad L, Barnett F, Riso K, Slots J. Extraradicular endodontic infections. *Endod Dent Traumatol* 1987; *3:* 86–90.
17. Tronstad L, Barnett F, Cervone F. Periapical bacterial plaque in teeth refractory to endodontic treatment. *Endod Dent Traumatol* 1990; *6:* 73–7.
18. Happonen R-P, Söderling E, Viander M, Linko-Kettunen L, Pelliniemi LJ. Immunocytochemical demonstration of Actynomyces species and Arachnia propionica in periapical infections. *J Oral Pathol* 1985; *14:* 405–13.
19. Melcer F, Melcer J, Dejardin J, Lancret J, Gautier J. Short- and middle-term results in human dentistry after CO_2 laser beam exposition. In: Atsumi K, Nimsakul N, eds. Proceedings of the 4th Congress of the International Society for Laser Surgery. Tokyo, Japan, 1981; session 12: 1–4.
20. Kantola S. Laser induced effects on tooth structure. VII. X-ray diffraction study of dentine exposed to a CO_2 laser. *Acta Odontol Scand* 1973; *31:* 381–6.
21. Nelson DGA, Jongebloed WL, Featherstone JDB. Laser irradiation of human dental enamel and dentine. *New Zealand Dent J* 1986; *82:* 74–7.
22. Brun J-P, Tardieu P. Applications of CO_2 laser in dentistry. 2nd World Dental Conference, Jerusalem, Israel, 1988.
23. Zakariasen KL, Dederich DN, Tulip J, DeCoste S, Jensen SE, Pickard MA. Bacterial action of carbon dioxide laser radiation in experimental dental root canals. *Can J Microbiol* 1986; *32:* 942–6.
24. Miserendino LJ, Pick R, Kos W. In vitro sterilization of

dental caries by CO_2 laser irradiation. *Lasers Surg Med* 1988; *8:* 148 (abst no. 26).

25. Miserendino LJ. The laser apicoectomy: endodontic application of the CO_2 laser in periapical surgery. *Oral Surg* 1988; *66:* 615–9.
26. Pecaro BC, Garehime WJ. The CO_2 laser in oral and maxillofacial surgery. *J Oral Maxillofac Surg* 1983; *41:* 725–8.
27. Clayman L, Fuller T, Beckman H. Healing of continuous-wave and rapid superpulsed carbon dioxide laser-induced bone defects. *J Oral Maxillofac Surg* 1978; *36:* 932–7.
28. Barahona JF, Hashimoto K, Kawaguchi T, Fukuda H, Mizuki H. The experimental study of the effects of CO_2 laser in periodontal tissue in dogs. In: Atsumi K, Nimsakul N, eds. Proceedings of the 4th Congress of the International Society for Laser Surgery. Tokyo, Japan, 1981; session 12: 9–12.
29. Fisher SE, Frame JW. The effects of the carbon dioxide surgical laser on oral tissues. *Brit J Oral Maxillofac Surg* 1984; *22:* 414–25.
30. Pascon EA, Introcaso JH, Langeland K. Development of predictable periapical lesion monitored by substraction radiography. *Endod Dent Traumatol* 1987; *3:* 192–208.
31. Kersten HW, Moorer WR. Particles and molecules in endodontic leakage. *Int Endod J* 1989; *22:* 118–24.
32. Mount GJ, Makinsos OF. Glass-ionomer restorative cements: Clinical implications of the setting reaction. *Oper Dent* 1982; *7:* 134–41.
33. Safavi KE, Spångberg L, Sapoulas G, MacAlister TJ. In vitro evaluation of biocompatibility and marginal adaptation of root retrofilling materials. *J Endodon* 1988; *14:* 538–42.
34. Andreasen JO, Rud J. Correlation between histology and radiography in the assessment of healing after endodontic surgery. *Int J Oral Surg* 1972; *1:* 161–73.
35. Zetterqvist L, Anneroth G, Nordenram A. Glass-ionomer cement as retrograde filling material. An experimental investigation in monkeys. *Int J Oral Maxillofac Surg* 1987; *16:* 459–64.
36. Walsh JT, Flotte TJ, Anderson RR, Deutsch TF. Pulsed CO_2 laser tissue ablation: effect of tissue type and pulse duration on thermal damage. *Lasers Surg Med* 1988; *8:* 108–18.