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Replantation of 45 avulsed permanent teeth: a 1-year follow-up study

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Abstract – Thirty-four patients with 45 avulsed and replanted permanent teeth were followed for 1 year. All teeth were soaked in tetracycline before replantation. In addition, enamel matrix derivative was used in teeth with dry storage times exceeding 30 min. Splinting was carried out with a non-rigid titanium splint and was limited to 7–10 days. Within that period, root canal treatment was begun in all teeth with a closed apex, whereas teeth with an open apex and ideal post-traumatic storage were not instrumented. All patients were given tetracycline systematically for 10 days. The survival rate of replanted avulsed permanent teeth was 95.6% at the 1-year follow-up. In 82.2%, root canal treatment was performed. Pulp survival was never observed, but three teeth had pulp canal obliteration. Normal periodontal healing was observed in 57.7% of teeth; 42.3% of teeth showed external root resorption (28.9% replacement resorption, 6.7% infection-related resorption, 6.7% surface resorption). The occurrence of replacement resorption correlated with the period of extraoral dry storage. Compared with other clinical studies on avulsed and replanted teeth, the present study reports a higher percentage of periodontal healing. The favorable treatment outcome may be associated with a strict protocol to enforce endodontic treatment, the use of topical and systemic tetracycline, and the relatively high number of ideally stored teeth following avulsion. In contrast, the present study has a follow-up period limited to 1 year.

Vivianne Chappuis, Thomas von Arx

Department of Oral Surgery and Stomatology, School of Dental Medicine, University of Berne, Berne, Switzerland

Key words: avulsion; replantation; periodontal healing; pulpal healing

Dr Vivianne Chappuis, Department Of Oral Surgery and Stomatology, School of Dental Medicine, University of Berne, Freiburgstrasse 7, CH-3010 Berne, Switzerland
Tel.: ++41 31 632 2545
Fax: ++41 31 632 9884
e-mail: vivianne.chappuis@zmk.unibe.ch

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Avulsion is a complex injury affecting the pulp, periodontal ligament and the alveolar bone. Avulsed permanent teeth can survive following replantation. However, post-traumatic external root resorption eventually resulting in loss of the traumatized tooth is a frequent finding (1–3). As avulsions mostly occur in children and adolescents, ankylosis following replantation of avulsed permanent incisors may also affect the growth of the alveolar ridge, and the eruption and position of the adjacent teeth (4–6). Functional and esthetic rehabilitation of ankylotic teeth still remain a challenge, with regard to regeneration of hard and soft tissues.

The storage medium and the duration of extraoral storage of an avulsed tooth is critical for periodontal healing (2, 7–10). The extent of damage to periodontal ligament cells and the condition of the pulp may both affect the outcome of periodontal healing (2, 11).

Recently, the use of chemotherapeutic agents has been advocated to manipulate pharmacologically the processes resulting in external root resorption. In particular, in experimental animal studies, tetracycline has been shown to be effective in the prevention or attenuation of external root resorption when applied systemically and/or topically (12–14). The rationale of using tetracycline is to benefit from its antiresorptive properties. Tetracycline has a direct inhibitory effect on collagenase activity and osteoclasts. In addition, its antimicrobial effect may

eliminate bacteria which have contaminated the alveolus, the periodontal and pulpal tissues (15, 16).

A new approach in the treatment of avulsed permanent teeth is the use of regenerative techniques for stimulation and/or differentiation of cells leading to periodontal regeneration. Enamel matrix derivative (EMD) has attracted recent interest to support periodontal healing following avulsion (17–20). The extent of damage to the root cementum appears to be correlated with the risk of post-traumatic external root resorption. Hence, the stimulation of cementogenesis, i.e. induction and deposition of new cementum, may be an important step for periodontal ligament healing.

The objective of the present study was to evaluate the treatment outcome of 45 avulsed and replanted permanent incisors after a 1-year follow-up period. In particular, the following aspects were to be assessed with regard to pulpal and periodontal healing: time and medium of extraoral storage, endodontic treatment, use of tetracycline, and application of EMD.

Material and methods

The material included 34 patients with 45 avulsed permanent teeth (31 maxillary central incisors, 2 maxillary lateral incisors, 11 mandibular incisors, 1 mandibular canine). Seventy-four percent of the patients were younger than 16 years. The mean age of all patients was 21 years (range 6–48 years). Cases were enrolled during a 2-year period from April 2001 to March 2003. All patients were followed for 1 year.

Exclusion criteria were concomitant root or complex crown-root fractures, teeth with preceding trauma, root canal-treated teeth, or teeth with large restorations. In addition, cases with avulsed teeth that were not found or were not replanted for other reasons were not enrolled in the present study.

On arrival at the department, the avulsed tooth was immediately placed into a special storage medium (Dentosafe; Medice, Iserlohn, Germany) for at least 30 min. In the meantime, clinical and radiographic examination were performed. The socket was rinsed with saline, and soft tissue lacerations were re-approximated and sutured when necessary. Before replantation, the avulsed tooth was soaked in 5% tetracycline (1 mg oxytetracycline HCL and 20 ml saline). In cases with extended dry storage (>30 min), EMD (Emdogain; Straumann Biologics, Waldenburg, Switzerland) was applied into the socket and onto the root surface. The tooth was then manually replanted and stabilized with a non-rigid splint (TTS; Medartis AG, Basle, Switzerland) for 7–10 days (21).

All teeth with a closed apex (diameter of apical foramen ≤1 mm) were subjected to root canal treatment within 7–10 days. Root canal treatment, carried out either at the Department of Operative Dentistry or by a private dentist, included the placement of Ledermix-paste (Lederle, Zug, Switzerland) for 2–3 weeks. Thereafter, Ledermix was replaced with calcium hydroxide dressings. Teeth with an open apex (diameter of apical foramen >1 mm) and ideal storage conditions following avulsion were not root canal treated, but were recalled after 2, 3, 4 and 8 weeks, and subsequently every 2 months.

Postoperative medication included analgesics and chlorhexidine digluconate mouthwash. All patients received a systemic tetracycline regimen for 10 days (Doxyclin; Spirig, Egerkingen, Switzerland). Patients weighing <50 kg were given 100 mg on the first day, and 50 mg for days 2–10. Patients >50 kg received double this dosage.

Follow-up examinations at 3, 6 and 12 months included a clinical and radiographic check focused on pulpal and periodontal changes. The clinical examination comprised inspection, palpation, percussion, periotest measurements, pulp sensitivity testing using CO_2-snow, and pulp vitality testing with laser Doppler flowmetry.

Results

The survival rate at the 1-year reexamination was 95.6% (43/45). Two replanted avulsed teeth had to be removed in the follow-up period: one tooth developed a progressive infection-related external root resorption (Fig. 1) and was extracted 20 weeks following replantation, another tooth developed a combined endo-perio lesion and was extracted 6 weeks after replantation.

During the 1 year follow-up period, 36 (80%) teeth were root canal-treated. A vital pulp was never found at the 1-year reexamination. In 29 teeth with

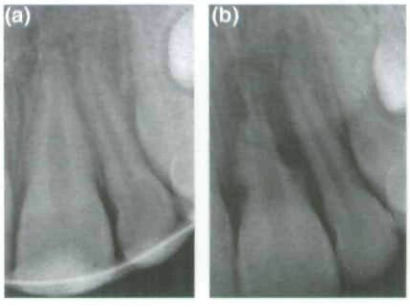

Fig. 1. (a) The avulsed left maxillary central incisor has been replanted and stabilized using a wire-composit splint. (b) The 3-month radiograph shows an advanced pulp-infection related external root resorption of the replanted incisor.

Table 1. Pulpal healing related to endodontic treatment and stage of apical closure ($n = 45$)

	Early root canal treatment (within 7–10 days)		Delayed root canal treatment		No root canal treatment		
	Apex open	Apex closed	Apex open	Apex closed	Apex open	Apex closed	Total (%)
Pulp survival	–	–	–	–	–	–	–
Pulp canal obliteration	–	–	–	–	3	–	3 (6.7)
Pulp necrosis	–	–	1	–	3	2	6 (13.3)
Endodontic obturation	2	25	7	2	–	–	36 (80)
Total	2	25	8	2	6	2	45 (100)
Total (%)	27 (60)		10 (22.2)		8 (17.8)		45 (100)

a closed apex, 25 teeth were root canal-treated within 7–10 days (Table 1). Two teeth were root canal-treated at a later time, and two teeth showing no endodontic treatment at the 1-year reexamination presented signs of pulp necrosis. Of 16 teeth with an open apex, two had an early root canal treatment (within 7–10 days), and eight had a delayed root canal treatment. Three teeth developed pulp obliteration (Fig. 2). In three cases in which a root canal treatment had been planned, the patient or the private dentist declined such treatment. At the 1-year follow-up, all these teeth showed signs of pulp necrosis (Table 1).

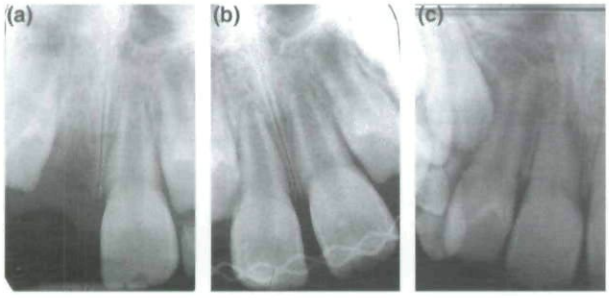

Fig. 2. (a) Avulsion of the right maxillary central incisor. (b) The avulsed tooth has been replanted and stabilized using a TTS splint. (c) The 1-year radiograph shows pulp canal obliteration and a normal PDL space in the right central incisor.

With respect to periodontal healing, 26 teeth (57.7%) showed normal periodontal healing during the 1-year follow-up (Table 2a). In teeth with an open apex, periodontal healing was found more often (62.5%) compared to teeth with a closed apex (55.2%) (Table 2b). Replacement resorption was seen in 13 teeth (28.9%) (Fig. 3). It was less frequent in teeth with an open apex (25%) compared to teeth with a closed apex (31%). Three replanted teeth developed an infection-related external root resorption. In one tooth, root resorption was successfully stopped following root canal treatment (Fig. 4). The other two teeth had to be extracted: one tooth developed a combined endo-perio lesion, and one tooth showed a progressive external root resorption (Table 2a).

The relationship between periodontal healing and pulp status is shown in Table 3. An infection-related external root resorption was always associated with pulp necrosis. All three teeth with pulp canal obliteration demonstrated periodontal healing.

The correlation of periodontal healing and post-traumatic dry storage is shown in Table 4. The occurrence of replacement resorption increased with extended periods of dry storage. Replacement resorption ranged from only 9.5% in teeth with a short dry storage of below 15 min to 100% in teeth with dry storage exceeding 60 min.

Table 2a. Periodontal healing related to endodontic treatment ($n = 45$)

	Immediate root canal treatment		Delayed root canal treatment		No root canal treatment		
	Apex open	Apex closed	Apex open	Apex closed	Apex open	Apex closed	Total (%)
Periodontal healing	1	14	4	1	5	1	26 (57.7)
Surface resorption	–	1	–	1	1	–	3 (6.7)
Infection-related resorption	–	1*	1†	–	–	1‡	3 (6.7)
Replacement resorption	1	9	3	–	–	–	13 (28.9)
Total	2	25	8	2	6	2	45 (100)
Total (%)	27 (60)		10 (22.2)		8 (17.8)		45 (100)

*Tooth developed endo-perio lesion and was extracted during follow-up period.
†Infection-related resorption successfully stopped following delayed root canal treatment.
‡Tooth had to be extracted due to progressive root resorption 20 weeks following replantation.

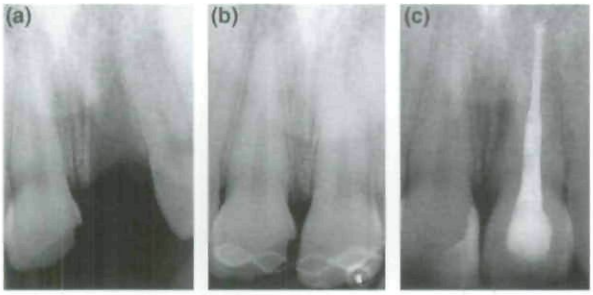

Fig. 3. (a) Avulsion of the left maxillary central incisor and crown fracture of the right maxillary central incisor. (b) The avulsed tooth has been replanted and stabilized using a TTS splint. (c) The 1-year radiograph shows external root resorption in the left central incisor (replacement resorption) and a normal PDL space in the right central incisor.

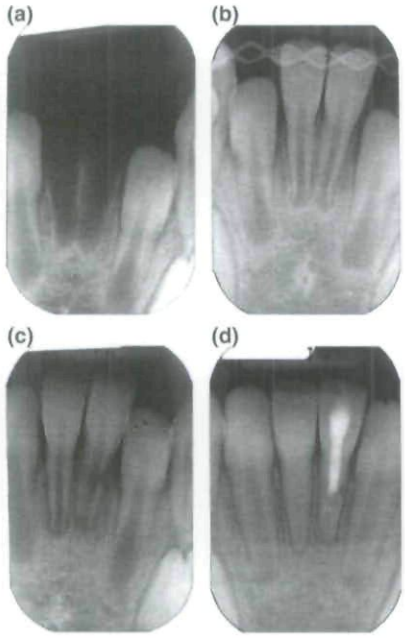

Fig. 4. (a) Avulsion of both mandibular central incisors. (b) The avulsed teeth have been replanted and stabilized using a TTS splint. (c) Two months following replantation the left central incisor shows an infection related root resorption. (d) The 1-year radiograph shows that root resorption could be halted in the left central incisor following root canal treatment. The right central incisor presents now with pulp canal obliteration. Both teeth have normal PDL spaces.

Table 2b. Periodontal healing-related stage of apical closure ($n = 45$)

	Apex open (%)	Apex closed (%)	Total (%)
Periodontal healing	10 (62.5)	16 (55.2)	26 (57.7)
Surface resorption	1 (6.25)	2 (6.9)	3 (6.7)
Infection-related resorption	1 (6.25)	2 (6.9)	3 (6.7)
Replacement resorption	4 (25)	9 (31)	13 (28.9)
Total	16 (100)	29 (100)	45 (100)

The effect of the storage medium on periodontal healing is demonstrated in Table 5. Seventeen teeth (37.8%) were stored in milk and 16 teeth (35.5%) were stored in a Dentosafe Box.

EMD was applied in a total of 10 replanted teeth. Replacement resorption was found in 50% of EMD-treated teeth compared to 22.8% in teeth without EMD treatment (Table 6).

Discussion

The present paper describes the 1-year treatment outcome of 45 avulsed permanent teeth following replantation. Special interest focused on pulpal and periodontal healing, and on efforts minimizing complications such as pulp necrosis and external root resorption.

Basically, three tissues are involved in healing after replantation of an avulsed tooth: pulp tissue, periodontal ligament, and alveolar bone of the tooth socket. Following trauma, the pulp can show three healing modalities: pulp survival, pulp obliteration, or pulp necrosis. The latter plays an important role in the development of post-traumatic external root resorption, and therefore, the term 'pulpal infection root resorption' has been suggested (22).

In consideration of earlier published data (see below) about avulsed permanent teeth, a relatively strict endodontic treatment protocol was utilized in the present study. The majority of avulsed teeth with a closed apex, or teeth with an open apex but non-physiologic storage, were subjected to root canal treatment within 7–10 days. Thereby, necrotic pulp tissue was removed, and none of these teeth developed an infection-related external root resorption except one tooth showing an endo-perio

Table 3. Periodontal healing related to pulp status ($n = 45$)

	Pulp canal obliteration (%)	Pulp necrosis (%)	Endodontic treatment (%)	Total (%)
Periodontal healing	3 (100)	3 (50)	20 (55.6)	26 (57.7)
Surface resorption	–	1 (16.7)	2 (5.5)	3 (6.7)
Infection-related resorption	–	2 (33.3)	1 (2.8)*	3 (6.7)
Replacement resorption	–	–	13 (36.1)	13 (28.9)
Total	3 (100)	6 (100)	36 (100)	45 (100)

*Endo-perio lesion.

Table 4. Periodontal healing related to period of dry storage ($n = 45$)

	Dry storage time <15 min (%)	Dry storage time 15–60 min (%)	Dry storage time >60 min (%)	Dry storage time unknown (%)	Total (%)
Periodontal healing	15 (71.5)	7 (53.8)	–	4 (50)	26 (57.7)
Surface resorption	2 (9.5)	–	–	1 (12.5)	3 (6.7)
Infection-related resorption	2 (9.5)	1 (7.7)	–	–	3 (6.7)
Replacement resorption	2 (9.5)	5 (38.5)	3 (100)	3 (37.5)	13 (28.9)
Total	21 (100)	13 (100)	3 (100)	8 (100)	45 (100)

Table 5. Periodontal healing related to storage medium ($n = 45$)

	Dentosafe Box (%)	Milk (%)	Saliva (%)	Other (%)	Total (%)
Periodontal healing	8 (50)	11 (64.7)	3 (60)	4 (57.1)	26 (57.7)
Surface resorption	1 (6.25)	1 (5.9)	–	1 (14.3)	3 (6.7)
Infection-related resorption	1 (6.25)	1 (5.9)	1 (20)	–	3 (6.7)
Replacement resorption	6 (37.5)	4 (23.5)	1 (20)	2 (28.6)	13 (28.9)
Total	16 (100)	17 (100)	5 (100)	7 (100)	45 (100)

Table 6. Periodontal healing related to use of EMD ($n = 45$)

	EMD treatment (%)	No EMD treatment (%)	Total (%)
Periodontal healing	2 (20)	24 (68.6)	26 (57.7)
Surface resorption	2 (20)	1 (2.9)	3 (6.7)
Infection-related resorption	1 (10)	2 (5.7)	3 (6.7)
Replacement resorption	5 (50)	8 (22.8)	13 (28.9)
Total	10 (100)	35 (100)	45 (100)

lesion. In two teeth with a closed apex, and in three teeth with an open apex, the patient or the private dentist had declined performing a root canal treatment, and pulp necrosis was diagnosed during follow-up. One of these teeth (with a closed apex) also developed a progressive infection-related external root resorption and had to be extracted. In three teeth with an open apex, pulp canal obliteration was found at the re-examination. Apparently, revascularization had taken place in these teeth following replantation allowing hard tissue formation within the pulp canal.

Andreasen et al. (11) analyzed factors related to pulpal healing in 400 replanted avulsed permanent incisors. They reported a 34% chance of revascularization for those teeth (32 of 94) in which pulpal revascularization was considered possible. Pulpal healing as represented by a positive sensibility response was found after a mean interval of 6 months, followed by marked pulp canal obliteration in 29 cases. The remaining three cases presented with formation of internal bone. A wide apex, a short pulp length, and wet and short extraoral storage were all significantly associated with pulp canal obliteration. In the present study, three (18.8%) of 16 teeth with an open apex, and without root canal treatment, showed pulp canal obliteration at the 1-year follow-up.

In contrast, four teeth with an open apex developed pulp necrosis. Initially, these teeth with unfavorable storage conditions were scheduled for root canal treatment but the parents or private dentist had declined such treatment. Similar findings were described by Andersson et al. (1) in replanted teeth with extended extraoral storage. In three teeth with incomplete apical closure, pulp extirpation was postponed to allow revascularization. All these teeth later showed periapical radiolucencies indicating pulp necrosis.

Ebeleseder et al. (4) analyzed pulp survival of replanted avulsed teeth in different age groups. They reported pulp survival in 41% of immature teeth in children (mean age 8 years), in 9% of mature teeth in adolescents (mean age 12 years), and in 0% of teeth in adults (mean age 25 years).

Replanted avulsed incisors with completed root canal treatment had a significantly higher probability of survival compared to teeth requiring prolonged treatment with calcium hydroxide (3). The same study also reported a decreased survival prospect of teeth with open apices, which, in part, may be explained by the duration of $Ca(OH)_2$ treatment required to induce apical barrier formation. This suggests that the chance of pulp survival in avulsed mature teeth is low, and therefore, these teeth should be subjected to root canal treatment.

With regard to periodontal healing, three different types of post-traumatic external root resorption have been distinguished in the literature (2, 22): surface resorption (repair-related root resorption), inflammatory resorption (infection-related root resorption, also termed pulpal infection root resorption, or in case of bacterial stimulation originating from the periodontal sulcus: periodontal infection root resorption), and replacement resorption (ankylosis-related root resorption). Surface (or repair-related) root resorption has no further clinical consequences. This healing modality was found in three teeth in the present study; however, one tooth

Table 7. Studies evaluating periodontal healing following replantation of avulsed teeth

	Present study (follow-up 1 year) (%)	Majorana et al. (23) (follow-up 5 years) (%)	Donaldson and Kinirons (10) (minimum follow-up 2 years) (%)	Ebeleseder et al. (4) (minimum follow-up 1 year) (%)	Andreasen et al. (2) (mean follow-up 5.1 years) (%)	Gonda et al. (24) (mean follow-up NA, range 3 months to 8 years) (%)
Periodontal healing	26 (57.7)	37 (50.7)	28 (32.6)	29 (28.2)	96 (24)	11 (40.7)
Surface resorption	3 (6.7)	9 (12.3)*	–	–	18 (4.5)†	–
Infection-related resorption	3 (6.7)	12 (16.4)	11 (12.8)	10 (9.7)	120 (30)†	12 (44.5)
Replacement resorption	13 (28.9)	15 (20.6)	47 (54.7)	64 (62.1)	243 (61)†	4 (14.8)
Subtotal of teeth with post-traumatic root resorption	19 (42.3)	36 (49.3)	58 (67.4)	74 (71.8)	304 (76)	16 (59.3)
Total	45 (100)	73 (100)	86 (100)	103 (100)	400 (100)	27 (100)

*Transient superficial inflammatory root resorption.
†Some teeth presented with different types of root resorption over time; percentages were calculated per total number of teeth.

with surface resorption was associated with pulp necrosis suggesting that an infection-related resorption might have ensued when root canal treatment had not been performed immediately.

A relatively high percentage (57.7%) of normal periodontal healing was found during the 1-year follow-up, either in teeth with a closed apex (55.2%) or in teeth with an open apex (62.5%). Several factors might have contributed to this favorable outcome: nearly half of all replanted teeth (46.7%; 21/45) had a short dry storage period of below 15 min, a relatively high number of avulsed teeth (84.4%, 38/45) were stored in a physiologic medium, and in 60% of teeth (27/45) root canal treatment was begun within 7–10 days following replantation.

In the present study 42.3% of avulsed teeth presented with post-traumatic external root resorption in comparison with 49.3–76% reported in other clinical studies (2, 4, 10, 23, 24) (Table 7). However, the favorable treatment outcome in the present study might be explained by a shorter follow-up period (1 year) compared to longer follow-up periods in the above-mentioned studies.

Replacement resorption was diagnosed as the prevalent type of post-traumatic external root resorption. This is in agreement with data from the literature (2, 4, 10, 23, 24). Only three teeth (6.7%) presented with an infection-related root resorption. This low rate of pulpal infection related root resorption might be attributed to the strict enforcement of root canal treatment.

Periodontal healing following replantation of avulsed teeth appears to correlate not only with the period of extraoral storage, but also with the type (and temperature) of storage media (25, 26). Several studies have emphasized that these parameters (short time of dry period, physiologic storage medium) are essential for the survival of periodontal ligament cells and post-replantation periodontal healing (8, 9, 27, 28). The data of the present study underscore the importance of the duration of extraoral dry storage upon periodontal healing. Cases with a short period of <15 min of dry storage showed a high percentage of normal periodontal healing at the 1-year follow-up. Only 9.5% of these teeth presented with replacement resorption compared to 38.5% of replacement resorption in teeth with dry storage of 16–60 min, and compared to 100% of replacement resorption in teeth with dry storage exceeding 60 min.

Similar time-related findings were reported by Donaldson and Kinirons (10). They also found a critical time limit of 15 min of dry storage. They described significantly earlier and more frequent root resorption in teeth with extended dry times. No such time correlation was found when avulsed teeth had been stored wet. The critical time limit of 15 min dry storage was further substantiated in an experimental study of replanted teeth and the progression of associated root resorption (29). In teeth replanted within 15 min the ankylotic area did not increase with time after replantation, but a periodontal membrane was re-established. In contrast, teeth replanted after an extraoral period of 1 h presented with increasing ankylotic areas over time. Most of the periodontal ligament was replaced by bone tissue.

A great number of avulsed teeth (84.4%) in the present study were correctly stored in a physiologic medium. In early 2001, an instruction poster for laymen about first aid measures following oro-facial trauma was distributed among all schools and local authorities in the canton of Berne. Patients, teachers and other caregivers apparently have learned from this information how to store an avulsed tooth. Andreasen et al. (2) found that non-physiologic storage (homemade saline, chloramines, alcohol) always led to root resorption, and storage in tap water for more than 20 min usually led to root resorption. In the present study, three teeth avulsed in indoor swimming pools and, although immedi-

ately stored wet, developed replacement resorption probably due to the deleterious effect of chlorinated pool water.

The frequency of replacement resorption following replantation of avulsed permanent teeth has also been associated with extended splinting times (30). Significantly more teeth with splinting periods of >10 days presented with replacement resorption compared to teeth with splinting periods of maximum 10 days. In the present study, splinting was limited to 10 days, which may have contributed to the favorable outcome of periodontal healing.

As all patients had been treated with topical and systemic tetracycline, the inherent effect of tetracycline cannot be determined with the present study. However, tetracycline may have been an important contributing factor to the favorable treatment outcome. Several experimental studies have demonstrated the beneficial effect of tetracycline with respect to periodontal healing following replantation (12–14). Besides soaking the avulsed tooth in tetracycline or administering systemic tetracyclines, this medicament can further be brought into the root canal, for instance with Ledermix paste. Ledermix also contains a corticosteroid that is a strong anti-inflammatory agent. In dogs (31) roots treated with immediate intracanal placement of Ledermix paste had statistically significantly more healing and less resorption than roots treated with $Ca(OH)_2$. The authors concluded that a possible synergistic effect of tetracycline and steroid components might have provided the favorable outcome. Similar positive findings of using Ledermix in replanted teeth were reported in other experimental animal studies (32, 33). In the future, the focus will be to control and shut down the initial post-traumatic inflammatory reaction that may cause and stimulate processes resulting in external root resorption (34, 35).

The use of EMD for treatment of avulsed teeth has also been analyzed in a limited number of studies. At this time it is impossible to be conclusive about this potentially regenerative material with regard to periodontal healing following replantation of avulsed teeth. In an experimental study of monkeys (36) EMD did not significantly reduce replacement resorption in teeth that had undergone delayed replantation. Similar findings were reported in dogs (37) in which EMD failed to positively interfere with the healing process after replantation of extracted mandibular premolars. In contrast, Iqbal and Bamaas (19) reported a lower incidence of replacement resorption in replanted dog teeth following application of EMD gel compared to teeth without EMD treatment. No clinical data have been published yet about the effect of EMD following replantation of avulsed permanent teeth. Filippi et al. (20) published the results of using EMD for treatment of replacement resorption. Treatment included extraction of a previously avulsed and replanted tooth, and application of EMD gel prior to intentional replantation. Eleven (73%) of 15 treated teeth showed no signs of recurrence of ankylosis after a mean follow-up period of 15 months.

In the present study, EMD was applied in only 10 of 45 teeth. All EMD-treated teeth actually had a prolonged or non-physiologic extraoral storage before replantation. This unfavorable pre-condition was the reason for utilizing EMD. These circumstances might explain why no beneficial effect was found in teeth with EMD treatment in the present study.

Conclusions

1. In the present study, tooth survival at 1 year following replantation of avulsed permanent teeth was 95.6%.
2. Replacement resorption was found in 28.9%.
3. The occurrence of replacement resorption positively correlated with the length of dry storage.
4. Strict enforcement of endodontic treatment kept the risk of infection-related root resorption low (6.7%).
5. Within the limits of the present study, no beneficial effect of using EMD was observed to avoid replacement resorption.

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