

Factors related to treatment and outcomes of avulsed teeth

Bojan Petrović¹, Dejan Marković²,
Tamara Perić², Duska Blagojević¹

¹Dentistry Clinic of Vojvodina, Novi Sad, Serbia;

²Clinic for Paediatric and Preventive Dentistry,
Faculty of Stomatology, Belgrade, Serbia

Abstract – Background: The aim of this study was to examine factors associated with avulsion injury and to specify the association between these factors and the treatment, as well as the outcomes of avulsed permanent incisors in children.

Materials and methods: The sample consisted of 51 children with 62 avulsed permanent incisors, whose injuries had been managed in the period 1998–2006. The study was prospective, recording the history of the accident, concomitant injuries, age, gender, apical maturity of the root, replantation rate, storage media, extra-alveolar duration, endodontic treatment, compliance and recall appointments response. Factors were analysed in relation to postoperative outcomes, classified as functional healing (FH), infection-related (inflammatory) resorption (IRR) and replacement resorption (RR). **Results:** The average age of patients was 10.7 years (range 7–19). In 16/51 patients, tooth avulsion was caused by a road traffic accident. Avulsion was accompanied by concomitant injuries in all cases. Thirty of 62 avulsed teeth were not replanted and 32 incisors were replanted after dry storage. Time until replantation ranged between 15 min and 9 h (median 60 min). The observation period ranged from 1 to 6 years (median 2 years). FH was observed in 5/32, IRR in 20/32 and RR in 7/32 incisors. Ten teeth were extracted during 5-years of observation. Immature incisors exhibited significantly more complications compared with mature teeth ($P = 0.04$). Storage media and extra-alveolar duration did not significantly affect the survival of replanted teeth ($P = 0.253$, $P = 0.350$). Teeth in which endodontic treatment was in temporary phase exhibited significantly more complications in comparison with teeth with completed endodontic treatment ($P = 0.016$). **Conclusion:** The combination of delayed replantation and unphysiological storage is followed by low survival. Incisors with open apices exhibited lower survival compared with incisors with closed apices. Replanted incisors that required prolonged treatment with calcium hydroxide exhibited more complications compared with incisors with completed root canal treatment.

Correspondence to: Bojan Petrović,
Dentistry Clinic of Vojvodina, Hajduk
Veljkova 12, 21000 Novi Sad, Serbia
Tel.: +38763342639
e-mail: bpetrovicns@yahoo.com

Accepted 7 August, 2009

Most avulsion injuries occur at an age which is crucial to facial growth and also psychosocial development of a child. Traumatic injuries to permanent anterior teeth are common during childhood and 0.5–16% of the 7- to 10-year age group experience tooth avulsion (1). In this age group the relatively resilient alveolar bone provides only minimal resistance to extrusive forces, and the maxillary central incisors are the teeth most commonly affected (2).

Duration of extraoral storage of an avulsed tooth is identified as critical for functional healing (FH) (3–5). Replantation of a tooth beyond 5 min has been defined by Andreasen (3) as delayed replantation and extraoral duration affects tooth survival. Practically, these ideal conditions rarely occur in cases presented to a clinician and replantations as well as further treatment of avulsed teeth are followed by complications, inflammatory and replacement resorption (RR) (4).

There are two main reasons for delayed replantation of avulsed teeth. People present at the site of injury are

usually lay persons, who rarely know how to manage an avulsed tooth (6–9). In addition, soft tissue lacerations and bleeding are almost always associated with injuries to the teeth, which mask the loss of teeth. It is therefore not unusual for avulsion to be overlooked at the time of injury.

The mechanism of the injury is a particularly important aspect of the history, because avulsion is frequently caused by severe trauma. Avulsions were found to be the most common type of dental injury recorded for children less than 15 years of age seeking treatment in hospital emergency rooms (10).

Treatment of avulsion injury is rather demanding, considering the fact that tooth avulsions most frequently occur in children aged 7–9 years. The child's acceptance of treatment procedures and cooperation are of utmost importance. These behavioural aspects, as well as the need to establish the confidence between a child and a dentist should be borne in mind, since the treatment of avulsion frequently lasts for many years.

The aim

The aim of this study was to examine factors associated with avulsion injury and to specify the association between these factors and the treatment, as well as the outcomes of avulsed permanent teeth in children.

Materials and methods

The sample

The sample consisted of 51 patients (17 girls, 34 boys) with 62 permanent incisors avulsions. Their injuries were managed at the Paediatric Department, Dentistry Clinic of Vojvodina, Novi Sad, and at the Clinic for Paediatric and Preventive Dentistry, Faculty of Dentistry, Belgrade, in the period between 1998 and 2006. The observation period ranged from 1 to 5 years.

Factors which were analysed

With respect to aetiological factors, the mechanism of injury and the presence of concomitant injuries were analyzed. The mechanism of injury was classified as follows: road traffic accident, fall, sporting activities, hit (collision), fight and other. Bicycle-related injuries were classified as road traffic accidents.

Demographic data comprised: age, gender and apical maturity of the root. Patients were classified in four age groups (I: 7–9, II: 10–12, III: 13–15 and IV: older than 15 years). The scale developed by Moorrees et al. (11) was used to classify the stage of root development as being either 'open apex' (stages 2–4) or 'closed apex' (stages 5–6).

Data on the reasons for non-replanting were collected from patients and their parents during the initial visit.

For every replanted tooth, total extra-alveolar duration and storage medium were analysed. Storage in saline, milk or saliva was considered as physiological according to the protocols at our clinics at the beginning of the study. With respect to the extraalveolar duration, replanted teeth were classified as follows: I: 15–60 min; II: > 60 min. Factors related to the treatment included: patient compliance, type and timing of endodontic treatment, recall appointments, as well as the occurrence of complications, type of complications and their treatment.

Management of avulsed teeth

Prior to replantation, avulsed teeth were cleansed with physiologic saline and placed in saline until further treatment. In cases with prolonged extra-alveolar duration (more than 60 min), attached soft tissue was removed with gauze using gentle pressure. The coagulum was removed with a stream of saline, the alveolar socket was examined and replantation was accomplished by inserting the tooth into the socket with gentle pressure. The position of a replanted tooth was confirmed clinically and with a periapical radiograph.

All replanted teeth were stabilized with a passive, flexible acid-etched composite splint for 10–14 days.

Each patient received a 7-day course of Doxycycline (Dovicin®; ICN Galenika, Belgrade, Serbia) at an appropriate dose for age and weight, tetanus coverage was evaluated and a suitable oral hygiene and dietetic regime were recommended. Initial follow-up examination was scheduled for 7–10 days after replantation.

Endodontic treatment

At the initial follow-up appointment, endodontic treatment of the replanted tooth was initiated, except for teeth where revascularization (RV) had been considered possible. At the beginning of the study, there were no strict criteria regarding waiting for RV at our clinics. In principle, for teeth with open apices and extra-alveolar duration of less than 30 min, endodontic treatment was postponed, despite the storage media.

Following pulpectomy, a non-setting calcium hydroxide paste (Calcicur, Voco, GmbH, Cuxhaven, Germany; Kalcipast®, ICN Galenika) was placed in the root canal. A periapical radiograph was taken to ensure that the material filled the canal and reached the apex.

In immature teeth the calcium hydroxide was left in the root canal of the replanted teeth. Calcium hydroxide was replaced when follow-up radiographs revealed a loss of material from the root canal. Root canal obturation with gutta-percha and sealer was completed following treatment with calcium hydroxide in 6–36 months after replantation. If clinical or radiographic signs of infection were present, the root canal was instrumented and filled with calcium hydroxide and an additional course of antibiotics was prescribed. In mature teeth, root canal obturation with gutta-percha and sealer was completed after 7–14 days of calcium hydroxide medication.

Follow-up treatment

The splint was removed at the first follow-up appointment, except in those cases in which avulsion had been followed by fracture of the alveolar process that required extended splinting. Prior to discharge, patients had follow-up appointments as follows: weekly, during the first 2 months; monthly during next 6 months, and once every 3 months after that. Periapical radiographs were taken every 3 months during the first year, and every 6 months after that.

Classification of postoperative outcomes

The outcomes of replanted teeth were classified according to the classification used by Pohl et al. (12) as FH, infection-related resorption (IRR) and RR. The outcome was classified as FH when infection-related complications and ankylosis could be excluded. Criteria were: asymptomatic or minimal symptoms, normal percussion tone, no reduced mobility, no infraposition, no clinical or radiographic signs for infection and intact lamina dura. The postoperative outcome was classified as RR when the tooth showed one or more of the following criteria: high percussion tone, no mobility, progressive infraposition, radiographic loss of periodontal space or osseous replacement of the root substance.

The outcome was classified as IRR when clinical signs of infection (swelling, pain, fistula, sensitivity to percussion and palpation) were present and/or the periapical radiograph showed sites with radiolucency periapically or along the lateral root surfaces. Teeth that had to be extracted were presented as tooth loss (E^x).

Statistical methods

Analyses were performed in relation to each replanted tooth, as some patients had more than one replanted incisor. Methods of standard descriptive statistics (percentage, SD, median, range) primarily were used. Comparative statistical evaluation was performed using chi-square test. A proportional hazards (Cox) regression was performed to determine whether any clinical variable was significantly related to survival of the replanted teeth. For variables that were found to significantly influence survival, Kaplan–Meier survival curves were produced and compared. The level of significance was set at $P < 0.05$.

Results

The mean age at the time of trauma was 10.7 years (SD = 3.3 years, range = 7–19 years, median = 10 years).

Road traffic accidents were the causes of 16/62 avulsions and seven of these were caused by cycling (Table 1). Only one patient was wearing a helmet.

Analysis of full history of the accident showed the presence of concomitant, regional and distant injuries in all presented cases. Concomitant injuries included: multiple teeth trauma, soft tissue injuries, head and neck trauma, skeletal fractures (Table 2). In five cases management of concomitant injuries delayed replantation up to 4 h.

Thirty out of 62 avulsed incisors could not be replanted. Replantation had been performed with all 32 teeth brought to the clinics in spite of a long extraoral period in several cases (7–9 h). Reasons for non-replanting lay mainly in accident details (12/30), lack of awareness that the tooth was avulsed (8/30) and lack of awareness that a tooth should be looked for (6/30). In four cases an avulsed tooth could not be found. In four cases patients were not conscious after the accident. The time until replantation ranged between 15 min and 9 h (median = 60 min).

The lowest replantation rate was found in cases of avulsions caused by traffic accidents, but the difference was not significant when compared with other injury mechanisms ($P = 0.306$, chi-square test).

Table 1. Mechanism of the injury

Traffic accident	16
Fall	14
Sporting activity	13
Hit (collision)	8
Fight	6
Others	5
Total	62

Table 2. Concomitant injuries

Multiple teeth trauma	51
Head and neck trauma	6
Skeletal fractures	9
Alveolar fractures	12
Soft tissue lacerations	60
Multiple answers	54

The observation period ranged from 1 to 6 years (median 2 years).

Thirteen replanted teeth were with uncompleted root development and 19 replanted teeth were mature. Root development of non-replanted teeth was evaluated according to radiographs of contralateral or adjacent teeth as well as its stage of eruption. Thirty of 62 avulsed teeth were immature.

Two teeth had been placed in saline prior to replantation, while four teeth had been placed in water. Twenty-six teeth had been brought to clinic dry, mainly wrapped in the paper tissue. There was no change of the storage medium during the transport. For teeth brought to the clinics in saline, dry time was less than 30 min.

In 6/32 replanted incisors endodontic treatment was delayed while waiting for RV to occur. In these six cases, the age of the patients was between 7 and 8 years and replanted incisors were immature. Extra-alveolar duration ranged between 15 min and 2 h. All teeth were brought to the clinic in dry storage medium.

In 26/32 teeth endodontic treatment had been initiated within 2 weeks after the injury. The splint was removed within 2 weeks, except in 5 teeth where avulsion occurred in conjunction with alveolar fractures, and these teeth were splinted for 6–8 weeks.

Endodontic treatment was performed in all replanted teeth. After the treatment with calcium hydroxide, 25 teeth were obturated with gutta-percha and sealer over a period that ranged from 2 weeks to 3 years.

Recall appointment response was 100% in the first 8 weeks after the injury, and then decreased to 50% during the first year.

The timing of detection of complications varied from 1 month to 2 years. Two types of resorption were observed, IRR in 20/32 teeth, while RR occurred in 7/32 cases. Out of these seven teeth, infraposition was detected in five replanted teeth. During the observation period, 10 teeth were extracted.

The highest IRR rate was observed in the 7–9 years age group, but the outcome of replanted teeth did not significantly differ between the age groups ($P = 0.247$, chi-square test, Table 3). Outcome of replanted teeth did not significantly differ between genders ($P = 0.919$, chi-square test).

Out of six teeth in which RV had been considered possible, IRR occurred in four cases during the period of waiting for RV to occur (two patients missed their scheduled appointments and presented with the symptoms of acute periodontitis). Neither FH, nor RR was observed in these teeth. In one case IRR was diagnosed while the endodontic treatment was still in the temporary phase, and in one case IRR was detected after the completion of endodontic treatment. Two out of these six teeth were extracted during this study.

Table 3. Outcomes of replanted teeth related to age of the patients

Age	7–9 years		10–12 years		13–15 years		>15 years		Total	
	N	E ^x	N	E ^x	N	E ^x	N	E ^x	N	E ^x
FH	/	/	3	/	2	/	/	/	5	/
IRR	14	6	3	3	2	1	1	/	20	10
RR	3	/	2	/	1	/	1	/	7	/
Total	17	6	8	3	5	1	2	/	32	10

Outcomes of replanted teeth did not differ between the age groups ($P = 0.247$, chi-square test).
FH, functional healing; IRR, infection-related resorption; RR, replacement resorption; E^x, tooth loss.

In relation to the phase of endodontic treatment, IRR was more frequently detected in teeth waiting for RV and during the temporary endodontic treatment compared with teeth with completed endodontic treatment ($P = 0.016$, chi-square test, Table 4). In all five cases of FH, endodontic treatment was completed within 2 weeks after the replantation.

In 8/20 teeth with IRR, when signs of further progression of root resorption were observed after the completion of endodontic treatment, retreatment was performed. Two of these eight teeth were extracted, in three teeth rapid progression of IRR was diagnosed and in three teeth slowly developing IRR was observed.

Four of ten teeth extracted were extracted in situations following non-attendance of the scheduled appointment.

Regarding the apical maturity of replanted teeth, IRR was detected in 12/14 immature, and in 8/19 mature teeth, and FH was observed in 5/19 mature teeth ($P = 0.04$, chi-square test, Table 5).

Table 4. Complications in relation to the endodontic treatment

	Waiting for revascularization		Temporary endodontic treatment		Completed endodontic treatment		Total
	N		N		N		
IRR	4		13		3		20
RR	/		2		5		7
Total	4		15		8		27

Complications rarely occurred in teeth with completed endodontic treatment ($P = 0.016$, chi-square test).
IRR, infection-related resorption; RR, replacement resorption.

Outcomes of replanted teeth in relation to the extra-alveolar duration are shown in Table 6. IRR was detected in 9/11 teeth with extra-alveolar duration longer than 60 min. FH was observed in 5/21 teeth with extra-alveolar duration 15–60 min.

With respect to the storage medium, occurrence of IRR was more frequent in teeth stored under dry conditions. Out of five teeth in which FH was observed one tooth was placed in saline prior to replantation, and one was placed in water. The remaining three teeth were replanted after dry storage. Nevertheless, the difference in outcomes with respect to the storage medium was not statistically significant ($P = 0.253$, chi-square test).

The overall survival during the observation period is shown in Fig. 1. No significant relation between the tested variables and tooth survival was found, except for the state of apical development at the time of

Table 6. Outcomes of replanted teeth related to extraalveolar duration

	Extra-alveolar duration 15–60 min		Extra-alveolar duration >60 min		Total	
	N	E ^x	N	E ^x	N	E ^x
FH	5	\	/	\	5	\
IRR	1	15	9	5	20	10
RR	5	\	2	\	7	\
Total	2	15	1	15	32	10

Outcomes of replanted teeth did not differ with respect to the extraalveolar duration ($P = 0.16$, chi-square test).
FH, functional healing; IRR, infection-related resorption; RR, replacement resorption; E^x, tooth loss.

Table 5. Outcomes of replanted teeth related to apical maturity of the root

	Open apex				Closed apex				Total	
	R = 15–60 min		R > 60 min		R = 15–60 min		R > 60min		N	E ^x
	N	E ^x	N	E ^x	N	E ^x	N	E ^x		
FH	/	/	/	/	5	/	/	/	5	/
IRR	5	2	7	4	6	/	2	4	20	10
RR	/	/	1	/	5	/	1	/	7	/
Total	5	2	8	4	16	/	3	4	32	10

Outcomes of immature and mature teeth differed significantly ($P = 0.04$, Chi-square test).
R, extraalveolar duration; FH, functional healing; IRR, infection-related resorption; RR, replacement resorption; E^x, tooth loss.

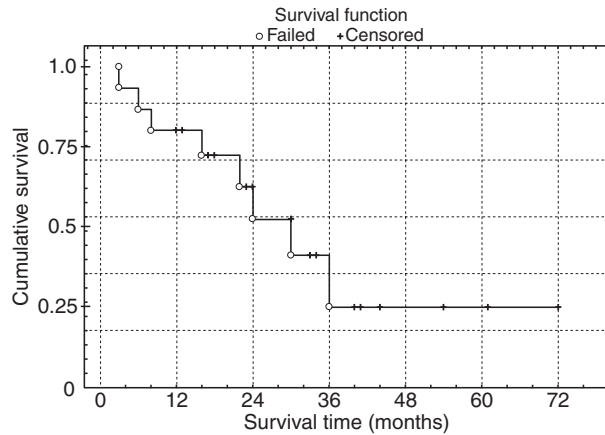


Fig. 1. Survival curve for the entire sample during the observation period. X-axis duration of observation period (months). Y-axis survival (0–1).

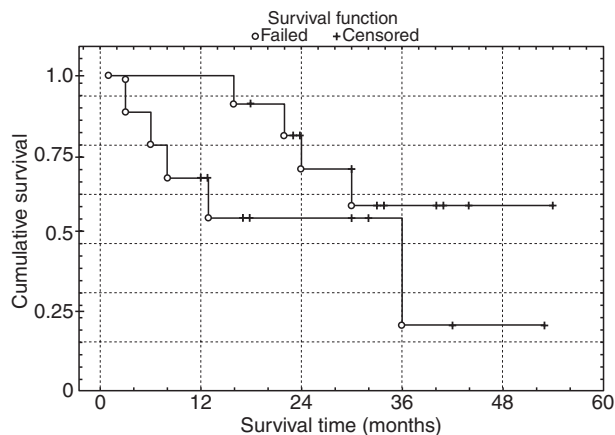


Fig. 2. Kaplan–Meier survival curves for the data related to apical maturity of the root at the time of replantation. The two curves differed significantly from each other ($P < 0.05$). The upper line represents incisors replanted with closed apices and the lower line incisors with open apices.

replantation. The relative risk of failure for incisors replanted with open apices was 6.4 times greater than for incisors replanted with closed apices ($P = 0.04$) (Fig. 2).

Discussion

Mechanism of the injury

Data regarding the mechanism of the injury in our study revealed that the aetiology of avulsion injury is complex, comprising different aspects of developmental, environmental and social factors. The only common feature is the fact that avulsion always presents severe trauma. High rates of avulsion injuries caused by road traffic accidents may be one of the reasons for delayed treatment in our sample. It is understandable that when a serious accident occurs, teeth are not the subject of greatest interest. Emergency treatment after the road traffic accident is aimed at registration of more serious

and complicated injuries. In these situations lost teeth are the price that has to be paid for the misfortune. While teeth are not of primary interest in an emergency situation endangering life, they are important for function and aesthetics.

Concomitant injuries

It is well-known that dental trauma occurs frequently in conjunction with facial trauma. The finding from our study that tooth avulsion is always accompanied with concomitant injuries may offer the explanation for delayed treatment. Avulsion injury itself is very dramatic, and when it is accompanied with other injuries, such as laceration of the lip, it can be masked or overlooked (13). In some cases patients and their parents realized that avulsion had occurred after arrival at our clinic. Emergency treatment of multitraumatized patients presents a factor that delays tooth replantation. In the present study, treatment of less urgent injuries was performed prior to the tooth replantation in several cases, even though patients brought their teeth. Consequently, all replantations have been performed at our clinics.

Age and gender of the patient

Both age of the patient and apical maturity of the root can influence treatment. In the present study, mean age of the patient was 10.7 years. An identical finding was reported by Barrett and Kenny (14) in a study based on 38 patients.

It is difficult to evaluate age of the patient separately from all other factors that influence the treatment and prognosis, but it could be useful to define its specific impact on the outcome of avulsed teeth. It is sometimes difficult to perform an adequate procedure, especially when a child has already been traumatized by the recent accident. The younger age of a patient decreases the chance to provide self-help or self-replantation at the scene of the accident.

Andersson et al. (15) found that the progression of root resorption in teeth with extended extraoral periods is related to age. In patients 8–16 years old at the time of avulsion, the rate of root resorption was significantly higher compared with 17–39 years old patients.

In the present study, a higher injury rate was found in boys compared to girls (1.89:1), which completely agrees with other epidemiological studies (1, 16). One study evaluated gender in relation to the replantation outcome and reported that the risk of infraposition after replantation was higher in young girls compared to young boys (17). Our results do not support this finding.

Replantation rate

Replantation was performed to all teeth brought to the clinics (32/62). A low replantation rate has been reported by Kinoshita et al. (18) who found that 18/32 avulsed teeth in their sample could not be replanted. Similar to the findings from the present study, Kinoshita et al. (18) reported that 18 teeth in 14 cases were lost at injury.

According to our results, the accident details, but also the inadequate reaction of the people present at the scene of the accident, are the main reasons for the low replantation rate. Lack of awareness about the type of the injury and lack of awareness that a tooth should be looked for appeared to be very important reasons for non-replanting. No replantation was performed either at the scene of the accident, or by medical staff that received patients prior to referral to our clinics. This suggests insufficient knowledge and an inadequate response in persons likely to be present at the scene of the accident. Numerous studies report low knowledge of lay people present at the accident scene (6–9, 13).

Apical maturity of the root

Apical maturity of the root presents an important factor that determines the outcome of the replanted tooth. In the present study 13/32 replanted teeth were with an open apex. This is a slightly higher immature/mature tooth ratio compared to findings from the studies by Barrett and Kenny (14) in which 20/52 teeth were immature, and Andreasen et al. (3) in whose study 41/272 replanted teeth had uncompleted root development. However, there are differences in age groups between these two studies and the present investigation.

Although a tooth with uncompleted root development possesses a strong reparatory potential and thicker periodontal ligament that may desiccate more slowly, the postreplantation outcome is usually worse compared to the mature tooth. IRR is frequent, and the treatment is often delayed while hoping for RV. In the present study not all replanted immature teeth with prolonged extra-alveolar duration were lost during the observation period. However, they had a worse prognosis and higher failure rate compared to replanted teeth with completed root development. Andreasen et al. (3) reported higher failure rates in teeth with open apices. Barrett and Kenny (14) reported that replanted incisors with open apices had a significantly reduced survival and the relative risk of failure was 4.2 times greater in immature than in mature incisors.

Storage media

The medium in which the tooth was stored influences the root resorption and pulp healing (13, 19). A strong connection between the storage medium and the occurrence of complications has been clearly demonstrated (3, 11).

It was shown that death of periodontal ligament cells could be delayed by storage in milk or saliva. However, this process is progressive and inevitable and even appropriate storage is limited to short periods (20–25). Limited storage in isotonic solution prior to the replantation of teeth with moderate damage to the periodontal ligament gave equal or even better healing results compared with immediate replantation (26). Pohl et al. (12) suggested storage in a cell-compatible culture medium, to maintain the vitality and proliferative capacity of periodontal ligament cells for extended periods.

In the beginning of our study storage in saline was considered as physiological, but during the study the criteria changed and we considered this media as appropriate or at least preferable compared to other storage media observed in our sample.

Regarding the storage medium, there were substantial differences between our study and the majority of published studies. In the study by Barrett and Kenny (14), 40/52 teeth were kept in a physiological storage medium, five were stored in water or ice and only five teeth were held in dry conditions. In the study by Pohl et al. (12), 6/28 teeth were stored in a Dentosafe box (medium consisting of different salts, amino acids, vitamins and glucose), 16 were temporarily stored in an unphysiological storage medium and 6 teeth were held in unphysiological medium. Similar findings were reported by Chappuis and von Arx (28).

Only 2/32 teeth in our study were considered as 'brought in an appropriate storage media'. Of two teeth brought in saline, FH was diagnosed in one and RR in the other. The sample comprising only two teeth is too small for any valid conclusions, but it could be underscored that IRR was not diagnosed in these teeth during the observation period. The majority of the IRR were detected in teeth brought to clinics after some time of complete dry storage, which corresponds with findings from similar clinical studies (3, 12, 14, 15, 27–29).

Extra-alveolar duration

Despite the importance of minimizing extra-alveolar duration, immediate replantation is usually not performed. Barrett and Kenny (14) concluded that prolonged extra-alveolar duration contributed to an uncertain prognosis for most replanted teeth. For almost all replanted teeth in our sample, extra-alveolar duration was much longer than in most other studies (19, 30). Consequently, it would be too much to expect a favourable FH free of complications. Shorter extra-alveolar duration resulted in more favourable replantation outcomes and, as a result, FH was observed in teeth replanted within 1 h after the accident. The highest rate of IRR was detected in teeth in which extra-alveolar duration was longer than 60 min.

Endodontic treatment

Endodontic treatment was carried out at 7–14 days after replantation in teeth in which RV of the pulp could not be expected. In teeth with delayed endodontic treatment, high rates of IRR were diagnosed.

The results of the present study support the findings that replanted avulsed incisors with completed endodontic treatment have a significantly higher probability of survival compared to teeth requiring prolonged treatment with calcium hydroxide (3, 14). In our study IRR was inevitable for the majority of the replanted teeth. This could be possibly related to the concomitant effect of unphysiological storage, the presence of necrotic pulp, prolonged extra-alveolar duration and high prevalence of immature replanted teeth. Under these conditions, calcium-hydroxide medication could not contribute to more favourable RR.

Patient's intraoperative compliance and recall appointments response

For some of our patients, it was the first experience of dental treatment. It was crucial for them to fully understand the treatment and cooperate. If this is not forthcoming, treatment is seriously compromised. However, the treatment procedure was frequently prolonged in order to explain the necessity of the treatment to the frightened patient. A concern regarding patient compliance was also raised in the study of Pohl et al. (12) that recommended extraoral endodontic treatment, partially because patients tolerated that kind of treatment perfectly.

The success of endodontic treatment depends on long-lasting and careful examination many years after the injury. Data collected in the present study showed that interest and responsibility for the replanted teeth decreased from 2 months after the injury. It is common for patients to forget about scheduled appointments, and to present after several months, mainly with the symptoms of acute inflammation. Pertl et al. (31) also reported patients missing scheduled appointments after emergency treatment. Thus, the confidence between patient and dentist, as well as patient's complete cooperation is an important factor in prognosis of replanted teeth.

Outcomes of replanted teeth

Recent clinical studies used different classifications of postoperative outcomes. Pohl et al. (12) classified the postoperative healing as FH, RR and IRR. Choppius and von Arx (28) classified periodontal healing according to Fuss et al. (32) as surface resorption (repair-related root resorption), inflammatory resorption (infection-related root resorption) and replacement resorption (ankylosis-related root resorption). Based on analysis of radiographs during our study, it was concluded that all teeth assigned as teeth with IRR comprised all subtypes of IRR described in those studies, as well as all teeth with surface resorption were in our study classified as FH.

Ebeleseder et al. (29) stated that for the survival of immature teeth in particular, pulp RV seemed to be an important factor and also in cases of delayed replantation. In their investigation RV occurred in 16/39 immature teeth, and in 3/35 mature teeth. Andreasen et al. (33) reported a 34% chance of RV for teeth in which RV was considered possible. Our results do not support these data. In the present study RV was not observed, although it was considered possible in 6/32 replanted immature incisors, which supports the findings reported by Barrett and Kenny (14). Because of the extended extra-alveolar duration neither pulpal RV nor the re-establishment of a functionally oriented periodontal ligament were expected in their sample. Similar results were reported by Andersson (15), where extirpation of the pulps was postponed to allow RV for three teeth with incomplete apical closure. All these teeth later showed periapical radiolucencies, indicating that RV had not taken place. Chappuis and von Arx (28) reported that RV was not found in a study on 45 replanted teeth, while in 3 teeth with open an apex pulp canal obliteration was found, suggesting that RV took place and allowed formation of hard tissue within

the pulp canal. In 4/6 teeth in our sample severe IRR was observed in the period of waiting for RV to occur, mainly in situations when patients missed their scheduled appointments. Endodontic treatment could probably have improved the prognosis for these teeth. This is completely in accordance with recommendation made by Andreasen, who stated that early endodontic treatment may be induced in order to avoid potential complications that may arise during healing if the patients fail to present at the follow-up appointments (34). Our results are completely in line with this recommendation and our clinical protocols have been changed according to this recommendation, since it was concluded that waiting for RV to occur gave poor results and increased the chances of developing IRR.

In the present study, FH was found in 5/32 teeth. This is a significantly lower FH rate compared with the majority of clinical outcome studies (3, 12, 14, 28).

Complications after the replantation of avulsed teeth are common, with a reported prevalence of 57–80% (3, 12, 14, 28). In the present study the complication rate was 84.4% (27/32) which is higher than previous studies. IRR was the predominant type of complication and its prevalence is discouraging when compared with the previously mentioned clinical studies. The higher rate of IRR detected in our sample is understandable taking into consideration all factors that have already been discussed. In contrast, the RR rate was significantly lower compared to similar studies. This finding once more emphasizes the deleterious effects of the factors influencing the treatment of replanted teeth.

When a complication is registered, making a decision about further treatment of the replanted tooth is a very sensitive step. Decisions about orthodontic, surgical and/or prosthetic treatment should be made together with the patient and its parents, once they are informed about the prognosis and nature of child's injury. Treatment strategies should always be designed on an individual basis comprising the treatment-related characteristics, developmental and psychological factors, and importantly the patient's expectations and unavoidable complications associated with avulsion injury.

Conclusions

This study supports the finding that delayed replantation after unphysiological storage is inevitably followed by high resorption rate and tooth loss. RV should not be anticipated in cases in which extra-alveolar duration exceeds 15 min. Apical development at the time of replantation is significantly related to tooth survival, since incisors with open apices exhibited lower survival compared with incisors with closed apices. Replanted incisors that required prolonged treatment with calcium hydroxide exhibited more complications compared with incisors with completed root canal treatment.

References

1. Andreasen JO. Etiology and pathogenesis of traumatic dental injuries. A clinical study of 1,298 cases. *Scand J Dent Res* 1970;78:329–42.

2. Andreasen JO, Andreasen FM, Andersson L. Textbook and colour atlas of traumatic injuries to the teeth, 4th edn. Oxford: Blackwell Munksgaard; 2007. p. 383–427.
3. Andreasen JO, Borum MK, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors. 4. Factors related to periodontal ligament healing. *Endod Dent Traumatol* 1995;11:76–89.
4. Andersson L, Bodin I. Avulsed human teeth replanted within 15 minutes – a long term clinical follow-up study. *Endod Dent Traumatol* 1990;6:37–42.
5. Pettiette M, Hupp J, Mesaros S, Trope M. Periodontal healing of extracted dogs' teeth air-dried for extended periods and soaked in various media. *Endod Dent Traumatol* 1997;13:113–8.
6. Hamilton FA, Hill FJ, Mackie IC. Investigation of lay knowledge of the management of avulsed permanent incisors. *Endod Dent Traumatol* 1997;13:19–23.
7. Raphael SL, Gregory PJ. Parental awareness of emergency management of avulsed teeth in children. *Aust Dent J* 1990;35:130–3.
8. Andersson L, Al-Asfour A, Al-Jame Q. Knowledge of first aid measures of avulsion and replantation of teeth: an interview of 221 Kuwaiti schoolchildren. *Dent Traumatol* 2006;22:57–65.
9. Cohenca N, Forrest JL, Rotstein I. Knowledge of oral health professionals of treatment of avulsed teeth. *Dent Traumatol* 2006;22:296–301.
10. Bhat M, Li SH. Consumer product-related tooth injuries treated in hospital emergency rooms: United States, 1979–87. *Community Dent Oral Epidemiol* 1990;18:133–8.
11. Moorrees CF, Fanning EA, Hunt EE Jr. Age variation of formation stages for ten permanent teeth. *J Dent Res* 1963;42:1490–502.
12. Pohl Y, Filippi A, Kirschner H. Results after replantation of avulsed permanent teeth. I.-II. *Dent Traumatol* 2005;21:80–101.
13. Trope M. Clinical management of the avulsed tooth: present strategies and future directions. *Dent Traumatol* 2002;18:1–11.
14. Barrett EJ, Kenny DJ. Survival of avulsed permanent maxillary incisors in children following delayed replantation. *Endod Dent Traumatol* 1997;13:269–75.
15. Andersson L, Bodin I, Sorensen S. Progression of root resorption following replantation of human teeth after extended extraoral storage. *Dent Traumatol* 1989;5:38–47.
16. Andreasen JO, Ravn JJ. Epidemiology of traumatic dental injuries to primary and permanent teeth in a Danish population sample. *Int J Oral Surg* 1972;1:235–9.
17. Kawanami M, Andreasen JO, Borum MK, Schou S, Hjorting-Hansen E, Kato H. Infraposition of ankylosed permanent maxillary incisors after replantation related to age and sex. *Endod Dent Traumatol* 1999;15:50–6.
18. Kinoshita S, Kojima R, Taguchi Y, Noda T. Tooth replantation after traumatic avulsion: a report of 10 cases. *Dent Traumatol* 2002;18:153–6.
19. Barrett EJ, Kenny DJ, Tenenbaum HC, Sigal MJ, Johnston DH. Replantation of permanent incisors in children using Emdogain. *Dent Traumatol* 2005;21:269–75.
20. Blomlof L. Storage of human periodontal ligament cells in a combination of different media. *J Dent Res* 1981;60:1904–6.
21. Doyle DL, Dumsha TC, Sydiskis RJ. Effect of soaking in Hank's balanced salt solution or milk on PDL cell viability of dry stored human teeth. *Endod Dent Traumatol* 1998;14:221–4.
22. Hiltz J, Trope M. Vitality of human lip fibroblasts in milk, Hanks balanced salt solution and Viaspan storage media. *Endod Dent Traumatol* 1991;7:69–72.
23. Huang SC, Remeikis NA, Daniel JC. Effects of long-term exposure of human periodontal ligament cells to milk and other solutions. *J Endod* 1996;22:30–3.
24. Lekic PC, Kenny DJ, Barrett EJ. The influence of storage conditions on the clonogenic capacity of periodontal ligament cells: implications for tooth replantation. *Int Endod J* 1998;31:137–40.
25. Andreasen JO, Schwartz O. The effect of saline storage before replantation upon dry damage upon the periodontal ligament. *Endod Dent Traumatol* 1986;2:67–70.
26. Cvek M, Granath LE, Hollender L. Treatment of non-vital permanent incisors with calcium hydroxide. III. Variation of occurrence of ankylosis of reimplanted teeth with duration of extra-alveolar period and storage environment. *Odontol Revy* 1974;25:43–56.
27. Andreasen JO, Paulsen HU, Yu Z, Bayer T, Schwartz O. A long-term study of 370 autotransplanted premolars. Part III. Periodontal healing subsequent to transplantation. *Eur J Orthod* 1990;12:25–37.
28. Chappuis V, von Arx T. Replantation of 45 avulsed permanent teeth: a 1-year follow-up study. *Dent Traumatol* 2005;21:289–96.
29. Ebeleseder KA, Friehs S, Ruda C, Pertl C, Glockner K, Hulla H. A study of replanted permanent teeth in different age groups. *Endod Dent Traumatol* 1998;14:274–8.
30. Boyd DH, Kinirons MJ, Gregg TA. A prospective study of factors affecting survival of replanted permanent incisors in children. *Int J Paediatr Dent* 2000;10:200–5.
31. Pertl C, Ebeleseder M, Lorenzoni M, Bantleon HP, Wegscheider WA. Contemporary treatment of the resorbed avulsed tooth: a case report. *Int Endod J* 1999;32:332–6.
32. Fuss Z, Tsesis I, Lin S. Root resorption-diagnosis, classification and treatment choices based on stimulation factors. *Dent Traumatol* 2003;19:175–82.
33. Andreasen JO, Borum MK, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors. 2. Factors related to pulpal healing. *Endod Dent Traumatol* 1995;11:59–68.
34. Andreasen FM. Pulpal healing following acute dental trauma. *Pract Proced Aesthet Dent* 2001;13:315–22.

This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.