Dental Traumatology

Dental Traumatology 2008; 24: 503–509; doi: 10.1111/j.1600-9657.2008.00652.x

Root fractures in children and adolescents: diagnostic considerations

Julie R. Molina[1], William F. Vann Jr[1], Judy D. McIntyre[2], Martin Trope[3], Jessica Y. Lee[4]

[1]Department of Pediatric Dentistry at the University of North Carolina at Chapel Hill, Chapel Hill, NC; [2]Department of Endodontics at the University of North Carolina at Chapel Hill and private practice of Endodontics in Boston, MA; [3]Department of Endodontics at the University of North Carolina at Chapel Hill and private practice of Endodontics in Philadelphia, PA; [4]Department of Pediatric Dentistry and School of Public Health at the University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Correspondence to: Julie R. Molina, UNC-CH – Pediatric Dentistry, 228 Brauer Hall CB#7450 Chapel Hill, NC 27517, USA
Tel.: 919 966 2743
Fax: 919 852 1230
e-mail: julie_molina@dentistry.unc.edu

Accepted 14 July, 2007

Abstract – The objectives of this study were to (i) characterize epidemiologic trends in anterior permanent tooth trauma in a sample of children and adolescents (ii) examine the relationship of crown fractures (CF) and concomitant root fractures (RF) to determine if CFs are protective against RFs and (iii) examine the radiographic evidence of RFs to determine the value of obtaining three vertical periapical radiographic projections. This was an 8-year cross-sectional study of patients aged 6–18 with anterior permanent tooth trauma. We examined cases involving maxillary central/lateral incisors for which three clearly diagnostic periapical radiographs were obtained during the initial emergency visit. Two trained and calibrated dentists served as expert examiners for the radiographic assessments. Kappa statistics were used to determine reliability. Tests for association of concomitant crown and root fractures were performed using Likelihood Ratio Chi-Square tests. The final sample included 185 teeth in 114 children. Our demographic and epidemiologic findings were comparable to those of previous studies. Experts reached this consensus: 22 RFs were detected, 9.6% (eight out of 83) teeth exhibited root fractures when no CFs was documented, and 13.7% (14 out of 102) teeth had both CFs and RFs as separate entities. Good examiner reliability was reached confirming the presence of RFs (Kappa = 0.81). The association of concomitant RFs and CFs was odds ratio = 1.97 (P = 0.052). CFs were not protective against RFs; indeed, teeth with CFs were twice as likely to have an RF as those without CFs. As the number of radiographic projections increased, RFs were identified more often; however, our data suggest that there is no reason to suspect a complete RF in preteen children unless the root exhibits clinical signs such as luxation or severe mobility. This study provides solid evidence to support obtaining multiple radiographic projections at different vertical angulations to rule out RFs in children and adolescents when RFs are suspected.

Root fractures are relatively uncommon comprising only 0.5–7% of all dental injuries in the permanent dentition (1). The most common age range for root fractures involving the permanent dentition in children is between 11 and 20 years (1) with 75% affecting maxillary central incisors (2). Typically, the mechanism of root fractures is a frontal impact that creates compression zones labially and lingually (1).

Root fractures often present clinically as a slightly extruded tooth, often lingually displaced. Such a tooth is often mobile, but the degree of mobility is determined by the fracture site. Root fractures are more commonly found in the middle third of the root (1). Without radiographic examination, usually it is impossible to distinguish between displacement due to a luxation injury versus a root fracture (3). The authors' clinical experience suggests that in children and adolescents, coronal fractures may be a protective and mitigating factor against root fractures, but to date, this clinical perception remains untested.

Diagnosis of root fractures in children and adolescents

Correct diagnosis of root fractures is essential to ensure proper treatment to achieve the best possible prognosis (2). A correct diagnosis will aid the clinician in decisions about immediate treatment and splinting strategies as well as the timing of follow-up examinations, radiographs, and sensitivity testing.

A root fracture can be seen only if the radiographic beam is directed through the plane of fracture. Many authorities argue that one radiograph often will not lead to optimal disclosure of root fractures. One protocol to diagnose or rule-out root fractures in children and adolescents is advocated by the guidelines (4) established by the International Association of Dental Traumatology (IADT). This protocol includes four periapical radiographs: an occlusal, a periapical central angle, periapical mesial and distal excentric projections (4). Currently, there are no published data to support this recommendation.

A multi-directional approach using a conventional periapical exposure and two additional vertical periapical projections that vary ±15–20° from the central beam has been advocated by Andreasen and Andreasen (1), Wilson (3), Degering (5), Bender and Freedland (6), Berman (7), and Herweijer (8). Both Andreasen and Andreasen (1) and Degering (5) have published eloquent illustrations involving artificial root fractures in human incisors, adding a weight of documentation to this radiographic protocol. At The University of North Carolina at Chapel Hill (UNC-CH) School of Dentistry, the protocol for examining permanent incisor root fractures in children and adolescents entering the Pediatric Dentistry or Endodontic Clinics is to obtain three periapical radiographic projections at different vertical angulations(1, 3, 5–8) for dental-related tooth trauma wherein root fracture is possible. This protocol has been the standard of care since the mid-1990s. While many authorities recommend a multi-projection clinical protocol for diagnosis of root fractures, it should be noted that there are no clinical trials to support these recommendations.

Treatment and prognosis of root fractures

Treatment and prognosis of root fractures in permanent teeth are dependent on a variety of factors including stage of root development, type of healing and optimal repositioning of coronal fragments and/or splinting of teeth. Both the IADT (4) and Andreasen and Andreasen (1) recommend repositioning the coronal fragment if displaced, and immobilizing the tooth with a splint with follow-up in 3–4 weeks. Recent research suggests that optimal repositioning may be more critical than splinting. With dislocation of coronal fragments, optimal repositioning enhances the likelihood of both pulp healing and hard tissue repair in mature and immature teeth (9). Cvek et al. (9) found no difference in the frequency of healing between splinted teeth and non-splinted teeth.

One exception to the concept of repositioning root fractures involves teeth with incomplete fractures with immature roots wherein fractures have been found to heal spontaneously (10). Similar findings have been reported by Freely et al. (11) as well as by Cvek et al. (9), both of whom found good root healing to occur most often in teeth with incomplete root development.

According to the current literature, root fractures in children and adolescents have a good prognosis, if a proper diagnosis is made at the time of the traumatic injury and if proper treatment is undertaken. Radiographic information is a key component for making such diagnosis and rendering the proper treatment. Accordingly, our findings should offer important insights for clinicians to consider in making a radiographic diagnosis of root fractures. These insights may lead to the development of new clinical standards of care that may save time, money and unnecessary radiation exposure.

Materials and methods

Specific aims

1. To characterize epidemiologic trends in anterior permanent tooth trauma in a sample of children and adolescents aged 6–18.
2. To examine the relationship of root fractures with and without concomitant crown fractures to answer the question: are crown fractures protective against root fractures in children and adolescents?
3. To examine carefully our patient population for radiographic evidence of root fractures and determine the diagnostic and clinical value of obtaining three vertical periapical radiographic projections to assess maxillary anterior root fractures in children and adolescents aged 6–18.

We tested two null hypotheses for children and adolescents aged 6–18: (i) crown fractures are not protective against root fractures and (ii) three vertical periapical radiographs at different angles are not necessary for the diagnosis of root fractures.

Sample size estimations

For sample size estimates, we used reported prevalence scores from a recent study of dental trauma in children (12) in which children (7–18 years of age) had a reported crown and root fracture prevalence of 32.1% and 2.1%, respectively. Assuming the same prevalence levels with an alpha error of 0.05 and beta of 0.80, we estimated a sample size of 134 cases would be needed to detect a difference using simple parametric tests such as chi-square tests. Because our inclusion criteria required three *clearly diagnostic* radiographs, we expected that some patient records would be hard to access, some radiographs would be missing from some records and others would not meet our strict standard of being *clearly diagnostic*.

Sample characterization

We reviewed our 8-year emergency registry and carefully selected only the cases involving permanent maxillary incisor trauma for which three diagnostic vertical periapical radiographs were available in each patient's record. All cases were then categorized by diagnostic category with tooth/bone-related trauma: uncomplicated, complicated, root fracture, crown-root fracture, alveolar fracture and luxation-related trauma: concussion, subluxation, luxation, intrusion, extrusion and avulsion. In classifying the type of trauma, we relied upon the diagnosis given by the treating dentists at the time of trauma.

We classified each trauma case according to ethnicity, gender, age, and etiology. The etiology was classified into seven groups: falls during free-play, sports-related accidents, bicycle accidents, automobile accidents, ATV/motorbike accidents, child abuse, and 'other.' For athletic injuries, we recorded whether an athletic mouthguard was in use by the child at the time of the injury.

Root fracture assessment by expert examiners

Two experienced dentists with expertise in dental trauma served as expert examiners for root fracture assessment. The examiners were trained in two consensus-building calibration sessions using a sub-sample of trauma cases that included three periapical radiographs obtained at different vertical angulations. All radiographic interpretations were accomplished using view boxes in a dark room. The purpose of each session was to (i) review the definition of root fractures, (ii) complete independent reviews of selected radiographs from sample cases including some with root fractures, and (iii) debrief all reviews to achieve calibration and build examiner consensus.

The current literature included no data on the degree of examiner agreement achievable. Our goal was to achieve a Kappa score of at least 0.80 for both intra- and inter-examiner reliability. After training and calibration, the examiners independently assessed the case-study radiographs for root fractures in a final, structured session under the supervision of the Principal Investigators. A random sample group of 20 cases were re-examined unknowingly by the examiners to provide data for the determination of intra-examiner reliability. Following a review of all cases, the examiners discussed those cases for which there were diagnostic disagreements and reached a diagnostic consensus. Kappa statistics were performed to determine the level of agreement for intra- and inter-examiner reliability.

Why expert examiners?

Considering that the patients in this study had undergone a comprehensive dental trauma examination and many had subsequent follow-up care during which root fractures could have been detected and diagnosed, the purpose of deploying expert examiners was to cross-examine the study sample to determine whether there were cases diagnosed with root fractures with actual clinical/radiographic assessments and follow-up care that would be missed or *undetected* by the expert examiners. Further, we also wanted to examine if the expert examiners would detect any *occult* fractures not detected by clinical/radiographic assessment and follow-up care. Finally, we wanted to generate data for intra- and inter-examiner reliability to illuminate the ease or difficulty in the radiographic diagnosis of root fractures in children and adolescents.

Statistical analysis

All analyses were conducted using STATA 9.0 (STATA Corp. College Station, TX, USA). We examined the relationship between crown fractures and root fractures using a Likelihood Ratio Chi-square test with the level of significance set at an alpha of 0.05. We determined the diagnostic value of obtaining three vertical periapical radiographs using inspection of our examiner-derived positive root fractures.

Human subject assurances

This study was approved by the Institution Review Boards of the Schools of Dentistry and Medicine at The University of North Carolina at Chapel Hill.

Results

Demographic findings

During the study time-frame (1997–2004), the total emergency visits ranged from 400–700 annually with an estimated 125 permanent anterior tooth trauma cases each year. A total of 114 patients experienced dental trauma to the permanent maxillary incisors for which three vertical radiographs were obtained at the initial emergency visit. Relevant demographic data for the patients are given in Table 1.

Table 1. Epidemiology and demographics (n = 114)

Variables	*n*	Percent
Gender		
Male	72	63
Female	42	37
Age (years)		
6	5	4
7	20	18
8	27	24
9	22	19
10	14	12
11	7	6
12	14	12
13	0	0
14	0	0
15	3	3
16	2	2
17	0	0
18	0	0
Etiology		
Falls	38	34
Bicycle accident	22	20
Playing sports	14	12
ATV/motorbike accident	2	2
Automobile accident	1	1
Child abuse	0	0
Other (i.e., free play, random accidents, etc)	37	31
Mouthguard use	0	0

Epidemiologic findings

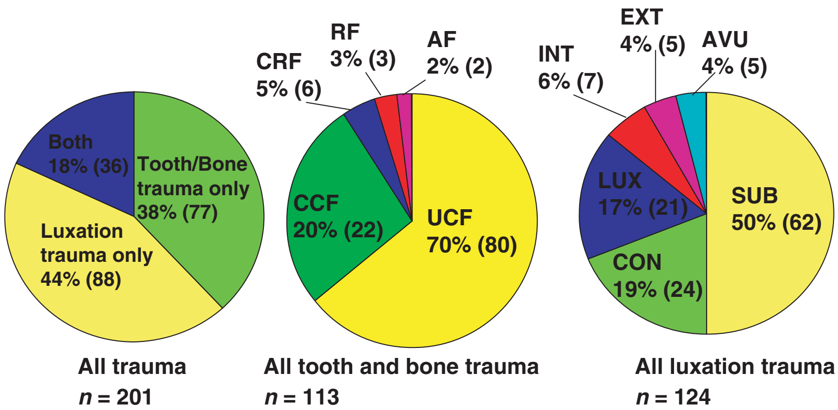
Our 114 patients experienced a total of 201 traumatized maxillary incisor teeth. The epidemiologic data are illustrated in Fig. 1. From our sample size of 201 traumatized teeth, using our strict inclusion criteria of three *clearly diagnostic* radiographs, 185 teeth met our inclusion criteria. The expert examiners assessed these images to generate data for root fractures.

Intra- and inter-examiner reliability

The radiographic assessment session for the study data generation yielded Kappa scores of 81% for inter-examiner reliability and 100% consensus for those cases wherein examiners at first disagreed. The intra-examiner reliability Kappa scores were 0.80 and 0.75 respectively for examiners 1 and 2.

Radiographic assessment findings

The expert examiners focused on the 185 teeth that met our strict inclusion criteria for the availability of three *clearly diagnostic* radiographs having been obtained at the initial trauma visit. The expert examiners assessed these images to generate data for root fractures as illustrated in Table 2. Crown fractures were not protective



Tooth and bone trauma: UCF = uncomplicated crown fracture, CCF = complicated crown fracture, CRF = crown-root fracture, RF = root fracture, AF = alveolar fracture.

Luxation trauma: SUB = subluxation, CON = concussion, LUX = luxation, INT = intrusion, EXT = extrusion, AVU = avulsion.

Fig. 1. Epidemiology of Maxillary Anterior Trauma in Children and Adolescents.

Table 2. Relationship between crown fractures and expert examiners' radiographic diagnosis of root fractures

Crown fracture presence	Radiographic root fractures' presence		
	No	Yes	Total
No	75 (41%)	8 (4%)	83 (45%)
Yes	88 (48%)	14 (7%)	102 (55%)
n = 185	163 (89%)	22 (11%)	185 (100%)

Likelihood Ratio Chi-square, $P = 0.052$; odds ratio = 1.97.

against root fractures; indeed, teeth with crown fractures were two times as likely to have a root fracture as those without crown fractures.

Findings related to the number of radiographic images

Our expert examiners reached a consensus on a total of 22 root fractures in the sample. Three root fractures (13%) were seen on only one of three images, 14 (64%) were seen on two of the three images, and five (23%) were seen on all three images.

Characteristics of the root fractures

Table 3 illustrates specific details of the root fractures in our study. The prevalence of the root fractures diagnosed by the clinicians at the time of injury was 1.6% (three out of 185). The prevalence of root fractures identified by the expert examiners was 11.9% (22 out of 185). The patients in our study for whom root fractures were identified were in the age range of 7 year 1 month to 13 year 6 month with a median of 8 year 10 month. The prevalence slightly favored males.

Table 3 illustrates concomitant tooth/bone and luxation injury relationships. Of special interest are location and fracture type categories. Note that half of the occult fractures were found in the mid-root location and half in the apical location. A more dramatic finding is that 100% of the occult fractures were classified as 'incomplete'. For purposes of this study, incomplete root fractures were defined as those that appeared to be partial rather than through and through fractures.

Discussion

Epidemiology

It should be recognized that ours is a select sample of trauma to only permanent maxillary incisors; however, relative to gender and etiology our epidemiologic findings are very similar to those reported by Rajab (13) and Andreasen and Andreasen (1). One difference in our patient population was the age of those patients. In our sample of 185 teeth, patients' ages ranged from 7 year 1 month to 13 year 6 month. Our patients are clearly younger and this is in contrast to root fractures reported by Rajab (13) that occurred in older children (10–15) and those reported by Andreasen and Andreasen (1) with ages ranging from 11 to 20.

None of our trauma cases involved mouthguard use, including the 14 children with sports-related injuries. Also, we were surprised that sports injuries were not higher among our study sample. Mouthguard use among school-aged athletes is relatively high in our community and we speculate that this phenomenon might have reduced the prevalence of sports-related trauma during the time-frame of the study.

Intra- and inter-examiner reliability

Our examiners were experienced clinicians with expertise in dental taumatology and both were active in the field. While the Kappa scores for intra-examiner reliability were acceptable, in general, the findings suggest that radiographic diagnosis of root fractures in children and adolescents is difficult, even under the most ideal conditions.

The challenge of root fracture diagnosis

It should be noted that our sample included only three root fractures that were diagnosed on the basis of the clinical/radiographic data at the time of injury and no

Table 3. Root fracture assessment by expert examiners

Case number	Patient age	Gender	Tooth number	Tooth injury	Luxation injury	Fracture type	Fracture location	Radiographic images*
1	7 years 1 months	M	8	None	SUB	INC	API	3
2	7 years 3 months	F	9	None	CON	INC	API	3
3	7 years 6 months	M	8	UCF	None	INC	MID	2
4	7 years 8 months	M	8	UCF	None	INC	API	2
5	8 years 0 months	M	8	UCF	None	INC	MID	2
6	8 years 0 months	M	9	UCF	SUB	INC	API	2
7	8 years 1 months	M	7	None	SUB	INC	API	2
8	8 years 3 months	M	9	None	SUB	INC	MID	2
9	8 years 5 months	F	9	UCF	None	INC	API	3
10	8 years 6 months	M	8	UCF	None	INC	MID	3
11	8 years 10 months	M	8	UCF	SUB	INC	MID	1
12	8 years 10 months	M	9	UCF	SUB	INC	MID	1
13	9 years 2 months	F	8	CRF	SUB	INC	MID	2
14	9 years 4 months	M	9	UCF	CON	INC	API	2
15	9 years 6 months	F	8	CCF	None	INC	API	2
16	9 years 8 months	F	9	UCF	None	INC	API	2
17	9 years 8 months	F	9	UCF	None	INC	MID	2
18	10 years 4 months	M	8	UCF	None	INC	API	2
19	10 years 11 months	M	9	None	SUB	INC	MID	3
20	11 years 6 months	M	8	None	SUB	INC	MID	2
21	11 years 6 months	M	9	None	SUB	INC	MID	2
22‡	13 years 6 months	M	8	RF	LUX	COM	API	1
n = 22								
Two root fractures not detected by expert examiners								
1	9 years 0 months	F	9	RF	LUX	COM	API	2
2†	10 years 3 months	M	8	RF	SUB	INC	MID	1

UCF, uncomplicated crown fracture; CCF, complicated crown fracture; CRF, crown-root fracture; RF, root fracture; CON, concussion; SUB, subluxation; LUX, luxation; INC, incomplete fracture; COM, complete fracture; CER, cervical third; MID, middle third; API, apical third.
*The total number of radiographic images on which the fracture was noted by the expert examiners.
†Conventional radiographs were obtained for all cases except Case 2 in those root fractures not detected by expert examiners. Digital radiographs were obtained for this case.
‡Case identified at the time of injury and by expert examiners as positive for root fracture.

additional diagnoses were made during trauma follow-up. Our examiners correctly identified only one of those three fractures. The examiners found an additional 21 *occult* fractures that were not detected by the treating dentists at the time of injury. These 21 fractures were either undiagnosed or not recorded by the attending dentist following the traumatic injury. The difficulty of root fracture diagnosis is highlighted by the results that even calibrated 'experts' in dental trauma had difficulty in detecting root fractures. This finding further emphasizes the importance of the additional clinical exam, as well as the radiographic exam to detect or suspect root fractures accurately; again, our experts did not have any information related to the clinical exams that had taken place. It is evident how even after 'sensitizing' examiners to detect root fractures, two remained undiagnosed.

It is interesting that all of the *occult* root fractures detected were incomplete. Andreasen and Andresean (1) define an incomplete or partial root fracture as a possible analog to 'green stick' fractures in long bones. They noted that such fractures usually are seen as a unilateral break in the continuity of the thin root canal/root surface of the immature root (1). They point out that such fractures heal with subsequent hard tissue formation and have an excellent prognosis (1). The one complete fracture identified by our expert examiners was located in the apical third, which authorities (1) suggest has an excellent prognosis with no treatment required.

One could also justify that it is not important to diagnose root fractures as long as repositioning is performed. Studies show optimal repositioning leads to better healing and a more favorable prognosis (9). These findings underscore the challenge of detecting root fractures in children and adolescents and also suggest that the clinical examination is an important adjunct to supplementing radiographic assessment for diagnosis at the time of injury. These results also emphasize the need to examine radiographs very carefully, using a dark room and close inspection. It is important to diagnose a root fracture because if it is missed, the diagnosis may be a severe luxation injury, which would typically necessitate root canal treatment. However, if a root fracture is correctly diagnosed, root canal treatment should NOT be performed and will eventually be needed only about 25% of the time (1).

Are coronal fractures protective against root fractures?

Clinical experience had suggested to us that coronal fractures seemed to be protective against root fractures in children and adolescents. The rationale is that injury to the tooth occurs at the site of impact and if a tooth has a coronal fracture, this is the focus of impact and the remaining tooth should remain sound. Yet, the results from the present investigation indicated that crown fractures were not protective against root fractures. In fact, teeth with crown fractures were almost twice as likely to have a root fracture.

These findings suggest that clinicians should be more suspicious of a root fracture in those teeth with uncomplicated crown fractures or no trauma to the coronal aspect of the tooth because these teeth were more likely to have an accompanying root fracture. Table 3 illustrates this point. This finding should heighten clinicians' awareness when evaluating and diagnosing dental trauma.

How many radiographic projections are needed?

The literature supports that multiple radiographic projections are needed to increase the likelihood of diagnosing a root fracture (1, 3, 5–8). Degering (5) looked at radiographs of experimental root fractures of the anterior teeth to find which angulations provided the most diagnostic information. His study revealed fractures were diagnostic at a latitude of ± 15–20° of vertical angulation relative to the fracture plane. Two additional radiographs should be obtained of the questionable area with a +15° and −15° vertical angulation in relation to the original tube position (5).

Our findings indicate that multiple radiographic projections are needed to increase the likelihood of diagnosing a root fracture. Under the conditions of our study, we were not able to say definitively that three radiographs are the best protocol. However, we hypothesize that a root fracture that can be detected in more than one image increases the clinician's confidence in the diagnosis and is more likely to be recorded and treated by the clinician as a true root fracture. Without obtaining more than one film, the root fracture may be overlooked or disregarded as a defect in root development, an artifact, or bone trabeculae/bony trabeculation.

Strengths and potential limitations

This study included all children and adolescents who presented with a traumatic dental injury over an 8-year period of time. Because we relied on patient records, we were not able to monitor root fracture outcomes over time because some patients did not return for follow-up. An ideal study design would be a prospective, randomized controlled trial; however, such a study for a population of this size for eight consecutive years would be strategically challenging and enormously costly. Our sample offered us an opportunity to study a relatively large cohort with relative ease, and at a fraction of the cost. At the same time, it would not be ethical to conduct a prospective, randomized controlled trial assessing one vs multiple projections under a scenario where the latter is the standard of care.

By using a research design that included two calibrated and 'sensitized' examiners, our findings yielded new information about the diagnostic challenge of radiographic interpretation of root fractures in children and adolescents.

Conclusions

Moving toward evidence-based practice guidelines

One area for which more evidence-based study is needed is in the realm of diagnosis and clinical management of dental trauma in children and adolescents. A 20-year (1985–2005) Medline search revealed 102 published studies on this subject, but only 20 were focused on children and adolescents and only three of these were scientific investigations and none established clinical guidelines or recommendations. These results were confirmed by a search in the Cochrane Collaboration systematic review database that revealed no studies on this topic (14). Our study seeks to fill a gap through the generation of evidenced-based clinically relevant guidelines for the diagnosis of root fractures in children and adolescents.

Conclusions and implications for clinical practice

Under the conditions of this study examining children and adolescents 6–18 years of age with anterior permanent tooth trauma, we conclude:

1. Crown fractures were not protective against root fractures. Teeth with crown fractures were almost twice as likely to sustain root fractures.
2. Radiographic root fractures were very difficult to detect. Radiographic images aimed at detection of root fractures should be reviewed carefully under ideal conditions of illumination to make a proper diagnosis.
3. Root fractures in children in the preteen years are likely to be incomplete and located in the apical or middle third of the root.
4. Our data would suggest that there is no reason to suspect a complete root fracture in preteen children unless the tooth exhibits clinical signs such as luxation or excessive mobility; in short, obtaining three radiographic images to examine for root fractures for all tooth trauma in this age group seems unnecessary.
5. When root fractures are suspected, multiple radiographic projections at different vertical angulations will increase the diagnostic precision for making a root fracture diagnosis.

Acknowledgements

AAPDF OMNII Research Fellowship and MCH Grant # 5 T17 MC 00015 15.

References

1. Andreasen JO, Andreasen FM. Textbook and color atlas of traumatic injuries to the teeth, 3rd edn. Copenhagen: Munksgaard; 1994: p. 151–8, 171–5, 279–81.
2. Majorana A, Pasini S, Bardellini E, Keller E. Clinical and epidemiological study of traumatic root fractures. Dent Traumatol 2002;18:77–80.
3. Wilson C. Management of trauma to primary and developing teeth. Dent Clin North Am 1995;39:133–67.
4. Flores MT, Andreasen JO, Bakland LK. Guidelines for the evaluation and management of traumatic dental injuries. Dent Traumatol 2001;17:97–102.

5. Degering C. Radiography of dental fractures: an experimental evaluation. Oral Surg 1970;30:213–9.
6. Bender IB, Freedland JB. Clinical considerations in the diagnosis and treatment of intra-alveloar root fractures. J Am Dent Assoc 1983;107:595–600.
7. Berman L. A clinical guide to dental traumatology, Chapter 4, Intraalveolar root fractures, 1st edn. Mosby: St. Louis; 2006. p. 51–71.
8. Herweijer JA, Torabinejad M, Bakland L. Healing of horizontal root fractures. J Endod 1992;18:118–22.
9. Cvek M, Andreasen JO, Borum MK. Healing of 208 intraalveolar root fractures in patients aged 7–17years. Dent Traumatol 2001;17:53–62.
10. Andreasen FM, Andreasen JO, Bayer T. Prognosis of root-fractured incisors: prediction of healing modalities. Endod Dent Traumatol 1989;5:11–22.
11. Feely L, Mackie IC, Macfarlane T. An investigation of root-fractured permanent incisor teeth in children. Dent Traumatol 2003;19:52–4.
12. Skaare AB, Jacobsen I. Dental injuries in Norwegians aged 7–18 years. Dent Traumatol 2003;19:67–71.
13. Rajab LD. Traumatic dental injuries in children presenting for treatment at the Department of Pediatric Dentistry, Faculty of Dentistry, University of Jordan, 1997–2000. Dent Traumatol 2003;19:6–11.
14. Cochrane Collaboration. Available at: http://www.cochrane.org/. Accessed February 10, 2006.