Dental Traumatology

Dental Traumatology 2012; **28**: 404–409; doi: 10.1111/j.1600-9657.2012.01132.x

Root fractures: the influence of type of healing and location of fracture on tooth survival rates – an analysis of 492 cases

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Key words: tooth survival, root fractures, healing, root fracture location

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Accepted 12 February, 2012

Abstract – *Aim*: The purpose of this study was to analyze tooth loss after root fractures and to assess the influence of the type of healing and the location of the root fracture. Furthermore, the actual cause of tooth loss was analyzed. *Material and methods*: Long-term survival rates were calculated using data from 492 root-fractured teeth in 432 patients. The cause of tooth loss was assessed as being the result of either pulp necrosis (including endodontic failures), new traumas or excessive mobility. The statistics used were Kaplan–Meier and the log rank method. *Results and Conclusions*: The *location of the root fracture* had a strong significant effect on tooth survival ($P = 0.0001$). The 10-year tooth survival of apical root fractures was 89% [95% confidence interval (CI), 78–99%], of mid-root fractures 78% (CI, 64–92%), of cervical-mid-root fractures 67% (CI, 50–85%), and of cervical fractures 33% (CI, 17–49%). The *fracture-healing type* offered further prognostic information. No tooth loss was observed in teeth with *hard tissue fracture healing* regardless of the position of the fracture. For teeth with *interposition of connective tissue,* the location of the fracture had a significant influence on tooth loss ($P = 0.0001$). For teeth with *connective tissue healing,* the estimated 8-year survival of apical, mid-root, and cervical-mid-root fractures were all more than 80%, whereas the estimated 8-year survival of cervical fractures was 25% (CI, 7–43%). For teeth with non-healing with *interposition of granulation tissue,* the location of the fracture showed a significant influence on tooth loss ($P = 0.0001$). The *cause* of tooth loss was found to be very dependent upon the location of the fracture. In conclusion, the long-term tooth survival of root fractures was strongly influenced by the type of healing and the location of the fracture.

Introduction

A previous histologic and clinical study has shown that three healing modalities exist for root fractures: hard tissue fusion, periodontal ligament interposition with and without bone, and non-healing with interposition of granulation tissue owing to coronal pulp necrosis (1).

A series of recent clinical studies on the long-term fate of intra-alveolar root fractures have shown that these healing modalities appear to be influenced by a number of factors such as the stage of root development, the extent of dislocation, the extent of repositioning, the type of splinting, the use of antibiotics, and the location of the fracture on the root (2–4).

An understanding of the effects of these and other parameters on the long-term survival of teeth with root fractures is important if accurate prognostic information is to be given to patients. Very little information is however available regarding the long-term risk of tooth loss after root fracture. The aim of this study is to provide information on long-term survival of teeth with root fractures by looking at the influence of healing modalities and fracture position on tooth survival rates in a large group of root-fractured teeth followed up over 10 years after injury.

Materials and methods

The present study used the material from the long-term follow-up of 492 root-fractured teeth from 432 patients collected by the late Dr. Miomir Cvek at the Eastman Dental Institute in Stockholm (5). These cases were all referred, treated, and evaluated at the Pedodontic Department at Eastman Dental Institute. Of the 534 teeth from 470 patients with root fracture in the study by Cvek et al. in 2008 (5), 492 teeth were included in the long-term survival analysis performed in the present study. The 42 excluded teeth were considered impossible to treat at the time of the initial examination and were extracted. Table 1 shows the number of teeth excluded from each root fracture location subgroup. A large number of teeth with cervical root fractures were considered impossible to treat (27/77) and were extracted at the initial examination. The included teeth were

Table 1. Excluded teeth from the root fracture survival study

	Cervical	Cervical/mid-root	Mid-root	Apical
Original study	77	47	285	125
Current study	50	45	272	125
Differences	27	2	13	0

divided into healing/non-healing groups representing one of the following healing types: hard tissue fusion, periodontal ligament interposition with and without bone, and non-healing with the interposition of granulation tissue owing to coronal pulp necrosis. This was performed according to a healing classification published by Andreasen and Hjørting Hansen in 1966 (1). The teeth were further divided into four subgroups in relation to the location of the root fracture: *apical*, *mid-root* or *cervical region* and a mixed group with teeth having oblique fractures located both in the *mid-root and in the cervical regions*. When teeth were lost during the follow-up period, the reasons were recorded and classified as *pulp healing complications* (including endodontic failure after the treatment of pulp necrosis), *new trauma,* or *excessive tooth mobility*. Comparative differences in the risk of tooth loss were determined for each fracture position and for each fracture position after stratification with the three healing modalities (hard tissue, connective tissue, and non-healing with granulation tissue). The statistical analyses were made using Kaplan–Meier survival curves and log rank tests. The Statistical Package for the Social Sciences (SPSS 19.0, IBM Corporation, Armonk, NY, USA) was used as statistical program.

Results

Fracture position

The tooth survival rates stratified by the position of fracture are illustrated in Fig. 1.

The cause of tooth loss for each type of root fracture position is presented in Figs 2–5. A significant relation ($P = 0.0001$) was found between the location of root fracture and tooth loss, with apical fractures having the best prognosis and cervical fractures, the worst.

Apical fractures (n = 125)
Only six teeth that suffered apical fractures had to be extracted. Five teeth were lost because of pulp healing complications and one because of secondary trauma (Fig. 2). At 10 years, the survival rate for apical fractures was 89% [95% confidence interval (CI), 78–99%].

Mid-root fractures (n = 272)
Twenty-three teeth with mid-root fractures were extracted, and seventeen of these extractions were because of pulp healing complications. Six teeth were lost because of new trauma (Fig. 3). At 10 years, the survival rate for mid-root fractures was 78% (95% CI, 64–92%).

Cervical- mid-root fractures (n = 45)
Forty-five teeth with oblique fractures presented a combined cervical and mid-root fracture location. Nine teeth had to be extracted owing to pulp healing compli-

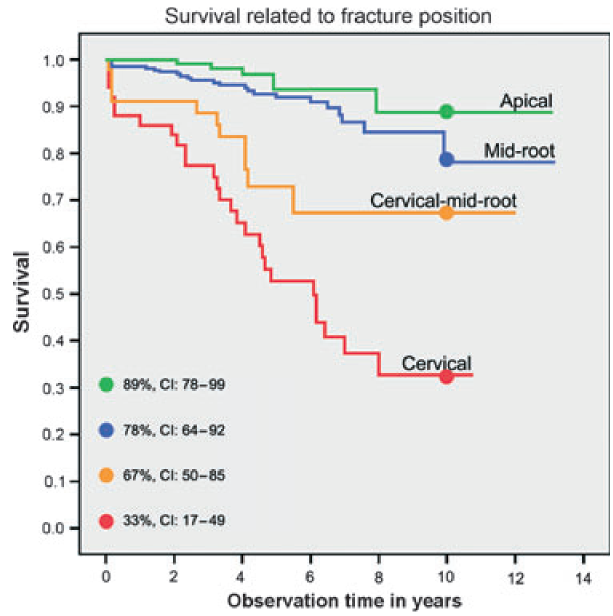

Fig. 1. Tooth survival related to fracture location on the root. Point estimates after 10 years with 95% confidence intervals (CI). Apical: Initial $n = 125$, 10 year point estimate: 89%, CI: 78–99%. Mid-root: Initial $n = 272$, 10 year point estimate: 78%, CI: 64–92%. Cervical-mid-root: Initial $n = 45$, 10 year point estimate: 67%, CI: 50–85%. Cervical: Initial $n = 50$, 10 year point estimate: 33%, CI: 17%–49%.

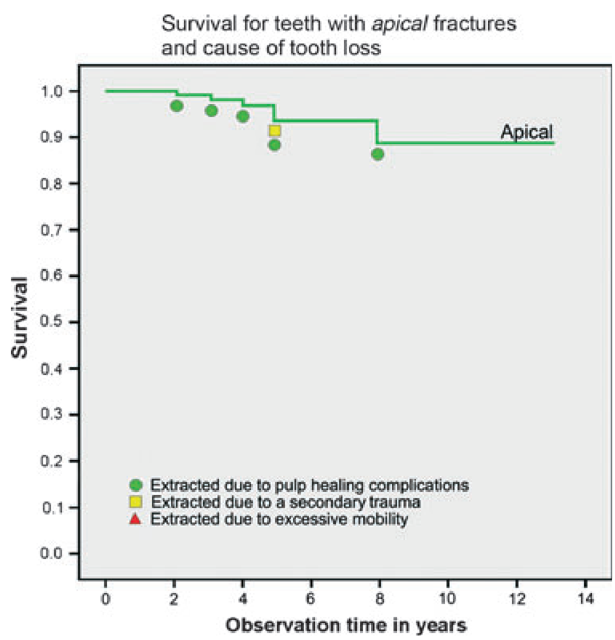

Fig. 2. Tooth survival for teeth with apical fractures and cause of tooth loss.

cations, one tooth because of excessive mobility, and one tooth because of new trauma (Fig. 4). At 10 years, the survival rate for cervical-mid-root fractures was 67% (95% CI, 50–85%).

Cervical fractures (n = 50)
Seven teeth with cervical fractures were lost in the initial period because of *pulp necrosis* in the coronal fragment

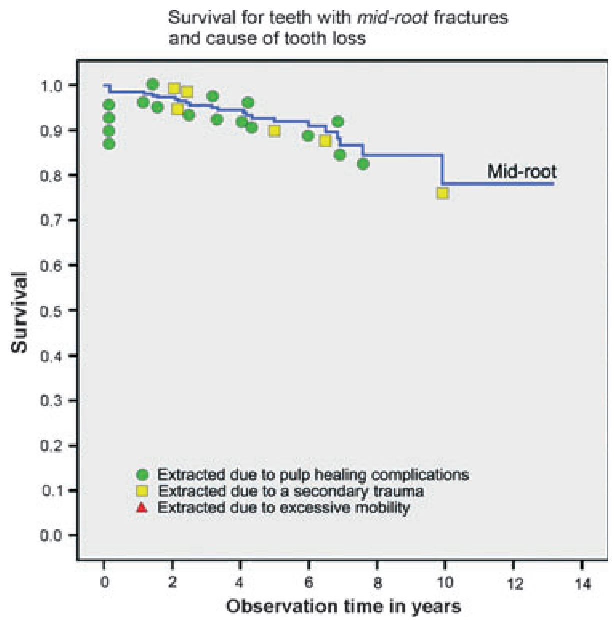

Fig. 3. Tooth survival for teeth with mid-root fractures and cause of tooth loss.

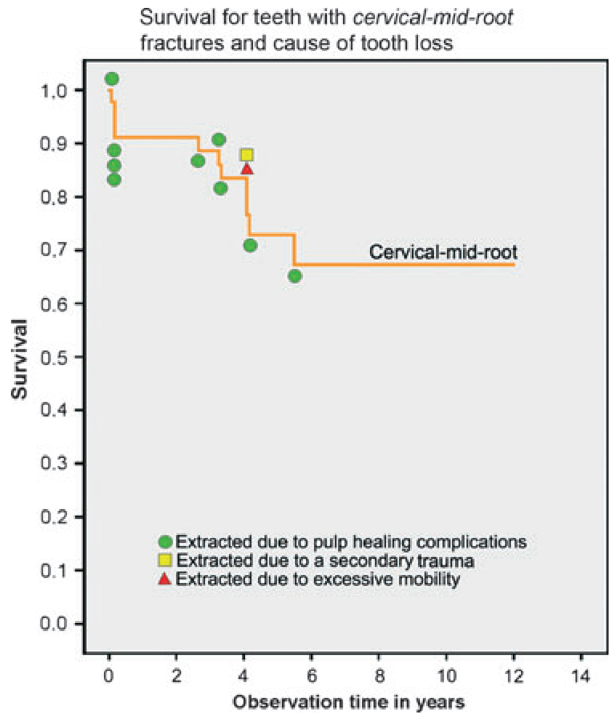

Fig. 4. Tooth survival for teeth with cervical-mid-root fractures and cause of tooth loss.

and where successful endodontic treatment was not considered likely due to the proximity of the gingival margin. After the initial period, some teeth were lost because of *excessive mobility* (10 cases) and *new traumas* (10 cases). At 10 years, the survival rate for cervical fractures was 33% (95% CI, 17–49%).

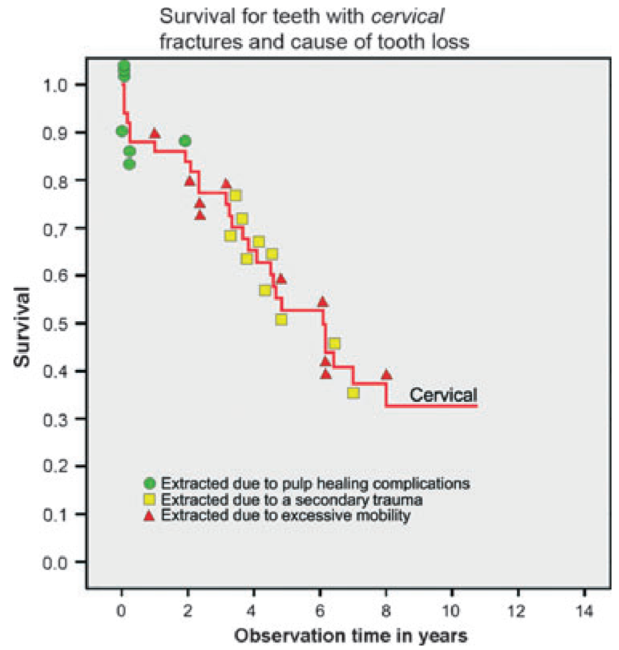

Fig. 5. Tooth survival for teeth with cervical fractures and cause of tooth loss.

Type of fracture healing

After 3–6 months, it becomes possible to make a reliable determination of the fracture-healing type (2). The results from this study can offer further prognostic information once this pattern of healing after root fracture has been established. In a Kaplan–Meier analysis stratified for the type of tissue healing in the fracture line, and using fracture position as a factor, the following results appeared for the three healing modalities:

Hard tissue healing
No tooth loss was observed in patients with hard tissue healing regardless of the position of the fracture.

Connective tissue healing
For teeth that healed with interposition of connective tissue, the location of the fracture was shown to have a significant influence on tooth loss ($P = 0.0001$). The estimated 8-year survival of apical, mid-root, and cervical-mid-root fractures was all more than 80%, whereas the estimated 8-year survival of cervical fractures was 25% (Fig. 6). The comparison was made at 8 years because no information was available for the 10-year survival of cervical root fractures. After 8 years, all teeth in this group had either been lost or censored as a result of the lack of further follow-up. The individual point estimates with 95% confidence intervals are listed in Fig. 6.

Non-healing with granulation tissue
For teeth with non-healing with granulation tissue, the location of the fracture was shown to have a significant influence on tooth loss ($P = 0.0001$). The overall finding being that apical and mid-root fractures had a much higher chance of survival than the estimated survival of

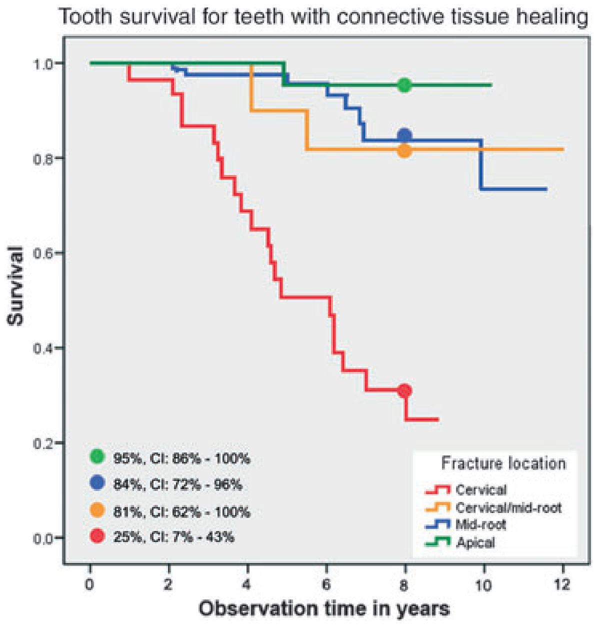

Fig. 6. Tooth survival for teeth with connective tissue healing shown for each of the four fracture locations. Point estimates after 8 years with 95% confidence intervals (CI). Apical: Initial n = 51, 8 year point estimate: 95%, CI: 86–100%. Mid-root: Initial n = 145, 8 year point estimate: 84%, CI: 72–96%. Cervical-mid-root: Initial n = 30, 8 year point estimate: 81%, CI: 62–100%. Cervical: Initial n = 32, 8 year point estimate: 25%, CI: 7%–43%.

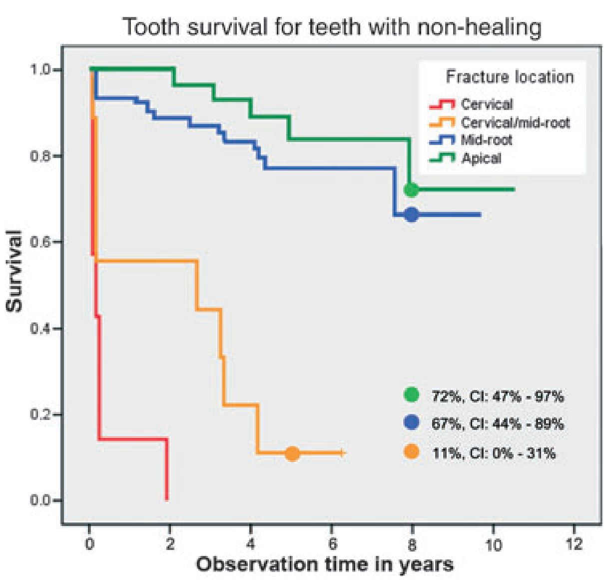

Fig. 7. Tooth survival for teeth with non-healing shown for each of the four fracture locations. Point estimates with 95% confidence intervals (CI). Apical: Initial n = 30, 8 year point estimate: 72%, CI: 47–97%. Mid-root: Initial n = 63, 8 year point estimate: 67%, CI: 44–86%. Cervical-mid-root: Initial n = 9, 5 year point estimate: 11%, CI: 0–31%. Cervical: Initial n = 7, 2 year point estimate: 0%, No CI available.

cervical and cervical-mid-root fractures for this subgroup of teeth with non-healing with granulation tissue (Fig. 7). Individual point estimates with 95% confidence intervals are listed in Fig. 7.

Fig. 8. Orthodontic palatal retainer.

Discussion

Dental trauma is a frequently used indication for extraction and implant insertion (6, 7), especially root-fractured teeth are often considered as having a doubtful or hopeless long-term prognosis and are therefore, by many, considered as prime candidates for replacement with implants. In one study by Rosenquist in 1996 (7), 13% of all indications for implants consisted of root fractures. The present study however indicates that most root fractures have a good and, in some cases, excellent long-term prognosis. This study can therefore be used as a guide for long-term treatment planning after a root fracture. After 3–6 months of observation when the healing modality can be identified, further prognostic information is available from this study as survival curves can be consulted corresponding to the respective fracture-healing modality and fracture location. The present study suggests that identification of the healing modality should be awaited before any definitive treatment is planned because even cervical fractures seem to have a good long-term prognosis if hard tissue healing occurs.

With regard to the estimated survival chance of cervical fractures, it should be kept in mind that a considerable number of cervical fractures were not considered treatable at the initial examination (Table 1) and were therefore excluded from the survival analysis. This implies that the overall prognosis of cervical fractures is possibly even worse than the survival rate demonstrated in this study.

An encouraging finding is that all teeth with *hard tissue healing* survived in the observation period. Even teeth with cervical fractures may have an excellent long-term prognosis if hard tissue healing is found at the radiographic examination after 3–6 months (11/11 survived during the observation period).

In teeth with *connective tissue healing,* the extent of mobility has in a previous study been found to be related to fracture location with coronal fractures having the largest mobility (8). Furthermore, for teeth with cervical fractures, the mobility appears to decrease with increasing observation time (8). The predominant reasons for tooth loss for teeth with cervical fractures were excessive mobility or new traumas. A new trauma can easily result in avulsion of the coronal fragment when the fragment is not healed with hard tissue.

The late occurring endodontic failures could be related to the known phenomenon of protracted healing after endodontics first described by Strindberg in his classical study in 1956 (9). In this study of 479 conservatively treated cases, uncertain healing was a frequent finding after 1 year. This uncertainty was however reduced over time and stabilized after 3–4 years. A similar finding was made in studies of 1000 surgical endodontically treated teeth reported by Rud et al. in 1972 (10, 11). In this study, it was furthermore shown histologically that these cases with uncertain healing after 4 years represented true failures in the sense that they showed periapical inflammation (11).

In the late extraction cases, we are possibly dealing with teeth classified as uncertain healing, that is, they have signs of healing in the fracture site but not complete normalization.

One could question whether persistent monitoring of these cases with uncertain healing is advisable in light of the potential risk of future bone loss. However, based on our experience, we think it is worth waiting additional 3–4 years before a final judgment is made. The risk of bone loss is small, and our experience has shown that a significant number of cases finally heal. Another possible explanation for some of the late extraction cases could be insufficient coronal restoration after endodontic treatment, leading to leakage and subsequent tooth loss (12, 13).

The problems associated with the endodontic management of root-fractured teeth with coronal pulp necrosis can, to a large extent, be resolved today with advances in endodontic techniques where calcium hydroxide is used to create a hard tissue barrier at the fracture level in the coronal fragment followed by a coronal gutta-percha root filling (14), and where MTA can be used to fill the root canal at the fracture site (15). However, the lack of hard tissue consolidation between fracture surfaces after successful endodontic treatment still represents a problem. Thus, the *mobility* of the coronal fragment of an otherwise healed root fracture after endodontic therapy can represent a problem in relation to new traumas. Recent developments in lingual stabilization devices for orthodontic and/or periodontal purposes could possibly reduce this problem of abnormal tooth mobility in cases of cervical-mid-root and cervical fractures. So far, the long-term experience with these orthodontic retainers has been consistently good in relation to stabilization after orthodontic treatment (16, 17) (Fig. 8). Whether such tooth stabilization can actually solve this problem after root fractures remains to be clarified through future studies.

Concerning new traumas, there is a 2–4% yearly incidence in a population (18). One study followed a group of trauma patients over a 12-year period and found that 49% of the participants had one or more new traumatic episodes affecting permanent teeth in the examination period (18, 19). The high frequency of tooth loss caused by secondary traumas found for cervical root fractures in this study might be the result of the relative structural weakness of PDL and/or granulation tissue compared to fractures healed with hard tissue.

While the risk of secondary trauma cannot be prevented, the use of lingual stabilization may, as mentioned from a theoretical point of view, reduce the risk of actual tooth loss caused by secondary traumas.

In conclusion, the long-term prognosis of root fractures in relation to tooth loss appears to be closely related to the type of healing and the position of the fracture. Cervical-located fractures with no hard tissue healing have a marked risk of tooth loss owing to excessive tooth mobility and new trauma.

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