



Outcomes for root-fractured permanent incisors: a retrospective study

R.R. Welbury, PhD, BDS, MB, BS, FDSRCS, FDSRCPS M.J. Kinirons, PhD, BDS, FFDRCS, FDSRCS
P. Day, BDS, MFDS K. Humphreys, BDS, MFDS T.A. Gregg, BDS, FDSRCS, FDSRCPS, FFDRCS

Dr. Welbury is professor, Department of Child Dental Health, Glasgow Dental Hospital and School, Scotland, UK; Dr. Day is specialist registrar, Department of Child Dental Health, Leeds Dental Institute, England, UK; Dr. Kinirons is senior lecturer, Department of Child Dental Health, Belfast Dental Hospital and School, Northern Ireland, UK; Dr. Humphreys is specialist registrar, and Dr. Gregg is consultant paediatric dental surgeon, Dental Hospital and Royal Hospital for Sick Children, Belfast, Northern Ireland, UK. Correspond with Dr. Welbury at R.R.Welbury@dental.gla.ac.uk

Abstract

Purpose: The objective of this study was to assess the outcomes for treated root-fractured permanent incisors with respect to pulp vitality, root tissue union, and tooth survival and to examine the effects of clinical and radiographic parameters and rigid splinting on the outcome.

Methods: Eighty-four teeth were identified and data extracted from case notes prior to transfer to an SPSS data base for analysis. The odds ratios for each factor were calculated and the significance of differences was determined. Tooth loss and relevant risk variables were examined using Cox's regression model and Kaplan-Meier survival curves.

Results: Fourteen (17%) had fractures in the apical third, 47 (56%) in the middle third, and 23 (27%) in the coronal (gingival) third. Twenty-four (29%) also had crown fractures involving enamel and dentine. Crown fractures were identified as significant risk factors for pulp vitality. Loss of pulp vitality, horizontal displacement, and extrusive displacement of the coronal fragment were significant risk factors for hard root tissue union. Survival was poorest with gingival third fractures with 14 (61%) of these teeth being lost. Splinting rigidly had no significant effect on pulp vitality and type of root tissue healing.

Conclusions: Loss of pulp vitality was significantly associated with enamel-dentine crown fracture. Hard root tissue union was significantly affected by pulp necrosis and luxation of the coronal fragment. Survival was poorest for root fractures within the gingival third of the root. Splinting with rigid fixation had no significant effect on pulp vitality and type of root tissue union. (*Pediatr Dent* 24:98-102, 2002)

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The established treatment procedure for root-fractured teeth for the last 30 years has been rigid splinting for 2-3 months.¹ However, a retrospective study by Cvek and colleagues has cast doubt on the efficacy of both long-term splinting and the types of splint currently used for root fracture healing.² Long-term splinting and immobilization for 2-3 months was thought to be necessary for root-fractured teeth to ensure hard tissue union between fragments.^{1,3-8} However, both shorter and longer periods of splinting have been advocated, depending on the level of the fracture and the amount of mobility.⁹⁻¹¹

In addition, it has also been reported, largely in case reports, that incomplete and complete root fractures in teeth with both mature and immature apices may heal spontaneously without any splinting at all.¹²⁻¹⁶ The literature relating

to the healing of root fractures shows that treatment protocols for repositioning, splinting, and the duration of splinting are mostly empirically determined and without a significant evidence base. The wound in root fractures involves damage to pulp, cementum, dentine, and periodontal ligament (PL).

The amount of pulpal damage will vary with the amount of displacement of the crown from concussion to complete rupture of the neurovascular bundle. In the latter case, repositioning of the crown would theoretically facilitate revascularisation in the coronal part of the tooth. The effects of splinting and of repositioning the displaced coronal fragment in root fractures on pulpal revascularisation in humans has not yet been clarified. However, experiments with extracted and replanted or transplanted teeth in

monkeys have actually shown a positive advantage to no splinting compared to rigid splinting in relation to the speed and extent of revascularisation.¹⁷

The PL injury, like the pulp injury in root fractures, may range in severity from negligible damage to complete rupture. This will be a key factor when considering the necessity and effect of splinting. There are no published studies on the effect of repositioning on the healing of the PL. However, observations during replantation experiments have shown that accurate repositioning is not an absolute necessity for PL healing and healing can even occur after a delay.¹⁸ Animal experiments have failed to show either a beneficial or a detrimental effect on either the speed or the nature of PL healing after rigid splinting.^{17,19,20}

The final tissues to heal after a root fracture are dentine and cementum, and their healing depends upon the activity of odontoblasts and cementoblasts. There is no information in the scientific literature on the effect of splinting upon the functions of either odontoblasts or cementoblasts.

A number of different splinting designs have been developed in recent years.²¹⁻²³ In luxation and replantation injuries the splint should allow some mobility to aid PL healing, whereas after root fractures the splint should be rigid to permit optimal formation of a dentine callus to unite the root fragments. Oikarinen et al²³ considered that suitable rigid splints were of the rigid-wire composite type, although no advice was given on how many abutment teeth to include on either side of the injured tooth. However, more recently an acid-etch/resin splint has been advocated for root fractures.¹

Until the study by Cvek et al,² there seemed to be little evidence of the effect on the involved tissues of different treatment modalities in root fractures. The purpose of the present study was to submit to retrospective analysis further treated cases and to assess the outcomes of treatment in terms

of pulp vitality, root tissue union, and overall tooth survival. These findings will contribute to the sparse literature on the topic and help to identify the most appropriate method of managing root fractures.

Methods

Presentation and treatment factors for root-fractured incisors in children, with or without enamel or enamel/dentine fractures, were recorded in the Dental Schools and Hospitals of Belfast and Newcastle upon Tyne between January 1, 1994 and July 31, 2000. Teeth were included in the study if they had a follow up period of greater than one year or, alternatively, until the time of tooth loss. In total, 84 teeth in 77 patients aged between 6.3-19 (mean 11.28) years were evaluated. Eighty (95%) of the teeth were in the maxilla and 4 (5%) were in the mandible.

Treatment protocols in both centers were identical for new cases of root fractures. The fractures were reduced and rigidly splinted for 2-3 months with a composite and wire (0.7 mm) splint. Two abutment teeth were included on either side of the root-fractured tooth and whenever possible these were the adjacent teeth in the line of the arch. Enamel dentine fractures were covered with a bonded restoration (bandage).

Factors which may exert an influence on the occurrence of pulpal necrosis included: the location of the injury in the apical, middle, or gingival thirds of the root; the stage of root development (divergent, parallel, convergent); the presence of single or multiple root fractures; horizontal displacement of the coronal fragment from the line of the arch (determined clinically); extrusion of the coronal fragment with marked separation at the fracture area (determined clinically by an elongated crown and radiographically when there was separation between the fragments at the root fracture site); and associated enamel or enamel/dentine crown fracture.

Factors relating to splinting were included as follows: the time to splint placement (days); the duration of splinting (days). All new fractures that required splinting were treated by a rigid method (above). The method of splinting, or not, for old fractures either presenting late or referred late was obtained from the practitioners.

Factors related to healing were included as follows: the type of fracture union classified as hard, connective tissue or osseous; pulp sensibility with an electric pulp tester; the status of the apical root fragment classified as sclerosed, resorbed/resorbing, or with pathosis; tooth loss; and tooth loss in days after trauma.

Data were transferred to an SPSS data base for analysis and cross tabulations of frequencies of factors and outcomes were prepared. The odds ratios for each factor were calculated and the significance of differences was determined using Fisher's Exact tests of probability. Risk variables for survival were entered into a Cox's regression model, with tooth survival set as the outcome variable. Subsequently, Kaplan-Meier survival curves were drawn for any factors that were significant in the Cox regression model.

Table 1. The Effect of Factors on Pulpal Vitality

	Non-vital	Vital	Odds ratio	P value
Coronal fracture	17	7	2.6	0.05
No coronal fracture	29	31		
Location gingival	16	7	2.4	0.07
Location middle/apical	30	31		
Horizontal displacement and extruded coronal fragment	9	8	3.7	0.07
No displacement	4	13		
Horizontal displacement	20	13	2.4	0.08
No horizontal displacement	11	17		
Extruded coronal fragment	19	13	2.2	0.09
Non-extruded	14	21		
Not splinted	19	15	1.5	0.28
Splinted	20	23		

Table 2. The Effect of Factors on Root Tissue Healing

	Hard tissue union	Fibrous/ osseous	Odds ratio	P value
Pulp vital	13	25	7.5	0.001
Pulp non-vital	3	43		
No horizontal displacement	10	18	5.6	0.01
Horizontal displacement	3	30		
Horizontal displacement and extruded coronal fragment	8	9	6.7	0.02
No displacement	2	15		
No extruded coronal fragment	12	25	3.6	0.03
Extruded	4	30		
Location middle/apical	14	47	3.1	0.12
Location gingival	2	21		
No coronal fracture	12	48	1.3	0.50
Coronal fracture	4	20		
Splinted	8	33	1.1	0.56
Not splinted	8	35		

Results

Of the 84 teeth in the study 14 (17%) had root fractures located in the apical third, 47 (56%) had fractures in the middle third, and 23 (27%) had fractures in the gingival third. At presentation 33 (39%) had horizontal displacement of the coronal portion, 34 (41%) had extrusion of the coronal portion with marked separation at the fracture area, and 17 (20%) showed both features. Twenty-four (29%) had crown fractures involving enamel or enamel and dentine. Twelve teeth (14%) had open apices (6 divergent and 6 parallel root canals) and 7 (8%) had multiple root fractures. Pulpal vitality was retained in 38 (45%) teeth. Odds ratios were calculated for the effects of factors on pulp vitality (Table 1). Higher odds ratios and lower *P* values indicate a stronger effect on pulp vitality and the effects are tabulated in order of importance.

The presence of a concomitant crown fracture had a significant effect on pulp vitality and the risk of loss of vitality was 2.6 times higher in cases with this additional damage. Gingival third fractures—those with horizontal displacement or extrusion of the coronal fragment—had a higher prevalence of loss of vitality, but these effects failed to reach statistical significance. The use of splinting had the least effect on vitality.

Hard tissue healing was found in 16 (19%) of the root fractures, fibrous healing in 36 (43%), and osseous healing in 32 (38%). Odds ratios were similarly calculated for the effect of factors on root healing (Table 2). Pulp vitality, horizontal displacement of the coronal fragment, and extrusion of the coronal fragment had a significant effect on

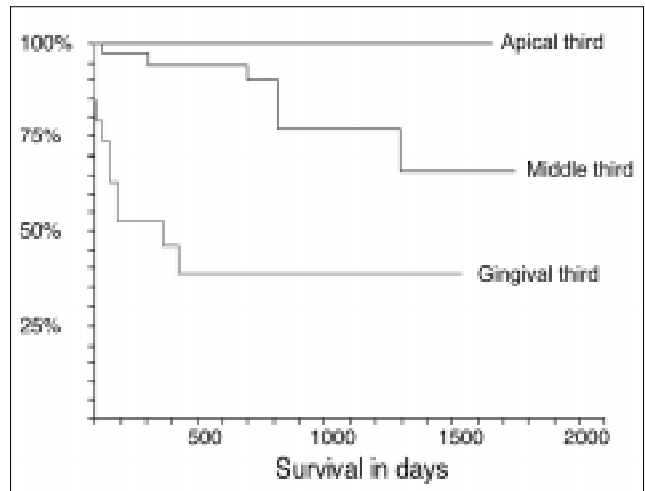


Fig 1. Kaplan-Meier curve of the survival of teeth with root fractures at different locations. The upper curve represents teeth with apical fractures, the middle curve those with fractures in the mid root and the lower curve those fractured in the gingival third. Cox's regression analysis indicates a significant difference in survival between the three groups ($P=0.0007$).

fracture healing. Little effect was noted for the location of the fracture, concomitant crown fracture, or splinting.

The root canal in the apical fragment was sclerosed in 38 (45%) teeth, resorbing in 11 (13%) teeth, and had pathosis in only 1 (1%). Forty-three teeth (51%) were splinted. For these, the mean duration of splinting was 115 days, with a range of 7-503 days. All cases were reviewed for a minimum of one year or until the time of tooth loss. Survival to the closure date of July 31, 2000 ranged from 1-3750 days (mean = 831 days). A total of 20 (24%) teeth were lost as a result of repeated infection and mobility.

Risk variables for survival were entered into a Cox's regression model, and the only statistically significant variable was the location of the root fracture. None of the 14 teeth with apical third fractures were lost compared to 6 (13%) of the 47 with middle third fractures, and 14 (61%) of the 23 with gingival third fractures (Fig 1).

Discussion

The protocols for the treatment of root fractures in Belfast and Newcastle upon Tyne are the same. The majority of cases were splinted by rigid means. However, due to delayed presentation to the centers, a number of teeth in both centers were not splinted initially.

The primary aim of the study was to assess the outcomes in terms of pulp vitality, root tissue union, and survival and to examine the effects of various clinical and radiographic parameters and rigid splinting on the outcome.

In the present report, the effect of different factors on pulp vitality are presented with an odds ratio and *P* value. The only significant effect at the 5% level on pulp vitality is the presence of concomitant crown fracture that presumably predisposes to pulpal necrosis.

Location of the fracture, horizontal displacement, and extrusive displacement of the coronal fragment nearly

achieved significance, but the effect of splinting was clearly not significant in maintaining pulp vitality.

The effect of different factors on root tissue healing was examined. Hard tissue union was significantly more likely to occur in the presence of a vital pulp, no horizontal displacement, and no extrusive displacement. Fibrous or osseous union was significantly more likely in the presence of a pulpal necrosis, horizontal displacement, and extrusive displacement. This agrees with previously published work.²⁴ It is difficult to obtain a hard tissue union in the presence of pulpal necrosis or displacement of the coronal fragment, and such instances were very rare in the present study. It is possible these rare cases were due to healing originating from the periodontium, but this was not specifically examined in the present study. No significant relationship to the type of root tissue healing was found with regard to location of the fracture, presence of concomitant crown fracture, or splinting. There were too few teeth with open apices and multiple root fractures to allow an examination of the impact of these factors.

As splinting did not have any significant effect either on pulpal vitality or the type of root tissue healing, teeth with minimal mobility and little periodontal injury or subluxation of the coronal element may have done equally well without splinting from the outset.

It would now seem reasonable to suggest that, because rigid splinting for 2-3 months does not appear to either create an environment in which hard root tissue healing is most likely to occur or to protect pulpal vitality, it should be discontinued for routine use and the duration of splinting should be judged by individual clinical need. A functional splint for 2-3 weeks that allows physiological movement and which is used in luxation injuries to promote normal healing of the periodontal ligament is now suggested as an option for root-fractured teeth. Certainly this would simplify trauma teaching because the only scenario that would then require a rigid splint would be the dento-alveolar fracture.

The strongest indicator of tooth survival was the location of the root fracture with those in the coronal or gingival third having the worst prognosis. It is likely that these were less stable, became non-vital, and had less favorable healing. This information suggests that strategic decisions need to be made early regarding these teeth rather than embarking on splintage and treatment that carries at best a guarded prognosis.

Pulp canal obliteration or sclerosis of the apical fragment occurred in 38 (45%) of teeth. This is not dissimilar to 30% reported previously.²⁵ Current endodontic teaching of root-fractured teeth that become non-vital recommends instrumentation only to the level of the fracture and aims to create a stop at the coronal side of the fracture prior to obturating with gutta percha. The apical fragment is said to rarely cause any significant problems. The results of this study would agree with this in that only one (1%) case had pathosis associated with the apical fragment.

Conclusions

1. Loss of pulp vitality in root-fractured teeth was significantly associated with concomitant crown damage.
2. Hard root tissue union was significantly affected by pulp necrosis and luxation of the coronal fragment.
3. Survival was poorest for root fractures located at the gingival third of the root.
4. Splinting rigidly did not seem to have any significant effect on pulpal vitality or type of root tissue union.

References

1. Andreasen FM, Andreasen JO. Root fractures. In: *Textbook and Color Atlas of Traumatic Injuries to the Teeth*. 3rd ed. Copenhagen: Munksgaard; 1994:279-311.
2. Cvek M, Andreasen JO, Borum MK. Healing of 208 intra-alveolar root fractures in patients aged 7-17 years. *Endod Dent Traumatol* 17:53-62, 2001.
3. Michanowicz AE, Michaanowicz JP, Abou-Ras M. Cementogenic repair of root fractures. *JADA* 82:569-579, 1971.
4. Zachrisson BV, Jacobsen I. Long-term prognosis of 66 permanent anterior teeth with root fracture. *Scand J Dent Res* 83:345-354, 1975.
5. Zachrisson BV, Jacobsen I. Repair characteristics of root fractures in permanent anterior teeth. *Scand J Dent Res* 83: 355-364, 1975.
6. Jacobsen I, Kerkes K. Diagnosis and treatment of pulpal necrosis in permanent anterior teeth with root fracture. *Scand J Dent Res* 88:370-376, 1980.
7. Andreasen JO, Hjorting-Hansen E. Intra-alveolar root fractures: Radiographic and histological study of 50 cases. *J Oral Surg* 25:414-426, 1967.
8. Benati FW, Biggs JT. Management of traumatized permanent incisor teeth with horizontal root fractures. *Okla Dent Assoc J* 65:30-33, 1994.
9. Rabie G, Barnett F, Tronstad L. Long-term splinting of maxillary incisor teeth with intra-alveolar root fracture. *Endod Dent Traumatol* 4:99-103, 1988.
10. Fountain SB, Camp JH. Traumatic injuries. In: *Pathways of the Pulp*. 4th ed. Cohen S, Burns RC, eds. St Louis: CV.Mosby; 1984:502-536.
11. Feiglin B. Clinical management of transverse root fractures. *Dent Clin North Am* 39:53-78, 1995.
12. Andreasen FM, Andreasen JO, Bayer T. Prognosis of root-fractured incisors: prediction of healing modalities. *Endod Dent Traumatol* 5:11-22, 1989.
13. Chang SP, Walker RT. Root fractures: a case of dental non-intervention. *Endod Dent Traumatol* 4:186-188, 1988.
14. Yates JA. Root fractures in permanent teeth: a clinical review. *Int Endod J* 25:150-157, 1992.
15. Tziafas D, Margelos I. Repair of untreated root fracture: a case report. *Endod Dent Traumatol* 9:40-43, 1993.

16. Caliscan MK, Pehlivan Y. Prognosis of root-fractured permanent incisors. *Endod Dent Traumatol* 12:129-149, 1996.
17. Andreasen JO. Periodontal healing after replantation and autotransplantation of incisors in monkeys. *Int J Oral Surg* 10:54-61, 1981.
18. Kristerson L, Andreasen JO. The effects of splinting on periodontal and pulpal healing after autotransplantation of mature and immature permanent incisors in monkeys. *Int J Oral Surg* 12:239-249, 1983.
19. Andreasen JO. The effect of splinting upon periodontal healing after replantation of permanent incisors in monkeys. *Acta Odontol Scand* 33:313-323, 1975.
20. Mandel U, Vidik A. Effect of splinting on the mechanical and histological properties of the healing periodontal ligament after experimental extrusive luxation in the monkey. *Arch Oral Biol* 34:209-217, 1989.
21. Oikarinen K. Functional fixation for traumatically luxated teeth. *Endod Dent Traumatol* 3:224-228, 1987.
22. Oikarinen K. Tooth splinting: a review of the literature and consideration of the versatility of a wire-composite splint. *Endod Dent Traumatol* 6:237-250, 1990.
23. Oikarinen K, Andreasen JO, Andreasen FM. Rigidity of various fixation methods used as dental splints. *Endod Dent Traumatol* 8:113-119, 1992.
24. Andreasen FM. Pulpal healing after luxation injuries and root fractures in the permanent dentition. *Endod Dent Traumatol* 5:111-131, 1989.
25. Andreasen FM, Andreasen JO. Resorption and mineralization processes following root fracture of permanent incisors. *Endod Dent Traumatol* 4:202-214, 1988.

ABSTRACT OF THE SCIENTIFIC LITERATURE



ORTHODONTIC TREATMENT IN LONG-TERM SURVIVORS AFTER PEDIATRIC BONE MARROW TRANSPLANTATION

Pediatric cancers represent about 1% of all cancers. It is estimated that 1 in every 900 adults in the year 2000 is a survivor of childhood cancers. Children treated for childhood cancers with both radiation and chemotherapy often exhibit disturbances in dental development. The aims of this study were to evaluate any adverse effects of orthodontic treatment on patients who were long term survivors following BMT. This report is a retrospective analysis of treatment outcomes in 10 orthodontically treated children. A questionnaire was sent to each child's orthodontist, and 5 orthodontists reported that the patient's medical condition influenced their choice of treatment plan. Three orthodontists, all treating patients with severely disturbed root development, reported using lighter forces than they used with the average patient. With regards to complications related to orthodontic treatment, 1 of the 10 patients showed evidence of root resorption. In 4 of the 10 patients, the treatment result was judged to be unsatisfactory. This study showed that, although ideal treatment results were not always achieved, orthodontic treatment did not produce any harmful side effects in children who were long-term survivors of childhood cancer.

Comments: As the population of long-term survivors of childhood malignancies increases, the feasibility of orthodontic treatment will become an issue. While it has been shown that orthodontic treatment did not have significant adverse effects, there are a number of cautions. Treatment was postponed for at least 2 years post-transplant, and the treatment forces and outcome modified due to the patients medical condition. Thirty-five patients were identified as requiring orthodontic treatment, however only 10 were represented here. It would be interesting to document why the remainder did not receive treatment. AOC

Address correspondence to Goran Dahllof, Dept. Pediatric Dentistry, Karolinska Institute, PO Box 4064, SE 141 04 Huddinge, Sweden. Goran.Dahllof@ofa.ki.se

Dahllof G, Jonsson A, Ulmner M, Huggare J. Orthodontic treatment in long-term survivors after pediatric bone marrow transplantation. *Am J Orthod Dentofacial Orthop* 2001;120:459-65.

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