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ORIGINAL ARTICLE

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Prevalence and quality of root canal fillings in a German adult population

A survey of orthopantomograms taken in 1983 and 1992

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Abstract The few studies in which prevalence, technical quality, and success rates of root canal fillings performed in daily practice have been assessed demonstrated a high proportion of inappropriate root fillings and a great variety of periapical radiolucencies (25–60%). The aim of the present retrospective radiographic study was to determine if changes in prevalence, technical quality, and success of root canal fillings had occurred within a decade. To achieve this goal, orthopantomograms taken in patients who attended a University Dental Clinic for the first time in 1983 (group A) and in 1992 (group B) were evaluated by a calibrated examiner. The following criteria were applied to assess the root-filled teeth: length and homogeneity of the root fillings and the periapical state. The prevalence of root-filled teeth increased significantly from an average 0.5 per person in 1983 to 0.8 per person in 1992. The increase was proportionally greater in older patients. In group A, 55.2% of the root fillings ended 0–2 mm before the radiographic apex and in group B this percentage was 56.8. Insufficient homogeneity was found in 25.0% (group A) and 21.9% (group B) of the root fillings. The prevalence of root-filled teeth without periapical destructions was 76.1% (group A) and 74.1% (group B). It is concluded that, in the future, endodontic treatment need will increase because of the steadily growing number of older people. Further efforts in research and dental education should focus on the treatment of curved root canals.

Key words Endodontology · Epidemiology · Orthopantomograms · Periapical lesions · Radiographic examination

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Introduction

To date, the success and quality of root canal treatments have been assessed in only a few studies. Success rates of 90% have been achieved by endodontic specialists or undergraduate students [6, 12, 14, 22]. In contrast, a high proportion of inappropriate root canal fillings performed by practitioners has been observed in numerous countries. Also, 25–60% of the root-filled teeth presented a periapical radiolucency [1–5, 7, 8, 10, 11, 13, 15, 19, 23]. Only some of these studies comprised all age groups [2–5, 13, 15, 23], whereas other authors confined themselves to selected age groups [1, 7, 8, 11]. All these studies were conducted either on representative population samples [7, 8, 11, 15, 17] or on patients who attended a university dental school or a dental clinic [3–5, 10, 13, 19, 23] for the first time. Information about changes in the prevalence and quality of root canal fillings is sparse [7, 13], although endodontic treatment need is supposedly increasing due to increased dental awareness together with a growth of the elderly population. The aim of the present retrospective radiographic study was to determine if changes in prevalence, quality, and success of root canal fillings performed in daily practice had occurred within a decade. In addition, the influence of age on these parameters was investigated.

Materials and methods

Selection of radiographs

The present study is based on the examination of orthopantomograms of patients who attended the Dental Clinic of the University of Marburg for the first time. Because of the great number of these radiographs, a selection was necessary. It was decided to examine every second orthopantomogram taken in the second half of the year 1983 and every third orthopantomogram dating from the corresponding period of the year 1992. The starting point was allotted among the first ten patients of the archives list.

All radiographs had been taken by radiological technical assistants of the central radiographic department with the aid of an Oralix (Philips) orthopantomograph. Cronex-4 film with reinforcing foil

was used. The films were developed in a Protec M45 (DuPont de Nemours) automatic developing machine.

Examination of the radiographs

The evaluation was done with a framed viewer light. All radiographs were examined with the aid of a double-magnifying glass. The following information was noted on a standardized form: age and sex of the patient, presence or absence of teeth. In addition, presence or absence of any root canal filling was registered per tooth. Subsequently, the evaluation of the root canal fillings was performed using the following criteria:

1. Distance between root canal filling and radiographic apex: more than 2 mm; 1–2 mm; 0–1 mm; overfilled canal.
2. Homogeneity of the root canal filling: acceptable or good; insufficient; not clear.

The radiographic state of the periapical region was assessed with the aid of the Periapical Probability Index (PRI) introduced by Reit and Gröndahl in 1983 [20]. The PRI consists of the criteria presented subsequently:

PRI 1: Periapical destruction of bone definitely not present
PRI 2: Periapical destruction of bone probably not present
PRI 3: Unsure
PRI 4: Periapical destruction of bone probably present
PRI 5: Periapical destruction of bone definitely present.

It must be noted that in cases of multirooted teeth, not all root canal fillings of such teeth were assessed separately but only the canal with the worst technical quality. If a multirooted tooth presented with different periapical status at different roots, the root canal with the most severe periapical condition was categorized.

The assessment of the radiographs was performed in 1993 by one examiner (O. C.), who had been calibrated before by a dentist very experienced in endodontics (A. S.). For the calibration, 30 orthopantomograms showing at least one root canal filling were used. These radiographs were not included in the study. During the period the radiographs were assessed, the examiner was recalibrated weekly.

Statistical methods

Since the data consisted of frequencies in discrete categories, the chi-square test was used to determine the significance of differences between two independent groups. The significance level was $P<0.05$. The statistical calculations were executed in the Hochschulrechenzentrum of the University of Marburg with the aid of the software package SPSS.

Results

Prevalence of root canal fillings

A total of 1830 orthopantomograms was evaluated. Of these, 930 radiographs originated from 1983 (group A) and 900 dated from 1992 (group B). The mean age of the patients in group A was 35.8 years, whereas for group B a mean age of 38.1 years was computed. The sex distribution was balanced in both observation periods: 52% were men and 48% were women. The age distribution is shown in Fig. 1.

In 26.8% of group A patients, at least one root-filled tooth was found. This increased to 35.8% in patients of group B, the difference being significant. The increase was observed in all age groups except the 6- to 20-year-olds and the 31- to 40-year-olds. The frequency distribution of root-filled teeth with age (Fig. 2) shows that the increase of the root-filled teeth in group B was greater in persons 51–60 and over 60 years old.

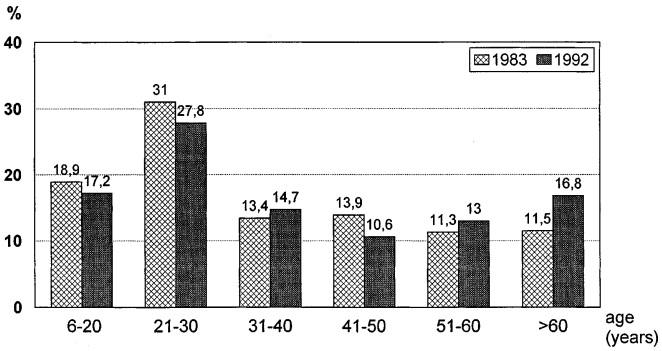

Fig. 1 Distribution of different age groups in 1983 and 1992 (%)

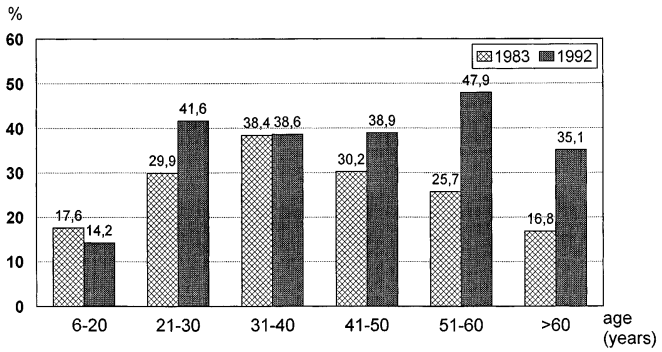

Fig. 2 Prevalence of patients with at least one root filling in different age groups in 1983 and 1992 (%)

A mean of 22.9 teeth was registered in patients of group A and, on average, 0.5 teeth per person had received a root canal filling. The corresponding values for group B are 22.4 and 0.8. The difference in the number of root-filled teeth per person was significant.

Compared to 1983, the absolute number of root-filled teeth increased in all tooth groups (Table 1) in 1992, but the relative distribution in the different tooth groups changed. The proportion of front teeth treated was reduced, while that of premolars and molars increased (Table 1).

Technical quality of the root canal fillings

In group A, 55.2% of the root canal fillings ended 0–2 mm before the radiographic apex and in group B the percentage was 56.8. In root canal fillings ending more than 2 mm before the apex, almost no difference was observed between the groups (Table 2). This state of root filling was not observed in all tooth groups to the same degree. The molars of the maxilla and the mandible demonstrated the highest frequency, with a prevalence of 67.1% and 63.8%, respectively, whereas only 24.2% and 21.5% of the front teeth showed root canal fillings too short of the apex. An

Table 1 Distribution of different root-filled tooth groups in 1983 (group A) and 1992 (group B) (* $P<0.05$, *n.s.* not significant)

	Maxilla			Mandible		
	Front teeth	Premolars	Molars	Front teeth	Premolars	Molars
Group A (1983) (436 root filled teeth)	44.3%	16.5%	9.2%	8.0%	12.6%	9.4%
Group B (1992) (681 root filled teeth)	35.8%	16.7%	10.3%	7.5%	15.9%	13.8%
Significance between groups A and B	*	n.s.	n.s.	n.s.	*	*

Table 2 Length of the root canal fillings in relation to the radiographic apex in 1983 (group A) and 1992 (group B). In multirooted teeth only the root canal filling with the worst quality has been assessed (*n.s.* not significant)

Distance root filling to roentgenologic apex	Group A (1983)	Group B (1992)	Significance
0–1 mm	33.9%	32.9%	n.s.
1–2 mm	21.3%	24.5%	n.s.
>2 mm	38.3%	38.5%	n.s.
Overfilled	6.5%	4.7%	n.s.

Table 3 Dependence of the periapical state on the length and homogeneity of the root canal fillings in group B (1992). In column 1 the number of root-filled teeth is indicated in parenthesis (*PRI* periapical probability index)

Separate classification of root fillings by length and homogeneity	PRI 1 and 2 (success)	PRI 3 (uncertain)	PRI 4 and 5 (failure)
0–1 mm (n = 219)	83.6%	4.5%	11.9%
1–2 mm (n = 167)	86.2%	7.2%	6.6%
>2 mm (n = 262)	63.4%	16.8%	19.8%
Overfilled (n = 33)	50.0%	34.4%	15.6%
Homogeneity acceptable (n = 519)	80.5%	8.9%	10.6%
Homogeneity unacceptable (n = 148)	57.7%	16.8%	25.5%
Homogeneity unclear (n = 14)	53.8%	46.2%	0.0%

excess of root filling material was observed in a number of roots (Table 2).

The analyses regarding the homogeneity of the root canal fillings revealed a significant difference. The prevalence of improperly obturated root canals was 25.0% in group A and 21.9% in group B. Homogeneity was not assessable in only 2.3% and 1.9%, respectively, of the endodontically treated teeth.

Assessment of the periapical region by means of the PRI

According to the recommendations of Reit and Gröndahl [20], root-filled teeth with PRI scores of 1 and 2 were judged successful, while teeth receiving scores 4 and 5 were rated as failures. No great difference in this distribution was found between the two groups. The prevalence of successfully root-filled teeth was 76.1% (group A) and 74.1% (group B), while the failure rate was 14.4% and 13.7%, respectively. The percentage of uncertain cases was 9.4 and 11.3, respectively.

A clear correlation was found between periapical state and technical quality of the root canal filling (Table 3). As the results for the two observation periods did not differ significantly, in Table 3 only the results of group B are listed. Teeth with root canal fillings short of the apex or of insufficient homogeneity showed significantly more periapical lesions than those with acceptable technical quality.

Discussion

Methods

A lack of information on the prevalence, technical standards, and success of root canal fillings has been recognized in several countries [4, 10, 11, 13, 15, 23]. The present study contributes to reduce this hiatus by assessing orthopantomograms of patients who attended a University Dental Clinic for the first time. The orthopantomogram has been considered as sufficient and acceptable in this epidemiological study, although this method is not ideal for the precise analysis of apical and periapical status. The authors are aware of the fact that analyzing orthopantomograms in the field of endodontic questions is regarded sceptically by some critics. In accordance with other authors [9, 21] we do not deny that periapical radiographs are usually superior with respect to individual diagnoses of periapical problems. Nevertheless, previous studies have used orthopantomograms because their quality is sufficiently reliable for epidemiological questions to be addressed [4, 7, 10, 13, 23]. In particular, De Cleen et al. [4] have evaluated a large number of studies, comparing the usefulness of orthopantomograms and full mouth sets, and underline this conclusion convincingly.

The special situation for collecting epidemiological data in the field of endodontics requires a more detailed consideration. It is becoming increasingly difficult to conduct these studies because they are based on the assess-

ment of radiographs and because, in an increasing number of countries, people refuse a radiographic examination. This explains the difficulties in selecting persons randomly out of the whole population in order to take radiographs for epidemiological purposes. Studies such as those conducted by Frode Hansen and Johansen [8] and Eriksen et al. [7], who had invited a representative sample of 35-year-old inhabitants of Oslo for a dental and a radiographic examination, would be rejected in Germany at the present time. Thus we are forced to assess radiographs which had been taken for medical reasons. Orthopantomograms appear very suitable for epidemiological studies in the field of endodontics. Because of the higher radiation dose, full mouth sets, consisting of 10–15 single radiographs, are taken in special situations only, as, for example, for severe periodontal problems.

The assessment of orthopantomograms taken in dental practice would have the advantage of selection from a great number of patients. On the other hand, this approach would have several disadvantages because very high organisational efforts would be required and, even more importantly, radiographs of very inconsistent quality concerning film, projection, and development would have to be analyzed. In contrast to this, orthopantomograms of a dental clinic are taken by specially trained roentgenological assistants, using the same development device. So we preferred to assess radiographs from our own clinic, allowing a good comparability for the assessment of root canal fillings and periapical regions.

Prevalence of root canal fillings

Compared to the observation period of 1983, the number of patients with at least one root-filled tooth increased by about 50% in 1992. It is remarkable that a proportionally greater increase of root-filled teeth was observed in 51- to 60-year-old and over 60-year-old patients. In 1983, the proportion of patients with at least one root-filled tooth did not increase with age, while this was observed in 1992. As the number of older persons will increase steadily in the next 20 years because of demographic changes, even a cautious interpretation allows the conclusion that in Germany the endodontic treatment need will increase.

A mean of 0.8 root-filled teeth per person was found in patients who attended our Dental Clinic for the first time in 1992. Similar values were reported from other German regions [10, 13]. In contrast to this, much higher mean values (1.4–3.0) of root-filled teeth were found in studies from Austria, Norway, Sweden, and USA [1–3, 5, 15, 23]. A lower prevalence (0.5) was only observed in a Dutch investigation [4].

In accordance with Hülsmann et al. [10] and Klimek et al. [13], most of the root fillings were found in front teeth, followed by those in premolars. The molars, however, were more rarely root filled (Table 1). Bergström et al. [2], de Cleen et al. [4], and Städtler et al. [23] reported a completely reversed order. At the moment we cannot explain why the prevalence of root fillings differs so much in western European countries. It must be assumed that the great differences in the health systems of these countries play an important role.

The fact that, compared to the mandible, in the maxilla about double the number of teeth were root filled (Table 1), was initially surprising, although in other studies this had also been reported [1, 3, 5, 11, 13]. A direct comparison of these studies is not possible because two of them are based on radiographs of over 65-year-old patients [1, 11]. The analyses of the present investigation and the studies of Buckley and Spangberg [3], Eckerbom et al. [5], and Klimek et al. [13] revealed that, in contrast to the front teeth of the maxilla, the incisors and canines of the mandible demonstrated nearly no root fillings. This explains the higher prevalence of root-filled teeth in the upper jaw because in premolars and molars no great difference was observed between upper and lower jaw. Probably two factors are responsible for this; the front teeth of the mandible are known to be very caries resistant and the front teeth of the maxilla are mainly involved when dental traumas occur.

Technical quality of root canal fillings

The technical quality of a root filling is determined by its length in relation to the apex and by its homogeneity. The present study demonstrates that, within a decade, there were no changes in this respect. In both groups A and B, about 57% of the root fillings were filled ideally or acceptably with respect to the length, about 38% of the root fillings were too short of the apex, and about 5% of the root fillings were overfilled (Table 2).

The results of our investigation can be compared with 11 other studies presented in Table 4. In these studies, nearly all the root canal fillings assessed had been placed by dentists in daily practice. It can be concluded that it is very difficult to perform technically acceptable root fillings under the conditions of daily practice. Only in five of these studies was the proportion of correctly root-filled teeth greater than the proportion of teeth with root fillings too short of the apex. It is therefore not surprising that, on average, only 43.8% (range 31–68%) of the root canal fillings were filled in an acceptable way. For the root canal fillings too short of the apex, a mean value of 50.2% (range 27–69%) was determined. The mean value for overfilled root fillings was 5.9% (0–17%). As in the present investigation root canal fillings too short of the apex were not observed to the same degree in all tooth groups but were particularly prevalent in molars, further efforts in research and dental education should focus on the treatment of curved canals.

Success and failure of root canal fillings

The prevalence of radiographically detectable periapical lesions did not differ significantly in orthopantomograms of the years 1983 and 1992. For reasons of clarity, our data

Table 4 Findings of 12 endodontic studies dealing with the technical quality of root canal fillings in chronological order, our own investigation included. The last column contains the amount of root fillings judged to have failed because of a periapical lesion. The majority of the endodontic treatments had been performed by practitioners (*OPG* orthopantomograms)

Authors	Country	Age of patients (years)	Radiographs assessed	Root fillings correct (%)	Root fillings too short (%)	Root fillings overfilled (%)	Failure of root fillings (%)
Allard and Palmqvist (1986)	Sweden	>65	Full mouth set	31.0	69.0	0	27.0
Eckerbom et al. (1987)	Sweden	20–>60	Full mouth set	45.7	44.9	9.4	26.4
Bergström et al. (1987)	Sweden	20–60	Full mouth set	36.6	57.3	6.1	28.8
Eriksen et al. (1988)	Norway	35	OPG and single radiographs	40.5	43.1	16.4	34.0
Ödesjö et al. (1990)	Sweden	20–80	Full mouth set	41.4	48.5	10.1	24.5
Imfeld (1991)	Switzerland	66	OPG and single radiographs	36.0	64.0	0	31.0
Hülsmann et al. (1991)	Germany	20–>60	OPG	36.0	62.0	2.0	60.0
De Cleen et al. (1993)	The Netherlands	20–>60	OPG	49.4	48.5	2.1	39.2
Städtler et al. (1993)	Austria	15–65	OPG	37.6	57.8	4.6	25.9
Klimek et al. (1995)[a]	Germany	20–>60	OPG	46.6	43.1	10.3	45.8
Buckley and Spanberg (1995)	USA	<20–>80	Full mouth set	67.8	27.4	4.8	22.6
This investigation[b]	Germany	6–>60	OPG	56.8	38.5	4.7	13.7

[a] Only the results of the 1991 observation period are presented
[b] Only the results of the 1992 observation period are presented

from 1992 will be used for a comparison with other investigations.

The frequency of root-filled teeth with periapical lesions was 13.7% in our study although in other studies a wide range of prevalence has been reported (Table 4). The mean value derived from these studies is 31.6% (range 14–60%). The comparison of our data with two other studies [10, 13] shows that there are obviously great regional differences in Germany. The performance of the three German studies was very similar. Orthopantomograms of a dental school were evaluated and the PRI introduced by Reit and Gröndahl [20] was used to assess the periapical region. Concerning the results of Hülsmann et al. [10] it should be taken into account that the orthopantograms they had assessed originated from patients of a periodontic department. It can be assumed that the periodontal problems of these patients had a negative influence on the periapical state of the root-filled teeth.

Although the assessment of periapical translucencies on radiographs in cross-sectional studies is limited by the fact that the observer does not know if the periapical lesions are in regression, stationary or developing, two findings suggest that cross-sectional studies can provide reliable information on the long-term success rate of endodontic treatment at the population level. Orstavik et al. [16] observed that most of the changes in periapical status occur within the first year after the placement of a root canal filling. In two other studies it was demonstrated that a number of endodontically treated teeth with apical periodontitis healed during the observation period. During the same time, approximately the same number of endodontically treated teeth presented with a new apical periodontitis [18, 24].

The fact that only slightly more than half of the root fillings too short of the apex or filled beyond the apex demonstrated a periapical lesion does not imply that proper root canal obturation should not be attempted. The analyses of our data showed a clear correlation between the presence of periapical lesions and bad quality root canal fillings. Thus, in 85% of the endodontically treated teeth with a root filling ending 0–2 mm before the apex, a sound periapical state was observed. Only 64.4% of the teeth where the distance between apex and root filling was more than 2 mm were without pathological periapical signs and in overfilled teeth this prevalence was reduced to 50%. The data presented in Table 3 show that, in general, the homogeneity of the root canal fillings also influences the periapical state. Root fillings too short of the apex but with homogeneous obturation demonstrated periapical lesions less often than the total of teeth with too short root fillings. Conversely, inhomogeneous root fillings but with acceptable length were more often associated with periapical lesions than the total of teeth filled to an acceptable length. The importance of the technical quality was demonstrated more clearly by the results of Eriksen et al. [7]. They found sound periapical states in 90% of optimally root filled teeth, while this was observed in only 38% of teeth with inadequate root fillings. Nevertheless, it should be mentioned that in other investigations the influence of the technical quality of the root canal filling could not be detected so clearly. De Cleen et al. [4] and Eckerbom et al. [5] reported only a weak correlation between improper root filling and the prevalence of periapical lesions. Further, Ödesjö et al. [15] could not demonstrate such a correlation. In a recent publication it was demonstrated that in root-filled teeth with insufficient coronal restorations, thus causing coronal leakage, significantly more periapical lesions had developed than in root-filled teeth without radiographic signs of coronal leakage [19]. As in our study the quality of the coronal restorations had not been assessed, we cannot discuss to what degree there was an influence of coronal leakage on the appearance of periapical lesions.

In conclusion, it should be kept in mind that not only the technical standard of the root fillings but also the quality of the whole root canal treatment, a successful reduction of canal infection and the avoidance of coronal leakage included, plays an important role in the success of root fillings.

References

1. Allard U, Palmqvist S (1986) A radiographic survey of periapical conditions in elderly people in a Swedish county population. Endod Dent Traumatol 2:103–108
2. Bergström J, Eliasson S, Ahlberg KF (1987) Periapical status in subjects with regular dental care habits. Community Dent Oral Epidemiol 15:236–239
3. Buckley M, Spangberg LSW (1995) The prevalence and technical quality of endodontic treatment in an American subpopulation. Oral Pathol Oral Radiol Endod 79:92–100
4. De Cleen MJH, Schuurs AHB, Wesselink PR, Wu MK (1993) Periapical status and prevalence of endodontic treatment in an adult Dutch population. Int Endod J 26:112–119
5. Eckerbom M, Andersson J-E, Magnusson T (1987) Frequency and technical standard of endodontic treatment in a Swedish population. Endod Dent Traumatol 3:245–248
6. Egli H (1963) Wurzelfüllmaterial AH 26. Röntgenologische Nachkontrollen über Erfolge und Mißerfolge. Dtsch Zahnarztl Z 18:407–413
7. Eriksen HM, Bjertness E, Örstavik D (1988) Prevalence and quality of endodontic treatment in an urban adult population in Norway. Endod Dent Traumatol 4:122–126
8. Frode Hansen B, Johansen J (1976) Oral roentgenologic findings in a Norwegian urban population. Oral Surg 41:261–266
9. Grasser B, Barth HH (1987) Die Diagnostik von Interdentalokaries und apikaler Ostitis im Vergleich zwischen Orthopantomogramm und Zahnfilm. Dtsch Zahnarztl Z 42:818–821
10. Hülsmann M, Lorch V, Franz B (1991) Untersuchung zur Häufigkeit und Qualität von Wurzelfüllungen. Dtsch Zahnarztl Z 46:296–299
11. Imfeld TN (1991) Prevalence and quality of endodontic treatment in an elderly urban population of Switzerland. J Endod 17:604–607
12. Kerekes K, Tronstad L (1979) Long-term results of endodontic treatment performed with a standardized technique. J Endod 5:83–90
13. Klimek J, Kockapan C, Borchert J (1995) Häufigkeit und Qualität von Wurzelkanalfüllungen in den Jahren 1983 und 1991. Dtsch Zahnarztl Z 50:154–156
14. Molven O, Halse A (1988) Success rates for gutta-percha and Kloroperka N-O root fillings made by undergraduate students: radiographic findings after 10–17 years. Int Endod J 1:243–250
15. Ödesjö B, Helldén L, Salonen L, Langeland K (1990) Prevalence of previous endodontic treatment, technical standard and occurrence of periapical lesions in a randomly selected adult, general population. Endod Dent Traumatol 6:265–272
16. Örstavik D, Kerekes K, Eriksen HM (1987) The clinical performance of three endodontic sealers. Endod Dent Traumatol 3:178–186
17. Petersson K (1993) Endodontic status of mandibular premolars and molars in an adult Swedish population. A longitudinal study 1974–1985. Endod Dent Traumatol 9:13–18
18. Petersson K, Hakansson R, Hakansson J, Olsson B, Wennberg A (1991) Follow-up study of endodontic status in an adult Swedish population. Endod Dent Traumatol 7:221–225
19. Ray HA, Trope M (1995) Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 28:12–28
20. Reit C, Gröndahl H-G (1983) Application of statistical decision theory to radiographic diagnosis of endodontically treated teeth. Scand J Dent Res 91:213–218
21. Rohlin M, Kullendorff B, Ahlqwist M, Stenström B (1991) Observer performance in the assessment of periapical pathology: a comparison of panoramic with periapical radiography. Dentomaxillofac Radiol 20:127–131
22. Sjögren U, Hägglund B, Sundqvist G, Wing K (1990) Factors affecting the long-term results of endodontic treatment. J Endod 16:499–504
23. Städtler P, Feldner J, Glockner K, Ebeleseder K (1993) Zustand von Endodont, Parodont und Zahnverlust bei 1117 Erwachsenen. Z Stomatol 90:179–186
24. Van Nieuwenhuysen J-P, Aouar M, D'Hoore W (1994) Retreatment or radiographic monitoring in endodontics. Int Endod J 27:75–81