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DENTAL TRAUMATOLOGY

# Conservative endodontic treatment of teeth fractured in the middle or apical part of the root

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Abstract – According to treatment type, root-fractured teeth with pulp necrosis or exposed pulps were divided into five groups, group 1: 17 teeth in which the root canal of the coronal fragment only was filled with gutta-percha (GP); group 2: seven teeth in which the root canals of the coronal and apical fragments were both filled with GP; group 3: 19 teeth in which the coronal fragment was filled with GP and the apical fragment was surgically removed; group 4: 68 teeth where the root canal of the coronal fragment was treated with calcium hydroxide and subsequently filled with GP; and group 5: five vital teeth with root and concomitant crown fractures in which the exposed pulps were treated by partial pulpotomy. The frequency of periodontal healing was 76% in group 1, zero in group 2, 68% in group 3 and 86% in group 4. Compared with groups 1 and 2 combined, healing in group 4 was significantly more frequent. In groups 1, 2 and 4, failures occurred significantly more often in teeth showing overfilling, i.e. protrusion of GP into the space between the fragments, compared with teeth without overfilling. All five teeth in group 5 showed healing. It was concluded that root canal filling with GP of the coronal fragment only, with or without surgical removal of the apical fragment, can be successful in selected cases. Treatment of the root canal with calcium hydroxide followed by GP filling appears to be the treatment of choice in root-fractured non-vital teeth. Partial pulpotomy of exposed pulps in five teeth showed results similar to root-unfractured teeth with pulp exposure treated with this technique.

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Key words: calcium hydroxide; endodontics; pulp necrosis; root fracture

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In 1958, Lindahl (1) observed that root fractures could heal even after endodontic treatment of the tooth. Basically, four types of conservative endodontic treatment have been described: cleansing and gutta-percha (GP) filling of the root canal of the coronal fragment only; cleansing and filling of the root canal in both fragments; cleansing and GP filling of the root canal of the coronal fragment and surgical removal of the apical fragment; and treatment of the root canal with calcium hydroxide followed by filling with GP (2–4). In 1971, Andreasen (5) reported healing of root fractures in nine of 14 teeth after treatment and root canal filling of either just the coronal or of both fragments with GP. More extensive studies of these types of treatment are lacking. In 1967, Andreasen and Hjörting-Hansen found that necrosis of the pulp usually occurs only in the coronal fragment, while the pulp of the apical fragment remains vital (6). This finding provided a basis for testing calcium hydroxide in the treatment of non-vital coronal root canal fragments, by analogy with the treatment of non-vital immature teeth (7). Such treatment was intended to achieve periradicular healing and formation of hard tissue that closed the canal apically and acted as a barrier against which the filling with GP can be adequately performed. This was reported to happen with a high frequency in two studies (4, 8) and subsequent confirmation has been provided in a number of case reports (9–16). However, all the reports comprise a limited number of teeth and no comparisons with other types of treatment have been presented. It appears that more comprehensive comparative studies are needed before a clear opinion on conservative endodontic treatment of root-fractured teeth can be formed.

The purpose of the present study was, therefore, to assess the effects of various treatment methods on the periradicular healing of non-vital root-fractured incisors and, regarding the calcium hydroxide treatment, on the formation of a hard-tissue barrier at the apical end of the root canal of the coronal fragment. Furthermore, the aim was to assess the outcome of partial pulpotomy of exposed vital pulps of root-fractured teeth.

## Material and methods

The original material consisted of 127 root-fractured non-vital incisors treated at the Department of Paediatric Dentistry, Eastman Dental Institute, Stockholm, between 1955 and 1994. From this material 29 teeth were excluded: in 21 the pulp had been removed immediately after the injury and in eight the endodontic treatment had been considered of no value because the fracture was situated in the cervical part of the root (17). This selection left 98 non-vital incisors in 95 patients, aged 11–20 years (mean = 13.6 years), with 69 root fractures in the middle part and 29 in the apical part of the root. In addition, five mature teeth with root fracture and a concomitant fracture of the crown with an exposed vital pulp were included in the material.

According to the type of treatment, the teeth were divided in five groups:

### Group 1

Seventeen teeth in which the root canal of the coronal fragment only was cleaned biomechanically and then filled with GP. The fracture was located in the apical part of the root in 14 of these teeth and in the middle part in the remaining three.

### Group 2

Seven teeth in which the root canals of both the coronal and the apical fragments were cleaned biomechanically and filled with GP. In six of these teeth the fracture was located in the middle part of the root and in one in the apical part.

### Group 3

Six teeth that had been treated shortly after injury and 13 teeth that had been re-treated after previous treatment had failed: three, five and five teeth from groups 1, 2 and 4, respectively. In general, the treatments had been performed at two appointments. During the first, the root canal in the coronal fragment had been cleaned and filled with GP. At the second, access through the alveolar bone to the site of the root fracture had been prepared, after which the apical fragment together with granulation tissue and any excess GP had been removed. In the eight teeth, previously treated antibacterially and filled with GP, surgical treatment including cleaning of the fracture site and removal of the apical fragment, was performed in one sitting.

### Group 4

Sixty-eight teeth in which only the root canal of the coronal fragment had been cleaned biomechanically and then filled with calcium hydroxide, while the apical fragment had been left untreated.

After periradicular healing and formation of a hard-tissue barrier apically in the root canal of the coronal fragment had been observed in the radiograph, the coronal fragment had been permanently filled with GP. The fracture was located in the middle of the root in 52 of these teeth and in the apical part in the remaining 16.

### Group 5

Five vital teeth suffering from both a root fracture and a complicated crown fracture. The exposed vital pulps had been treated by partial pulpotomy (18). Briefly, the treatment involved removal of superficial layers of the exposed pulp and surrounding dentin to a depth of about 1.5–2 mm. The superficial layers were cut intermittently at short intervals, using high-speed equipment, a diamond bur and continuous cooling with water spray. Thereafter, the pulp wound was covered with calcium hydroxide and the created cavity was sealed with zinc-oxide eugenol cement.

### Clinical and radiographic data

The clinical and radiographic status of the teeth at the time of treatment is presented in Table 1. The status was recorded from the patients' files and radiographs. The files were examined with regard to

Table 1. Clinical and radiographic status of 98 root-fractured teeth at the time of treatment, distributed according to type of endodontic treatment: 1, coronal fragment filled with gutta-percha (GP); 2, both fragments filled with GP; 3, coronal fragment filled with GP, apical fragment surgically removed; and 4, coronal fragment treated with calcium hydroxide and subsequently filled with GP

| | Treatment group | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | Total |
| Clinical status | | | | | |
| Discolored tooth crown | 15 | 6 | 5 | 59 | 85 |
| Negative sensibility | 7 | 7 | 6 | 66 | 86 |
| Pulp necrosis* | | | | | |
| Coronal fragment | 14 | 4 | 3 | 68 | 89 |
| Both fragments | 3 | 3 | 3 | | 9 |
| Radiographic status | | | | | |
| Root development | | | | | |
| Immature root | | | | 5 | 5 |
| Mature root | 17 | 7 | 6 | 63 | 93 |
| Fracture position | | | | | |
| Middle part of root | 3 | 6 | 6 | 52 | 67 |
| Apical part of root | 14 | 1 | | 16 | 31 |
| Periradicular | | | | | |
| No pathologic changes | | | | 2 | 2 |
| Widened, diffusely outlined periodontal space | 2 | 1 | | 16 | 19 |
| Radiolucency at | | | | | |
| Fracture site | 15 | 6 | 6 | 50 | 77 |
| Periapical | | | 3 | | |
| Increased diastasis between fragments | 12 | 3 | 6 | 41 | 62 |
| Number of teeth | 17 | 7 | 6 | 68 | 98 |

*Clinical diagnosis at the time of treatment.

clinical symptoms such as discoloration of the crown and loss of pulp sensibility. Radiographs were studied with respect to root development, increased diastasis between the fragments and any pathologic periradicular findings. Eight teeth exhibited immature roots: five in group 4 and three in group 5. Root development was complete in the remaining teeth. Pulp necrosis had been diagnosed and endodontic treatment initiated on the basis of a combination of clinical and radiographic findings in all but two teeth, for which endodontic treatment had been performed on the basis of clinical symptoms only. At the time of treatment the teeth in group 5 showed, besides the pulp exposure, no clinical or radiographic pathologic symptoms 3–12 h after the injury.

Pulp necrosis had been diagnosed and endodontic treatment performed within 3 months after the injury in all but two teeth, for which the patients had missed routine controls and the diagnosis had been made 13–16 months after injury. In five teeth with a previously healed root fracture (one in group 1 and four in group 4), a new injury with luxation of the coronal fragment resulted in pulp necrosis.

Regarding the treatments, the files were examined with respect to the drugs used for mechanical cleansing and antibacterial treatment of the root canal before this was filled with GP or calcium hydroxide. In general, antibacterial drugs were placed in the root canal once to three times except for two teeth in group 3, in which the root canals were dressed six and nine times, respectively, with a formaldehyde-containing drug. The root canals of all teeth were filled with GP using the lateral condensation technique and a sealer; either chloropercha (19) or resin-chloroformium. The drugs used are listed in Table 2. In group 4, calcium hydroxide was placed in the root canals once to seven times (mean = 2.5) at intervals of 4–8 months.

In the material as a whole, clinical and radiographic follow-ups after the initial treatments ranged from 13 to 144 months (mean = 66 months). At the end of the control time, healing was considered to have occurred when the radiograph showed a periodontal space of normal width surrounded by a periradicular lamina dura. Healing in group 4 was evaluated at the end of the calcium hydroxide treatment and at the final control of the subsequent root-canal filling with GP. At the end of the treatment with calcium hydroxide, the closure of the root canal apically with hard tissue was rated as complete or partial. Healing in group 5 was considered to have taken place if there were no clinical symptoms, the exposure site was walled-off by hard tissue and no periradicular changes were present radiographically. Healing was said not to have occurred if the radiographs showed persistent or new periradicular radiolucency.

The radiographic assessments were made by one of the authors (MC) and the other two authors

Table 2. Cleansing drugs and antibacterial treatment and sealers used for root canal filling with gutta-percha (GP), distributed according to type of treatment: 1, GP filling of coronal fragment only; 2, GP filling of both fragments; 3, GP filling of coronal fragment, surgical removal of apical fragment; and 4, treatment of coronal fragment only with calcium hydroxide and subsequent filling with GP

| | Treatment group | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | Total |
| Cleansing | | | | | |
| Saline | 2 | 1 | 1 | 63 | 67 |
| Biosept[1] | 10 | 2 | 3 | 1 | 16 |
| 0.5 or 5.0% Natrium hypochlorite solution | 5 | 4 | 2 | 53 | 64 |
| Antibacterial treatment | | | | | |
| 10% Choromycetin topical[2] | 16 | 4 | 1 | 7 | 28 |
| 3.0 or 5.0% Iodine potassium-iodide solution | 3 | | 1 | 2 | 6 |
| Tricresolformalin[3] | 3 | 1 | 5 | | 9 |
| Triolin[4] | 2 | 3 | | | 5 |
| Calcium hydroxide[5] | | | | | 68 |
| Sealers for filling with GP | | | | | |
| Chloropercha[6] | 17 | 7 | 5 | | 29 |
| 5% resin-chloroform[7] | | | 1 | 68* | 69 |
| Number of teeth | 17 | 7 | 6 | 68 | 98 |

[1]Recip, Stockholm, Sweden; [2]Parke Davis, Morris Plains, NY, USA; [3]Tricresolformalin: tricresol 10 g, solution formaldehyde 90 g; [4]Triolin: (glycerol 8.10 g, solution formaldehyde 1.78 g, phenol 1.74 g); [5]Calasept, Scania Dental AB, Knivsta, Sweden; [6]According to Nygaard Östby (19); [7]ATL-K Apoteksbolaget, Stockholm, Sweden.
*At filling with GP after calcium hydroxide treatment.

assessed every fifth case independently. In the event of disagreement, a consensus was achieved.

The statistical analysis was made with the chi-square test. The level of significance was set at 0.05.

## Results

The results for the four treatment groups are presented in the Tables 3 and 4.

### Group 1

Healing had taken place in 13 of the 17 teeth (76%.) Overfilling with GP between the fragments occurred in eight teeth and all the failures were found among these teeth. Three teeth showing no healing were given additional treatment: refilling of the root canal of the coronal fragment and surgical removal of the apical fragment. One tooth was extracted (Figs 1 and 2).

### Group 2

Filling of the root canal of both the coronal and the apical fragment resulted in an excess of GP between the fragments and the subsequent failure of all seven teeth (Fig. 3). Five teeth were given additional treatment: refilling of the coronal fragment and surgical removal of the apical fragment, and two teeth were extracted.

### Group 3

Combined endodontic and surgical treatment was followed by healing in 13 of the 19 teeth (68%),

Table 3. Frequencies of healing/no healing distributed according to three types of treatment: 1, cleansing and gutta-percha (GP) filling of coronal fragment only (17 teeth); 2, cleansing GP filling of both fragments (seven teeth); and 3, cleansing and GP filling of coronal fragment, surgical removal of apical fragment (19 teeth)

| | Treatment group | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Healing | 13 (76%) | 0 (0%) | 13 (68%) |
| No healing | 4 | 7 | 6 |
| Total | 17 | 7 | 19 |

Table 4. Frequencies of healing of 68 incisors after treatment with calcium hydroxide ($CaOH_2$) with complete or incomplete hard-tissue closure of the coronal fragment's apical opening in 59 teeth after filling with gutta-percha (GP) and in 65 teeth after combined $CaOH_2$-treatment and GP filling

| | $CaOH_2$ treatment | GP filling | $CaOH_2$ & GP |
|---|---|---|---|
| Healing | 60 (88%) | 57 (96%) | 56 (86%) |
| Complete closure | 41 | 40 | |
| Incomplete closure | 19 | 17 | |
| No healing | 8 | 2 | 9** |
| Total | 68 | 59* | 65 |

*Eight teeth with failed calcium hydroxide treatment and three teeth that could not be followed up after filling with GP are excluded. **One tooth showing no healing after completed $CaOH_2$treatment showed healing after filling with GP.

(Figs 2 and 3). Of the six teeth in which the treatment was judged to have failed, two also showed ankylosis radiographically and infraposition of the tooth clinically (Fig. 4); the dressing of the root canal with a formaldehyde-containing drug was carried out seven to nine times in these two teeth.

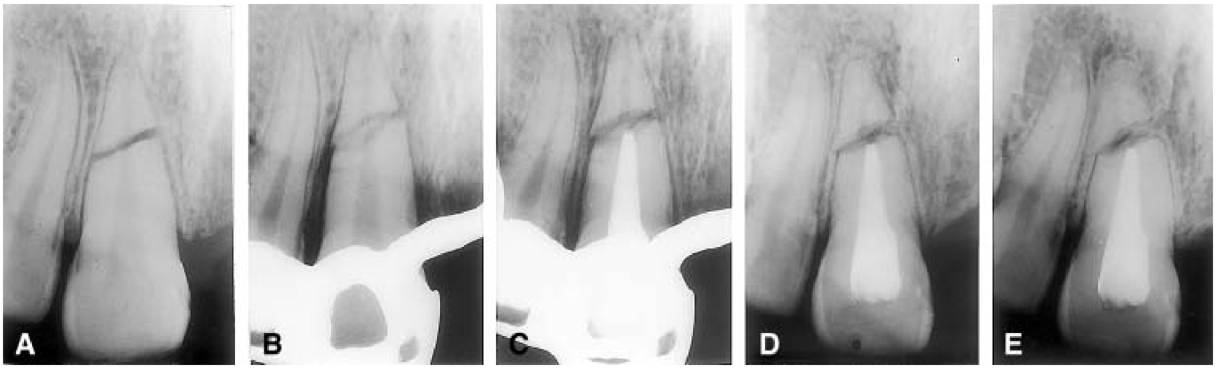


*Fig. 1.* (A) Status at the time of injury. (B) After 6 weeks; note radiolucency at the fracture site. (C) Root canal filling of the coronal fragment with gutta-percha. (D and E) Status after 4 and 6 years.


*Fig. 2.* (A and B) Status at the time of injury and after 4 months; note increased diastasis between the fragments and periradicular radiolucency adjacent to the fracture site. (C) Root canal filling of the coronal fragment with excess of gutta-percha in between the fragments. (D) Persistent radiolucency 12 months after root canal filling. At this time, the root canal treatment was revised and the apical fragment removed. (E) Periradicular healing 5 years after the revised root canal treatment and surgical removal of the apical fragment.

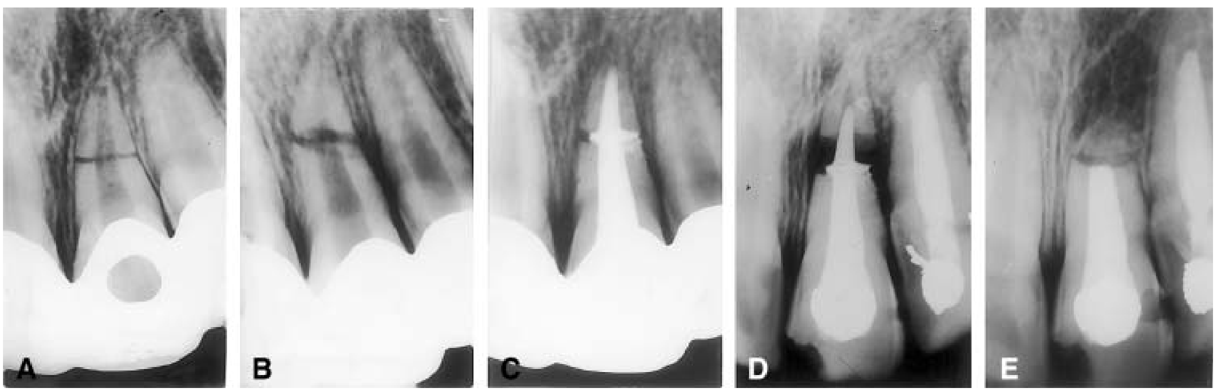


*Fig. 3.* (A) Status at the time of injury after splinting. (B) Radiolucency at the fracture site 4 months later. (C) Root canal filling of both fragments with excess of gutta-percha in between the fragments. (D) Eight months later; note widened diastasis between the fragments and increased radiolucency adjacent to the fracture site. At this time, the root canal treatment was revised and the apical fragment was surgically removed. (E) Periradicular healing 6 years after the revised root canal treatment.

All six of the teeth showing failures had been extracted; four because of persistent radiolucencies and increased mobility of the crown and two because of infraposition of the tooth.

### Group 4

Upon completion of the treatment of the coronal fragment's root canal with calcium hydroxide,

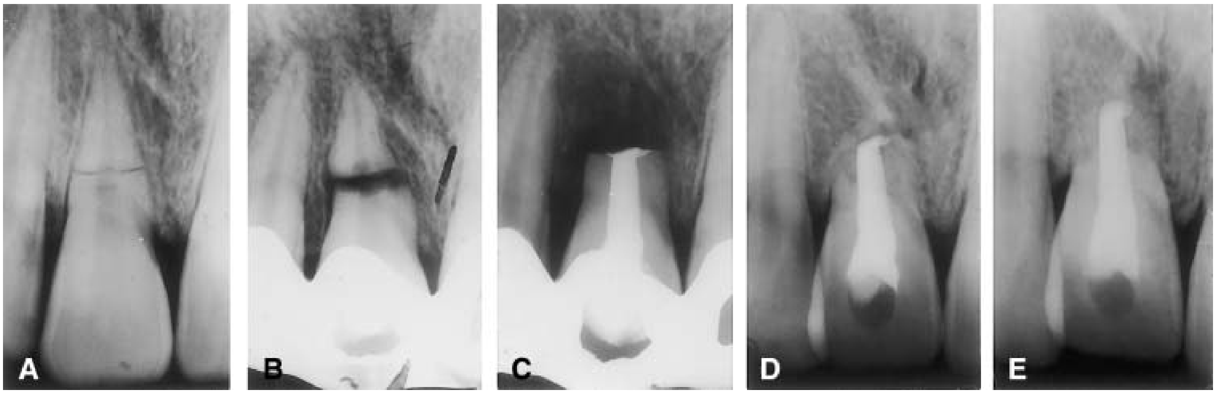


*Fig. 4.* (A and B) Status at the time of injury and 3 months later; not increased diastasis and radiolucency adjacent to the fracture. (C) Root canal treatment and surgical removal of the apical fragment. (D and E) Increasing external root resorption with ankylosis of the root and infraposition of the tooth.

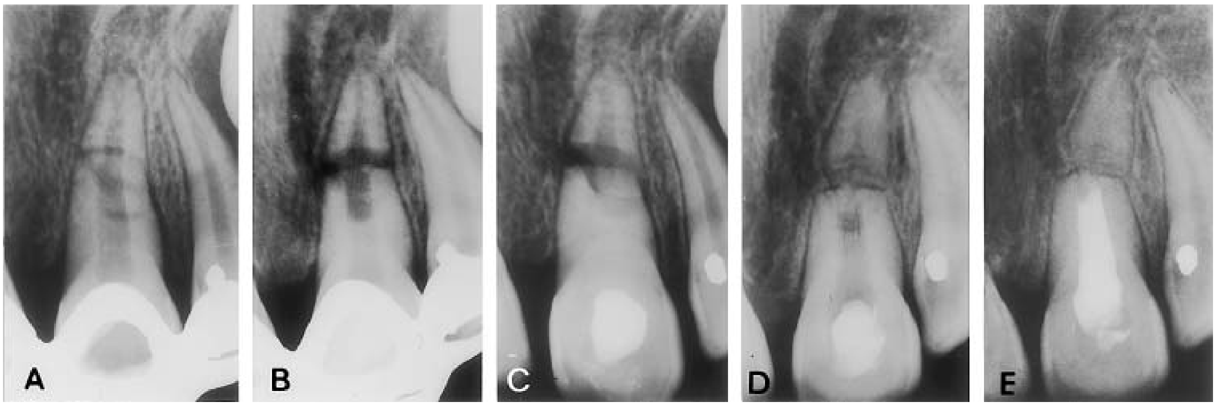


*Fig. 5.* (A) Status 6 weeks after injury and splinting; note the periradicular radiolucency adjacent to the fracture site. The root canal of the coronal fragment was treated and filled with calcium hydroxide. (B) Six months after the initial treatment and re-filling of the root canal; note the periradicular healing. (C) Clinical exploration of the continuity of the hard tissue barrier 16 months later. (D) Status at the time of root canal filling with gutta-percha and (E) status after 6 years.

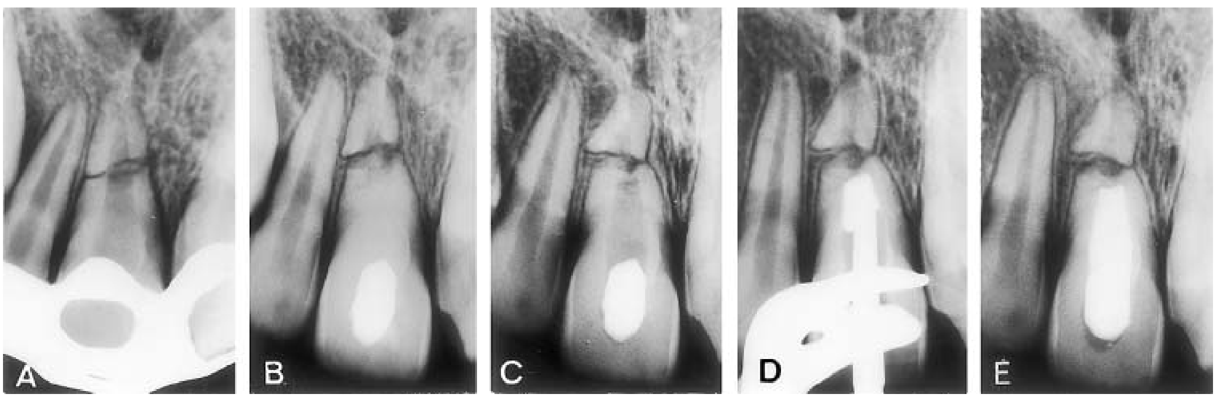


*Fig. 6.* (A and B) A tooth with a non-vital coronal fragment and a wide pulpal lumen treated with calcium hydroxide. (C and D) After 16 months; note formation of a hard tissue barrier against which an adequate filling with gutta-percha was performed. (E) Status after 6 years.

which lasted from 7 to 30 months (mean = 14 months), healing was observed in 60 of the 68 teeth (88%); in 41 teeth with complete and in 19 with incomplete closure of the apical part of the root canal (Table 4, Figs 5 and 6). Of the eight teeth exhibiting a failure, five had been additionally treated with GP filling of the coronal fragment and surgical removal of the apical fragment, two had been extracted and in one tooth the root canal had been filled with GP. Of the 19 teeth with incomplete hard-tissue closure, filling with GP resulted in protrusion of the material between the fragments in 13 teeth, of which two exhibited a new radiolucency during the observation time. One tooth that showed incomplete closure and no healing after calcium hydroxide treatment exhibited healing after filling with GP. Three teeth that could not be followed for more than 6 months after filling with GP were excluded from the final evaluation. Thus, of 68 teeth initially, 65 could be followed throughout the calcium hydroxide treatment and subsequent filling with GP. At the end of the observation period, 56 teeth (86%) showed healing (Table 4).

### Group 5

At the end of follow-up, all teeth showed healing of the pulp, walling-off of the exposure site with hard tissue and completed root development in two immature teeth (Fig. 7).

### Intergroup analysis

Because of the relatively small number of teeth in some of the groups and the nature of the treatments, healing frequencies were compared only for groups 1 and 2 vs. group 4; the results showed that healing in group 4 was significantly more frequent than in groups 1 and 2 ($P = 0.001$). Furthermore, for teeth filled with GP (groups 1, 2 and 4), a comparison was made of the frequencies of tooth healing with overfilling vs. no overfilling with GP. This revealed that failures occurred significantly more often if GP had protruded into the space between the fragments ($P < 0.001$).

## Discussion

Intra-alveolar root fracture is a rare injury in permanent teeth (0.5–7%) and among these teeth, the frequency of pulp necrosis is also relatively low (5– 25%), (20). Taking this into account, the present material can be considered comprehensive. Since 1974, calcium hydroxide has been the only treatment procedure for root-fractured non-vital teeth at the Department of Paediatric Dentistry at the Eastman Dental Institute in Stockholm. In order to include other treatment procedures in the study, it was necessary to extend the material back in time to treatments performed in the period 1955–73. This extension over several decades also reflects the changes that have taken place in the use of drugs for treating infected root canals. Thus, two of the failed teeth in group 2 also showed ankylosis of the root and infraposition of the tooth. In these teeth the root canals had been dressed seven to nine times with formaldehyde-containing drugs. In experimental series it has been found that high concentrations of formaldehyde in a dressing may increase the frequency of ankylosis in dog and rat teeth (21, 22). Corresponding studies in humans have not been reported. However, during preparations for a study in luxated teeth, it was observed that the frequency of ankylosis in teeth treated with formaldehyde-containing dressings was 10 times higher than in teeth treated with drugs that did not contain formaldehyde (23). It is therefore conceivable that repeated dressings with a formaldehyde-containing drug may have caused ankylosis of the two teeth in the present material.

The present results clearly show that in most of the teeth, pulp necrosis was confined to the coronal fragment, which is in accordance with the histological

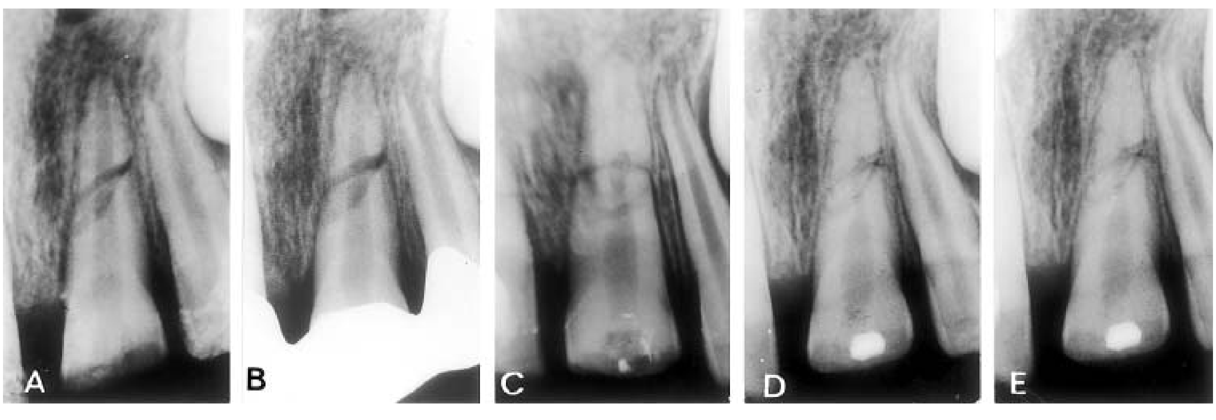


*Fig. 7.* (A and B) An intra-alveolar and concomitant crown fracture with exposure of vital pulp tissue. Before splinting the exposed pulp was treated by partial pulpotomy and the crown temporarily restored. (C) Exploration of the hard tissue barrier 4 months later. The hard tissue barrier was covered with calcium hydroxide and the cavity sealed with zinc-oxide eugenol cement. (D and E) Pulp and periradicular healing 3 and 7 years after the injury.

findings by Andreasen and Hjörting-Hansen (6). The periradicular radiolucency was also limited to the site of the fracture and extended changes including the apical fragment were seen only in five teeth.

Endodontic treatment and GP filling of the coronal fragment only or of both fragments of the root canal in fractured teeth seem to pose problems similar to the treatment of immature teeth. The wide root canal openings at the fracture site and the diastasis between the fragments make it difficult to achieve proper mechanical cleansing and adequate filling of the root canal without unintentional overfilling. Overfilling with GP *per se* was earlier found to have little or no influence on treatment results (24). In the present material, however, a close relationship was found between overfilling with GP between the fragments and the frequency of failures. It is possible that contaminated tissue between the fragments could not be removed in connection with filling or that residual infected material in the root canal was pressed out into the space between the fragments together with GP and consequently caused a persistent or new radiolucency (Figs 2 and 3). The fracture was situated in the apical part of the root in 14 of the 17 teeth in group 1. It is possible that the narrowness of the canal in this part of the root in mature teeth facilitated adequate filling. That could explain the relatively high frequency of healing of these teeth (76%), (Fig. 1).

The beneficial result of root canal treatment with calcium hydroxide was probably because of its antibacterial effect and its ability to promote the formation of a hard-tissue barrier at the canal's apical opening in the coronal fragment, thereby facilitating adequate filling with GP. The frequency of healing (86%) in the present material is similar to that reported for treatment of immature teeth without a root fracture (7, 25), i.e. healing after calcium hydroxide treatment and subsequent filling with GP. This may also indicate that a non-vital coronal fragment in root-fractured teeth should be regarded and treated as a non-vital immature tooth. The time and the re-filling of the canal with calcium hydroxide that are required to obtain these results may be seen as a drawback but at present there is no alternative treatment procedure that gives the same or better results.

The five vital teeth with a root fracture and concomitant complicated crown fracture (group 5) represent a very rare type of injury. The exposed pulps of these teeth were treated by partial pulpotomy and the results were similar to those obtained with this technique in other vital root-unfractured teeth with pulp exposure (26). These teeth were included in the present study in an attempt to cover the range of possible conservative endodontic treatments of root-fractured teeth.

In conclusion, the results indicate that in the treatment of teeth with a fracture in the middle or apical part of the root and necrotic pulp in the coronal but not the apical fragment, filling of only the coronal fragment with GP can be a successful procedure. Treatment and root canal filling of both fragments is not to be recommended. Filling of the canal of the coronal fragment and surgical removal of the apical fragment, is a rather arduous procedure, especially for children and adolescents. However, it has a reasonable prognosis, provided the remaining coronal fragment can support the crown.

At present, root canal treatment of a coronal fragment with calcium hydroxide followed by filling with GP appears to be the treatment of choice for non-vital root-fractured teeth. However, the choice between endodontic treatment and the alternative of extraction should always include consideration of the patient's age, maturity of the root, position of the fracture and, in doubtful cases, the possibility of replacing the tooth with a single implant at adult age (27).

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