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Incidence of periapical lesions and clinical symptoms after pulpectomy—A clinical and radiographic evaluation of 1- versus 2-session treatment

Andrea Gesi,[a] Magnus Hakeberg,[b] Johan Warfvinge,[c] and Gunnar Bergenholtz,[d] Siena, Italy, and Göteborg and Jönköping, Sweden
UNIVERSITY OF SIENA, GÖTEBORG UNIVERSITY, AND JÖNKÖPING UNIVERSITY

Objective. Outcome of pulpectomy in 2 treatment sessions with calcium hydroxide as an intracanal dressing was compared to a procedure comprising instrumentation and root-filling in 1 session.
Study design. Subjects with a vital pulp condition (N = 256) were recruited to a randomized clinical trial. Outcome parameters included radiographic signs of apical periodontitis and painful symptoms at clinical follow-ups 1 week and 1-3 years after treatment.
Results. Of 244 subjects available for final recall, 17 presented with periapical radiolucency. Lesions were evenly distributed among the 2 treatment groups. Postoperative pain recorded 1 week after permanent filling was significantly associated with overfilling ($P = .001$), with no difference between treatment groups. There was no association with presence of overfilling and radiographic lesion at end point of recall.
Conclusions. Study confirms that pulpectomy may be carried out at a high rate of success if due attention is given to aseptic operating procedures, proper instrumentation and filling. Under these conditions an interappointment dressing with calcium hydroxide does not seem to influence outcome.
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In recent years a growing perception has emerged that root canal treatments, from being routinely conducted in 2 or multiple appointments, can or even should be completed with final filling in one and the same treatment session as the instrumentation procedure. The treatment of vital pulp conditions with pulpectomy is especially considered amenable to such an approach.[1]

A commonly claimed rationale is that the pulpal tissue, even though it may have been exposed to caries for an extended period, is not infected more than superficially and rarely to the apical portion of the pulp tissue.[2-6] Therefore the need for root canal disinfection may not be as strong in these cases as is the case with treatment of an infected pulp necrosis. As reviewed by Trope and Bergenholtz,[7] a single treatment session also has both practical and monetary advantages, including reduced total time for the treatment and less travel time for the patient. From a management aspect, on the other hand, the 2-step treatment allows the clinician to optimize the preparation of the root canal space. Pulp tissue remnants may inadvertently, and not infrequently, be left on the canal walls.[8] Such tissue elements may compromise a tight fit of the subsequent root filling to the canal walls, thus elevating the potential risk for leakage[9] and subsequent development of apical periodontitis. Tissue remnants may also support bacterial growth in case of bacterial contamination during the treatment session.

Calcium hydroxide has been regarded a highly useful chemical for interappointment medication in endodontics (see reviews by Staehle[10] and Siqueira and Lopes[11]).

[a]Clinical Associate Professor, Department of Endodontics and Restorative Dentistry, Faculty of Dentistry, University of Siena.
[b]Professor, Department of Endodontology and Oral Diagnosis, Faculty of Odontology, Sahlgrenska Academy at Göteborg University; School of Health Sciences, Jönköping University.
[c]Associate Professor, Department of Endodontology and Oral Diagnosis, Faculty of Odontology, Sahlgrenska Academy at Göteborg University.
[d]Professor Emeritus, Department of Endodontology and Oral Diagnosis, Faculty of Odontology, Sahlgrenska Academy at Göteborg University.
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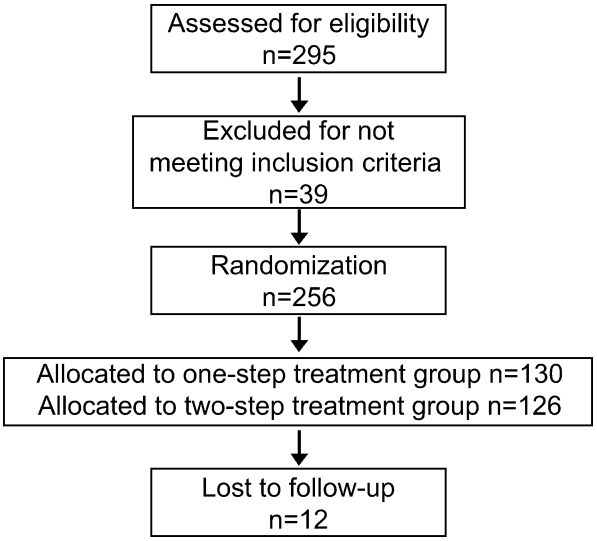

Fig. 1. Flow diagram on the enrollment and follow-up of the subjects in the study.

Studies have shown that, owing to its high pH as a slurry in water, it can necrotize soft tissue elements, which more easily become dissolved by NaOCl.[12-14] Another apparent advantage demonstrated is that hard tissue repair at soft tissue interfaces is enhanced.[15] Thereby, after some time, a biologic block to extrusion of a tissue-irritating root filling material to the periradicular tissue compartment may be established in the apical region of the root canal and at lateral canal orifices.[15]

As for many of the treatment measures undertaken in endodontics and considered important for a successful outcome, there is little scientific support from randomized prospective clinical trials (RCT) for either single-session or 2-step approaches to pulpectomy.[16] Three papers have utilized the RCT design to explore the effect of intracanal calcium hydroxide dressings on periapical tissue healing in treatments of infected pulp necrosis.[17-19] In these studies an equally high rate of healing was attained regardless of dressing or filling the root canals permanently in 1 treatment session. The present study, organized as an RCT, compared the incidence of periapical radiolucencies and painful symptoms at follow-up after pulpectomy and root filling carried out in 1 or 2 treatment sessions. Specifically the research was aimed to assess the extent to which benefit of an interappointment intracanal dressing with calcium hydroxide could be confirmed.

MATERIAL AND METHODS

Participants

Subjects to be included in the study were recruited among patients attending 2 private dental practices operated by 1 of the authors (AG) in Pisa and Pistoia, Italy. Over a 24-month period, all patients with a tooth indicated for the pulpectomy of a vital pulp were considered for the study. The teeth had to be restorable and having no severe attachment loss from periodontal disease. Both painful and nonpainful vital pulp conditions were employed. Other inclusion criteria were:

- positive test of dentin sensitivity by thermal and mechanical stimuli prior to anesthesia and bleeding response on access to the pulp
- an unremarkable medical history
- no physical or mental disability
- no pain medication or treatment for systemic or local infection
- readiness to appear for the necessary appointments required for completion of treatments and recalls.

During the recruitment period a total of 295 patients fulfilled the inclusion criteria. A total of 39 patients had to be excluded from the randomization procedure (see further below). Twenty-two patients were on pain or antibiotic medication, 9 patients were not to be available for recall, 5 patients needed a 1-step treatment because of need for immediate prosthodontic therapy, and 3 patients refused radiographic examinations. This reduced the sample to 256 patients (Fig. 1).

The gender distribution was 115 men (45%) and 141 women (55%). Cause for treatment and gender and age distribution of the patients are shown in Table I and Fig. 2, respectively.

Table I. Causes of endodontic therapy

Cause of treatment	*Number of patients*
Penetrating decay	184
Restorative procedure	40
Technical reasons	21
Varied reasons	11
Total	256

Patient consent

Patients identified as suitable for the trial were asked to give their consent to be involved. A detailed explanation of the purpose of the study was given. It was further explained that both treatments were regularly used in dental practices and would not generate any additional risks or adverse sequelae beyond those normally occurring during and after endodontic treatment.

Patients were also informed about the confidentiality of the data to be collected. In addition, they were told that participation was entirely on a voluntary basis. As part of their commitment to the study, each patient was asked to assess the degree of pain they could potentially experience 1 week after each treatment. In addition they were requested to be available for the necessary recall appointments.

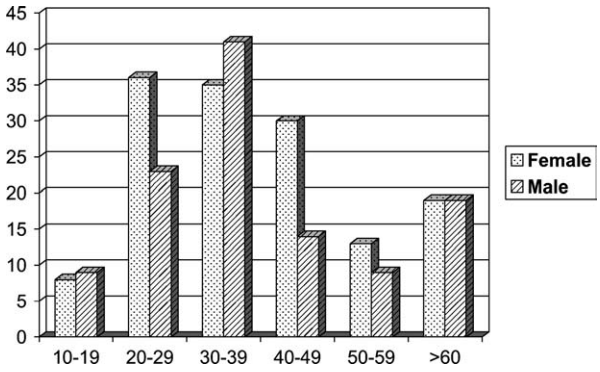

Fig. 2. Distribution of the patient material by gender and age. Number of patients is given on the y-axis and age groups on the x-axis.

Allocation to treatment group

Patients were enrolled in the study consecutively as they appeared in the dental offices. By a simple randomization procedure (toss of a coin) patients were allocated either a calcium hydroxide interappointment dressing (2-step treatment group) or a 1-step treatment procedure. The latter included completion of instrumentation and root canal filling in one and the same session (see further below). If sufficient time was available, the assigned treatment was completed in the very same session. If not, patients were asked to reappear for completion of the treatment protocol within 1 week after having received a pulpotomy and a temporary restoration. This applied to symptomatic as well as nonsymptomatic patients where caries excavation had resulted in a pulpal exposure. Five patients were subjected to this measure, of which 3 were assigned 1-step treatment and 2 2-step treatment. In all these cases, recording of the preoperatory pain condition was taken at the first visit.

The randomization procedure assigned 126 patients to the 2-step group and 130 to the 1-step group. No substratification of the patient material—eg, on tooth number, age or gender of the patients—was carried out.

In patients having more than 1 tooth available for the study, only 1 was selected by random. This applied to 2 patients. The distribution of the allocated procedures by tooth number is given in Table II.

Table II. Distribution of teeth by tooth type in the 2 treatment groups

	One-step group	*Two-step group*
Maxillary teeth		
Central incisors	4	2
Lateral incisors	5	1
Canines	8	9
First premolar	11	14
Second premolar	22	15
First molar	22	21
Second molar	8	8
Third molar	0	0
Total	80	70
Mandibular teeth		
Central incisors	0	0
Lateral incisors	0	0
Canines	0	3
First premolar	1	5
Second premolar	9	2
First molar	15	25
Second molar	19	21
Third molar	6	0
Total	50	56

Endodontic treatment procedures

At the first visit, and in most instances, at the second appointment, patients were anesthetized with mepivacain (Carbocain; Astra, Södertälje, Sweden) administered when appropriate with or without vasoconstrictor. Before initiating the endodontic treatment, caries, deposits of plaque, and calculus as well as defective restorations were meticulously removed. In order to ensure an aseptic field of operation in teeth with grossly destroyed tooth structure either a copper band fixed with zinc phosphate cement or a temporary glass-ionomer restoration was placed to restore the defect. All teeth were isolated with a well sealed rubber dam disinfected with 30% hydrogen peroxide and 5% iodine tincture according to the protocol advocated by Möller.[20] After accessing the canals, another wash with 5% iodine tincture was undertaken.

All subsequent procedures were carried out with sterilized instruments and maintenance of a careful aseptic technique. A standardized protocol for canal instrumentation was employed using the balanced force technique[21] and hand instrumentation with flexo-files (Maillefer, Baillagues, Switzerland). The crown-down concept was followed by first enlarging the coronal 2/3-3/4 of the canal with Gates-Glidden burs. With the aid of a trial file radiograph, the working length was established to within 0.5-2 mm from the radiographic apex. Canals were prepared to working length and to a size ISO 30 or larger, but in no case exceeding ISO size 60.

During all instrumentations, canals were repeatedly irrigated with large amounts of 3% nonbuffered sodium hypochlorite. In all cases instrumentation was completed during the first visit.

Two-step procedure

The instrumented canals were filled with calcium hydroxide (DT temporary dressing; Dental Therapeutics,

Saltsjö-Boo, Sweden) by the use of a Lentulo spiral. Access cavity was closed with a temporary filling material (Coltosol; Coltene/Whaledent, Altstätten, Switzerland) until the second treatment session to take place within 1 week. Prior to final root canal fill (see below) the temporary dressing was meticulously removed and the root canals irrigated with NaOCl and hand instrumented.

Root-filling procedure

Standardized master cones (Inline, BM Dentale, Torino, Italy) and nonstandardized accessory cones (DeTrey Dentsply, Konstanz, Switzerland) were employed for final root canal filling using lateral condensation. A zinc-oxide−eugenol based sealer was used (Pulp Canal Sealer; Kerr Co, Romulus, Mich).

A master cone 2 sizes larger than the file size used for the apical preparation was selected. The tip of this cone was dipped for a few seconds in chloroform, inserted in the canal, and adapted to the working length and the apical canal configuration. The master cone was then removed from the canal, coated with a small quantity of sealer and reinserted to the established working length. The remaining part of the canal was filled according to the lateral condensation technique. A permanent restoration was normally completed immediately after the completion of the root filling or within 1-2 weeks.

Clinical assessments

To make sure that all teeth included in the study had a vital pulp condition, bleeding upon access of the pulpal chamber was recorded. If not, the case was excluded from the study.

Prior to initiation of treatment and at each subsequent treatment or recall session, patients were asked to assess their pain experience. A verbal rating scale (VRS) graded 0-3 was used. Patients were asked to designate 0 for no, 1 for mild, 2 for moderate, and 3 for severe pain. Teeth were also tapped for percussion sensitivity. If the treated tooth displayed increased sensitivity in comparison to neighboring teeth, it was designated percussion sensitive.

Follow-up

Patients were asked to return for clinical examination 1 week after completion of the root filling and then annually for 3 years. At the annual follow-up, both clinical and radiographic assessments were carried out. Clinical assessments included test for percussion sensitivity. Furthermore, the soft tissue was carefully inspected and the alveolar areas over the roots was palpated to reveal signs of inflammatory process.

Radiographic technique and analysis of radiographs

Preoperative, final fill, and recall radiographs were taken using a Rinn XCP film holder (Rinn Corp, Elgin, Ill). The focus-object distance was 20 cm and the voltage 70 KV. Kodak Ultraspeed film 31 × 41 (DF58) or 22 × 35 (DF54) (Eastman Kodak Co, Rochester, NY) was used and developed according to the manufacturer's instruction. During the endodontic treatment, working-length or master-cone images, when appropriate, were obtained by freehand.

Two endodontists, well experienced in radiographic assessment of endodontic treatments, neither of whom was the operator and both masked to the assigned treatment group, carried out the analysis of the radiographs. Both preoperative radiographs and radiographs taken immediately after treatment and at recalls were examined for presence of osteolytic lesion. The root fillings were also assessed with regard to length and density (see further below).

Calibration of examiners. To calibrate the examiners prior to the examination of the study material, 50 radiographs different from the study material were chosen from the practices. Radiographs were selected to represent cases with and without root fillings as well as with and without periapical radiolucencies.

These radiographs were evaluated on slide copies of the originals in a room with dimmed light. Each slide was placed in a slide projector and projected onto a screen under a linear magnification of ×25.

The radiographs were assessed jointly until a consensus was reached. Parameters were presence or absence of periapical radiolucency (radiographic lesion), density, and length of root filling. Periapical lesion was regarded as present when there was a distinct radiolucent area associated with the apical portion of the root (Fig. 3, *D* and *E*). Two categories were used for absent lesion: normal periapical condition or unclear apical condition (widened apical periodontal space or diffuse lamina dura). In 2- or multirooted teeth, the tooth was classified according to the diagnosis of the worst root.

Root fillings were categorized with regard to length in relation to the radiographic apex and the extent to which they had properly filled the instrumented canals. Groups of length determination were 0-2 mm, > 2 mm from the radiographic apex, and overfill. Overfill was defined as an obvious extrusion, even small, of root filling material either beyond the apical contour of the root or within the confines of the image of the root. The designation of the latter type of overfill was based on the appearance of diverging root filling material. A multirooted tooth was categorized as overfilled even if other roots were filled short or to within 0-2 mm.

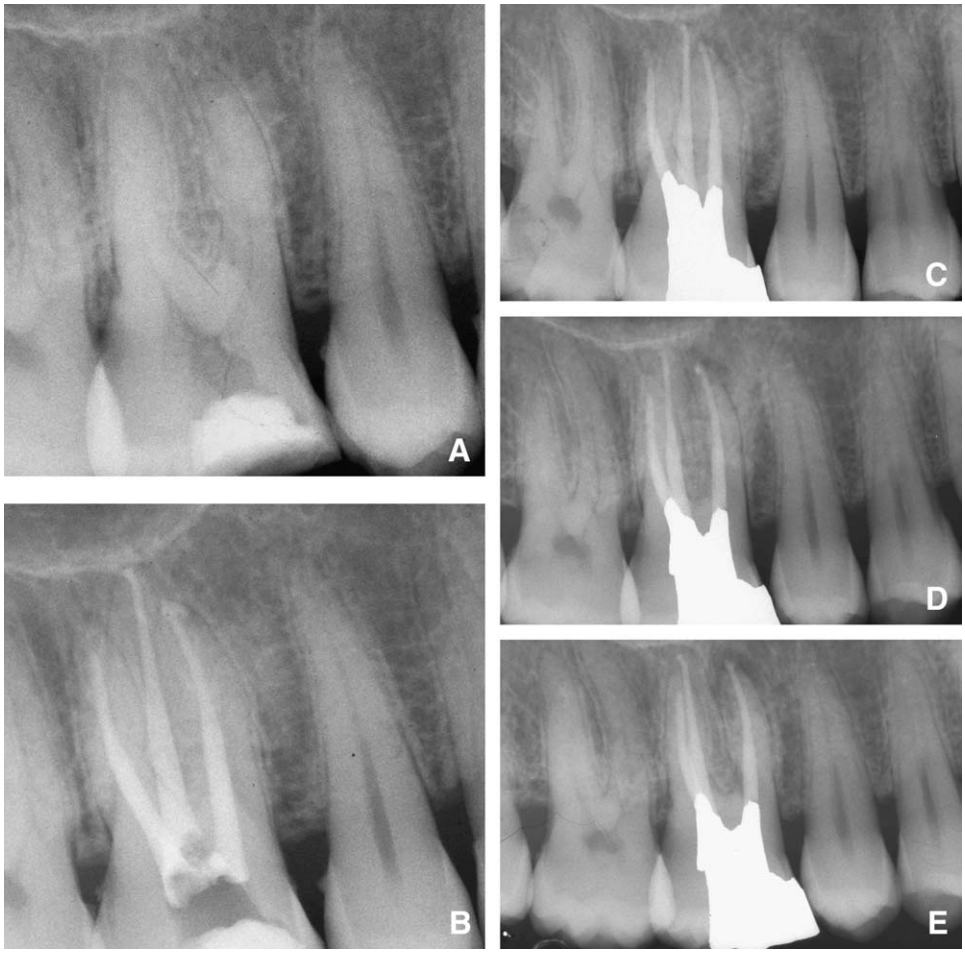

Fig. 3. Demonstration of a case with development of postoperative periapical lesion. **A**, Preoperative radiograph. **B**, Immediate postoperative check. Note presence of a small overfilling on the mesial root. **C**, One-year follow-up. A small radiolucency is seen on the mesial root. **D**, Two-year follow-up. Presence of radiolucency of a larger dimension than in *C*. **E**, Three-year follow-up. Lesion appears manifest.

Density of the fills was deemed adequate when there were no discernible voids or lateral spaces to the root canal walls in the apical 1/3 of the root. When root fillings did not fulfill these criteria and/or if there was an obvious space apical to the root filling indicating underfill, filling was considered inadequate. In multirooted teeth with overfilling or inadequate fill of only 1 of the roots, the tooth was categorized as inadequately filled. The radiographs were examined twice, 5 months apart, and a measure of agreement between the 2 examinations was assessed according to kappa statistics.[22]

Cross-tabulation of the recordings at the 2 examinations showed a kappa value of 0.96 for the presence or absence of periapical lesion. A total of 20 lesions were identified at the first examination, of which 19 were seen at the second examination. Recording of length of root fillings reached a kappa value of 0.83. The assessment of root filling density reached $\kappa = 0.48$. Only 3 teeth were seen with inadequate root filling density, of which 2 were not recorded at the second examination.

Analysis of the radiographs belonging to the study material. All radiographs belonging to the study material were digitalized with a scanner (Epson 1240) at a resolution of 800 dpi and saved in the JPEG format. The images were evaluated on a 17-inch computer monitor. Using Adobe Photoshop, brightness and contrast were optimized when needed.

Radiographs were given a code number to conceal the treatment procedure assigned. For each case, however, each phase of the treatment and recalls were made known to the examiners as well as the time sequence. Beyond giving each tooth a recording, according to the criteria established, individual roots of multirooted teeth were evaluated as well, but only when apices were clearly discernible. Radiographs were accepted only if they were with proper angulation, properly processed,

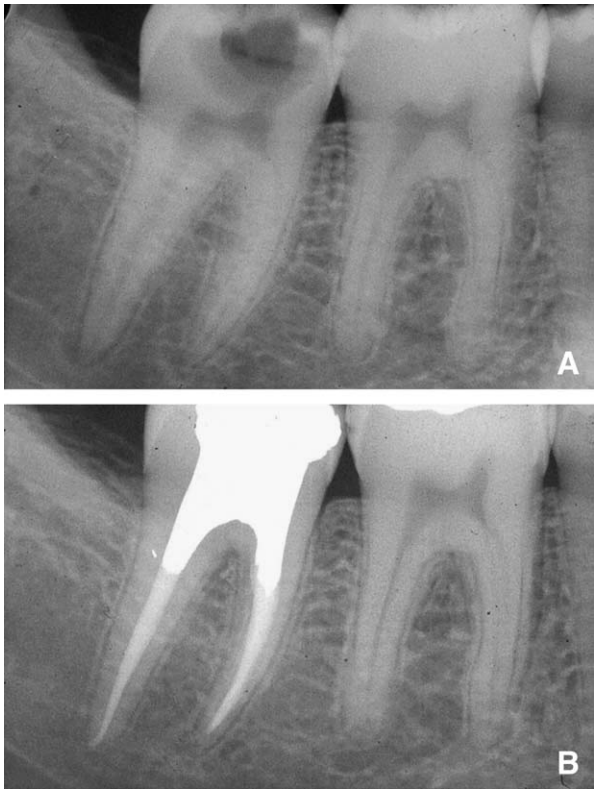

Fig. 4. Preoperative (**A**) and 2-year postoperative (**B**) recall radiographs of tooth #31. A small radiolucency was present preoperatively on the distal root.

and with bone tissue included below or above the root apices.

Statistical analysis

Raw data were entered onto a spread-sheet, and analyses of frequencies and statistical comparisons as to outcome parameters (periapical lesion at follow-up, pain, and percussion sensitivity at recall) between the 1-step and the 2-step group were carried out. The *t* test and the Mann-Whitney test were used for continuous variables. Chi-square test and logistic regression analysis were performed for categoric variables.

RESULTS

Preoperative conditions

Clinical parameters. Two hundred four (80%) of the 256 subjects included in the study reported preoperative pain, of which the majority (84%) assigned either a VRS score of 2 or 3. Penetrating decay accounted for 75% of the painful conditions. A good number (23%) were associated with previous dental restoration.

Percussion sensitivity was noted in a total of 79 (31%) patients, of which 64 (81%) gave a simultaneous report of severe pain (VRS 3). The recording of this symptom was occasionally affected by a distinct degree of uncertainty, because neighboring teeth could also be percussion sensitive. Nearly as many patients with severe pain displayed no percussion sensitivity.

Table III. Postoperative pain and length of root filling. *1* = Root filling within the confines of the root canal and ending 0-2 mm off the radiographic apex; *2* = short filling <2 mm off the radiographic apex; *3* = overfill. Category 3 differed significantly from 1 and 2 (P = .000)

	1	*2*	*3*	*Total*
Pain	9	2	23	34
No pain	160	10	52	222
Total	169	12	75	256

Occurrence of periapical lesion. Small preoperative periapical radiolucencies were observed in 42 patients (16%) with an equal distribution on the 2 treatment groups (Fig. 4, *A*). No statistically significant association of these lesions could be observed with tooth type, cause of treatment, and presence of painful symptoms. The patients were significantly younger than those in which such lesions were not diagnosed (P = .003).

Immediate postoperative conditions

Root fillings. Even though an attempt was made to confine the instrumentation procedure and the subsequent root filling to the canal space, 75 (29%) of the 256 fillings resulted in overfilling in 1 or more roots. In most of these instances the overfilling was minor and had only resulted in small extrusion of what may have been sealer material. The distribution of overfilled teeth was similar among the 2 treatment groups. A small portion (n = 12) of the fillings were shorter than 2 mm off the apex.

Pain reports. All patients returned for postoperative controls. On this occasion patients were interviewed with respect to perceived pain, and percussion sensitivity was tested. For the patients in the 1-step group there was only 1 check, whereas the patients of the 2-step group were checked twice, 1 week apart.

A total of 25 patients reported some form of pain at the 1 week, of which only 1 patient gave a VRS of 2. All other patients reported mild pain (VRS 1). Thus, there was a distinct reduction of the number of patients in pain. Also, the pain intensity reported by the patients had been substantially reduced. Although there was a numerical difference (16 vs 9 for the 1-step and the 2-step groups) there was no statistically significant difference between the 2 treatment groups in this respect. Of the patients that initially sought treatment because of pain (n = 204) a total of 181 (89%) attained complete pain relief by 1 week after treatment.

In the 2-step group, more patients (n = 18) gave report of pain after final filling. Although some of these patients

Table IV. Display of 17 teeth identified in the material with radiographic lesion at the final recall. Preoperative and postoperative clinical features are given. Figures characterizing preoperative and postoperative pain relate to the VRS ratings. *A*, Adequate filling quality

	Case #	*Age of patient*	*Tooth #*	*Preop caries*	*Preop lesion*	*Preop pain*	*Filling quality*	*Filling length*	*Postop pain*	*Postop percussion*
1*	15	30	30	No	Yes	3	A	1	0	1
2	85	61	03	Yes	No	2	A	3	1	1
3	106	44	14	No	No	1	A	3	0	1
4	108	27	15	Yes	Yes	2	A	1	0	0
5	122	23	14	Yes	Yes	3	A	1	0	1
6	140	60	14	No	Yes	2	A	3	1	1
7	205	17	03	Yes	No	3	A	3	2	1
8	206	25	30	No	No	3	A	1	0	0
9	217	60	32	No	No	0	A	1	0	0
10	251	31	30	No	Yes	2	A	3	0	0
11	252	23	14	Yes	No	2	A	2	0	0
12	261	23	09	No	No	0	A	1	0	0
13	266	24	15	Yes	Yes	3	A	1	0	1
14	290	45	29	No	No	3	A	3	0	0
15	355	25	30	Yes	Yes	1	A	3	1	1
16	371	42	30	Yes	No	3	A	2	0	1
17	416	41	11	No	No	3	A	1	0	0

*Presence of lesion in both mesial and distal roots.

reported pain on both occasions, most patients experiencing pain after permanent filling were not experiencing pain at the 1-week check. There was no significant correlation between report of preoperative pain and occurrence of postoperative pain in either treatment group.

Postoperative pain as recorded on the last appointment, 1 week after permanent filling, was significantly associated with overfilling ($P = .000$) (Table III).

Percussion-sensitive teeth were recorded in 28% of the patients of the 1-step group and in 19% of the patients of the 2-step group at the 1-week check. The difference was not statistically different. The number of patients with percussion sensitivity did increase in the 2-step group after permanent filling and reached an equal number to those in the 1-step group. There was a statistically significant association between percussion sensitivity and overfilling ($P < .001$). No association was observed between postoperative pain and presence of preoperative lesion or preoperative percussion sensitivity.

Patients seen at follow-up visits

A total of 12 (5%) patients were never seen for any of the 1-3 year follow-up visits. It was not possible to explore the reasons because no answers were received to any of the telephone calls or written messages to these patients. Seven of the nonappearing patients were in the 1-step group and 5 in the 2-step group. In terms of tooth number and pre- and postoperative features (occurrence of pre- and postoperative pain, percussion sensitivity, and root filling status), no systematic differences were found between the treatment groups.

Of the remaining patients some (5%) were seen only at the first follow-up at 1 year, and for 72% of the patients 3-year follow-up data were obtained. For 230 patients (90%) there were either 2- or 3-year recalls or both.

After the first year, 1 tooth had to be extracted owing to root fracture and 2 patients had moved from the area and were not available for further follow-ups. After the second year, 2 patients were deceased. One tooth, because of pain and signs of acute apical periodontitis, was retreated after the second-year check. From that point this patient was eliminated from the study.

Observations at endpoints of follow-up

Periapical lesions and clinical symptoms. A total of 17 patients (7% of the total number of followed subjects) presented with periapical lesion at the last follow-up visit. These lesions were evenly distributed between the 2 treatment groups, with 9 in the 1-step group and 8 in the 2-step group. For 9 of these patients the cause of endodontic treatment had been penetrating caries and for 6 restorative procedure. In the remaining 2 cases technical reason and crown fracture were the causes for endodontic intervention.

In 13 of the patients the osteolytic lesions were observed at the first follow-up. Eight of these teeth were identified at the 1-year recall, 4 at the 2-year recall, and 1 at the 3-year recall. In 2 instances a periapical lesion was seen at the 2-year recall which was not visible at the 1-year recall. In 2 instances the lesion was seen for the first time at the 3-year recall and not identified at the previous observations. Clinical features associated with these cases are outlined in Table IV.

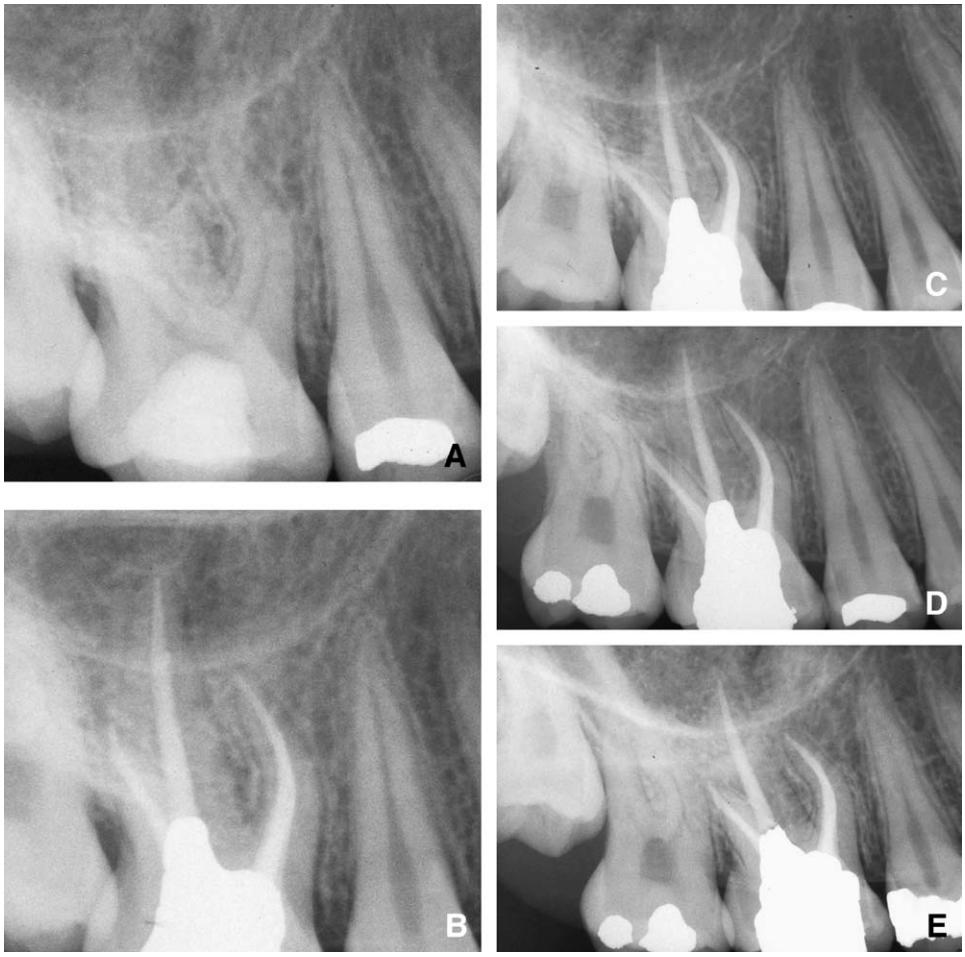

Fig. 5. Sets of preoperative (**A**) and postoperative (**B-E**) radiographs of a successfully treated tooth #03. **B**, Postoperative control. **C**, one-year follow-up. **D**, Two-year follow-up. **E**, Three-year follow-up.

Five patients presented with pain and percussion sensitivity at the last follow-up. Three of these cases belonged to the 1-step group and 2 to the 2-step group. These teeth had developed periapical lesion.

On associating postoperative lesion to root level it was noted that mesial roots of mandibular molars and mesiobuccal roots of maxillary molars were the most commonly affected. Of a total of 18 separate lesions, 12 were seen with either the mesial root of lower molars (n = 5) or with the mesiobuccal root of upper molars (n = 7). Three other lesions were also with molars whereas single-rooted premolars and incisors were affected in 3 instances.

Root filling appearance. Excess fills recorded immediately postoperatively disappeared in 23 patients (31%). In this respect there was no significant difference between treatment groups ($P = .123$) On examining the material on a root level, excesses disappeared in 33 (38%) of the initially recorded roots with overfills. There was not a statistically significant association between presence of overfilling and osteolytic lesion at the endpoint of recall.

DISCUSSION

The character of the dental practices employed to recruit patients may explain the fact that pain symptom was a dominating reason for treatment. None of these practices were referral practices in a true sense, although many patients were referred because of acute pulpitis. Most often, caries was the cause. Prior restorative procedure also contributed to a good number of the painful teeth enrolled in the study. It should be recognized that caries-preventive programs are not common in Italy[23] and most patients may only seek dental care when in pain. This condition may explain why the mean age of the patients was quite low, with the large majority of the patients being between 20 and 40 years of age.

A surprisingly high number of the cases displayed preoperative periapical radiolucency (16%). Clearly,

periapical bone lesion is not normally recognized as a diagnostic feature of an inflamed pulp. Although localized abscess formations in pulpitis cases may drain off upon entry to the tissue, such lesions are generally confined and localized to the area of injury and bacterial challenge,[24] and rarely is the apical portion of the pulp involved.[6,25] Yet the small radiolucencies identified in some of the teeth cannot be attributed to misdiagnosis of the pulpal condition, because bleeding tissue upon access was invariably confirmed. As a matter of fact, small periapical radiolucencies on teeth with vital but inflamed pulps have been seen in several other studies, although the incidence is not well established. In their material of 270 teeth treated with pulpectomy, Grahnén and Hansson[26] had 20 cases (7%) with widened or diffuse periodontal contour, 2 with "nonresorptive osteitis," and 1 with "resorptive osteitis." Kerekes and Tronstad[27] observed a similar ratio in their material of 260 treated roots. Lin et al.[25] saw, in a histologic study of 75 cariously involved teeth, that pulps associated with small periapical radiolucency, though responding to pulp testing, displayed slight areas of necrosis in the coronal pulp. Other studies have noted that radiographic lesions associated with vital pulps of teeth with deep caries may resolve following "indirect pulp capping."[28,29] Jordan et al.[29] reported that they had 24 cases with apical radiolucency, of which 11 healed subsequent to this kind of treatment. These cases, similar to those in the present study, were most often in young patients aged 11 to 24 years.

The results demonstrated that most teeth with preoperative pain symptoms became nonsymptomatic with either treatment mode. In fact, of patients initially seeking treatment because of painful pulpitis nearly 90% became asymptomatic 1 week after treatment. Of those who continued to be symptomatic, the pain felt was generally of a slight nature. This finding confirms the results of several other studies[30-34] and substantiates the view that pulpectomy is effective in attaining pain relief in pulpitis cases.

It is interesting that the number of patients experiencing pain increased after final root filling in the 2-step group. A common denominator for lingering or emerging painful teeth in both treatment groups was overfilling (Table III). The finding that 13 patients, who reported no pain after dressing with calcium hydroxide, experienced postoperative discomfort after final filling is an illuminating example. In 11 of these cases there was evidence of overfilling. With respect to percussion sensitivity there was a similar pattern. Collectively, these findings indicate that extrusion of root canal content in conjunction with the filling procedure (whether infectious or not), and in combination with the irritating effect of the filling material, may at least temporarily cause postoperative discomfort after pulpectomy. Consequently, for this reason a safety distance of 1-2 mm off the radiographic apex for instrumentation and filling seems reasonable. For years this concept has remained firm and has been recommended in numerous texts.[35-38]

The overall recall rate was satisfactory and in line with those reported in other studies.[27,39] For a 1-year follow-up 95% of the patients could be seen, but more importantly 90% of the patients were followed up for either 2 or 3 years or both.

An obvious conclusion of the findings is that regardless of treatment protocol (1- vs 2-step treatment) pulpectomy may be carried out at a very high rate of success (Fig. 5), confirming data of previous reports.[27,40] This applied to patient satisfaction in terms of attaining pain relief in both the short and long term. It also applied to the more objective outcome parameter of low periapical lesion development. In fact, in 93% of the patients treatment objectives were met for both treatment groups. Consequently, no support was gained in this study for the need of calcium hydroxide as an interappointment dressing after pulpectomy.

Although having masked observers reduced the risk for biased interpretations, some caution is warranted on making generalizations from the data. While providing high internal validity, only 1 operator carried out the treatments. Also, no stratification was carried out on covariables. No significant influence on outcome, however, was observed for factors such as preoperative pain, preoperative radiographic bone lesion, gender, tooth number, age, and cause of treatment. Yet molar roots, especially the mesiobuccal root of upper molars and mesial roots of lower molar, appeared overrepresented among the cases showing lesion at endpoint. This condition is likely to be explained by the greater difficulty to technically manage these roots, especially with stainless steel hand instruments as used in the current study. Modern rotary instrumentation techniques may more effectively shape and prepare root canals for proper cleaning, disinfection, and filling than hand instrumentation techniques are likely to.

The findings also demonstrated that length of filling did not impact the long-term outcome, contrary to many previous reports.[26,27,39,41-44] Though overfilling was significantly associated with increased rate of pain and percussion sensitivity in the immediate follow-ups in comparison with nonoverfilled teeth, this parameter did not prevail as a significant factor.

Several follow-up studies have reported reduction or disappearance of overfills over the course of time,[41,45,46] and especially small overfills may be rapidly eliminated.[45] This was also noted in the present study.

On the basis of the results obtained it seems reasonable to conclude that single-session pulpectomy

may be carried out successfully if strong emphasis is given to an aseptic operating protocol and proper instrumentation and filling. Under these conditions there seems to be no added benefit of an interappointment dressing with calcium hydroxide.

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Reprint requests:

Gunnar Bergenholtz
Faculty of Odontology
Box 450
S-405 30 Göteborg
Sweden
gunnar.bergenholtz@odontologi.gu.se