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ORIGINAL ARTICLE

Survival of root filled teeth in general dentistry in a Swedish county: a 6-year follow-up study

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ABSTRACT

Objective: The purpose of the present study was to investigate the survival rate of root filled teeth in general dentistry in a Swedish county and to identify risk predictors with a significant influence on the survival rate.

Materials and methods: This is a retrospective 6-year follow-up study on 1642 recall patients with 1720 teeth root filled in general dentistry in the Public Dental Service in the county of Stockholm, Sweden. Background variables were collected from the database at baseline as potential predictors of tooth loss. The outcome variables were extraction during the 6-year follow-up period and the reason for the extraction. Stepwise Cox regression analysis was adopted in order to investigate the influence of the potential risk predictors on the risk for tooth extraction.

Results: Nine percent of the root filled teeth were lost after 6 years. The most frequent reason for tooth loss was fracture and/or cracks (58%). The survival rate of the root filled teeth increased significantly for younger patients, root filled teeth with metal crowns (96%) and high quality of the root filling (93%). The survival rate differed significantly between tooth groups with the lowest survival for molars (83%). Composite fillings were significantly associated with lower quality of the root fillings.

Conclusions: Ninety-one percent of the root filled teeth survived after 6 years. The survival rate was significantly higher for teeth with root-fillings of high quality and metal crowns as well as for root filled teeth in younger patients. The lowest survival rate was found for molars.

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Introduction

Endodontic treatment is a common field within general dentistry. The caries prevalence has certainly been reduced in western countries during the last 30 years but the frequency of endodontic treatments is the same as earlier probably as a consequence of previous restorations [1].

A review of tooth survival after non-surgical endodontic treatment found that the survival rate ranged between 86 and 93% over 2–10 years [2]. The review included 14 studies and a majority were retrospective investigations. In two 20-year studies from general dentistry in Sweden, the survival rates of root filled teeth were found to be 71 and 65%, respectively [3,4], and the 10-year survival in another Swedish study from a public endodontic specialist clinic was 81% [5]. In the review [2], four variables were found to significantly increase the survival rate of root filled teeth. The most significant factor was a crown restoration after endodontic treatment. The other factors were proximal contacts both at the mesial and distal site, not being an abutment tooth for removable or fixed prosthesis, and non-molar teeth. In a 20-year follow-up study from Sweden [4], the baseline variables mandibular molar, maxillary premolar, prefabricated posts, severe marginal bone loss, caries and apical periodontitis were significantly associated with low odds for tooth survival. However, the detailed knowledge on the long-time survival of root filled teeth and what factors that have a significant influence on the survival rate is scarce [6]. Since a majority of the endodontic treatments in Sweden are performed in general practice, it is important to study the outcome of root canal treatment in that context.

The purpose of the present study was to investigate the survival rate of root filled teeth in general dentistry over six years and to identify risk predictors with a significant influence on tooth survival.

Methods

The study was conducted as a retrospective follow-up study including all patients with teeth that had been root filled from July to December 2008 in 53 clinics for general dentistry in Public Dental Service in the County of Stockholm and that were recall patients during the following six years. The patients were collected from a computer database and were followed during the years 2008–2014. The material included 1720 teeth in 1642 patients.

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The following recordings of the clinical and radiographic examinations were collected from the database at baseline as potential predictors of tooth loss:

- Age;
- Sex;
- Tooth number;
- Type of restoration after endodontic treatment;
- Tooth- and root fractures/cracks;
- Proximal marginal bone loss >1/3 of root-length;
- Proximal angular bony defect with depth >2 mm;
- Cast gold post;
- Carbon fibre post;
- Screw post;
- Fragment of separated file;
- Abutment tooth;
- Presence of proximal contact;
- The quality score of the root-filling after treatment according to Molander et al. [7] with registration of four factors: The apical distance, the quality of the seal, presence of taper and canal transportation. The range of the quality score was 1–5. Score 1 signified the highest quality of the root filling while score 5 signified the lowest quality. In roots with two canals and in multi-rooted teeth, the canal or root with the lowest quality score was recorded. The length of the root filling was evaluated as adequate if it ended within 2.0 mm of the radiographic root apex. The quality of the seal was assessed in the apical two-thirds of the canal.
- The periapical status was registered pre-treatment and at the time of tooth extraction using the periapical index (PAI) described by Orstavik et al. [8].

Outcome variables:

- Extraction during the follow-up period registered per year;
- Reason for tooth extraction registered from the dental records.

The measurements on the radiographs were performed using Planmeca Romexis® dental imaging software. Images were shown on a 22-inch computer screen and brightness, contrast and image size could be adjusted. One observer (HG), specialist in endodontics, assessed the images. The observer (HG) and another observer (TL) were calibrated to the PAI according to Orstavik et al. [8] using a calibration program containing 100 radiographs with an inter-observer agreement of 0.67 (weighted kappa, $p < .01$). In order to estimate the reliability of the assessments performed by the investigator HG, the other observer (TL) evaluated periapical status and the quality of the root-fillings and the weighted kappa values for 50 randomly selected cases were 0.69 and 0.61, respectively ($p < .01$). The quality of the radiographs was inadequate for evaluation of the periapical conditions in 22 cases and for evaluation of the quality of the root filling in 25 cases. In cases of uncertainty the interpretations were discussed with a third observer (specialist in endodontics) and consensus was reached. The study was conducted in full accordance with the World Medical Association Declaration of Helsinki and was approved by the Regional Ethics Board in Stockholm (2015/2165-31/4).

Statistical analysis

The descriptive statistics and statistical analyses were performed using a statistical package (IBM SPSS 21.0, Armonk, NY). Missing data vary between variables and the number of observations (*N*) are presented in the tables. The weighted kappa was calculated in order to determine the inter-observer reliability. Chi-square analysis or Fischer's exact test was used in order to analyse differences between dichotomous variables. Wilcoxon's rank sum test was adopted to analyse the correlations between the periapical condition or the quality of the root filling and dichotomous variables. Stepwise Cox regression analysis was adopted in order to investigate the influence of potential risk predictors on the risk for tooth extraction. The Kaplan–Meier plot was applied for survival analysis of the root filled teeth according to the type of coronal restoration. Results were considered statistically significant at $p < .05$.

Results

The mean age of the patients was 49 years (range 20–90) and 50.2% were females. For 1573 patients (96%), one root filled tooth was included, for 61 patients two root filled teeth, for seven patients three and for one patient four root filled teeth were included. The distribution of root filled teeth according to tooth group is presented in Table 1. The most frequently root filled teeth were mandibular molars (27%), followed by maxillary molars (22%) and maxillary premolars (22%).

The highest relative frequencies for loss of root filled teeth during the follow-up period was found for mandibular molars (12%), while mandibular incisors and canines had the

Table 1. Frequency distribution of number of root filled teeth and number of lost root filled teeth during the follow-up period.

Tooth group*	Number of root filled teeth	Number (%) of extracted root filled teeth
Maxillary molars	375	40 (10.7%)
Maxillary premolars	380	26 (6.8%)
Maxillary incisors and canines	225	16 (7.1%)
Mandibular molars	462	55 (11.9%)
Mandibular premolars	218	12 (5.5%)
Mandibular incisors and canines	60	3 (5.0%)
Total	1720	152 (8.8%)

*p=.02 for comparison between groups (Fischer's exact test).

lowest frequency (5.0%, Table 1). The number of extracted root filled teeth differed significantly between the tooth groups ($p = .02$).

The most frequent reason for extraction was fracture and/or cracks (58%, Table 2). Acute or chronic apical periodontitis was a reason for extraction for 16.3% of the root filled teeth. Marginal periodontitis was considered to be the reason for extraction in 3.3% of the cases (Table 2).

The distribution of extracted root filled teeth according to potential risk predictors is presented in Table 3. Teeth with marginal bone loss >1/3 of the root length were extracted more frequently compared to teeth with less bone loss ($p < .05$). Teeth with composite fillings were lost significantly more often (11.8%, $p < .001$), while the percentage of extracted root filled teeth with metal crowns was significantly lower (3.7%, $p < .001$).

Wilcoxon's rank sum test was used to study the correlation between factors. Composite fillings were significantly ($p < .001$) associated with lower quality of the root-fillings, while no significant correlation ($p = .62$) between presence of composite filling and periapical status was found.

Fifty-one percent of the extracted teeth were considered to have sound periapical condition (PAI 1–2) at baseline, while 49% had apical periodontitis (PAI 3–5) (Table 4). The percentage of teeth extracted during the follow-up period did not differ significantly between teeth with sound periapical conditions (PAI 1–2) and presence of apical periodontitis at baseline (PAI 3–5) ($p = .47$). The periapical status at baseline was not significantly associated with tooth fracture/crack in extracted teeth ($p = .74$).

Table 2. Distribution (*N* (%)) according to main reason for extractions of root filled teeth.

Diagnosis	*N* (%)
Fracture/crack	88 (57.9)
Chronic apical periodontitis	23 (15.1)
Caries	12 (7.9)
Unknown	10 (6.6)
Fracture/crack and chronic apical periodontitis	9 (5.9)
Marginal periodontitis	5 (3.3)
Acute apical periodontitis	2 (1.3)
Internal root resorption	2 (1.3)
Trauma	1 (0.7)

Table 3. Distribution of extracted root filled teeth according to investigated potential risk predictors at baseline.

Variable	Number of studied teeth	Number (*N*) of root filled teeth	Number (*N* (%)) of extracted root filled teeth
Proximal marginal bone loss >1/3 of root length			
Yes	1713	47	9 (19.1)*
No		1666	143 (8.6)*
Proximal angular bony defect with depth >2 mm			
Yes	1712	25	4 (16)
No		1687	148 (8.8)
Cast gold post			
Yes	1713	6	1 (16.7)
No		1707	151 (8.8)
Carbon fibre post			
Yes	1694	131	7 (5.3)
No		1563	144 (9.2)
Abutment tooth			
Yes	1713	100	9 (9.0)
No		1613	143 (8.9)
Screw post			
Yes	1697	41	3 (7.3)
No		1656	148 (8.9)
Fragment of separated file			
Yes	1708	39	6 (15.4)
No		1669	145 (8.7)
Presence of proximal contact			
Yes	1713	1671	146 (8.7)
No		42	6 (14.3)
Composite filling			
Yes	1720	953	112 (11.8)***
No		767	40 (5.2)***
Composite crown			
Yes	1720	240	21 (8.7)
No		1479	131 (8.9)
Metal crown			
Yes	1720	538	20 (3.7)***
No		1182	132 (11.2)***

*$p<.05$, ***$p<.001$ for comparison within groups (Chi-square test or Fischer's exact test).

Table 4. Frequency distribution (*N*) for periapical index (PAI) for the root filled teeth at baseline ($N = 1698$).

PAI at baseline	Number of remaining root filled teeth	Number of extracted root filled teeth	Total number of evaluated teeth
1	732	73	805
2	58	5	63
3	47	0	47
4	168	10	178
5	541	64	605

$p=.47$ for comparison between groups (Wilcoxon's rank sum test).

Table 5. Frequency distribution (*N* (%)) for quality of the root-fillings for the root filled teeth at baseline ($N = 1695$).

Quality of the root-filling at baseline	Number of remaining root filled teeth	Number of extracted root filled teeth (%)	Total number of evaluated teeth
Index 1	408	30 (6.8)	438
Index 2	401	27 (6.3)	428
Index 3	323	20 (5.8)	343
Index 4	156	19 (10.9)	175
Index 5	258	53 (17.0)	311

$p < .001$ for comparison between groups (Wilcoxon's rank sum test).

Table 6. The Cox regression analysis using the cumulative incidence for extraction of root filled teeth during six years as dependent variable ($N = 1695$).

Independent variable	Hazard ratio (95% confidence interval)	*p* Value
Age (years)	1.03 (1.02; 1.04)	<.001
Coronal restoration		<.001
Metal crown	0.27 (0.16; 0.45)	<.001
Composite crown	0.64 (0.39; 1.06)	.08
Composite filling	1.00	
Quality of root-filling		<.001
Index 1	0.52 (0.33; 0.84)	.007
Index 2	0.42 (0.26; 0.68)	<.001
Index 3	0.38 (0.22; 0.63)	<.001
Index 4	0.76 (0.45; 1.29)	.31
Index 5	1.00	
Tooth group		.04
Maxillary molars	2.59 (0.77; 8.70)	.22
Maxillary premolars	2.16 (0.64; 7.34)	.21
Maxillary incisors and canines	2.21 (0.64; 7.68)	.21
Mandibular molars	3.44; 1.05; 11.30)	.04
Mandibular premolars	1.37 (0.38; 4.93)	.63
Mandibular incisors and canines	1.00	

The relative frequency of extracted teeth with the lowest quality of the root-filling (index 5) was 17%, while the corresponding percentage for those teeth with the highest quality of the root-filling (index 1) was 6.8% (Table 5). A significant correlation ($p < .001$) was found between the quality of the root-filling and the survival rate of root filled teeth during the follow-up period (Table 5). Using Wilcoxon's rank sum test, presence of a metal crown was significantly and positively correlated to the quality of the root-filling ($p < .01$), while presence of apical periodontitis at time of tooth extraction was significantly and negatively associated with the quality of the root-filling ($p < .05$, Wilcoxon's rank sum test). The quality of the root-fillings was not significantly associated with tooth fracture/crack in extracted teeth ($p = .49$).

The stepwise Cox regression, with extraction of the root filled teeth as dependent variable, showed that four variables had a significant influence on the risk of tooth loss (Table 6). The risk of loss of root filled teeth increased significantly with increasing age ($p < .001$, Table 6). The survival of root filled teeth with metal crowns was significantly higher compared to teeth with composite fillings ($p < .001$) as well as compared to composite crowns ($p = .01$), while the difference was not significant ($p = .08$) between composite crowns and composite fillings (Table 6, Figure 1). The survival rate differed significantly between tooth groups ($p = .04$) and was significantly influenced by the quality of the root-filling (Table 6).

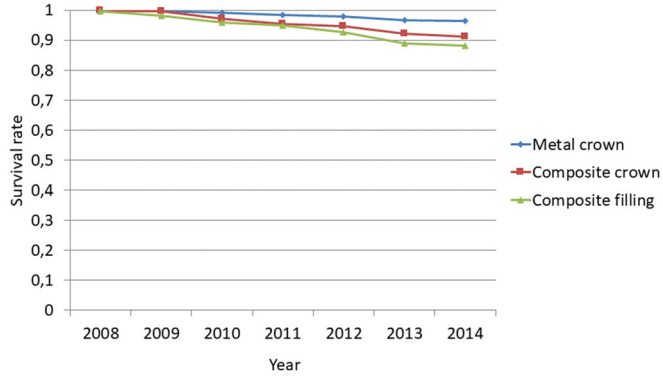

Figure 1. The Kaplan–Meier survival curves for root filled teeth according to tooth restoration.

Discussion

The purpose of the present study was to investigate the survival rate of root filled teeth in general dentistry in Stockholm, Sweden over six years, 2008–2014, and to identify risk predictors with a significant influence on the survival rate. The main finding was a mean survival rate of root filled teeth over six years of 91%, which differed significantly between tooth groups. The results indicated that type of crown restoration and quality of the root-filling were strong predictors of tooth extraction beside an increasing age. Most of the dentists, whose patients were involved in this study, participated in a program on root canal treatment, including lectures and hands-on training in nickel-titanium rotary instrumentation (NTRI) 2007–2008 in Stockholm [9].

This study has some limitations to discuss. The retrospective design may affect the validity of the data and the relative influence of the predictors should be interpreted with caution. Missing data are more frequent in retrospective studies which might result in loss of statistical power. In addition,

only associations can be inferred from the data in observational studies and unknown confounders may have had an influence on the results. The material consisted of patients who showed up at recall visits for six years and their habitude to visit a dental clinic on a regular basis can influence the outcome. Missing data were caused by inadequate quality of the radiographs for evaluations of the quality of the root fillings and apical conditions for 47 cases (2.7%), which may produce biased results. The main reason for extraction of the root filled teeth was noted in the dental record by the responsible general dentist. The factors behind the decision to extract a tooth can be complex and the main reason for extraction is not always obvious. The ability to discover tooth cracks, for example, may be a diagnostic challenge. Thus, the frequency distribution for reasons for tooth extractions should be analysed with caution. The periapical conditions at baseline were evaluated by an experienced specialist in endodontics after the use of a calibration program containing 100 radiographs. The reliability of assessments according to PAI and the quality of the root filling was calculated by comparison between two observers and the inter-observer agreement was high. The PAI is based on a validated system to score the periapical conditions on an ordinal scale 1–5 [8].

The mean survival rate of 91% of the root filled teeth over six years are in agreement with earlier studies [2]. A retrospective 10-year follow-up study in a public endodontic specialist clinic found that the main reason for extraction of root filled teeth was root fracture (36% of the cases) [5]. An American retrospective study reported that tooth fracture was the most frequent reason (60% of the cases) for loss of root filled teeth [10]. The results in the present study are in accordance with these results. The increased susceptibility of tooth fractures in root filled teeth might be explained by factors such as loss of tooth structure and increased brittleness of dentine [11].

Fifteen percent of the loss of root filled teeth was caused by presence of apical periodontitis at time of extraction, while the periapical status at baseline was not associated with the loss of root filled teeth. This latter result is in accordance with some other longitudinal studies [2,5,12]. However, a 20-year follow-up study from Sweden found that teeth with apical periodontitis at baseline had a significantly lower survival rate [4].

Prolonged survival of root filled teeth is affected by several factors. Most epidemiological studies agree that improving the quality of endodontic treatment is crucial. The technical quality of root canal treatment is often evaluated from X-rays, but radiographic interpretation is highly subjective and can be influenced by a variety of factors [13]. The technical quality is important for the outcome of the treatment, but is not the only parameter to influence the periapical status. The antiseptic and aseptic efforts during treatment plays an important role for the outcome [14]. Several *in vitro* studies have shown that even the best root canal treatment can have leakage of bacteria and their by-products through a well-filled canal-system [15–17]. The coronal restoration together with the root canal obturation should therefore act as a blocking of communication between the oral cavity and the periradicular tissue [18].

It has been indicated that the survival of root filled teeth was significantly associated with metal crown restoration after the obturation [1,19]. Even so, it has been assumed that the prognosis of the endodontic treatment must be considered favourable in order to motivate the patient to choose crown therapy. It should be noted that in the present patient material, a metal crown was chosen significantly more often in cases with high quality of the root-filling. In the final regression analysis, both variables (metal crown and quality of the root-filling) were significantly associated with tooth survival after compensation for other predictors.

Patients choosing crown therapy may have had a higher socioeconomic status and awareness, both of which have been associated with increased tooth survival [20]. In a recent study of the Swedish adult population such socioeconomic differences were identified between those receiving indirect restoration (crown therapy) and direct restoration [21]. The success rate of single crowns on root filled teeth in a study by Ploumaki et al. [22] was 92% after 6 years in accordance with a systematic review by Stavropoulou and Koidis [23], who reported a cumulative survival rate for single crowns on root filled teeth of 81% after 10 years. Restoring such teeth preferably with single crowns, as opposed to direct restorations, was shown by numerous studies to be favourable for the longevity of both the restoration and the involved teeth [2,5,24]. In Sweden, composite resins are nowadays the first choice as a posterior restoration material. The major causes for complications with composite restorations are secondary caries and restoration fractures [25]. A weakness of the present study is that the quality of the coronal restorations including the composite fillings was not evaluated. However, a radiographic assessment of the quality of coronal restorations has been found to be an unreliable method since microleakage might not be registered in radiographs [26]. Application of a good coronal seal is essential to prevent the root canals from microleakage [27]. No significant association was found between presence of composite restorations and the periapical status in our study in accordance with Dawson et al. who found no difference in periapical status for teeth restored with laboratory fabricated restorations (crown restoration) compared with direct restorations if the restorations were of adequate quality [28]. In the referred study, the restoration quality was judged based on clinical photographs. However, in another Swedish study, it was reported that presence of apical periodontitis was significantly more frequent for root canal treated teeth with composite restorations [29].

The significant reduction in the survival of molars compared to other tooth types may be the result of increased occlusal stress and more difficult endodontic treatment due to anatomy, accessibility and limited visibility. Other epidemiological studies have also reported that the survival rate of molars is generally lower than for other teeth [1,4,30].

Our finding that presence of marginal bone loss has a significant impact on increased tooth mortality are in accordance with earlier studies [4,31]. Possible explanations of this

relationship include suggestions that bacteria or toxins from the infected root canal may spread through dentinal tubules to the marginal periodontal tissue, or that marginal inflammation may progress to the apical area [32]. Increased age was one of four variables that had a significant influence on the risk for extraction of root filled teeth and is probably caused by forces and wear for a longer period of time and are just something that can be expected [1,5,33].

In conclusion, within the limits of the present study, 91% of the root filled teeth survived after 6 years. The survival rate was significantly higher for teeth with root-fillings of high quality and metal crowns as well as for younger patients. The lowest survival rate was found for molars.

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Disclosure statement

The authors report no conflicts of interest, and are responsible for the content and writing of the paper.

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