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Survival rate after endodontic treatment in general dentistry for cracked teeth with different coronal restorations

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ABSTRACT

Objective: The aim of this study was to analyse the survival rate of cracked teeth after endodontic treatment. The secondary aim was to compare the survival rate of cracked teeth restored with composite filling/crown and those restored with a full crown.
Materials and methods: The study was conducted retrospectively from three general dental clinics in Stockholm, which are all part of the national dental service organisation. Two-hundred patients with teeth receiving endodontic treatment due to symptomatic cracks were included. The patient data range from year 2001 to 2016.
Results: The mean age of the patients was 48 years (range 29–69). Fifty-five per cent had cracks located above the pulpal cavity, 11% within the pulpal cavity and 3% located in the root canal. The cracks were located most commonly on the proximal surfaces. The survival rate for teeth with cracks was 68% and 54% after 5 and 10 years, respectively. The survival rate was significantly higher (97%) for cracked teeth receiving a full crown after endodontic treatment compared to teeth restored with either a composite filling or composite crown.
Conclusion: The overall survival rate for cracked teeth was 68% after 5 years, while it was significantly higher for cracked teeth restored with a full crown. The results suggest within the limitations of this study that cracked teeth should be restored with a full crown after endodontic treatment.

Introduction

Tooth cracks are a frequent clinical problem in general dentistry [1] and described as an incomplete tooth fracture [2] or as the cracked tooth syndrome [3]. In a published document by the American Association of Endodontics (AAE), in 2008, the 'cracked tooth syndrome' is characterised by an acute pain from mastication and a sharp, brief pain with cold. There are however other signs and symptoms associated with longitudinal cracks such as irreversible pulpitis, pulp necrosis and apical periodontitis. The term 'cracked tooth syndrome' is therefore not longer considered a valid description for cracked teeth. The AAE define a cracked tooth as an incomplete tooth fracture initiating from the crown and extending subgingivally [http://www.aae.org/specialty/wp-content/uploads/sites/2/2017/07/ecfesum08.pdf].

Depending on the location of the cracks, the symptoms could either originate from the pulp or the periodontal space. If the pulp is involved it could lead to pulpitis or pulp necrosis [2]. In an earlier stage, the patient could experience a variety of symptoms including a sharp sensitivity to cold, pain when biting and sometimes pain to hot and sweet. Some patients have difficulty locating the exact tooth and some experience discomfort for weeks to months [4]. For

some cases, the cracks develop into vertical root fractures occurring in both vital and endodontically treated teeth [5].

The prevalence of cracked teeth varies according to gender and age. In a study at a dental hospital, the prevalence was found to be equal according to gender and mostly occurring in patients between 40 to 50 years of age [6], while a review reported an incidence rate of 34–74% and described that the prevalence was more predominant in women [7]. The prevalence of cracks was 9.7% of 8175 examined teeth and were most frequent in mandibular first molars, maxillary first molars and mandibular second molars [8].

The incidence of cracked teeth is commonly associated with previous dental trauma, previous restorations, tooth location regarding to intersection of stress planes, tooth grinding and brittle dentine in an aging dentition [4,9]. Four categories have been suggested to describe the aetiology of cracked teeth: restorative procedures, occlusal factors (bite force), developmental factors and miscellaneous factors (thermal cycling, foreign body and dental instruments) [10].

The available diagnostic methods for cracked teeth are the following: dental history, periodontal probing, dye test, vitality test, bite test, radiograph, transillumination and microscopic detection [7]. Microscopic magnification

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visualises enamel cracks and, depending on the angles and numbers of cracks, it could help to assess the risk for a non-symptomatic tooth in an early stage [11]. A recent study concluded that swept source optical coherence tomography (SS-OCT) was superior or equal to the more tested methods of transillumination and microcomputer tomography. For a non-invasive technique the SS-OCT proved to have as high sensitivity and specificity as transillumination, but has the advantage of identifying crack lines from craze lines [12].

Treating a symptomatic cracked tooth may be difficult depending on the depth of the cracks. Usually the existing restoration needs to be removed in order to investigate the extent of the cracks. The treatment is often based on both subjective symptoms as well as clinical findings. After a 6-year evaluation, the survival rate was 93% for cracked teeth without the need of endodontic treatment [13]. Another study showed a significant difference of success rate after 7 years between groups with restorations that had cuspal coverage and those without [14].

The prognosis varies depending on three factors: the extent of the cracks, time elapsed until treatment was initiated and the choice of coronal restoration [15,16]. A 5-year follow-up study demonstrated that teeth with coronal cracks receiving full crowns after endodontic treatment performed by endodontists had a 95.2% survival rate [17]. Another study showed a survival rate of 85.5% after two years [18]. A recently published study confirmed a survival rate of 90% for cracked teeth undergone endodontic treatment after 2 years, although the presence of deep periodontal pockets >6mm was a significant clinical factor for failure [19].For the majority of the outcome studies the treatment was performed by specialists, with access to a dental operating microscope aiding in crack detection, localization and extension. There is however scarce evidence concerning the survival rate for cracked teeth following endodontic treatment in general dentistry, where endodontic treatment is often performed without the help of microscopic visualization. More research is needed to evaluate if endodontic treatment of cracked teeth should be considered an effective choice in general dentistry. Evidence for which type of coronal restoration should be used for cracked teeth following endodontic treatment is also lacking with a need for further research. Earlier studies have mostly looked at the difference of survival rate between cracked teeth restored with either a direct restoration or a full crown, or just by restoring the cracked tooth with a full crown [17–20]. There is a lack of evidence comparing a composite crown and a full crown of cracked teeth following endodontic treatment.

The primary aim of this study was to analyse the survival rate of cracked teeth after endodontic treatment in general dentistry. The secondary aim was to compare the survival rate between cracked teeth restored with a full crown and those restored with a composite filling or composite crown after endodontic treatment.

Methods

This was a retrospective study including 200 patient cases selected from three general dental clinics located in the central parts of Stockholm, which all belong to the regional Swedish Dental Service (Folktandvården). The distribution of the number of cases selected from the three clinics were 43, 67 and 90 cases. The inclusion criteria in the study were teeth with a visible, incomplete fracture originating in the crown reported by the general practitioner (GP) in the dental records, before the initiation of endodontic treatment. Endodontically treated teeth were included if they were diagnosed with an incomplete tooth fracture prior to endodontic retreatment and if the patient regularly visited the dental clinic during the follow-up period. To rule out other causes for endodontic treatment and tooth extraction the following exclusion criteria were applied:

- Teeth restored with a post prior to a diagnosis of cracks.
- Endodontic treatment and extraction due to other causes than incomplete tooth fractures, for example caries, periodontitis or trauma.
- No records of incomplete tooth fractures originating in the crown before endodontic treatment.
- Teeth diagnosed with a vertical root fracture before endodontic treatment.
- Extraction following endodontic treatment due to other causes than crack propagation.
- Teeth with deepened periodontal pocket depths caused by marginal periodontitis.

The study was conducted retrospectively using electronic dental records at the Swedish Dental Service in Stockholm between the year 2001 and 2016. A power calculation showed that 200 participants were needed for power 80% and significance level 0.05 if the incidence rate according to survival differed 20% between two groups [https://clincalc.com/stats/samplesize.aspx].

During the study period, all dental treatment performed at the Swedish Dental Service in Stockholm were reported together with a diagnostic code provided by the Swedish social insurance agency. The cases included in the study were collected from a list of patient data extracted from the patient database using the available diagnostic codes: 'symptomatic cracks', 'longitudinal root fracture' and 'crown-root fracture'. Because the diagnostic codes are not directly associated with an incomplete tooth crack, the study included only cases that complied with the inclusion criteria described. The inclusion and exclusion process were based on available data in the dental records, and radiographs were used to assess the presence of caries and periodontitis. All data was collected by the first author from the received list of patient data until 200 cases were included to the study. This was done in a random process by not starting from the top of the list but instead choosing to revise cases from different parts of the list by chance during each session. Extraction following endodontic treatment of a cracked tooth was confirmed from the patient's dental records, where the extraction was established due to crack propagation. The outcome was measured by tooth survival in years after endodontic treatment.

Table 1. Distribution of the patients according to background variables.

Age	N	Females/Males	Smokers (%)	Tooth grinding (%)	Bite splint (%)
29-40	42	22/20	14	48	14
41-50	94	41/53	3.2	39	15
51-60	50	20/30	4.0	34	18
61-70	14	5/9	0	43	36
Total	200	88/112	5.5	40	17

Table 2. Distribution according to tooth group and type of crack.

Tooth group	N	Crack(s) located above the pulp chamber (%)	Crack(s) located within the pulp chamber (%)	Crack(s) located in the crown and extending in the root canal (%)	Unspecified (%)
Maxillary molars	84	51	11	4	34
Maxillary premolars	15	80	0	0	20
Maxillary incisors and canines	0	–	–	–	–
Mandibular molars	100	53	13	3	31
Mandibular premolars	0	–	–	–	–
Mandibular incisors and canines	1	1	0	0	0
Total	200	55	11	3	32

The following variables were registered from the dental records: Age at baseline, sex, smoking habits, tooth grinding, use of night guard, tooth position, type and location of the crack, initial treatment, the presence of restoration, periodontal pocket depth, time elapsed between diagnosis of cracks and endodontic treatment, pulp diagnosis, type of coronal restoration after endodontic treatment, time (years) elapsed until extraction.

The study was conducted in full accordance with the World Medical Association of Helsinki and was approved by the Regional Ethics Board in Stockholm (2016/1856-31/1). Informed consent from the participants was not obtained since the data were made anonymous before included in the database. The study followed the 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) checklist (www.strobe-statement.org/index.php?id=strobe-home).

Statistical analysis

Descriptive statistics and statistical analyses were performed with a computer statistical package (IBM SPSS 21.0, SPSS Inc., Chicago, IL, USA). Stepwise cox regression for survival analysis was adopted for investigating the effect of potential predictors upon the time to the outcome of extraction of root-filled teeth with cracks. Kaplan–Meier analysis was used for construction of the cumulative survival function for root-filled teeth over 15 years. Results were considered statistically significant at $p < .05$.

Results

The mean age of the patients was 48 years (range 29–69). Fifteen percent of the teeth had periodontal pocket depths ≥4 mm next to a visible crack on at least one site. Almost half of the patients (40%) experienced tooth grinding, although only 17% used a bite splint (Table 1). The majority of the cases (55%) involved upper and lower molars and

Table 3. Distribution of teeth according to crack location and number of cracks per tooth.

Variable	N
Crack location	
Mesial	95
Buccal	35
Distal	105
Lingual/palatal	63
Unspecified	20
Number of cracks per tooth	
1	83
2	78
3	14
4	7
Unspecified	18

more than half of the teeth had visible cracks stopping above the pulp chamber (Table 2). The mesial and distal surfaces were the most common location of the cracks and the majority of the teeth had 1–2 visible cracks (Table 3). About 95% of the teeth had either an occlusal or proximal filling prior to endodontic treatment and 78% of the antagonising teeth had an occlusal filling (Table 4). The periodontal pocket depths were ≤4 mm for a great majority (94%) of the teeth.

The most common initial treatments of a cracked tooth were replacement of an existing filling or an access cavity preparation (Table 5). For 74.5% of the cases, a complete endodontic treatment was performed less than a year afterwards and 93% of the teeth were root-filled within two years. Prior to endodontic treatment, approximately half of the teeth were diagnosed with pulp necrosis (51%) and 38% were diagnosed with irreversible pulpitis. The diagnosis prior to endodontic treatment was unknown for 8% of the cases and 2.5% was revision of previous endodontic treatment. More than half of the teeth (61%) were restored with a composite filling after endodontic treatment. A full crown was made in 24% of the cases and 14% were restored with a composite crown.

The mean observation time was 4.5 years (range 1–15). The survival rate for teeth with cracks was 68% after five years and 54% after 10 years. The survival rate did not differ

Table 4. Frequency distribution for type of tooth restoration before endodontic treatment and type of restoration of the antagonist tooth.

Tooth	No restoration	Occlusal filling	Occlusal and proximal filling	Composite crown	Dental technician manufactured crown
With crack(s)	7	98	93	0	2
Antagonist	31	157	9	1	2

Table 5. Frequency distribution for initial treatment of the teeth with cracks and time elapsed between initial treatment and endodontic treatment.

Initial treatment	N	Time (years) between initial treatment and endodontic treatment (mean (S.D.))
Occlusal adjustment	18	0.67 (0.77)
Replacement of filling	85	0.75 (1.3)
Access cavity preparation	96	0.08 (0.28)
Crown	1	1 (-)

Table 6. Stepwise Cox regression analyses for root-filled teeth with cracks using tooth extraction between the years 2001 and 2017 as the dependent variable.

Independent variable	Category	Hazard ratio (95 % confidence interval)	p
Coronal restoration after endodontic treatment	Full crown	1	
	Composite filling	16 (3.9; 65)	<.001
	Composite crown	8.6 (1.9; 40)	.005

Odds ratios with 95% confidence intervals are presented. N = 200.

significantly between the three participating clinics. The risk of tooth extraction was significantly higher for teeth with composite fillings or composite crowns compared to teeth with full crowns (Table 6). None of the other potential predictors were significantly associated to tooth survival in the last step of the regression analysis. Type of coronal restoration after endodontic treatment was not significantly associated with investigated predictors.
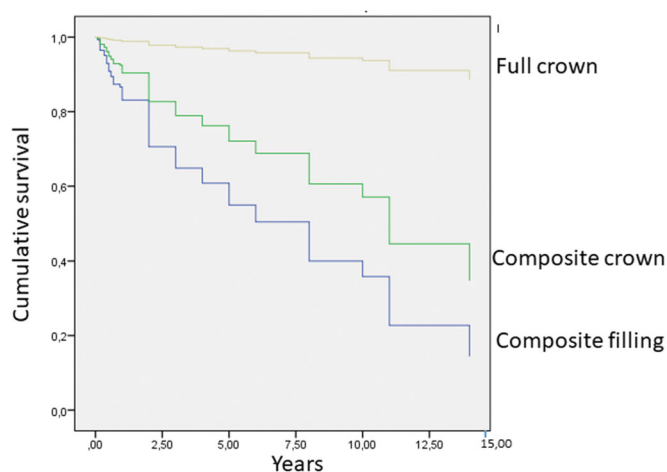
The tooth extraction rate did not differ significantly between teeth with composite fillings and composite crowns ($p = .08$). Cumulative survival curves for the three groups of teeth are presented in Figure 1. The survival rate for teeth restored with a full crown was 97% after 5 years and 95% after 10 years compared to 57% and 37% after 10 years for teeth restored with a composite crown and a composite filling, respectively.

Figure 1. Survival function (Kaplan–Meier analysis) for root-filled teeth over 15 years.

Discussion

The age distribution in this study is similar to those of others studies, showing that the group with the highest incidence of cracks was between the ages of 41 to 60 [6,20,21]. Some studies propose that this could be explained by less elasticity in dentine, more restorations and overall stress fatigue on the teeth with increasing age [2,22]. The study showed no difference between male and female patients (112/88) which resemble the results in other studies [6,20,22].

In a recent study by Hilton et al. [23], 48% of the patients reported tooth grinding or clenching at night, while 16% used a night guard. Quite similar numbers were found in the present study where 40% of the patients experienced parafunctional activity and only 17% used a bite splint.

The prevalence of root-filled teeth with cracks was higher for molars compared to the other tooth groups in this and other studies. The results in the present study showed that the mandibular molars had the highest prevalence of cracks

and similar results have been found in other studies [8,16,19,20]. Some authors have described this occurrence to be correlated to a bite force ratio of 4:2:1 (molars: premolars: incisors). This could partly explain why the molars, being subjected to a higher force, also have the highest incidence of cracks [22,23]. The mesial and distal surfaces where the most common crack locations, which corresponds to findings in other studies [6,24].

The majority of the teeth with cracks had either class I or class II restorations. Only 3.5% of the teeth were intact prior to diagnosis of cracks. These findings also correspond to findings by previous studies [6,21,22]. According to Lynch et al. [10] restorative procedures are one of the main causes of cracks. Restorative procedures could lead to insufficient cuspal protection, deep fossa-cusp relationship and stress concentration on the cavity walls, which results in a higher risk of crack formation. A calculation made by Ratcliff et al.

[25] showed that teeth with an intra-coronal restoration had 29 times higher risk of cracks compared to un-restored teeth.

The majority of the cracked teeth in the present study were restored with a composite filling/or crown after endodontic treatment (76%) and a smaller proportion received a full crown (24%). There was however a significant difference of survival rate between teeth that received a full crown and those receiving a composite filling/or crown. Earlier studies have discussed the importance of full cuspal coverage for cracked teeth in order to prevent further cracking. A full crown would be able to stabilise the individual fragments together and thereby enable the occlusal forces to be distributed evenly [15,20,25]. The study by Opdam et al. [14] reported a significant difference in restoration failure for cracked teeth restored without cuspal coverage compared to those with coverage. The study could not show any significant difference in tooth survival between the groups. The present study could not show any significant difference in survival rate for composite crowns compared to composite fillings, which is in accordance with Opdam et al. [14]. Another explanation for a low tooth survival for composite crowns would be the retrospective nature of the study, where the information about the coronal restoration is based on the description in the patient's dental records. There was no possibility to control for the quality of the composite crown or that the composite crown provided full cuspal coverage in all cases.

There are few studies made prospectively involving a pre-planned research protocol to register tooth location, placement of cracks and the extent of the cracks before endodontic treatment. One study made by Tan et al. [18] where cracked teeth underwent endodontic treatment had a follow-up period of two years. All the teeth were restored with a full-coverage crown. The survival rate was calculated to 85.5% and teeth that most likely were to be extracted had multiple cracks and a periodontal pocket >3mm next to a crack. Another study with a 5-year follow-up found a survival rate of 92% and the main risk of tooth loss would be cracks extending along the pulp chamber floor [17]. The present study showed a survival rate of 97% after five years for teeth restored with a full crown after endodontic treatment.

The limitations in this study were mostly due to the varying quality of information from the dental records, during the inclusion and exclusion process. There were cases where a necrotic tooth looked intact in the dental radiograph aside from a small amalgam filling. The probability of pulp necrosis being caused by an incomplete tooth fracture in these cases would be high, but the dental records did not contain any assessment of cracks before endodontic treatment. These cases were therefore excluded from the study. All teeth were treated at general dental practices, where the majority of the GPs work without a dental operating microscope. This will in most cases prevent the GP from detecting cracks located in the root canal, making it more difficult to reach a qualified prognosis estimation before endodontic treatment. This may also lead to a higher risk of underestimation for the presence and true extension of visible cracks prior to endodontic treatment. Although working without a microscope is a limitation

for both diagnosis and prognosis estimation of the cases included in the study, this does also indicate the clinical relevance of this study in general dentistry.

The survival rate of cracked teeth restored with a full crown following endodontic treatment was relatively high (95% after ten years) in the present study compared to other outcome studies [17,18]. This may be explained by a difference in cut off points between the GPs and specialists when treating a cracked tooth. Difficult cases of cracked teeth may be commonly referred to a specialist by the GP or extracted. The reasons behind the choice of coronal restoration for the cracked tooth following endodontic treatment was not fully elucidated in this study. It may be hypothesized that the GP would not recommend the patient to invest in a full crown in difficult cases of incomplete fractures due to uncertainties for the outcome of the endodontic treatment. Those teeth restored with a full crown may have been easier cases where the GP was more confident in the overall treatment outcome.

In conclusion, the overall survival rate for teeth with cracks was 68% after five years and 54% after 10 years. In addition, for cracked teeth restored with a full crown after endodontic treatment, the survival rate was significantly higher than teeth restored with a composite filling/or crown. Since endodontic treatment can be both time consuming and costly for the patient, the prognostic factor tooth restoration is of great interest for both the patient and the GP. Thus, the results suggest within the limitations of this study that cracked teeth should be restored with a full crown after endodontic treatment.

Disclosure statement

Funding

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