Periapical health related to the quality of coronal restorations and root fillings

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Abstract

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Aim To evaluate the impact of the quality of coronal restorations scored on a clinical and radiographic basis and the quality of root fillings on periapical health.

Methodology Periapical radiographs were taken of 745 root-filled teeth, randomly selected from patients attending the Ghent University Dental School. The teeth had not received restorative treatment in the previous year. The coronal status was scored both clinically according to modified Ryge's criteria, and radiographically by evaluating the presence of signs of marginal leakage or decay. The quality of the root filling was scored according to criteria of length and homogeneity and the periapical status was categorized on the basis of presence or absence of radiographic signs of apical periodontitis. The relationship between coronal status, quality of root filling and periapical health was determined. The data were analyzed using χ^2 test, Odds ratio, Spearman's r_S and logistic regression.

Results Thirty-three percent of the teeth had apical periodontitis as diagnosed radiographically. Teeth with good and poor coronal restorations scored clinically had apical periodontitis in 31.1 and 36.8%, respectively; this difference was not statistically significant. The quality of the coronal restorations scored radiographically had a statistically significant influence on the periapical condition ($P < 0.001$) with apical periodontitis in 23.8 and 49.1%, respectively, for acceptable and unacceptable restorations. Marginal decay did not influence the periapical status. Teeth restored without a base under the coronal filling had apical periodontitis in 41.3%, whereas teeth with a base had significantly less ($P < 0.005$) apical periodontitis (25.9%). Composite-restored teeth exhibited apical periodontitis in 40.5% of cases whilst amalgam-restored teeth had apical periodontitis in 28.4% of cases; this difference was statistically significant ($P < 0.01$). Root-canal posts had no influence on periapical health. The length and homogeneity of the root-canal fillings had a significant influence ($P < 0.01$ and $P < 0.001$, respectively) on the presence of apical periodontitis, as well as the quality of the coronal restoration scored radiographically ($P < 0.001$).

Conclusion The importance of a good coronal restoration, as well as of a good root filling should be emphasized as the technical quality of both influencing the periapical status.

Keywords: apical periodontitis, clinical and radiographic evaluation, coronal leakage, coronal restoration, quality of endodontic treatment, root-canal treatment.

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Introduction

Follow-up studies on root-canal treatment (Grossman *et al.* 1964, Sjögren *et al.* 1990, Eriksen 1991, Friedman 1998) have reported the impact of the quality of the root-canal filling on the prognosis of root-canal treatment. In addition, several authors have described the importance of apical leakage on the treatment outcome of root-canal treatment (Strindberg 1956, Schilder 1967, Harty *et al.* 1970, Adenubi & Rule 1976, Ingle *et al.* 1985, Cohen & Burns 1998). The first to point out the effect of coronal leakage were Marshall & Massler (1961), although it was some time before this failure mode was

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discussed again in the literature (Swanson & Madison 1987).

Apical leakage is still considered as a factor in the failure of endodontic treatment, but in recent years, more attention has been paid to coronal leakage (Saunders & Saunders 1994). Several authors have reported that even with satisfactory root fillings, leakage of bacteria and bacterial products along the length of the root canal is inevitable (Swanson & Madison 1987, Torabinejad *et al.* 1990, Khayat *et al.* 1993, Trope *et al.* 1995). Recent radiographic studies have further investigated the importance of coronal leakage. Ray & Trope (1995) and Kirkevang *et al.* (2000) found that the technical quality of coronal restorations scored only on radiographs had a significantly greater impact on periapical health than the technical quality of the root filling. Tronstad *et al.* (2000) found that the technical quality of the coronal restoration was significantly less important than the technical quality of the root filling. It remains unclear whether radiographic evaluation is effective when assessing coronal leakage owing to the limitations of radiographs, or whether clinical inspection of the coronal restoration is also necessary.

No study has yet investigated the impact of the technical quality of coronal fillings radiographically and intraorally, and the technical quality of root-canal treatment on periapical health. The aim of the present study was, therefore, to evaluate the quality of both root fillings and coronal restorations, using radiographic and clinical criteria, as related to the prevalence of periapical radiolucencies in a Belgian subpopulation.

Materials and methods

Patient selection and clinical examination

Root-filled teeth were selected on panoramic radiographs of randomly selected patients attending the Dental School, Ghent University Hospital, Ghent, Belgium, for dental treatment. Only those teeth that were not treated in the preceding year (according to the patient-file or the patient's recollection) were included in the study. A periapical radiograph was taken of each selected tooth using an Endo Ray film holder (Rinn Corp., Elgin, IL, USA). The coronal status clinically was scored according to a modification of Ryge's criteria for marginal adaptation (Ryge 1980) (Table 1).

Radiographic examination

All periapical radiographs were evaluated using an X-ray viewer with 5× magnification. The coronal restoration, the presence of a post in the canal, the root-canal treatment and the periapical condition were scored according to the criteria listed in Table 1 (multirooted teeth were classified according to the root exhibiting the most severe periapical condition).

Two examiners were calibrated before the start of the study and at regular intervals during the study. Interobserver (51 teeth were double scored clinically and radiographically) and intraobserver agreement were assessed by computing Cohen's Kappa (Hunt 1986, Valachovic *et al.* 1986). All Kappa (κ) values were between 0.70 and 0.96. Because of the good interobserver κ values, the teeth selected were only scored on each occasion by one of the examiners. The data were then pooled.

Statistical analysis

SPSS software was used for data processing and statistical analysis. χ^2 test and Odds ratio were used as the univariate approach to detect statistically significant differences between groups. Logistic regression (multivariate approach) was used to explain the periapical condition by explanatory variables. Spearman's r_S values were calculated to detect correlations between clinical and radiographic parameters.

Results

A total of 745 teeth were scored clinically and radiographically in 228 subjects, i.e. an average number of 3.3 root-canal treatments per subject. A total of 242 (32.5%) of the teeth had signs of apical periodontitis, including 92 (12.3%) teeth exhibiting a widened apical periodontal ligament and 150 (20.1%) teeth a periapical radiolucency.

Coronal restoration and periapical condition

An overview of the coronal status in relation to the periapical condition is presented in Table 2. Seventy-five percent of the coronal restorations were clinically acceptable. Radiographic signs of apical periodontitis were detected in 31.1% of teeth with acceptable restorations and 36.8% of teeth with unacceptable restorations; the difference was not statistically significant. This trend was repeated for the presence of marginal

Table 1 Parameters scored on endodontically treated teeth

Parameter	Score
Clinical coronal status	1. Good margin (acceptable) 2. Catching of the explorer, no visible crevice (acceptable) 3. Crevice limited to the enamel (acceptable) 4. Crevice penetrating the dentine (unacceptable) 5. Fracture of restoration (unacceptable) 6. Detached restoration (unacceptable) 7. Lost restoration (unacceptable) Marginal decay Crown or filling
Radiographic coronal status	1. Intact restoration without signs of leakage (acceptable) 2. Restoration with open margin (unacceptable) 3. Restoration with recurrent decay (unacceptable) Presence or absence of a base under the restoration Amalgam or composite Presence of a post in the root canal
Length of the root filling	1. Root filling terminating 0–2 mm from the radiographic apex (acceptable) 2. Root filling terminating >2 mm from the radiographic apex (unacceptable) 3. Root filling extending beyond the radiographic apex (unacceptable)
Homogeneity of the root filling[a]	1. Homogeneous root filling, good condensation, no voids visible (acceptable) 2. Inhomogeneous root filling, poor condensation, voids visible
Periapical status	1. Normal: good periapical condition 2.Widening of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament 3. Periapical radiolucency in connection with the apical part of the root, exceeding at least two times the width of the lateral periodontal ligament

[a]Only root-canal fillings terminating 0–2 mm from the radiographic apex and homogeneous were listed acceptable if data were grouped for further analysis.

caries clinically as well as radiographically. When the coronal restorations were scored radiographically, 78.1% were found acceptable. Of these cases, 23.8% showed signs of apical periodontitis. Forty-nine percent of the restorations scored unacceptable on radiographs were associated with signs of apical periodontitis. In this respect, the radiographic coronal parameters had a statistically significant impact on the periapical health ($\chi^2 = 32.027$, $P < 0.001$). When the clinical and radiographic criteria for the coronal restorations were combined, the acceptable restorations (67.4% of the total) had statistically significantly less apical periodontitis than the unacceptable ones ($\chi^2 = 4.054$, $P < 0.05$, Odds ratio: $1.008 < 1.392 < 1.921$). The Spearman's r_S correlation between the coronal quality of restorations scored clinically and radiographically was 0.485. For the agreement of the presence of caries scored clinically or radiographically, κ was 0.441.

Teeth with a base material under the restorations had significantly less apical periodontitis than those without ($P < 0.005$), as did teeth restored with amalgam as compared to composite ($P < 0.01$).

Root-canal treatment and periapical condition

Table 3 shows data on the quality of root-canal treatment and its relation to the presence of apical periodontitis. A root-canal post was present in 59.5% of teeth, but its presence had no statistically significant influence on apical periodontitis (31.9% vs. 32.9% without post). Forty-two percent of the root canals were filled to an acceptable length (0–2 mm from the radiographic apex), with apical periodontitis in 27.2% of cases. Of the 58.0% of teeth not filled to adequate length (short or overfilled), 36.4% had apical periodontitis; this difference was statistically significant ($\chi^2 = 6.983$, $P < 0.01$, Odds

Table 2 Quality of the coronal restoration and the relation to periapical health ($n = 745$)

Parameter	Subparameter	Total (%)	Periapical condition		
			Normal	AP	% AP
Filling or crown	Filling	55.4	272	141	34.1
	Crown	40.9	215	90	29.5 °
	Lost restoration	3.6	16	11	40.7
Coronal restoration (clinically)	Good margin (a)	18.0	96	38	28.4
	Catching of the explorer (a)	43.0	224	96	30.0
	Crevice limited to enamel (a)	14.2	66	40	37.7
	Crevice penetrating to dentine (u)	19.3	93	51	35.4 °
	Fracture of restoration (u)	1.2	7	2	22.2
	Detached restoration (u)	0.7	1	4	80.0
	Lost restoration (u)	3.6	16	11	40.7
Coronal restoration (clinically)	Acceptable	75.2	386	174	31.1
	Unacceptable	24.8	117	68	36.8 °
Marginal decay (clinically)	No caries	81.9	420	190	31.1
	Caries	18.1	83	52	38.5 °
Coronal restoration (radiographically)	Intact restoration (a)	78.1	420	162	23.8
	Open margin (u)	12.3	54	38	41.3 *
	Marginal decay (u)	9.5	29	42	59.2
Marginal decay (clinically or radiographically)	No caries	79.1	407	182	30.9
	Caries	20.9	96	60	38.5 °
Coronal restoration (clinically and radiographically)	Acceptable	67.4	351	151	30.1
	Unacceptable	32.6	152	91	37.4 *
Presence of a base	No base	53.1	131	92	41.3
	Base present	46.9	146	51	25.9 *
Obtuaration material	Amalgam	53.6	161	64	28.4
	Composite	46.4	116	79	40.5 *

AP: apical periodontitis.
°: no statistically significant difference ($P > 0.05$).
*: statistically significant difference ($P < 0.05$).
(a): acceptable.
(u): unacceptable.

Table 3 Quality of the endodontic treatment and the relation to periapical health ($n = 745$)

Parameter	Subparameter	Total (%)	Periapical condition		
			Normal	AP	% AP
Root-canal post	No post	59.6	298	146	32.9
	Post	40.4	205	96	31.9 °
Length of the root filling	Good (0–2mm) (a)	42.0	228	85	27.2
	Overfilled (u)	5.1	18	20	52.6 *
	Underfilled (>2 mm) (u)	52.9	257	137	34.8
Homogeneity of the root filling	Homogeneous (a)	74.6	403	153	27.5
	Inhomogeneous (u)	25.4	100	89	47.1 *
Quality of the root filling overall	Acceptable	34.4	197	59	23.0
	Unacceptable	65.6	306	183	37.4 *

AP: apical periodontitis.
°: no statistically significant difference ($P > 0.05$).
*: statistically significant difference ($P < 0.05$).
(a): acceptable.
(u): unacceptable.

ratio: 1.115 < 1.531 < 2.103). The homogeneity of the root filling also had a statistically significant influence on the presence of apical periodontitis, i.e. 27.5% apical periodontitis for a homogeneous root filling as opposed to 47.1% for those that were not homogeneous ($\chi^2 = 99.304$, $P < 0.001$, Odds ratio: 4.595 < 6.898 < 10.354). There was no correlation between the length and the homogeneity of root fillings ($r_S = 0.140$). When length and homogeneity were considered, acceptable (homogeneous root filling ending 0–2 mm from the radiographic apex) root fillings were present in only 34.4% of cases. Apical periodontitis was evident in 23.0 and 37.4% of the root fillings scored, respectively, as acceptable and unacceptable; this difference was statistically significant ($\chi^2 = 15.835$, $P < 0.001$, Odds ratio: 1.416 < 1.997 < 2.816).

Coronal restoration and root-canal quality combined

The periapical condition was analyzed using the logistic regression model. Table 4 shows the results of this analysis performed on all teeth. The following parameters had a significant influence on the periapical condition: the homogeneity of the root filling ($P < 0.001$), the radiographic appearance of the coronal restoration ($P < 0.001$) and the length of the root filling ($P < 0.05$). Table 5 shows the results of the same analysis, but only on filled teeth (all crowned teeth excluded). The homogeneity of the root filling ($P < 0.005$) and the radiographic appearance of the coronal restoration ($P < 0.005$) also had a significant influence on the periapical condition, as well as the presence of a base ($P < 0.05$).

Table 8 presents the results of the combination of the parameters poor and good for coronal restorations and root fillings and is similar to the Tables in the studies of Ray & Trope (1995) (Table 6) and Tronstad *et al.* (2000) (Table 7). Table 9 shows the parameters for the combined clinical and radiographic quality of the coronal restoration and for the quality of the root filling regarding length and homogeneity. When both qualities were acceptable (group A), apical periodontitis was present in 22.5% of cases. When the coronal restoration was good and the endodontic treatment poor (group B), 34.4% of the teeth exhibited apical periodontitis. The difference between these two groups was statistically significant ($\chi^2 = 7.743$, $P < 0.01$, Odds ratio: 1.187 < 1.801 < 2.734).

Table 6 Periapical status of endodontically treated teeth according to Ray & Trope 1995

Coronal restoration	Endodontic treatment	Normal	AP	%AP
Good	Good	302	28.5	8.6
Good	Poor	204.5	98	32.4
Poor	Good	72.5	92	55.9
Poor	Poor	34	154	81.9

AP: number of teeth with signs of apical periodontitis.

Table 7 Periapical status of endodontically treated teeth according to Tronstad *et al.* 2000

Coronal restoration	Endodontic treatment	Normal	AP	%AP
Good	Good	294	70	19
Good	Poor	168	131	44
Poor	Good	101	41	29
Poor	Poor	111	85	43

AP: number of teeth with signs of apical periodontitis.

Table 4 Regression table of the periapical condition explained by explanatory variables (all teeth ($n = 745$))

			95% CI for Odds ratio	
	Significance, *P*	Odds ratio	Lower	Upper
Homogeneity of the root filling	0.000	2.092	1.473	2.973
Radiographic appearance of the coronal restoration	0.000	2.673	1.744	4.097
Length of the root filling	0.046	1.402	1.006	1.954

Table 5 Regression table of the periapical condition explained by explanatory variables (filled teeth only ($n = 420$))

			95% CI for Odds ratio	
	Significance, *P*	Odds ratio	Lower	Upper
Presence of a base	0.045	0.624	0.394	0.988
Homogeneity of the root filling	0.003	2.014	1.263	3.212
Radiographic appearance of the coronal restoration	0.002	2.542	1.390	4.324

Table 8 Periapical status of endodontically treated teeth as related to the radiographic quality of the coronal restoration combined with the quality of the root-canal treatment determined by the length and homogeneity of the root filling ($n = 745$)

Coronal restoration	Endodontic treatment	Normal	AP	%AP	
Good	Good	168	44	20.8	A
Good	Poor	252	118	31.9	B
Poor	Good	29	15	34.1	C
Poor	Poor	54	65	54.6	D

AP: number of teeth with signs of apical periodontitis.
Statistics: A vs. B: $\chi^2 = 8.32$, $P = 0.004$, Odds ratio: $1.202 < 1.788 < 2.660$; A vs. D: $\chi^2 = 39.581$, $P = 0.000$, Odds ratio: $2.815 < 4.596 < 7.504$; B vs. D: $\chi^2 = 19.865$, $P = 0.000$, Odds ratio: $1.686 < 2.571 < 3.920$; C vs. D: $\chi^2 = 5.418$, $P = 0.020$, Odds ratio: $1.132 < 2.327 < 4.782$.

Table 9 Periapical status of endodontically treated teeth determined by the radiographic and clinical quality of the coronal restorations combined with the quality of the root-canal treatment determined by the length and the homogeneity of the root filling ($n = 745$)

Coronal restoration	Endodontic treatment	Normal	AP	%AP	
Good	Good	141	41	22.5	A
Good	Poor	210	110	34.4	B
Poor	Good	56	18	24.3	C
Poor	Poor	96	73	43.2	D

AP: number of teeth with signs of apical periodontitis.
Statistics: A vs. B: $\chi^2 = 7.743$, $P = 0.005$, Odds ratio: $1.178 < 1.801 < 2.734$; C vs. D: $\chi^2 = 7.824$, $P = 0.005$, Odds ratio: $1.283 < 2.366 < 4.363$; A vs. D: $\chi^2 = 17.069$, $P = 0.000$, Odds ratio: $1.647 < 2.615 < 4.151$.

The combination of poor coronal restoration and good endodontic treatment (group C) resulted in a 24.3% failure rate. This was not statistically significantly different from group A, or from group B. When the coronal restoration and the root filling were poor (group D), 43.2% of the endodontically treated teeth had apical periodontitis. This was statistically significantly different from the results in groups A and C, but not from the results in group B.

Table 10 depicts the data on comparison of the presence of a coronal base and the quality of the root filling. When no base was placed above the root-canal filling, the quality of the root filling had a statistically significant influence on the presence of apical periodontitis. In the presence of a base, there was still a difference amongst groups C and D, but this was not statistically significant.

Table 10 Periapical status of endodontically treated teeth determined by the presence of a base combined with the quality of the root-canal treatment determined by the length and the homogenity of the root filling ($n = 745$)

Base	Endodontic treatment	Normal	AP	%AP	
No base	Good	42	20	32.3	A
No base	Poor	89	72	44.7	B
Base	Good	46	10	17.9	C
Base	Poor	100	41	29.1	D

AP: number of teeth with signs of apical periodontitis.
Statistics: A vs. B: $\chi^2 = 14.379$, $P = 0.000$, Odds ratio: $1.792 < 3.436 < 6.591$; B vs. C: $\chi^2 = 12.754$, $P = 0.000$, Odds ratio: $0.127 < 0.269 < 0.570$; B vs. D: $\chi^2 = 7.855$, $P = 0.005$, Odds ratio: $0.314 < 0.507 < 0.818$.

Discussion

The design of the present study repeated that of Ray & Trope (1995), but also included the clinical evaluation of the coronal restoration. It is not possible to score the quality of a coronal restoration from a radiograph with certainty, as it provides only a two-dimensional image. In the present study, only a weak correlation existed between radiographic and clinical coronal parameters ($r_S = 0.485$ for quality of restoration and $r_S = 0.441$ for the presence of caries). Because of this weak correlation, the need to score restorations radiographically as well as clinically in order to assess the impact of coronal leakage was obvious. It was, therefore, essential to complement radiographic information with clinical data.

The current study is a cross-sectional design. It is, therefore, not possible to determine whether a periapical lesion is healing or expanding, although Petersson *et al.* (1991) found that after a 10-year period the number of healed periapical lesions was equal to the number of newly developed lesions, indicating the reliability of cross-sectional studies for scoring the long-term success of endodontic treatments. This is also supported by data from Hugoson *et al.* (1995).

The incidence of apical periodontitis associated with root-filled teeth in this study was 32.5%. In a previous epidemiological study (De Moor *et al.* 2000), an incidence of apical periodontitis was 40.4%, based on panoramic radiographs. This figure is comparable to that of other studies, with data ranging from 20 to 60% (Bergström *et al.* 1987, Eckerbom *et al.* 1987, Ödesjö *et al.* 1990, Eriksen & Bjertness 1991, Imfeld 1991, De Cleen *et al.* 1993, Buckley & Spångberg 1995, Eriksen *et al.* 1995, Saunders *et al.* 1997, Weiger *et al.* 1997, Marques *et al.* 1998, Sidaravicus *et al.* 1999, Kirkevang *et al.* 2001). Seventy-eight percent

of the coronal restorations were found acceptable on the radiographs. This is higher than in the studies by Tronstad *et al.* (2000) (66.2%), Ray & Trope (1995) (62.7%) and Kirkevang *et al.* (2000) (73.5%). When the coronal restoration was scored radiographically and clinically (Table 2), 67.4% were found acceptable. Adequate restorations (a) showed signs of apical periodontitis in 30.1% of the teeth. This was statistically different from the 37.4% apical periodontitis in endodontically treated teeth with inadequate restorations (u). When restorations were only scored radiographically (Table 2), this difference was more pronounced (23.8% (a) vs. 49.1% (u)). This difference was statistically significant, as indicated by the χ^2 test and the logistic regression. Other percentages were found by Tronstad *et al.* (2000) (30% (a) and 37% (u), respectively) and Ray & Trope (1995) (20% (a) and 69.8% (u), respectively) for these relationships.

In the present study, the prevalence of apical periodontitis was not influenced by the presence of a root-canal post. This is in agreement with other studies (Kvist *et al.* 1989, Tronstad *et al.* 2000). Eckerbom *et al.* (1991) found the opposite, but their study only included crowned teeth.

Root-canal treatment performed to high technical standards remains a prerequisite for long-term success (Strindberg 1956, Bergenholtz *et al.* 1979, Eckerbom *et al.* 1987, Ödesjö *et al.* 1990, Sjögren *et al.* 1990). Agreement exists in the literature that the length of the root filling is an important factor in endodontic treatment success (Sjögren *et al.* 1990, De Moor *et al.* 2000, Wu *et al.* 2000) and this is confirmed by the results of the present study. There is still some disagreement, however, about the effect of the homogeneity of the root filling on the periapical status. Ödesjö *et al.* (1990), Sjögren *et al.* (1990) and Eriksen *et al.* (1995) found no difference between compact and poorly compacted root fillings in relation to periapical lesions. We found the homogeneity of the root filling to have a statistically significant influence on the prevalence of apical periodontitis (Tables 3–5). This is supported by others (Bergström *et al.* 1987, Petersson *et al.* 1991, Kirkevang *et al.* 2000).

Twenty-three percent of the adequate root fillings (a) and 37.4% of the inadequate ones (u) had apical periodontitis (Table 3). Similar figures were presented by Tronstad *et al.* (2000) (22% (a) and 44% (u), respectively). Ray & Trope (1995) (24.3% (a) and 51.4% (u), respectively) found a more pronounced difference.

As in the studies of Ray & Trope (1995) and Tronstad *et al.* (2000), the lowest prevalence of apical periodontitis (22.5%) was found in teeth with both a good root filling and a good coronal restoration (Table 7). A comparable figure was found when the quality of the coronal restoration was poor and the quality of the root-canal treatment was good (24.3%). When the two groups with poor endodontics were compared, there was a better result when a good restoration was present, but this difference was not statistically significant. On the basis of the present data, it became clear that the quality of the coronal restoration (scored clinically and radiographically) did not have a statistically significant influence on the periapical status when it was combined with the endodontic quality (Table 9: A vs. C and B vs. D). This is in contrast to the findings of Ray & Trope (1995). Tronstad *et al.* (2000) found the quality of the coronal restoration scored radiographically only to be significant when combined with good endodontics.

When the endodontic status of the teeth in the present study was combined with the quality of the coronal restorations (Table 9: A vs. B and C vs. D), a statistically significant influence on the periapical status was seen. An explanation for the difference in findings in this study, as compared to the findings of Ray & Trope (1995) and Tronstad *et al.* (2000), is not obvious. In the latter studies, there was no information on the use and the influence of bases and filling materials. Coronal leakage of a restoration can be prevented by the placement of a base (Saunders & Saunders 1990, Heys & Fitzgerald 1991, Guerra *et al.* 1994). Our results confirm that the use of bases under coronal restorations is beneficial for the long-term outcome of root-canal fillings (Tables 2 and 5). Also more apical periodontitis was detected in teeth filled with composite material than with amalgam. This was confirmed by Buckley & Spångberg (1995). Gap formation at gingival margins and subsequent bacterial colonization under the restoration is a common problem when composites are utilized (Qvist 1980, Qvist 1993, Retief 1994, Ciucchi *et al.* 1997).

The technical quality of a root filling, as scored on a radiograph, can be taken as an indication of the care taken for the overall quality of treatment (especially cleaning of the root canal). Canal cleanliness cannot be scored on a radiograph, although it is very important for endodontic success. Bacteria left in the root canal at the time of canal obturation influence the success of treatment (Nair *et al.* 1990, Sjögren *et al.* 1997, Molander *et al.* 1998, Sundqvist *et al.* 1998).

A limitation of the present and other studies remains the incomplete diagnostic value of radiographs. It is commonly known that lesions limited to the cancellous bone are almost impossible to detect with conventional radiographic techniques (Le Quire *et al.* 1977, Bender 1982,

van der Stelt 1985); moreover, the microbiological status of the root canals cannot be derived from a radiograph.

The question remains as to how important a well-sealed coronal restoration is for the long-term success of endodontic treatment. Studies by Ray & Trope (1995) and Kirkevang *et al.* (2000) found the coronal restoration to be of relatively greater importance than the root-canal filling. Tronstad *et al.* (2000) found the quality of root-canal treatment to be more important; the present study found both to be of equal importance. The Odds ratios in Tables 4 and 5 for the radiographic appearance of the coronal restoration and the homogeneity of the root fillings are of the same magnitude, indicating an equal effect on the periapical condition. This is in contrast with the study by Ray & Trope (1995) who found the Odds ratio for quality of restoration to be four times higher than for endodontic quality. Ricucci *et al.* (2000) found no statistically different prevalence of apical periodontitis in root fillings exposed to the oral environment compared with a control group. It is clear that bacterial ingress should be avoided, but the importance of both the coronal restoration and the root filling should be emphasized as good technical quality of both is a prerequisite for long-term success.

Conclusion

The results of this study indicate that a well-sealing coronal restoration and a well-performed root-canal treatment are both important for the overall success of root-canal treatment. For the assessment of coronal leakage as related to apical periodontitis, radiographic evaluation of the coronal restorations is of greater importance than the quality scored only on a clinical basis. Data suggested that the problem of coronal leakage may not be of such clinical impact as indicated by previous studies, provided endodontic treatment procedures are carefully carried out. In addition, it is clear that the use of a base under restorations is beneficial in reducing apical periodontitis.

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