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Factors Affecting the Long-term Results of Endodontic Treatment

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The influence of various factors that may affect the outcome of root canal therapy was evaluated in 356 patients 8 to 10 yr after the treatment. The results of treatment were directly dependent on the preoperative status of the pulp and periapical tissues. The rate of success for cases with vital or nonvital pulps but having no periapical radiolucency exceeded 96%, whereas only 86% of the cases with pulp necrosis and periapical radiolucency showed apical healing. The possibility of instrumenting the root canal to its full length and the level of root filling significantly affected the outcome of treatment. Of all of the periapical lesions present on previously root-filled teeth, only 62% healed after retreatment. The predictability from clinical and radiographic signs of the treatment-outcome in individual cases with preoperative periapical lesions cases was found to be low. Thus, factors which were not measured or identified may be critical to the outcome of endodontic treatment.

Numerous studies have been published evaluating success and failure of endodontic therapy (1–12). Success rates varying from 40 to 93% have been reported (1, 4, 8). The wide range in success rate may depend on differences in experimental design and clinical procedures, criteria for evaluation of the periapical healing, and the length of the postoperative observation period. It is likely, however, that the most important factor influencing the prognosis of endodontic treatment is the preoperative status of the teeth. A large number of studies have demonstrated that the success rate in endodontic therapy is significantly influenced by the presence or absence of a pretherapeutic radiographic lesion (1–7, 9–11). Teeth with an apical radiolucency may show up to 20% lower success rate than teeth without such lesions (2, 3, 11).

In a recent study, we found that the healing pattern of periapical lesions was dependent on the initial size of the radiographic lesion and that an observation period of 5 yr was necessary before complete healing had taken place (13). This is in agreement with Strindberg's (11) original observation that the disappearance of periapical lesions occasionally could take up to 9 yr following treatment. The uncertainty which exists concerning the influence of size of the preoperative periapical lesion (2, 6, 8, 10), and the effect of excesses of root-filling material in periapical tissues (10, 11, 14) on the outcome of endodontic treatment may be due to too short observation periods.

When strict anaerobic techniques were applied to endodontic samples, it was found that obligate anaerobic bacteria dominated in infected root canals and could constitute as much as 90% of the flora (15, 16). The decisive role of bacteria for the development of apical periodontitis was revealed when these techniques were used (16, 17). These techniques were not available when earlier studies evaluating success and failure of endodontic therapy were made (2, 9, 12) and were not used in later studies (1, 5, 6).

The aim of the present study was to assess the long-term results of endodontic treatment and to determine the influence of various factors on the outcome of treatment when the treatment had been controlled with anaerobic bacteriological techniques.

MATERIALS AND METHODS

The patients treated by the undergraduate students at the Department of Endodontics at the University of Umeå during 1977, 1978, and 1979 were recalled after 8 to 10 yr for reexamination to evaluate the results of the treatment. Of 770 recalled patients, 356 were reexamined. The various reasons for the rest of the patients not having been examined are presented in Fig. 1. The mean age of the patients was 54 yr (range, 28 to 82). Fifty-four percent were males. A total of 635 teeth and 849 roots were included in the study.

Those teeth, which for various reasons had been extracted during the treatment period, were excluded from the study. Sixty-eight of the root-filled teeth had been extracted during the follow-up period (Table 1). The distribution of the material according to type of tooth, preoperative status of the pulp, and periapical status are presented in Table 2. Information on the endodontic treatment and radiographs were taken from the patient records.

The preoperative diagnosis of a vital pulp was made in 267 of the roots. Among them, 72 roots were treated because retention for a post was necessary or because the pulp had been exposed due to trauma. The remaining roots with vital pulps were treated as the result of carious lesions or symptomatic pulpitis. There was pulp necrosis in 306 roots, of which

204 revealed apical radiolucency. In roots with pulp necrosis but no apical periodontitis, the necrosis was usually restricted to the coronal part of the canal. Of the 267 roots which had been filled earlier, 94 were retreated for the presence of periapical lesions and 173 due to defective root fillings, which were observed on roots which were to be prepared for a post.

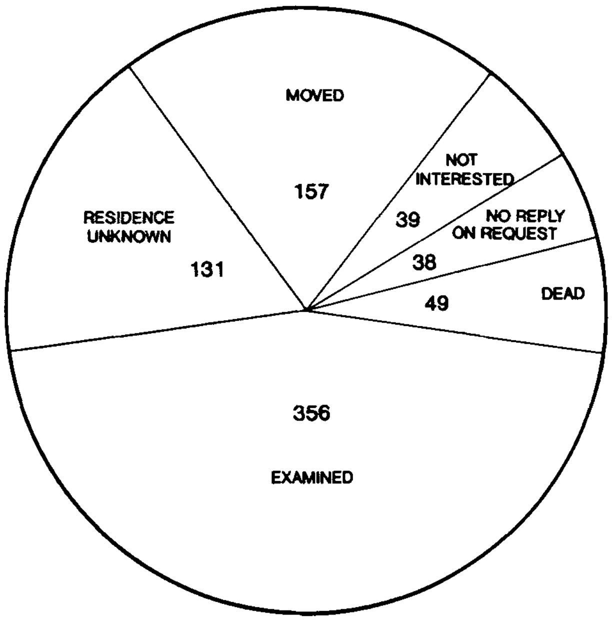

FIG 1. Pie chart showing the outcome of our attempt to recall patients who were treated by undergraduate students during the period from 1977 to 1979.

TABLE 1. Causes for extraction of 68 teeth during the observation period

	No. of Teeth
Perforation when prepared for a post	3
Endodontic failure	2
Root fracture	21
Caries	11
Marginal periodontitis	10
Unknown	21

Clinical and Radiographic Examination

Pain, swelling, tenderness to apical and gingival palpation, and percussion were recorded at the recall examination. Mobility of the tooth, traumatic occlusion, depth of the gingival pockets, presence of caries, and the type of restoration made on the tooth were also recorded. Radiographic examination was performed using the long-cone technique (Philips, Oralix 65) with Kodak Ultraspeed film (22 × 35 mm) in a film holder (18). Two radiographs were taken on each tooth, one with an orthagonal and the other with an eccentric projection. Standardized exposure and processing were used in order to obtain optimal diagnostic quality of the radiographs. The same X-ray unit was used for all examinations and the radiographs were processed manually following the recommendations of the manufacturer.

Strindberg's (11) criteria were used to judge the success rate of root canal therapy. Treatment was considered successful when: (a) the contours, width, and structure of the periodontal margin were normal or (b) the periodontal contours were widened mainly around an excess of filling material. All cases in which those criteria were not fulfilled were judged as unsuccessful. In cases with apical radiolucencies, the size of each lesion was calculated by taking the average of the lesion's largest dimension and its extent in the direction perpendicular to the largest dimension. The level of the root filling in relation to the root apex was also recorded. The technical standard of the root filling was judged. The root filling was considered adequate when there was no lumen apical to the filling and no void in the apical part.

In evaluating the results of treatment, the radiographs were analyzed separately by two independent observers using a viewbox with variable illumination and a viewer with magnification. The observers were calibrated as described by Halse and Molven (18). Furthermore, all radiographs were evaluated twice by each observer with an interval of about 2 months

TABLE 2. Number of roots and final result of treatment according to type of teeth and preoperative status of pulp and periapical tissues

Type of Teeth	Preoperative Status							
	Healthy Pulp*	Carious lesion, Pulpitis	Necrosis	Necrosis, Periapical Lesion	Previously Root-Filled	Previously Root-Filled, Periapical Lesion	Unknown Diagnosis	Total
Maxillary								
Central incisors	2/2†	5/6	9/9	12/13	2/2	6/7	1/1	37/40
Lateral incisors	11/11	11/11	6/6	17/23	7/7	8/12	—	60/70
Canines	7/7	8/8	1/1	16/18	10/10	8/9	1/1	51/54
Premolars	9/9	35/39	13/13	26/30	50/52	13/25	2/2	148/170
Molars	19/19	24/24	23/23	14/18	26/26	2/13	2/2	110/125
Mandibular								
Incisors	3/3	5/5	4/4	32/35	3/3	3/6	—	50/56
Canines	4/5	16/16	5/5	14/15	4/5	1/1	2/2	46/49
Premolars	8/10	33/33	15/15	27/31	35/36	10/12	1/1	129/138
Molars	6/6	51/53	26/26	18/21	32/32	7/9	—	140/147
Total	69/72 (96%)	188/195 (96%)	102/102	176/204 (86%)	169/173 (98%)	58/94 (62%)	9/9	771/849 (91%)

* Treated because retention for a post was necessary or because the pulp had been exposed due to trauma.

† Number of roots judged to be successful/total no. of roots.

between the evaluations. The intraobserver agreement was 95 and 98% for the two observers. The interobserver agreement of the judgment between the two observers was 97%. In cases of disagreement, the two observers discussed those cases in an effort to come to a consensus. If the two observers still disagreed on a particular case, the opinion of a third specialist was taken as final.

Some intraobserver agreement can be expected to occur by chance. The number of diagnosis groups and their expected random frequencies are factors which influence the degree of expected random agreement. By using Cohen's formula a correction of the agreement can be made for these expected random frequencies (19). The corrected agreement is calculated as:

$$\frac{\text{observed agreement} - \text{expected random agreement}}{1 - \text{expected random agreement}}$$

The expected random frequencies are calculated as they are in a chi-square test. In this study, the corrected agreement between the two observers was 82%.

Original Endodontic Procedure

All treatments were performed with a rubber dam and aseptic technique. The tooth, the clamp, and the rubber dam were cleansed with 30% hydrogen peroxide solution and then swabbed with a 5% tincture of iodine. The pulpectomies were performed with Hedstrom files under local anestethic. The widening and shaping of the canals were done with a step-back technique. Thin K files were used initially in nonvital cases. Subsequently Hedstrom files were used to widen and shape the canals. During the preparation, the canals were frequently irrigated with 0.5% sodium hypochlorite solution. In the vital cases efforts were made to leave an apical pulp stump of about 2 mm in length. The pulp was completely removed in cases in which there was necrosis in the coronal part. In cases where the apical foramen was not indentifiable on radiographs, the canals were reamed to a level of 1-mm short of the root apices. When previously root-filled teeth were retreated, the root fillings were softened with chloroform and removed with files.

Calcium hydroxide was used as an intracanal dressing between appointments in the majority of cases (20). Potassium iodide (2%, 5%) and comphorated phenol were used in some cases. The access cavities were sealed with zinc oxide-eugenol cement. All root canals were filled with gutta-percha using the lateral condensation technique. The master cone was adapted to the canal by dipping it in rosin chloroform, and then multiple accessory cones were laterally condensed after having been softened in chloroform. The treatments were all performed by undergraduate students under the supervision of experienced endodontists.

Bacteriological Control

In all nonvital and pulpitis cases, the effect of the antiseptic treatment was bacteriologically controlled. A liquid thioglycolate medium (11260; Baltimore Biological Laboratories, Cockeysville, MD) supplemented with agar was used (21). This medium is highly effective in reducing oxygen and no toxic intermediates of oxygen accumulate in the medium even if it is exposed to atmospheric oxygen for a short while (22). Furthermore, the agar of the culture medium prevents any oxygen to which the medium might be exposed during the sampling procedure from diffusing deeply into it. This medium has proven to be very successful for transport and initial subculture of samples taken from root canals (21). The root canals were filled when a sample cultivated for at least 7 days did not show any bacterial growth.

Statistics

Differences between treatment results for groups of cases with different preoperative diagnoses and different clinical or radiographic signs were evaluated statistically using chi-square and Fischer's exact tests. We chose to reject the null hypothesis at the 5% level ($p \leq 0.05$). The relationship of the treatment results to the presence or absence of clinical and radiographic signs was determined for groups of cases in which the treatment results were less than ideal. Stepwise logistic regression analysis was performed on these data using the PLR section of BMDP Statistical Software, University of California Press, Berkley (1983) on a CYBER 850 computer.

RESULTS

The overall success rate of endodontic treatment in 356 cases which could be followed-up was 91% (Table 2). The success rate was 96% for roots with vital pulps which had to undergo root canal therapy. All roots with pulpal necrosis but without preoperative periapical lesions and 98% of the roots which underwent root refilling due to technical inadequacies showed normal radiological features in the periapical region at the follow-up examination. Eighty-six percent of the periapical lesions present in cases with pulpal necrosis healed after treatment. A still lower success rate (62%) was observed for roots with periapical lesions which were previously filled and were retreated. In other words, prognosis for the treatment was found to be significantly better for roots without apical radiolucency than for those with apical radiolucency ($p < 0.0001$).

For the roots with preoperative apical periodontitis, a statistical analysis of various factors which may influence the outcome of treatment was made using chi-square tests. The level to which it was possible to instrument the root canal had a significant influence on the prognosis of the treatment for roots with pulpal necrosis. When it was possible to instrument the canal to the apical constriction, 90% of the periapical lesions healed. Only 69% of the cases healed when it was not possible to instrument the canal to its total length. This difference was statistically significant ($p = 0.002$). The level of instrumentation had no influence when previously root-filled teeth with periapical lesions were retreated. No distinction could be made in this study among canals obliterated by denticles, tertiary dentin, and/or obturations caused by improper instrumentation.

The apical level of the root filling also had a significant influence on the outcome of the treatment for roots with necrotic pulps and periapical lesions (Fig. 2). The best prognosis was found for roots in which the filling reached within 2 mm of the apex. Of these, 94% revealed normal periapical conditions at the follow-up examination. Corresponding figures for roots with excess root filling and for roots with fillings more than 2-mm short of the apex were 76% and 68%, respectively. These values were significantly different from the 94% success rate (p = 0.003 and p = 0.0004, respectively). The apical level of root filling had no significant influence on the outcome of treatment when previously root-filled teeth with periapical lesions were retreated (Fig. 3).

The technical standard of the root filling had no significant influence on the prognosis of the treatment for roots with pulp necrosis undergoing initial treatment (Table 3). However, for previously root-filled teeth which were retreated with adequate seal, the success rate (67%) was significantly (p = 0.03) higher than for teeth inadequately sealed (31%).

The preoperative size of the periapical lesion did not influence the outcome of the treatment for roots with necrotic pulps when treated for the first time (Table 4). However, only three lesions were initially larger than 10 mm. For previously root-filled teeth, the rate of success of retreatment for lesions with an average diameter of 5 mm or less was found to be 65%, compared with the 38% success rate for teeth with larger lesions (Table 4). This difference, however, was not statistically significant (p = 0.1).

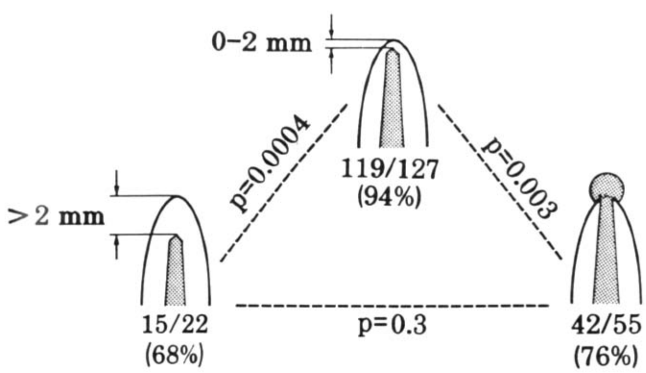

FIG 2. Outcome of treatment according to the level of the root filling in relation to the root apex in cases with pulp necrosis and apical periodontitis preoperatively. Number of healed lesions/number of preoperative lesions.

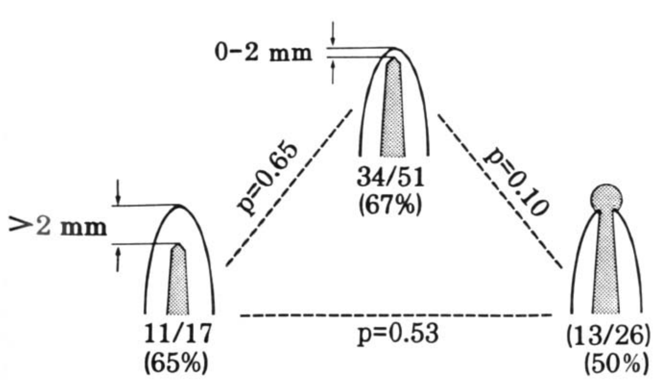

FIG 3. Results of retreatment of previously filled roots with apical periodontitis with regard to the level of the final root filling in relation to the root apex. Number of healed lesions/number of preoperative lesions.

TABLE 3. Effect of the technical standard of the root filling on the rate of successful treatment of roots with periapical lesions

	Inadequate Seal	Adequate Seal	Test of Difference
Necrotic pulp	9/11 (82%)	167/193 (87%)	p = 0.36
Retreatment	4/13 (31%)	54/81 (67%)	p = 0.03

TABLE 4. Effect of the preoperative size of the periapical lesion on the rate of treatment success

	Size of Lesion		
	≤5 mm	>5 mm	Test of Difference
Necrotic pulp	132/151 (87%)	44/53 (83%)	p = 0.32
Retreatment	53/81 (65%)	5/13 (38%)	p = 0.12

The prognosis was slightly less favorable for roots with preoperative pulp necrosis and periapical lesions when the root was restored with a crown or acted as an abuntment for a bridge (p = 0.02 and p = 0.04, respectively). For the retreatment group, no significant influence on the result of treatment was found when the teeth were crowned or acted as abutments.

Factors such as age and sex of the patient, presence of deep periodontal pockets, whether the roots were provided with posts or not or were used as abutments for partial dentures, and the number of bacterial sampling done before filling the root had no influence on the outcome of treatment. Neither a flare-up occurring during the treatment nor the presence of an initial acute periapical abscess influenced the result of treatment.

The frequencies of file fractures and perforations to the periodontal ligament were low. For all examined roots, file fractures occurred in 11 roots (1.3%) and perforations in 13 roots (1.5%). Periapical lesions were later noted on two such roots with file fractures and on three roots with perforations.

The stepwise logistic regression analysis was used to ascertain which clinical and radiographic signs may be of use in predicting the outcome of endodontic treatment (Tables 5 and 6). The analysis revealed that the presence of canal obliteration, root resorption, bridge abutment, or root perforation was of importance to the prediction of the treatment failure in cases with pulpal necrosis. In retreated cases, the size of the periapical lesion and the extent of the root filling to the root apex were found to be important. However, the prediction of the frequency of failure in these two groups was poor (3% predicted failure in cases with pulp necrosis versus 14% in the data; 18% predicted failure in retreated cases versus 38% in the data). The predicted success or failure of individual cases was also poor with both models. Only 3 of 28 (11%) failures in cases with pulp necrosis and 10 of 36 (28%) of retreated cases were correctly classified as failures by the models.

DISCUSSION

Among the various factors analyzed, the preoperative periapical status appears to be decisive for the outcome of endodontic treatment. More than 96% of the teeth without preoperative periapical lesions were treated successfully, whereas only 86% of cases having necrotic pulps and periapical lesions

TABLE 5. Results of the stepwise logistic regression analysis on the results of treatment in cases with pulp necrosis*

Variable	Pulp Necrosis	
	t	Factor
Constant	—	−0.45
Canal obliteration	−3.23	−0.80
Resorption	−3.13	−0.96
Bridge abutment	−2.40	−0.59
Perforation	−1.80	−0.90

Prediction model:

$U = -0.45 - 0.80 \times \text{obliteration} - 0.96 \times \text{resorption} - 0.59 \times \text{abutment} - 0.90 \times \text{perforation}$

Prediction	Treatment Results: Success	Treatment Results: Failure	Total	%
Success	173	25	198	97
Failure	3	3	6	3
Total	176	28	204	100
%	86	14	100	

* The regression model is linear: $U = a + \sum b_i \cdot x_i$. The prediction of the probability of treatment failure from the model is calculated as $e^U/(1 + e^U)$.

TABLE 6. Results of stepwise logistic regression analysis on the results of retreated cases*

Variable	Retreatment	
	t	Factor
Constant	—	−0.91
Lesion size	2.03	+0.21
Technical standard of root filling	−1.92	−0.60

$U = -0.91 + 0.21 \times \text{size} - 0.60 \times \text{technical standard}$

Prediction	Treatment Results: Success	Treatment Results: Failure	Total	%
Success	51	26	77	82
Failure	7	10	17	18
Total	58	36	94	100
%	62	38	100	

* The regression model is linear: $U = a + \sum b_i \cdot x_i$. The prediction of the probability of treatment failure from the model is calculated as $e^U/(1 + e^U)$.

healed. The least favorable results (62% success) were associated with teeth with root fillings which had to be revised due to the failure of previous endodontic treatment. Our results corroborate earlier findings that teeth with apical periodontitis have a significantly lower rate of success than those without such lesions (1–7, 9–11). The unfavorable prognosis for endodontic retreatment is in accordance with the previously published results of Strindberg (11), Grahnén and Hansson (3), and Bergenholtz et al. (23).

The outcome of treatment for roots with pulp necrosis and apical periodontitis was dependent on the level of the root filling in relation to the root apex (Fig. 2). Roots which could be filled to the apex or within 2 mm of the apex showed 94% treatment success. This means that the prognosis for treatment of nonvital teeth with periapical lesions was as good as that for vital teeth when the instrumentation and filling of the root canal could be carried out to an optimal level. In cases where the roots were filled to excess or the fillings were more than 2-mm short of the root apex, the lesions healed in only 76% and 68% of the cases, respectively. All of the cases with short fillings and periapical lesions were included among the roots that could not be instrumented to their full length. The inability to instrument a canal to its full length may have been due to a preexisting obstruction of the canal by the accumulation of tertiary dentin or by branching of the canal into an apical delta. A further reason for incomplete instrumentation is obliteration of a previously patent apical portion of the canal by dentin chips during debridement. Thus, the lower success rate in underfilled roots may be due to the inability to debride the apical segment of the canal or to the accumulation of infected dentin chips which may harbor persistent infections at the root apex (24, 25).

The negative impact of root-filling excess on the healing of periapical lesions may indicate a cytotoxic effect of gutta-percha. However, several studies have shown that gutta-percha is well tolerated by tissues (26, 27). This is also supported by our finding that root-filling excess had no impact on the prognosis of vital cases. Thirty roots were filled to excess in this group and no radiographic signs of periapical inflammation could be noticed on any of them at the follow-up examination. The finding that the adverse effect of root-filling excess was present in primarily infected root canals corroborates earlier results (2, 14, 23). The adverse effect of root-filling excess on the outcome of treatment may be due to overinstrumentation which normally precedes overfilling (23). This may force infected dentin chips into the periapical tissue. Yusuf (28) observed that periapical granulomas from cases of failed root treatment often contain foreign material such as dentin or cementum chips and/or root-filling material. The dentin and cementum chips were associated with active inflammation whereas the root-filling materials were generally encapsulated in fibrous tissue. In animal experiments, infected chips which were forced into the periapical tissues during canal enlargement have been shown to intensify the inflammation and impair the repair process (25, 29).

The essential role of bacteria in the development of apical periodontitis has been established when strict anaerobic culturing techniques have been applied to endodontic samples (16, 17). These studies have shown that there is a strong correlation between infection of the root canal and development of apical periodontitis. The pathogenesis of apical periodontitis persisting after endodontic treatment or developing subsequent to treatment has not been as well documented as the pathogenesis of primary apical periodontitis. Nevertheless a bacterial etiology is suspected in most cases (13, 30–33).

The results of the stepwise logistic regression analysis in the present study indirectly support the hypothesis that bacteria may be the primary cause of treatment failure. While the stepwise logistic regression analysis showed several variables to be of some value in predicting treatment failure in cases with pulpal necrosis and in retreated cases (Tables 5 and 6), the prediction accuracy of these regression models was low, i.e. only 11 and 28% (3 of 28 and 10 of 36), respectively, of the treatment failures were correctly classified by the models. This indicates that these statistical models lack variables which are critical to the treatment outcome. One probable variable is the presence of bacteria which escaped sampling and/or culture. Another variable which may have some bearing on treatment results in retreated cases may be the presence of materials (e.g. dentin filings) in the periapical area. Neither of these variables could be properly assessed with the methods used in this study.

Negative bacterial culture was the prerequisite for filling the canals in the cases studied here. The bacterial technique which was used is highly effective in promoting growth of the flora which may be found in infected root canals (21). This may appear to contradict the hypothesis that persistent infection was the primary cause of the failures. However, it is important to recognize that bacteria may be present at sites which cannot be reached by the sampling procedure such as accessory canals and/or dentinal tubules. Bacteria invade the dentinal tubules of the apical part of the root (34) and, when an apical granuloma affects root cementum, the associated dentinal tubules may be infected in their total length (35). These bacteria may not be reached by the sampling procedure or by the antiseptics used in therapy. Bacteria may also persist on the root surface in exposed dentinal tubules, in lacunae of cellular cementum, or in apical formamina (30–32). Establishment of bacteria outside the root canal in the periapical tissue has, in fact, been shown in some periapical lesions which failed to heal in spite of careful bacteriological monitoring before root filling (13, 33).

Several studies have shown that the prognosis for treatment of large periapical lesions is not as good as that for small lesions (2, 6, 10). The posttreatment observation period in these studies was 1 to 5 yr. In Strindberg's study (11), the final follow-up was made 7 to 9 yr after completion of endodontic treatment. He found no significant differences in healing frequency between lesions initially larger than 5 mm and those smaller than 5 mm. Our results are in accordance with Strindberg's results. We found that the preoperative size of the lesions had no influence on the outcome of treatment when roots with necrotic pulps were treated (Table 4). The presence of extremely large lesions in the earlier studies might have influenced the results in such a way that the observation periods were too short to reestablish normal periodontal contours in such large lesions (2, 6, 10).

The size of the preoperative lesion did, however, have an effect on the outcome of treatment when teeth that had been root filled earlier were retreated (Table 4). Engström et al. (2) also reported a low rate of success when root-filled teeth with large periapical lesions were retreated. The reasons for the low frequency of healing in retreated cases are at present unknown. In this context, it may be of interest to note that bacteria of the genera Actinomyces and Arachnia have been found in periapical lesions refractory to conventional endodontic therapy (13, 33). Such extraradicular infections could contribute to the low rate of success in the retreated cases in as much as these bacteria are unaffected by conventional endodontic treatment. Apical surgery as a supplement to retreatment of the root canal may be indicated in these cases.

CONCLUSIONS

This study shows that teeth with no preoperative periapical lesions do not constitute a therapeutic problem as more than 96% of these teeth were treated successfully. On the other hand, teeth with pulp necrosis and periapical lesions and those with periapical lesions undergoing retreatment constitute major therapeutic problems as can be seen from the lower success rates of only 86 and 62%, respectively. The predictability of the outcome of treatment for individual cases within these groups was found to be low. This indicates that information may be lacking on factors which may be critical to treatment outcome. It is likely that persistence of bacteria at sites inaccessible to the bacterial sampling procedures may be a factor of importance which deserves further investigation.

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