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Assessment of the periapical and clinical status of crowned teeth over 25 years

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ABSTRACT

Objectives: The purpose of this study was to examine radiographically changes in the periapical status and compare the clinical status of teeth with a vital pulp and root-filled teeth restored with crowns and bridge retainers during 25 years.

Methods: During 1967/68, 114 patients received prosthodontic treatment by senior dental students at the Oslo Dental Faculty. In all, 291 teeth with a vital pulp and 106 root-filled teeth were restored with 158 prostheses. All root-filled teeth were restored with a cast dowel and core. The casts were made in a type-3 gold alloy, and cemented with zinc phosphate cement. Forty-six teeth were restored with crowns and 351 teeth with bridge retainers. Radiographs were taken preoperatively, immediately after cementation, and every fifth year. Two independent observers assessed the periapical status on the radiographs according to the PAI-index. At the 25 years examination, 32 patients (28%) with 101 restored teeth (24%) remained in the study. Survival rates of the prostheses and of the restored teeth were estimated using Kaplan–Meyer non-parametric statistics.

Results: The PAI-score of the periapical status deteriorated in 13 vital and four root-filled teeth. The survival rates of the fixed prostheses were not influenced by the pulp vitality of the restored tooth at the baseline. The survival rates of the restored teeth with a vital pulp and of the root-filled teeth were similar. Clinical failures were recorded on approximately one-third of the restored teeth. The main reason for tooth failure was caries (12%), and for the teeth with a vital pulp also pulpal deterioration (10%). Estimates of the proportions of crowned teeth with a vital pulp that will remain free from signs and symptoms of pulpal deterioration were 98% after five years, 92% after 10 years, 87% after 20 years and 83% after 25 years.

Conclusions: The incidence of periapical lesions on radiographs of crowned teeth was low during 25 years observation. Crowned, root-filled teeth with a high quality endodontic treatment and an optimal morphology of the dowel and core have a similar survival rate as crowned teeth with a vital pulp. A high proportion of crowned teeth with a vital pulp will remain free from signs and symptoms of pulpal deterioration over 25 years. © 1997 Elsevier Science Ltd. All rights reserved.

KEY WORDS: Fixed dental prosthetics, Endodontics, Longevity, Radiographs, Survival

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INTRODUCTION

The preparation of teeth for fixed prostheses usually involves extensive removal of enamel and dentin. In addition, the application of a variety of dental materials and operative procedures on the prepared tooth may have significant biological consequences for the dental pulp[1]. Furthermore, several studies have shown that common luting cements dissolve more or less in the oral environment depending on the material properties and fit of the fixed prosthesis[2]. It is, therefore, probable that at some time damage to the pulp tissue will occur in a proportion of the restored teeth. However, although many histological studies have documented pulp and dentin reactions after prosthodontic therapy[3], the incidence and the risk period of loss of pulp deterioration remain uncertain. Different results have been presented in clinical studies[4–23] (*Fig. 1*). Other data have been

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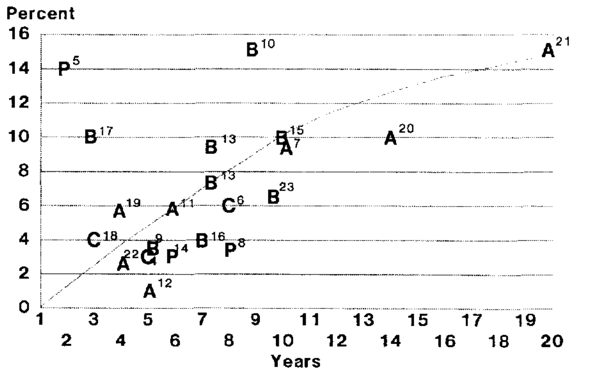

Fig. 1. Reported frequencies of periapical changes on teeth restored with crowns and bridges assessed in cross-sectional clinical studies. Letters indicate the type of prostheses reported: A, crowns and bridges; C, full crowns; B, bridges; P, partial crowns. The diagonally traced line indicates approximate mean values.

presented as ratios of pulp deterioration as a reason for failure of prosthodontic therapy[16,24-29]. The ratios range between 4% in a 13-year-old study sample[25] and 3% in an 11-year-old study sample[24] to 22% in a six-year-old sample[28] and 21% in a 14-year-old sample[29].

These studies do not provide a clear-cut picture of the risk involved for pulpal breakdown in teeth subjected to fixed prosthodontic therapy. The reason is differences in study aims and study designs, as well as study populations and types of fixed prostheses. Furthermore, the criteria for failure and choice of observation unit vary in these studies. The observation unit and criteria for failure can be divided into five categories: removal of the prosthesis, repair or removal of the prosthesis, removal of a retainer in the prosthesis, repair of a restored tooth, or removal or repair of a restored tooth. From a biological view, however, the most interesting question is to what degree prosthodontic therapy maintains the integrity of the restored tooth in the long run, i.e. the data on restored teeth remaining intact would seem the most relevant. The preparation techniques and procedures, size of prosthesis, cantilever extension, materials used, oral hygiene and patient selection will probably also influence the prognosis of prosthodontic therapy[23]. Few studies have focused on the prognosis of prosthodontic therapy in patients who have received regular follow-up and oral hygiene controls[30].

There is a controversy whether a root-filling and/or a dowel and core may jeopardize the prognosis of prosthodontic therapy[31]. The contrary results often presented probably reflect differences in study parameters and study design as well as definitions of criteria for failure.

The purpose of the present investigation was to examine radiographically changes in the periapical status of teeth restored with crowns and bridge retainers during 25 years of observation. A second study aim was to assess and compare the incidence of failure of crowns and fixed prostheses cemented on teeth with a vital pulp and on root-filled teeth. The third aim was to compare the frequency of adverse clinical sequelae to teeth with a vital pulp and to root-filled teeth restored with crowns and bridge retainers.

MATERIALS AND METHODS

The patients consisted of individuals receiving prosthodontic treatment by the senior students at the Department of Prosthetic Dentistry, University of Oslo, in the academic year 1967/68. Patients that could not attend annual re-examinations during a five-year period and patients more than 70 years old were not included in the study.

Before the prosthetic treatment the patients received periodontal treatment including instruction in oral hygiene, scaling and surgical elimination of deep pockets. Non-vital teeth and teeth with large amounts of hard tissue loss were root-filled. Patients in need of endodontic treatment had this undertaken at the Department of Conservative Dentistry. For pulp canal obturation a technique using a standardized endodontic procedure with gutta-percha points coated with chloropercha (Kloroperka N–Ö, N–O Therapeutics, Oslo, Norway) as a sealer was used[32]. A description of the endodontic procedures has been published[33].

The indications for prosthodontic treatment were tooth damage due to caries, wear or trauma, crown replacements, or as supporting abutments in bridges. All root-filled teeth were restored with an individually fitted dowel and core cast in a type-3 gold alloy (Gamma Gold, K.A. Rasmussen, Hamar, Norway). Dowel space was prepared such that if possible the depth of the dowel was at least equal to or longer than the length of the artificial crown. The intention was also to maintain a minimum of 3 mm of the gutta-percha filling in the apical part of the canal. The gutta-percha was removed with rotating reamers. The casts were controlled for passive fit and rotation resistance and cemented with zinc phosphate cement (De Trey Zinc Phosphate Cement, De Trey, Zürich, Switzerland) before the final preparation and impression taking for the cast.

The time between endodontic treatment and the preparation of the teeth was at least one week. The teeth were prepared using rotary cutting instruments cooled with water spray in a low-speed handpiece. One goal of the tooth preparation was to maintain maximum conservation of tooth tissue. The preparations were made with a 1 mm buccal shoulder when veneered with acrylic resin. The location of the crown margins was mostly subgingivally (65%)[34]. The prepared teeth were temporized during the period between the preparation and the cementation. The temporary crowns were cemented with zinc oxide–eugenol based cements.

Table I. Number and dimensions of the fixed prostheses in the present study

No. units	*No. retainers*								
	1	2	3	4	5	6	7	8	Sum
1	46								46
2	5	2							7
3		58							58
4		36	33						69
5		6	24						30
6		6	12	16					34
7			3	4	5				12
8				4	10	6			20
9					5		14		19
10					10	6			16
11					15	12		8	35
12					5	6	14		25
13					5		7		12
14						6		8	14
Sum	51	108	72	24	55	36	35	16	397
Per cent	13	27	19	6	13	9	9	4	

Table II. The location of the restored teeth, and dimension of the fixed prostheses

	Single crowns	*1–3 Retainer bridges*	*>3 Retainer bridges*	*Sum*	*Per cent*
Upper incisors	17	48	62	127	32
Upper cuspids	5	42	37	84	21
Upper premolars	5	32	30	67	17
Upper molars	3	24	21	48	12
Lower incisors	2	4	2	8	1
Lower cuspids	2	15	6	23	6
Lower premolars	10	15	5	30	8
Lower molars	2	7	1	10	3
	46	187	164	397	

The fixed prostheses were cast in a type-3 gold alloy (Gamma Gold, K.A. Rasmussen, Hamar, Norway) and 80% were buccally veneered with heat-cured acrylic resin (Hue-lone, L.D. Chaulk Co., Toronto, Canada). All crowns and bridges were made by the same dental laboratory, ensuring the use of identical materials and technical procedures during the fabrication.

Zinc phosphate cement was used for the final cementation (De Trey Zinc Phosphate Cement, De Trey, Zürich, Switzerland). The cement mixing procedure was carried out manually, and according to the manufacturer's instructions. Before cementation, the crowns and the bridge retainers were controlled for passive fit on the tooth, which was cleaned with a slurry of pumice, isolated with cotton rolls and air dried. The crowns and the bridge retainers were seated with finger pressure at the cementation.

The study group consisted of 114 patients with 158 fixed prostheses on 397 teeth. The mean age of the patients at the time of cementation was 48 years, varying between 25 and 69 years. The patients had an average of 9.5 teeth in the maxilla and 10.6 in the mandible.

The fixed prostheses were either single crowns ($n = 46$) or bridges ($n = 112$) with up to 14 units (*Table I*). The location of the restored teeth and the size of the prostheses is shown in *Table II*. The average ratio of retainers to pontics of the bridges was 1.3:1.

The teeth with a vital pulp ($n=291$) were restored with full ($n=276$) or partial crowns ($n=15$) and the root-filled teeth were restored with a full crown with dowel and core ($n=106$, 27%).

Clinical assessments

During the first 10 years the patients received oral hygiene prophylaxis by a dental hygienist every six months, and were examined annually. Later examinations were made after about 15, 20 and 25 years. All the clinical examinations were done by one of the authors (J.V.). The recall examinations included recordings of the patients' dental and periodontal status, calculus removal, restorative therapy and oral hygiene remotivation. The clinical examination for evaluating quality and failures of the fixed prostheses followed the procedures described in the California Dental Association (CDA) quality-evaluation system[35]. Besides the CDA evaluation criteria, all restored teeth were examined clinically. The criterion for failure of the restored tooth was either a fractured, lost or mobile crown or

Table III. Distance between the end of the root-filling material and the radiographic apex and extent of remaining root-filling material. Column numbers indicate total number and row percentages

	Distance between the end of the root-filling and the radiographic apex (mm)						
Remaining root filling material	*>3*	*1.1–3*	*0–1*	*Excess 0.1–1*	*Excess >1*	*Root amputation*	*Sum*
>3 mm remain	6	25	33	9	12	2	87
	7%	29%	38%	10%	14%	2%	
<3 mm remain	6	7	4	0	1	1	19
	32%	37%	21%		5%	5%	
Sum	12	32	37	9	13	3	106

Table IV. Reasons for not attending the clinical examination after 25 years

	No. of patients	*No. of prostheses*	*No. of teeth*
Patients examined	32 (28%)	38 (23%)	101 (24%)
Patient dead	35 (31%)	44 (30%)	117 (30%)
Patient lost*	21 (18%)	32 (17%)	52 (13%)
Patient loss due to prosthesis failure	26 (23%)	44 (30%)	127 (33%)
Sum	114	158	397

*Twelve patients due to remote address change, six due to illness, three due to lack of interest.

bridge retainer, tooth fracture, marginal caries, loss of periodontal support, or a pathological finding on the radiograph.

Radiographic assessments

Intraoral radiographs were taken of all teeth before the prosthodontic treatment, and immediately after cementation. Later radiographs were taken every fifth year using a periodic standardized technique[36]. Two independent observers examined the radiographs and categorized the periapical status of all restored teeth according to the PAI-index[37]. The PAI-index has an ordinal scale of five scores ranging from 1 ('healthy') to 5 ('severe periapical lesion with exacerbating features')[37]. The PAI-scores were dichotomized, with PAI-scores 1 and 2 in group A and PAI-scores 3 to 5 in group B, to reduce the chance of false positive scores for periapical periodontitis.

At the time of prosthodontic treatment, recordings were also made of the density of the root-filling material in the apical region, the distance in millimetres between the root-filling end and the radiographic apex, as well as the length of the remaining root-filling apically to the dowel. The root-filling density was classified as poor when an inhomogenous zone was seen in the root-filling material.

The average distance between the root-filling end and the radiographic apex of the root-filled teeth is shown in *Table III*.

Any differences between the two scorers in their PAI-scores and other measurements of the radiographs were solved by mutual, acceptable agreement on one value, or in case of disagreement, by use of the lowest score.

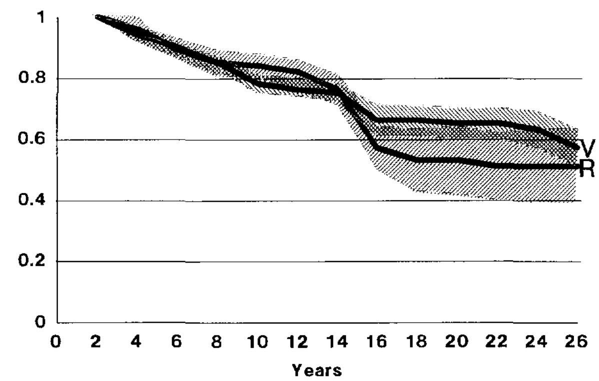

Fig. 2. The estimated probability of survival of the teeth with a vital (V) pulp (*n*=291) and dowel-and-core-restored root-filled (*n*=106) teeth restored with cast restorations and bridge retainers (R). The shaded areas represent the 95% confidence intervals.

Statistics

Survival rates were computed using Kaplan–Meyer non-parametric estimations[38]. The survival rates were estimated using survival rate defined as (i) restored tooth remaining intact, (ii) fixed prosthesis remaining intact, and (iii) restored tooth remaining free from radiographic and clinical signs and symptoms of pulp deterioration.

RESULTS

After five years 96 patients attended the clinical examination, 80 were examined after 10 years, 63 after 15 years[30], 46 after 20 years and 32 after 25 years. The reasons for not attending the examinations after 25 years are listed in *Table IV*.

Table V. Percentage (S.E.) of restored teeth (n=397), which remain intact, and type and size of the fixed prosthesis. Crowns (n=46), teeth in small bridges with up to four units (n=135), teeth in large bridges with more than four units and a ratio less than 2:1 between pontics and retainers (n=170) and teeth in large spanbridges, i.e. bridges with more than five units and a 2:1 ratio between pontics and retainers (n=46)

	5 Year	*10 Year*	*15 Year*	*20 Year*	*25 Year*
Crown	96.5(3.4)	82.1(6.1)	*	*	*
Small bridge	93.4(2.3)	80.8(4.2)	62.7(6.3)	62.7(8.0)	56.0(9.2)
Large bridge	96.6(1.4)	80.6(3.7)	66.4(5.5)	64.1(6.5)	58.3(7.2)
Large spanbridge	97.8(2.2)	81.7(6.9)	62.2(10.5)	62.2(13.3)	57.1(14.6)

* Not computed due to many patient dropouts.

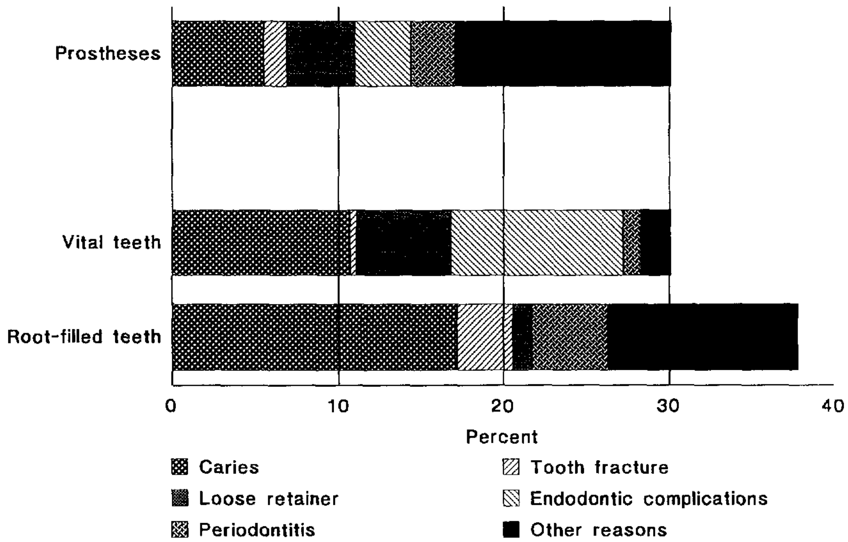

Fig. 3. The frequencies and reasons for repair or removal of the fixed prostheses (30%), and frequencies of failure of the teeth with a vital pulp (30%), and dowel-and-core-restored root-filled (37%) teeth restored with cast restorations and bridge retainers.

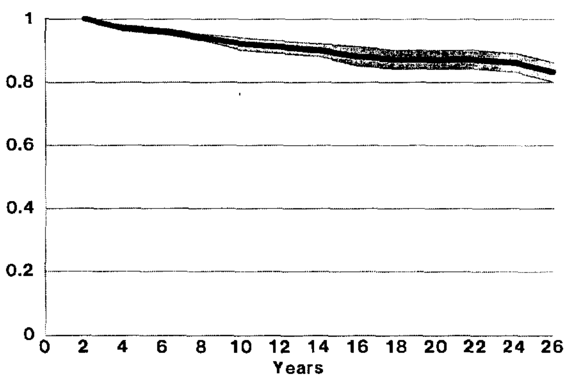

Fig. 4. The estimated probability of endodontic treatment due to pulpal signs and symptoms of teeth with a vital pulp restored with cast restorations and bridge retainers (n=291). The shaded area represents the 95% confidence interval.

Deterioration of the periapical status according to the PAI-score was observed in four teeth with a vital pulp and in three root-filled teeth after five years. After 25 years the accumulated sums of teeth with deteriorated PAI-scores were 13 teeth with a vital pulp and four root-filled teeth. The low number of observations in the latter group invalidated further assessments between deterioration and root-filling density, root-filling end location and length of remaining root-filling material apically to the dowel.

When survival rate was defined as the restored tooth remaining intact, the survival rates were similar for the teeth with a vital pulp and the root-filled teeth (*Fig. 2*). The survival rates of the individual, restored teeth could not be related to the type and size of the fixed prostheses (*Table V*). Furthermore, there were no differences in survival rates depending on the patients' age and gender or on the gingival location of the crown margin at the basis observation. Finally, the survival rate of the root-filled teeth could not be related to the root-filling density, location of the root-filling end location and the length of root-filling material remaining apically to the dowel.

When survival rate was defined as the fixed prosthesis remaining intact, the survival rates were 97% after five years, 80% after 10 years, 70% after 20 years and 65% after 25 years. Statistically insignificant differences in survival rates were noted depending on the type and size of the fixed prosthesis. Among the bridges, the relative proportion of teeth with a vital pulp to root-filled teeth used as abutments could not be related to survival rate or to specific failure reasons. Nor did the presence of partial crown retainers or cantilever solutions influence the survival rate of the bridges.

Thirty per cent of the teeth with a vital pulp (n=86) and 37% of the root-filled (n=40) teeth failed during the observation period. The main reason for tooth failure was caries (12%), and for the teeth with a vital pulp also pulpal deterioration (10%). Other reasons for failure varied slightly in frequency for the teeth with a vital pulp and the root-filled teeth (*Fig. 3*). The reasons for repair or removal of the fixed prostheses (n=44, 30%) were different from the reasons for failure of the teeth (*Fig. 3*). The main reasons for repair or removal of the fixed prostheses were inclusion into larger prostheses and esthetics, caries and loose bridge retainers.

During the observation period, 30 (10%) of the teeth with a vital pulp required endodontic treatment due to signs and symptoms of pulpal deterioration. Endodontic treatment was indicated mainly in the upper molars and lower posterior teeth compared with the anterior teeth, upper cuspids and premolars.

When survival rate was defined as the restored tooth remaining free from radiographic and clinical signs and symptoms of pulp deterioration, the survival rates were 98% after five years, 92% after 10 years, 87% after 20 years and 83% after 25 years. The decrease in survival rate occurred primarily during the first two to seven years after cementation (*Fig. 4*). The survival rates varied slightly with the type and size of the fixed prosthesis after 10, 15, 20 and 25 years. A lower frequency of pulp deterioration was estimated among the abutments in the small bridges (85% survival rate at 25 years, n=102) compared with the abutments in the large bridges (81% survival rate, n=125) and in the large bridges with more than five units and a 2:1 ratio between pontics and abutments (76% survival rate, n=37), However, the differences were not statistically significant at the P<0.05 level.

DISCUSSION

The patients included in the present study were individuals seeking treatment at the dental school. The age, gender and dental status of the participants were representative of the patients treated at the prosthodontic department at the time[39]. The patient dropout rate for reasons besides mortality and prosthesis failure was exceptionally low, and only three out of 114 patients were unwilling to come for a clinical examination (*Table II*). Thus, the risk of selection bias due to absentees can be considered small.

That the reasons for failure of the restored teeth were different from the reason for failure of the prostheses supports previous findings[40]. The lack of differences in survival rate of teeth with a vital pulp compared with root-filled teeth contrasts some cross-sectional studies that suggest a better survival rate of teeth with a vital pulp compared with root-filled teeth, despite whether these have been restored with a dowel and core or not[23,40,41]. The lack of a corresponding result may be due to the qualities of the root-fillings and the dowel-and-core morphology and adaptation in the present material (*Table III*), compared with the average situation observed in population samples[42,43].

The risk of failure of dowel-and-core restored crowns is possibly related to the dowel length[44]. In the present study, the length of the dowel was not measured relative to the crown height. However, it was mandatory in the student clinic to make dowels with lengths exceeding the crown height before cementation. Other factors related to the quality of the dowel that were not measured was the fit of the dowel in the prepared canal, and the size of the unfilled space of the root canal visible apically to the dowel end. These factors were presumed to be adequate, since the criteria for acceptance of the clinical work in the student clinic required fulfilment of specific minimum standards.

The survival rate of the restored root-filled teeth study agree with other clinical data, e.g. 95% after three years[45], 88% after five years[46,47], 90% after six years[48], and 82% and 93% after 10 years[49,50]. The variation in survival rates may be due to differences in the intraoral location of the crowned teeth[41,49]. The low number of failed teeth in the present study invalidated further assessments of this relationship. The reasons for failure of the restored root-filled teeth differed from other studies. In the literature, dowel loosening and tooth fractures have been reported as the most common problems[46,51]. The small percentage of dowel and core loosening and tooth fractures in the present study support the hypothesis that the quality and morphology of the dowel and core influences markedly the prognosis of a restored root-filled tooth.

The incidence of pulpal deterioration in the present study was low compared with several other studies (*Fig. 1*). One reason may be that the students made comprehensive assessment of the pulpal health before the restorative treatment. The assessment resulted often in endodontic treatment of teeth with dubious pulpal conditions or in the revision of an existing root-filling. Also the preoperative condition of the tooth, e.g. caries, tooth wear or fracture, probably influences the incidence of development of endodontic complications[52]. Other factors that influence the risk of pulpal deterioration are the cutting temperature and duration[3], use of local anaesthetic and retraction tissue cord during the operative procedures[23], temporization[1], and the size of exposed root surface[10].

One reason for the different results in the clinical studies (*Fig. 1*) may be due to different methods used to evaluate the status of the pulp. Direct measurements of pulp vitality in the clinic are only possible if irreversible test methods are used. Therefore, pulp vitality is usually diagnosed based on the patient anamnestic data, as well as tooth, tissue and radiographic examination and evaluation of the tooth response to thermal or physical stimulation. The diagnosis of pulp necrosis is probably lower when the diagnosis is limited to radiographic examinations compared with when irreversible tests are used[53]. Thus, in the present study there is a possibility that the frequency of pulp necrosis may have been underestimated, since deterioration may occur and remain undetected due to lack of radiographic changes and clinical sign and symptoms. However, it was considered that due to the long observation period in the present study, the chance of failing to detect teeth with pulp deterioration was small.

During the first 10 years the caries incidence was low, and the standard of oral hygiene was high[34]. The endodontic complications were, therefore, probably not due to poor oral hygiene and caries, but rather due to the operative procedures used as a wide term, or to a deterioration of the interface between the tooth and the fixed prosthesis. The reason that most pulp deteriorations were recorded after two to seven years may be because damaged or non-vital pulp tissue causes periapical tissue destruction only after a certain period. Thus, if necrosis occurs during the preparatory phase, it may take some time before infection develops and pulp destruction is detected. Few teeth developed endodontic complications later in the study. This situation has also been reported in other studies[15,23], but contrasts observations of restored teeth with denuded root surfaces[10].

The observations in the present study that the frequency of pulp deterioration in abutment teeth in bridges seemed to be related to the size of the bridge, support other investigations[9,13,23]. The correlation may be an effect of biomechanical complexity, i.e. loss of retention precedes pulp complications. The higher incidence of pulp complications in large, fixed prostheses may also be due to a more complex alignment of preparations with possible iatrogenic tissue removal and overtapered abutments[31]. Large, fixed prostheses are also difficult to cast with an acceptable fit compared with single crowns. Furthermore, there may be a tendency to accept small discrepancies in large, fixed prostheses compared with single crowns, which otherwise would result in recasting. Finally, large, fixed prostheses may also indirectly increase the risk of pulp deterioration due to more complex oral hygiene procedures and the development of secondary caries.

Deterioration of the periapical status of the root-filled teeth according to the PAI-score could not be related to the density, the end location or the length of apically remaining root-filling material. However, this observation does not validate inadequate endodontic treatment. Unfortunately, the preoperative status of the restored teeth before endodontic treatment was not recorded in the present study, a decisive factor for the outcome of endodontic treatment[33,54].

There is disagreement in the literature regarding how much root-filling material that should remain apically to the dowel[55]. Some authors suggest 5 mm, while others claim that 3 mm are sufficient. The present observations show also that root-filled teeth with less than 3 mm remaining root-filling material may have a satisfactory prognosis. It is possible that different suggestions of minimum remaining root-filling material apically to the dowel may reflect differences in the sealing capabilities of the root-fillings, which primarily is a result of the endodontic technique being used. Consequently, a discussion and definition of the minimum remaining length of root-filling material apically to the dowel should always be related to the endodontic technique that has been used.

CONCLUSIONS

The estimated survival rates and the reasons for failure of the teeth with a vital pulp and the root-filled teeth were similar.

The incidence of pulpal deterioration among the restored teeth with a vital pulp was low. One reason may be that the students made comprehensive assessments of pulpal health before the restorative treatment.

The reasons for failure of the restored root-filled teeth differed from other studies, with a small percentage of dowel and core loosening and tooth fractures. These findings are probably the result of high quality endodontic treatment and an optimal morphology of the dowel and core.

Given good assessment, tooth selection and careful technique, the risk for the development of pulp deterioration and periapical lesions in teeth with a vital pulp seems to be low during a 25-year period.

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