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Periodontal healing complications following concussion and subluxation injuries in the permanent dentition: a longitudinal cohort study

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Abstract – *Purpose*: The purpose of the study was to analyze the risk of periodontal ligament (PDL) healing complications following concussion and subluxation injuries in the permanent dentition. *Material and method*: A total 469 permanent teeth (358 patients) with concussion and 404 permanent teeth with subluxation were included in the study. All teeth were examined according to a standardized protocol including clinical, photographic, and radiographic registration. Statistics: The risk of repair-related resorption (surface resorption), infection-related resorption (inflammatory resorption), replacement-related resorption (ankylosis), marginal bone loss, and tooth loss were analyzed with the Kaplan–Meier method. *Results*: Concussion: In teeth with immature root development, no healing complications were observed. For teeth with mature root development, the risk of repair related resorption after 3 years was 3.2% (95% CI: 0.3–6.0%) and occurred only in cases where several teeth were injured simultaneously (multiple-trauma cases). The risk of marginal bone loss in teeth with mature root development was 0.7% (95% CI: 0–1.6%). Infection-related resorption, replacement resorption, and tooth loss were not observed among teeth with concussion. Subluxation: In teeth with immature root development, the risk of infection-related resorption after 3 years was 1.7% [95% confidence interval (CI): 0–3.8%]. Infection-related resorption occurred significantly more often in teeth with concomitant crown fracture ($P = 0.004$). For teeth with mature root development, the risk of periodontal healing complications after 3 years was: repair-related resorption, 3.6% (95% CI: 0–7.6%); infection-related resorption, 0.6% (95% CI: 0–1.7%); replacement-related resorption, 0.6% (95% CI: 0–1.7%); and marginal bone loss, 0.6% (95% CI: 0–1.7%). No teeth were lost in the observation period. *Conclusion*: The risk of periodontal healing complications after concussion as well as subluxation injuries in permanent teeth is very low.

The concussion and subluxation injury was first described as separate types of periodontal ligament (PDL) and pulp injury in 1972 (1). A concussion injury is defined as an injury to the tooth-supporting structures without abnormal loosening or displacement, but with a marked reaction to percussion. A subluxation injury is defined as an injury to the tooth-supporting structures with abnormal loosening but without tooth displacement (2).

The etiology of a concussion injury is assumed to be a minor impact to the tooth, where the energy released has only resulted in edema or bleeding and sometimes minor lacerations in the PDL. The etiology of subluxation is probably the result of a minor impact to the PDL where the energy released results in bleeding, edema, and tearing of PDL fibers leading to abnormal loosening. An experimental study in rats has shown such minor changes in the PDL as well as bleeding in the odontoblastic layer near the apical foramen in teeth with concussions and subluxations (3, 4). Previous studies on concussion and subluxation have primarily focused on pulp healing and pulp complications (5–13).

The prognosis for the periodontal healing has only been briefly discussed (5, 11, 12).

Stålhane and Hedegård (5) analyzed the frequency of replacement resorption (ankylosis) and infection-related resorption in subluxated permanent teeth in children aged 7–15 years, and they reported a frequency of replacement resorption of 0.6% and a frequency of infection-related resorption of 0.2%. No results were given for repair-related resorption.

The purpose of this study was, therefore, to analyze the following parameters for concussion and subluxation injuries:

1 What is the risk of PDL healing complications?

2 What is the long-term prognosis in respect of tooth survival?

Material and methods

The material includes patients treated at the Department of Oral and Maxillo-Facial Surgery, Copenhagen University Hospital, Rigshospitalet, Denmark, in the period from 1972 to 1990.

Patients were included in the study if they fulfilled the following criteria:

1 The permanent tooth had suffered a concussion injury defined as an injury to the tooth-supporting structures without abnormal loosening or displacement, but with a marked reaction to percussion or the tooth had suffered a subluxation injury defined as an injury to the tooth-supporting structures with abnormal loosening, but without displacement.

2 Tooth-specific clinical information and radiographs from the time of injury and the subsequent controls according to a standardized protocol were present.

3 Clinical photographs from the time of injury were present.

4 A follow-up period of minimum 10 months.

5 The tooth had not previously been submitted to a trauma.

6 No destruction of the crown caused by dental caries or restorations.

The general follow-up program scheduled controls after 3, 6 weeks, 6 months, 1, 5, and 10 years. The follow-up period ranged from 324 days (10.8 months) to 8045 days (22.0 years) with a median of 420 days (1.3 years).

Clinical registration

At the time of the injury, the following parameters were registered on a special trauma chart: sex and age of the patient; cause, date, and time of injury; number of injured teeth; and condition of supporting tissue.

For each tooth, objective clinical information from the time of injury as well as follow-up examinations was recorded using a standardized form including: tooth color (normal, yellow, red, gray, or crown restoration), dislocation (mm in vertical and horizontal direction), loosening (scale 0–3), tenderness to percussion, percussion tone (normal or high metallic sound indicating ankylosis).

Furthermore, electrometric sensibility was registered on the incisal edge using a Sirotest II® pulp tester (scale 0–4). Injured and non-injured adjacent control teeth were tested at the time of the injury and at follow-ups. At the follow-up examinations, the registrations were supplemented with registration of presence or absence of fistulous tracts, gingivitis, gingival dehiscence, and a normal or abnormal gingival pocket depth (i.e. >3 mm).

Photographic registration

Horizontal and axial photographs were routinely taken at the time of injury.

Radiographic registrations

Three radiographs of the same area (orto-, mesio-, and distoradial angulation) and a steep occlusal exposure were made at the initial examination and a periapical exposure at the follow-up controls. All radiographs were taken by the use of filmholders (14).

Root development

The stage of root development was determined by evaluation of radiographs from the initial examination. The teeth were divided into two groups. Immature root development: the root development was incomplete and/or the apex was not fully formed. Mature root development: the tooth had full root formation with a closed apex. Teeth with immature and mature root development were analyzed separately.

Treatment

The majority of the teeth (n = 320) received no treatment of the subluxation injury, but splinting was applied in the remaining 84 teeth. Splinting was performed either by orthodontic bands and resin or by acid-etch and a flexible temporization material (Scutan® or Protemp®; 3M ESPE, Neuss, Germany). A few teeth with concussion injury were splinted if adjacent teeth required splinting because of a more severe luxation injury.

Diagnosis of periodontal healing and complications

Abnormal PDL healing was usually diagnosed within 2–3 months, when root resorption became apparent.

According to a previous clinical study by Andreasen and Andreasen (14), periodontal healing after luxation injuries was divided into the following four groups: (i) normal periodontal healing, (ii) repair-related resorption (surface resorption), (iii) infection-related resorption (inflammatory resorption), and (iv) replacement-related resorption (ankylosis).

The resorption diagnose was based on radiographic analysis. Two dentists analyzed the radiographs independently. In case of disagreement, a common verdict was obtained. Infection-related resorption only occurred in teeth with pulp necrosis.

The extent of marginal bone loss was determined radiographically (bisecting angle radiographs). The dis-

tance between the cemento-enamel junction and the alveolar crest was measured mesially and distally with a sliding caliper on a bisecting angle radiograph. This distance measured at radiographs from the initial examination was compared with the same distance measured on radiographs taken at follow-up controls. If this distance was >2 mm, the condition was considered to be pathological and defined as loss of marginal attachment.

Statistical methods

Teeth with mature and immature development were decided to be analyzed separately, because of the expected different healings potential in the two groups. The risk of repair-related resorption, replacement resorption, infection-related resorption, marginal bone loss, and tooth loss was analyzed by Kaplan–Meier method. Robust confidence limits were obtained to account for the dependencies of teeth placed in the same patients (15, 16). These methods can, however, not be applied if no events are recorded during the follow-up period. For healing complications with no events during the follow-up period, exact binomial confidence limits were computed based on the number of teeth still under observation after 3 years that is the time point used for all point estimates. All analyses were performed with the statistical software R. (R Development Core Team, Vienna, Austria, 2010).

Results

Teeth with concussion Injury

Four hundred and sixty-nine permanent incisors with a concussion injury were included in the study, 169 teeth with immature root development (107 of teeth had an additional crown fracture) and 300 with mature root development (185 of the teeth had an additional crown fracture). The study group has previously been described in relation to pulp healing (13). One hundred and sixty-five of these teeth have furthermore been previously used in an earlier study by Andreasen (11, 12).

No periodontal healing complications were observed in teeth with immature root development.

Table 1 gives the distribution of teeth in relation to gender, age, number of injured teeth in each patient, and the time elapsed from the trauma occurred until treatment was performed (treatment delay). Table 2 resumes the results for the risk of periodontal healings complications in teeth with concussion injuries (mature as well as immature root development).

Repair-related resorption (surface resorption)
For teeth with mature root development, the risk of repair related after 3 years was 3.2% (95% CI: 0.3–6.0%) (see Table 2). All cases were diagnosed within the first 3 years. Repair-related resorption occurred only in cases where several teeth were injured (multiple-trauma cases). The resorption was located in the apical part of the root and manifested as slight rounding of the apex (Fig. 1). In two teeth, pulp necrosis was also diagnosed (Fig.2). Figure 3 shows the healing process for a case with internal surface resorption.

Table 1. Distribution of gender, age, number of injured teeth, and treatment delay in teeth with immature and mature root development

	Immature root development No. patients (%)	Mature root development No. patients (%)	Total No. patients (%)
Concussion			
Gender			
Female	41 (30.6)	91 (40.6)	134 (37.4)
Male	93 (69.4)	133 (59.4)	224 (62.6)
Age			
< 20 years	134 (100.0)	183 (81.7)	317 (88.6)
≥ 20 years	0 (0.0)	41 (18.3)	41 (11.4)
No. of injured teeth in each patient			
One	42 (31.3)	34 (15.2)	76 (21.2)
Two	61 (45.5)	90 (40.2)	151 (42.2)
Three or more	31 (23.1)	100 (44.6)	131 (36.6)
Treatment delay			
<5 h	88 (92.6)	135 (80.4)	218 (84.8)
5–24 h	6 (6.3)	28 (16.6)	34 (12.9)
More than 24 h	1 (1.1)	5 (3.0)	3 (2.3)
Subluxation			
Gender			
Female	64 (38.3)	37 (30.3)	101 (35.0)
Male	103 (61.7)	85 (69.7)	188 (65.0)
Age			
< 20 years	167 (100.0)	102 (83.6)	269 (93.1)
≥ 20 years	0 (0.0)	20 (16.4)	20 (6.9)
No. injured teeth in each patient			
One	38 (22.8)	14 (11.5)	52 (18.0)
Two	80 (47.9)	37 (30.3)	117 (40.5)
Three or more	49 (29.3)	71 (58.2)	120 (41.5)
Treatment delay			
<5 h	85 (86.7)	63 (84.0)	148 (85.5)
5–24 h	11 (11.2)	11 (14.7)	22 (12.7)
More than 24 h	2 (2.0)	1 (1.3)	1 (1.3)

Marginal bone loss
Marginal bone loss was found in two cases; both cases were found in mature teeth with a concurrent crown fracture. The risk of marginal bone loss after 3 years was 0.7% (95% CI: 0–1.6%) (see Table 2).

Infection-related resorption (inflammatory resorption) and replacement-related resorption (ankylosis)
Infection-related resorption (inflammatory resorption) and replacement-related resorption (ankylosis) were not observed in the follow-up period.

Tooth loss
All teeth included in this study survived the entire observation period.

Teeth with subluxation injury

Four hundred and four permanent incisors with a subluxation injury were included in the study, 230 teeth

Table 2. The risk of periodontal healing complications and tooth loss estimated after 3 year in teeth with immature and mature root development

	Number of patients	Number of injured teeth	Teeth lost to follow-up	Number of teeth with healing complication	Risk of healing complications	95% CI
Immature						
Repair-related resorption	137	169	109	0	0	0–6
Infection-related resorption	137	169	109	0	0	0–6
Replacement resorption	137	169	109	0	0	0–6
Marginal bone loss	137	169	109	0	0	0–6
Tooth loss	137	169	109	0	0	0–6
Mature						
Repair-related resorption	228	300	179	8	3.2	0.3–6
Infection-related resorption	228	300	179	0	0	0–3.1
Replacement resorption	228	300	179	0	0	0–3.1
Marginal bone loss	228	300	179	2	0.7	0–1.6
Tooth loss	228	300	179	0	0	0–3.1

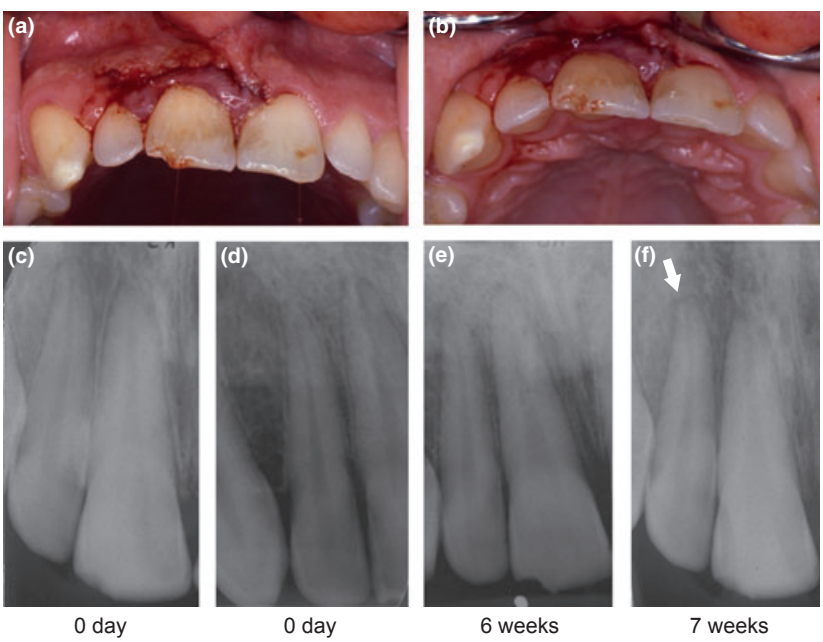

Fig. 1. Surface resorption affecting the apex of right lateral incisor after concussion injury in a 27-year-old man. (a) Frontal view at the time of injury (Day 0). (b) Axial view. (c–f) Radiographs from time of injury and follow-up. Note repair-related resorption affecting the apex after 7 weeks (arrow).

with immature root development (75 of these had an additional crown fracture) and 174 with mature root development (62 of these had an additional crown fracture). The study group has previously been described in relation to pulp healing (13). Furthermore, 218 of these teeth have been previously used in a study by Andreasen (11, 12).

Table 1 gives the distribution of teeth in relation to gender, age, number of injured teeth in each patient, and the time elapsed from the trauma occurred until treatment was performed (treatment delay). Table 3 resumes the results for the risk of periodontal healings complications in teeth with subluxation injuries (mature as well as immature root development).

Treatment delay

A total of 231 teeth were examined and left without further treatment. Treatment delay for the remaining 173 teeth ranged from 65 min–82 h (3.5 days) with a mean of 4.6 h. The majority of the teeth (85.6%) were treated within the first 5 h.

Repair-related resorption (surface resorption)

Repair-related resorption was found in three of 404 cases.

All teeth with repair-related resorption were found in patients older than 11 years of age at the time of injury, and all had a closed root apex. The risk of

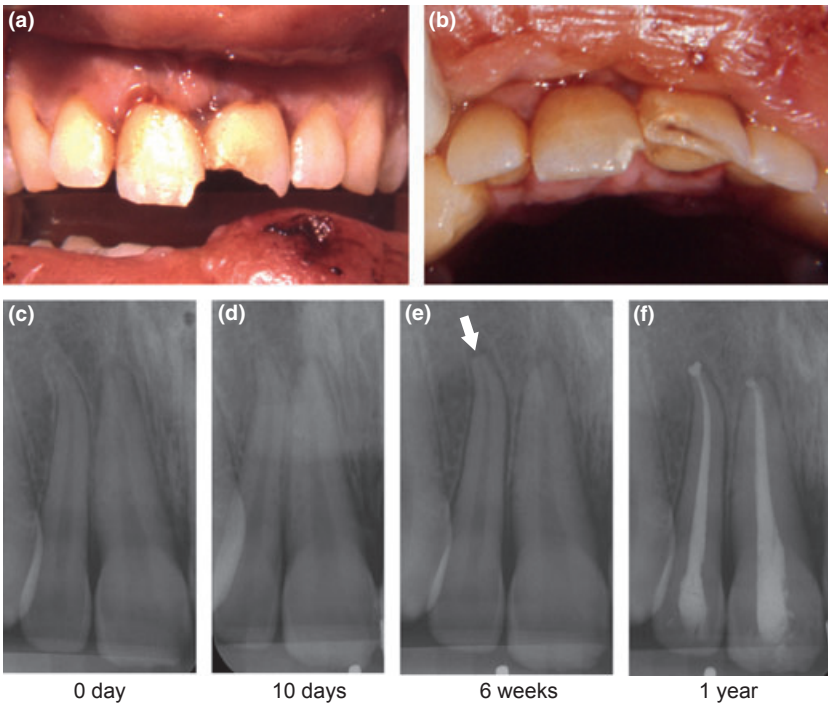

Fig. 2. Surface resorption and pulp necrosis in a right maxillary lateral incisor suffering a concussion injury in an 18-year-old man. (a) Frontal view at the time of injury (Day 0). It is noted the right maxillary lateral incisor was not the only tooth that was injured in the accident. (b) Axial view. (c–f) Radiographs from time of injury and at follow-up. Note surface resorption and periapical radiolucency related to pulp necrosis.

repair-related resorption after 3 years was 3.6% [95% confidence interval (CI):0–7.6%] in teeth with mature root development (Table 3).

The resorptions were all located around the apex of the root, and in two of these teeth, pulp necrosis was also diagnosed. All cases were multiple-trauma cases where several teeth were injured. In a single case, the tooth had been splinted with orthodontic bands/acrylic splinting.

Infection-related resorption (inflammatory resorption)
Infection-related resorption was found in five cases. The estimated risk of infection-related resorption after 3 years was 1.7% [95% confidence interval (CI): 0–3.8%] in teeth with immature root development and 0.6% (95% CI: 0–1.7%) in teeth with mature root development (see Tables 1 and 3, as well as Fig. 4). All five cases had an associated crown fracture. A concomitant crown fracture significantly increased the risk of infection-related resorption in teeth with immature root development ($P = 0.004$). In two cases, the resorption involved the apical, mid-root, and cervical part of the root surface whereas in the remaining three cases, the resorption was located in the mid-root and cervical part of the root.

Table 3. The risk of periodontal healing complications and tooth loss estimated after 3 year in teeth with immature and mature root development

Complications	Number of patients 95% CI	Number of injured teeth	Teeth lost to follow-up	Number of teeth with healing complication	Risk of healing	95% CI
Immature						
Repair-related resorption	167	230	132	0	0	0–3.8
Infection related resorption	167	230	132	4	1.7	0–3.8
Replacement resorption	167	230	132	0	0	0–3.8
Marginal bone loss	167	230	132	0	0	0–3.8
Tooth loss	167	230	132	0	0	0–3.8
Mature						
Repair-related resorption	125	174	116	3	3.6	0–7.6
Infection related resorption	125	174	116	1	0.6	0–1.7
Replacement resorption	125	174	116	1	0.6	0–1.7
Marginal bone loss	125	174	116	1	0.6	0–1.7
Tooth loss	125	174	116	0	0	0–6.5

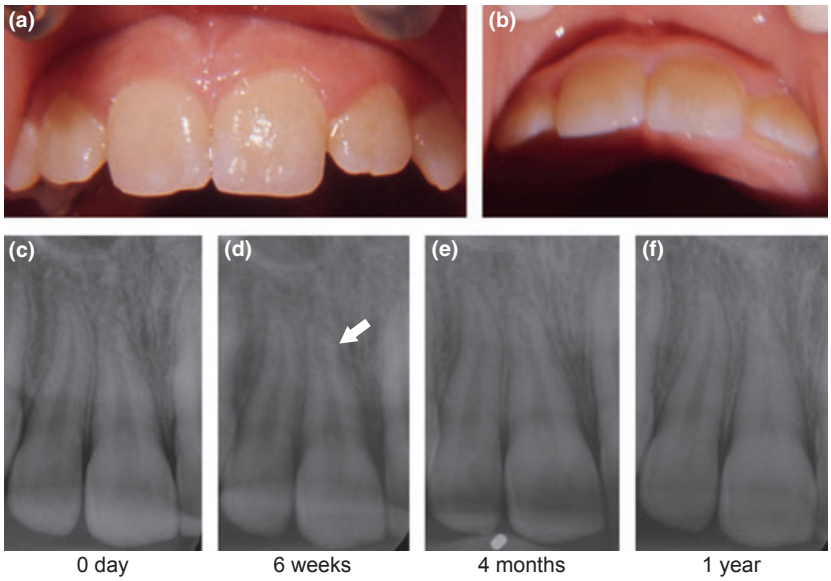

Fig. 3. Internal surface resorption and later pulp canal obliteration in a left maxillary central incisor after a concussion injury in a 10-year-young girl. (a) Frontal view at the time of injury (Day 0). (b) Axial view. (c–f) Radiographs from time of injury and at follow-up. Note appearance of internal surface resorption at the 6 weeks control (arrow). (e) Four months after the injury, the internal surface resorption is still present. (f) After 1 year, the resorption has healed and the pulp canal has become obliterated.

Replacement resorption (ankylosis)
Replacement resorption was found in a single case in a tooth with mature root development and a concomitant crown fracture. The risk of replacement resorption after 3 years was 0.6% (95% CI: 0–1.7%) in teeth with mature root development (Tables 1 and 3). The resorption was located in the cervical part of the root (Fig. 5).

Marginal bone loss
Marginal bone loss was found in one of 404 teeth. The tooth had mature root development and was part of a multiple-trauma where several teeth were injured at the same time. It was splinted with orthodontic bands/acrylic splinting. The risk of marginal bone loss after 3 years was 0.6% (95% CI: 0–1.7%) in teeth with mature root development (Table 3).

Long-term tooth survival
All teeth included in this study survived throughout the study period.

Discussion

Occurrence of pulp healing, pulp canal obliteration, and pulp necrosis following different types of luxation (e.g. concussion and subluxation) has been discussed in detail in several previous studies (5–13). Periodontal healing after concussion and subluxation has only been briefly mentioned in connection with previous studies on prognosis of luxated permanent teeth, which focused on the development of pulp necrosis (6, 11, 12). However, Stålhane and Hedegård (5) analyzed the frequency of replacement resorption (ankylosis) and infection-related resorption in subluxated permanent teeth in children aged 7–15 years, and they reported a frequency of replacement resorption of 0.6% and a frequency of infection-related resorption of 0.2%, figures very similar to ones found in this study.

The current study showed that periodontal healing complications after a concussion or a subluxation injury are extremely rare. In teeth that suffered, a concussion injury repair-related resorption occurred only

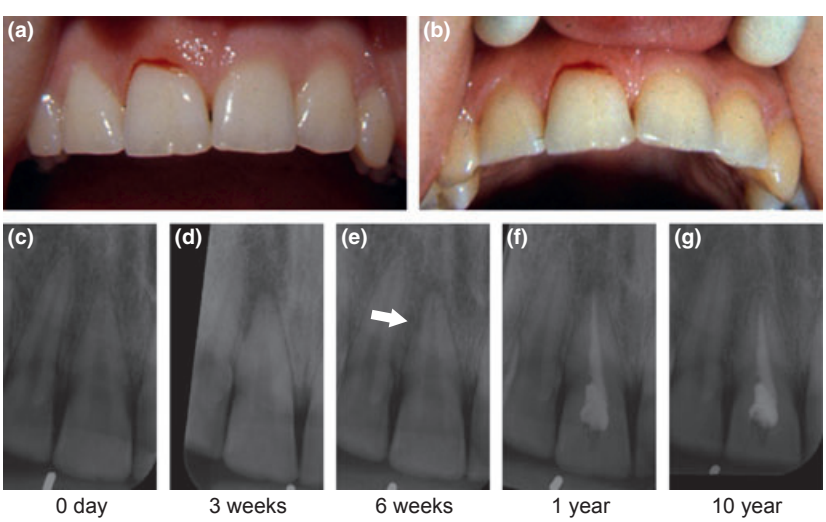

Fig. 4. Infection-related resorption and development of pulp necrosis in a right maxillary central incisor after a subluxation injury in a 17-year-young girl. (a) Frontal view at time of injury (Day 0). (b) Axial view. (c–f) Radiographs from time of injury and at follow-up. Radiographic signs of infection-related resorption are evident after 6 weeks (arrow).

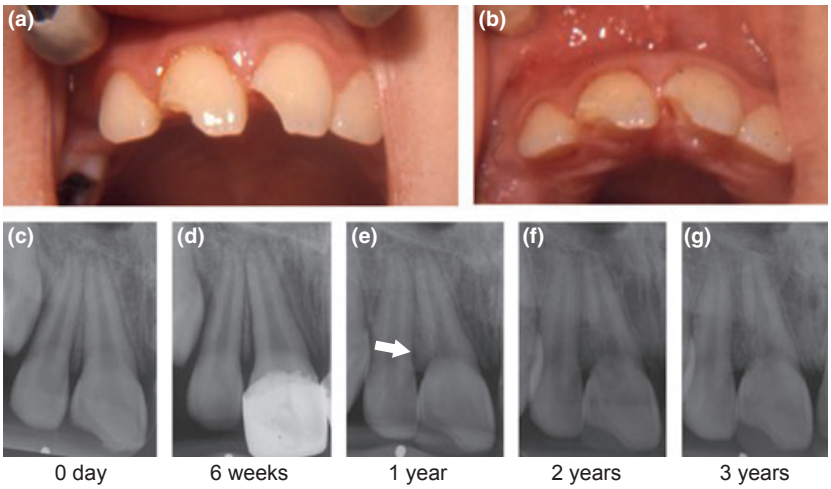

Fig. 5. Replacement-related resorption after subluxation of a right central incisor in a 15-year-old girl. (a) Frontal view at time of injury. (b) Axial view. (c–g) Radiographs from time of injury and at follow-up. Replacement-related resorption is evident cervically at the 1 year control and has progressed further at the 2 and 3 years controls.

in teeth with closed apices and in cases where several teeth were included in the same traumatic event (multiple tooth traumas).

The relation between repair-related resorption and multiple injured teeth could possibly be related to an under-diagnosis of the severity of the luxation injury in cases with multiple traumatized teeth. The difference between a concussion and a subluxation injury is based on a subjective decision. If several teeth are involved in the injury, the examiner's attention may be focused on the teeth with a more severe diagnosis (e.g. extrusion, lateral luxation, alveolus fracture, or avulsion), and a subluxation may in this case be categorized as a concussion. For the teeth with a subluxation injury, repair-related resorption occurred only in teeth with closed apices, and in two of three cases, pulp necrosis was also present. In these cases, the resorption may not be caused by the trauma but rather be related to the healing of an apical periodontitis arisen from the infection in the root canal.

The low risk of repair-related resorption indicates that the damage caused by the trauma must have been very limited. Actually, the frequency of repair-related resorption was not higher in the teeth with subluxation injuries than in teeth with concussion injuries.

In replantation studies in monkeys, repair-related resorption has been located in areas with moderate injury to the PDL (17–19). It is also of interest that histological studies of 'normal' human teeth showed that repair-related resorption was found in almost all teeth (20). These resorption areas were usually superficial (<0.1 mm deep) implying that they cannot be diagnosed radiographically (21).

Infection-related resorption occurred only in teeth with a subluxation injury that had suffered an additional crown fracture. A recent study by Lauridsen et al. (22) has shown that the risk of pulp necrosis is increased in teeth with subluxation and concomitant crown fractures. Pulp necrosis is one of the prerequisites for the initiation of the inflammatory resorption process and one might hypothesize that concomitant crown fractures, by increasing the risk of pulp necrosis, also increases the risk of inflammatory resorption. This hypothesis is supported by the significantly higher risk of inflammatory resorption for immature teeth with concomitant crown fracture found in this study ($P = 0.004$).

Marginal bone loss was found in three cases, two of the cases were found in mature teeth with a concussion and a concurrent crown fracture and one case was in a mature tooth with a subluxation injury. It is most likely that the later observed marginal breakdown was associated to the restoration of the crown fracture.

In conclusion, the risk of periodontal healing complications following concussion and subluxation injuries in the permanent dentition is very low. The few complications that occurred were usually cases where more than one tooth were involved in the injury.

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