

Practicability of a tooth rescue concept – the use of a tooth rescue box

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Abstract – Healing following replantation of avulsed teeth is dependent upon short unphysiologic periods during the extraalveolar phase. A commercially available tooth rescue box was developed and distributed at schools in Hessen, a state in Germany. Aim of the study was to evaluate the availability times of rescue boxes and the storage periods of rescued teeth within the boxes. Two thousand one hundred tooth rescue boxes together with a questionnaire were distributed predominantly at schools. In case of usage of a box, the questionnaire should be filled out by patients and dentists and sent back for evaluation. One hundred seventy-two (8.2%) questionnaires were sent back. Eighteen questionnaires were incomplete. In the remaining 154 tooth rescue boxes, a total of 201 avulsed teeth and tooth crown fragments were rescued. When accidents occurred near a stored rescue box, the availability time was short (median: 5 min). It was significantly longer (median: 35 min) when the location of the accident was distant to a stored box. Storage of avulsed teeth in the tooth rescue box was longer (median: 2 h) than storage of fractured crown fragments (median: 1 h). Lay people (teachers, pupils) used the rescue boxes correctly without professional help or even advice through telephone. The usage of the tooth rescue box seemed to be self-explanatory and plausible to lay persons, very short availability times resulted when accidents occurred near stored boxes. Thus, an excellent healing prognosis can be anticipated after replantation. The storage periods of avulsed teeth before the commencement of treatment exceed by far the periods that are acceptable for alternative but unphysiologic media (saline, saliva, milk). It is concluded that tooth rescue boxes should be distributed at locations prone to tooth traumas (schools, kindergartens, sporting facilities, public pools) to enhance the prognosis of avulsed teeth. Emergency units (hospitals, ambulances) should be equipped with tooth rescue boxes as well as every dentist. Tooth rescue boxes are recommended for families with children.

Healing following avulsion and replantation of teeth is dependent on the extent of damage to the periodontal ligament (PDL) and on the endodontic condition. When the damage is limited to smaller areas, functional healing (FH) with a reestablishment of a PDL may occur (1). When the damage exceeds certain limits, replacement resorption (RR) and ankylosis will result (1). An endodontic infection will induce infection-related resorption (IRR) (2, 3). IRR is related to early tooth loss (2, 4). It can be prevented by immediate extraoral endodontic treatment (5–8). Teeth with RR may survive for years and decades in adults (9, 10). In growing patients, resorption progresses more rapidly, and complete resorption of the root substances must be expected within 3–7 years (9, 10). The teeth get into an infra-position which leads to functional and esthetic problems. Therefore, early removal is often necessary and the survival is limited to months or few years (4, 8, 11, 12). Extensive and sometimes very difficult follow-up therapies are necessary, and the lifelong costs may

be quite high. There was no loss of avulsed and replanted teeth exhibiting FH in two long-term clinical studies (4, 11).

Damage in the PDL of avulsed teeth is primarily related to the conditions during the extraoral phase. Dry storage rapidly leads to cell death in the PDL [for overview, see (13)]. By storage in wet but unphysiologic media (milk, saline, saliva), cell death is delayed, however, progressive and inevitable (14–23). From a clinical study on avulsed and replanted teeth, the probability of FH was calculated in relation to the development of the tooth root [root stage according to Moorrees (24)] and to the extraoral time. It was calculated to be 85% (root stage 6) to 97% (root stage 3) for teeth with an extraoral time of less than 5 min, and decreased rapidly with longer dry storage but also with storage in saline and saliva. Replantation after dry storage for 5–20 min and subsequent storage in saline/saliva for more than 5 min resulted in a healing probability of just 8–36% (Table 1) (25).

Table 1. Probability of healing following avulsion and replantation according to Andreasen (25)

Storage/replantation	Root development			
	3	4	5	6
Dry + wet < 5	97	95	92	85
Dry < 5; wet < 5; 5 < total < 10	84	73	60	45
Dry < 5; wet ≥ 5	60	45	31	20
Dry 5–20; wet < 5	66	51	36	23
Dry 5–20; wet ≥ 5	36	23	14	8
Dry > 20; wet < 5	41	27	17	9
Dry > 20; wet ≥ 5	17	10	5	3

Teeth are usually not replanted at the site of the accident (26). The avulsed teeth should then be stored in the best medium available. Numerous studies investigated a considerable number of potential storage media. The studies showed that only cell culture media completely maintained vitality and viability of PDL cells *in vitro* and resulted in best healing results when used for storage of teeth to be replanted in animal experiments (14, 15, 17–21, 27–34). In clinical studies, the healing results after storage in saline or saliva (25) were disappointing. About 76% of teeth replanted immediately after a dry storage of up to 9 min showed FH. When teeth were stored in saline after an initial dry phase of up to 9 min, the healing rate was 9%. There were no differences between the healing results after storage in saline or in saliva (25). In an actual study after storage in saliva, milk, other media and the tooth rescue box, a high rate of FH was observed 1 year after replantation but no information on a primary dry phase or on the duration of the storage were given (35). In another study, only one of four teeth stored in milk for about 1 h after an initial dry phase of less than 15 min showed FH (36). All avulsed teeth that were stored within 15 min in a commercially available tooth rescue box (Dentosafe®, Dentosafe GmbH, Medice, Iserlohn, Germany; EMT Tooth Saver, SmartPractice.com, Phoenix, AZ, USA) exhibited FH irrespective of the storage duration that was up to 53 h (36). The teeth had been replanted after extraoral endodontic treatment by retrograde insertion of posts to prevent infection-related complications. In some cases, antiresorptive-regenerative therapy (ART) was used including topical application of glucocorticoids and enamel matrix derivative and systemic application of doxycycline (8, 11, 36). The tooth rescue box contains a specially composed medium including aminoacids, vitamins and glucosis. An added protect medium and a preservative allow a shelf life of 3 years at room temperature of the unopened box. The medium was shown to maintain vitality and proliferative capacity of PDL cells for up to 48 h at room temperature *in vitro* (37, 38) and to be successful for storage of avulsed teeth in clinical use (5, 8, 11, 36). Since the introduction and distribution of tooth rescue boxes in parts of Germany, the rate of FH after replantation of avulsed teeth increased to 50% (39).

Aim of the study was to evaluate the practicability of the usage of tooth rescue boxes concerning the

availability time of tooth rescue boxes and the storage duration of rescued teeth.

Material and methods

In 1999, tooth rescue boxes were distributed in schools and some emergency facilities in Hessen, a state in Germany. The boxes were bought by the 'Unfallkasse Hessen', a public insurance for accidents in public areas like schools. They were distributed with the support of the 'Arbeitskreis Jugendzahnpflege (AKJ) für Frankfurt/Main und den Main-Taunus-Kreis', a public dental service of an association of public health insurances, the public health bureau of Frankfurt and dentists.

Two thousand one hundred rescue boxes came along with a questionnaire which should be filled out by patients and dentists and sent back when a rescue box was used. Patients and dentists were offered a tooth rescue box free of charge for every questionnaire that was sent back. Of main interest were the time until an avulsed tooth or a fractured fragment had been put into the rescue box (pregiven time groups: 10–20–30–45–60–more than 60 min), the storage time until commencement of professional treatment (replantation), storage location of the tooth rescue box and location of the accident. It was tried to update incomplete data by telephone interviews with dentists and patients. After 3 years (maximum shelf life of tooth rescue box), the collected data were evaluated. The statistic programme SPSS 10 was used on a WinXP-Computer for descriptive statistics, chi-square and ANOVA calculations.

Results

Of the 2100 distributed questionnaires, 172 (8.2%) were sent back after usage of the tooth rescue box. In 18 cases, information concerning types of injuries and/or number of rescued teeth were insufficient. In the residual 154 tooth rescue boxes in total 201 avulsed teeth and tooth crown fragments were stored.

Availability time – time groups

Availability time is the time period that elapsed between the accident and the storage of the avulsed tooth/the crown fragment in the tooth rescue box. In 166 of 172 questionnaires the availability time groups were marked, and in 154 questionnaires, the storage location of the tooth rescue box and the location of the accident were noted. About two-thirds of the tooth rescue boxes were used within 10 min after trauma (Table 2, Fig. 1). In 131 rescue situations, the storage location of the tooth rescue box was near the location of the accident. Ninety-five (72.5%) rescues were carried out within 10 min, and additional 26 (19.8%) within 11–20 min. Thus, in 92.3% of the accidents, the avulsed teeth/fractured fragments were rescued within 20 min when the accident occurred near a storage location of the tooth rescue box. In 23 rescue situations, the tooth rescue box was stored distant to the location of the accident. The availability times were clearly higher (Table 2, Fig. 2). The differences were significant (chi-square, $P < 0.0001$).

Table 2. Availability time (availTime) of tooth rescue boxes in rescue actions, grouped according to the markings of the pre-given time groups on the questionnaire

	Total	Availability time group (min)											
		Up to 10		11–20		21–30		31–45		46–60		>60	
		n	%	n	%	n	%	n	%	n	%	n	%
All data with given availTime	166	109	65.7	35	21.1	10	6.0	3	1.8	4	2.4	5	3.0
All data complete infos ¹	154	101	65.6	32	20.8	9	5.8	3	1.9	4	2.6	5	3.2
Near ²	131	95	72.5	26	19.8	6	4.6	0	0.0	2	1.5	2	1.5
Distant ³	23	6	26.1	6	26.1	3	13.0	3	13.0	2	8.7	3	13.0

¹Complete information on availability time, location of accident and storage location of tooth rescue box; ²tooth rescue box stored near location of accident; ³tooth rescue box stored distant to location of accident.

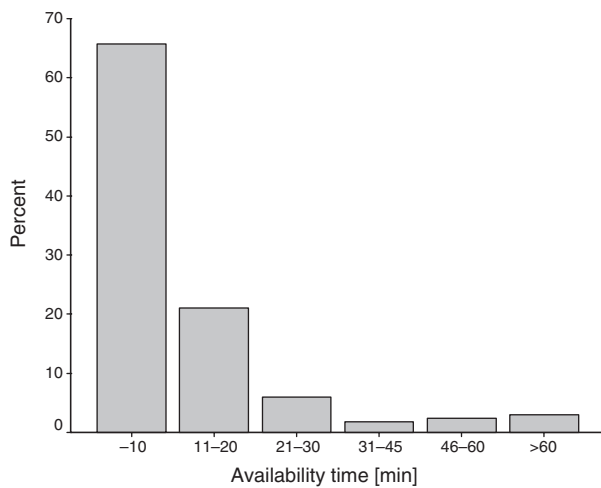


Fig. 1. Availability time of tooth rescue boxes in rescue actions: time between accident and storage of avulsed teeth/crown fragments in tissue culture medium of tooth rescue box. All data with given availability time (n = 166, Table 2).

Availability time – exact time

Beyond the marking of the time groups given by the questionnaire, exact availability times had been noted additionally in 42 rescue actions representing 55 rescued teeth/fragments. The storage location of the rescue box was near the location of the accident in 25 rescue situations (28 teeth). The median of the availability time was 5 min (mean: 9.8 min). In 12 rescue situations (21 teeth), the storage location of the box was distant to the accident. The median of the availability time was 35 min (mean: 41.7 min) (Table 3, Fig. 3). The differences were significant (ANOVA, P = 0.0002).

Location of accident distant to storage of rescue box

The cases were further analysed in which injured teeth were rescued in a tooth rescue box that was not stored near the accident. In four rescue situations (eight teeth), the box was stored in an ambulance that was called after the accident. The availability time was between 11 and 20 min.

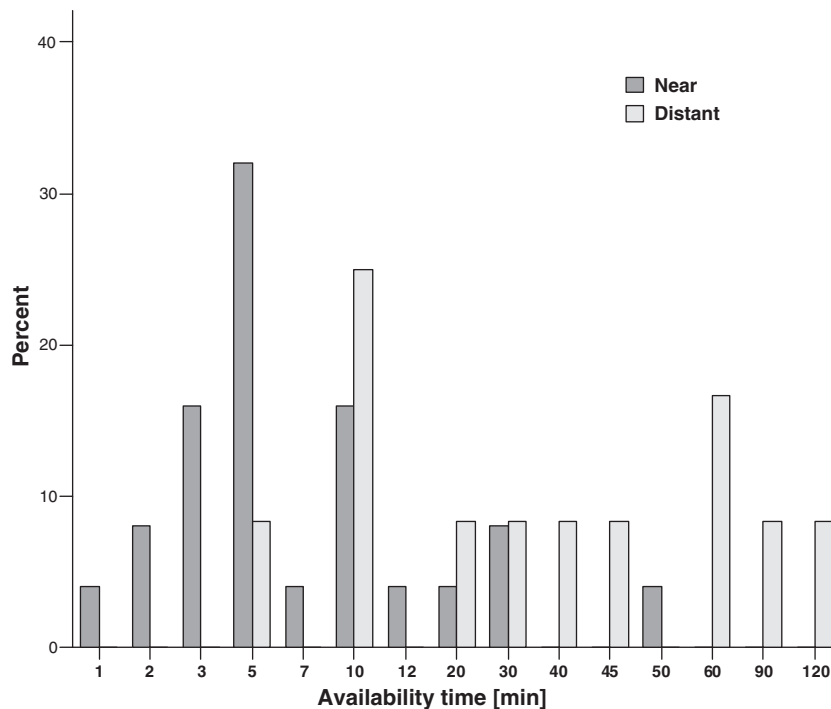


Fig. 2. Availability time of tooth rescue boxes in rescue actions: time between accident and storage of avulsed teeth/crown fragments in tissue culture medium of tooth rescue box, stratified for distance between location of accident and storage location of tooth rescue box (n = 154, Table 2).

Table 3. Detailed availability time of rescue boxes in rescue actions, according to notifications on the questionnaires

	n	Median	Mean	SD	Min.	Max.
All data	42	10	19.07	25.1	1	120
All data, complete infos ¹	37	10	20.16	26.59	1	120
Near ²	25	5	9.84	11.4	1	50
Distant ³	12	35	41.67	35.82	5	120

¹Complete information on availability time, location of accident and storage location of tooth rescue box; ²tooth rescue box stored near location of accident; ³tooth rescue box stored distant to location of accident.

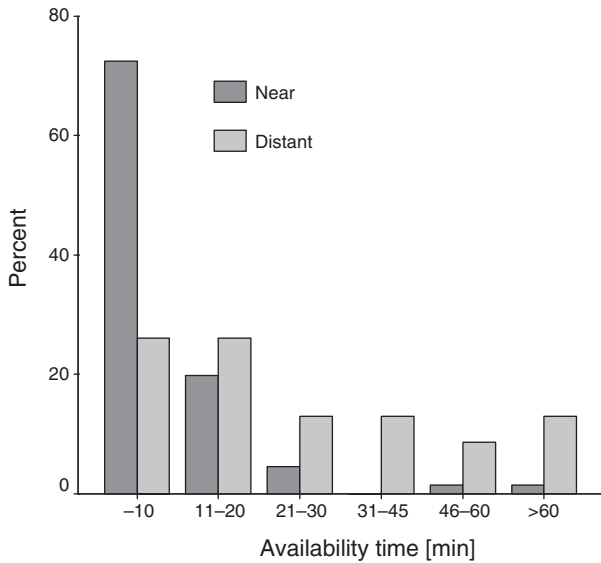


Fig. 3. Detailed availability time of rescue boxes in rescue actions (n = 37, Table 3). Time between accident and storage of avulsed teeth/crown fragments in tissue culture medium of tooth rescue box, stratified for distance between location of accident and storage location of tooth rescue box.

In seven rescue situations (eight teeth), the box was stored at schools or kindergartens; the availability time was between less than 10 and 45 min. The accidents occurred on the way home at the bus stop or in the street near the school or kindergarten. The children remembered that tooth rescue boxes were available at school and transported the avulsed teeth/fragments to the boxes.

In 12 rescue situations (21 teeth), patients sought professional help at a dentist, where the avulsed teeth/fragments were put into the rescue box. The availability time was between less than 10 min and more than 60 min, and in 7 of 12 rescue situations (15 of 21 teeth), the availability time exceeded 30 min (Table 4). The difference between storage location ‘dentist’ and ‘other’ was significant (cross tabulation, Fisher’s exact test, two-sided, P = 0.027).

Storage time

In 89 of 172 rescue actions, representing 123 teeth/fragments, the duration of storage within the tooth

Table 4. Location of accident distant to storage location of tooth rescue boxes. Availability time in rescue actions: time between accident and storage of avulsed teeth/crown fragments in tissue culture medium of tooth rescue box, stratified for storage location of rescue boxes

Storage rescue box	Availability time						Total
	Up to 10	11-20	21-30	31-45	46-60	>60	
Kindergarten	1		1	1			3
School	2	1	1				4
Ambulance		4					4
Dentist	3	1	1	2	2	3	12
Total	6	6	3	3	2	3	23

Table 5. Duration of storage of rescued avulsed teeth/fractured crown fragments in the tissue culture medium of the tooth rescue box until commencement of dental treatment (89 rescue actions)

	Storage (h)							Total
	Up to 1	Up to 2	Up to 6	Up to 12	Up to 24	Up to 48	>48	
n	50	15	10	3	2	6	3	89
% Total	56.2	16.9	11.2	3.4	2.2	6.7	3.4	100.0

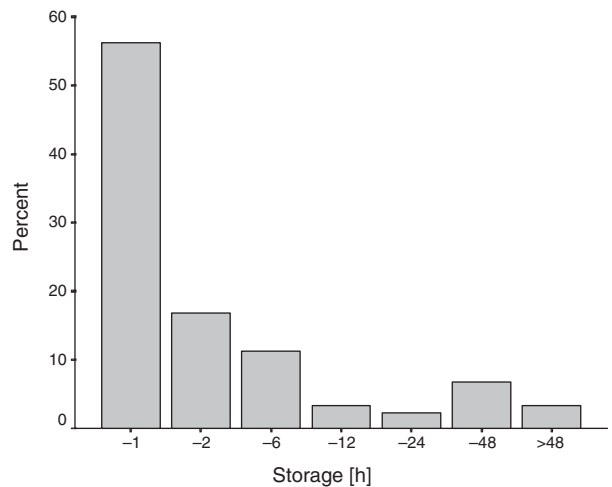


Fig. 4. Duration of storage of rescued avulsed teeth/fractured crown fragments in the tissue culture medium of the tooth rescue box until commencement of dental treatment (89 rescue actions, Table 5).

rescue box until the commencement of dental treatment had been noted on the questionnaires. Storage duration was 10 min up to 54 h (median: 1 h, mean: 10.2 h; Table 5, Fig. 4). Storage of avulsed teeth was longer (median: 2 h) than storage of crown fragments (median: 1 h). The difference was highly significant when grouped storage times were tested against trauma-type (cross tabulation, chi-square, P = 0.00055; Table 6, Fig. 5). A further analysis revealed that 87.5% of avulsed teeth were stored longer than 30 min and more than

Table 6. Duration of storage of rescued avulsed teeth ($n = 53$) and fractured crown fragments ($n = 70$) in the tissue culture medium of the tooth rescue box until commencement of dental treatment (123 rescued teeth/fragments)

Trauma	Storage (h)							Total
	Up to 1	Up to 2	Up to 6	Up to 12	Up to 24	Up to 48	>48	
Avulsion								
<i>n</i>	19	9	10	7	2	5	1	53
% Trauma	35.8	17.0	18.9	13.2	3.8	9.4	1.9	100.0
Fracture								
<i>n</i>	51	10	3	1	0	3	2	70
% Trauma	72.9	14.3	4.3	1.4	0.0	4.3	2.9	100.0
Total								
<i>n</i>	70	19	13	8	2	8	3	123
% Total	56.9	15.4	10.6	6.5	1.6	6.5	2.4	100.0

two-thirds longer than 60 min before commencement of dental treatment (Fig. 6).

Discussion

After avulsion of teeth, an immediate storage in physiologic surroundings is crucial for FH after replantation (25, 35, 36). Such a prompt rescue is not as important for fractured crown fragments since they may be rewetted prior to rebonding for good fracture strength (40). Nevertheless, the data obtained can be used for evaluation of the reaction of lay people in case of losing a whole tooth or parts of it.

The present study evaluates data on accidents and injured persons. The questionnaires had to be filled out by lay people, and were completed by dentists. It may be

speculated that the data obtained by lay people may not be correct. However, the questions were kept simple and the results were consistent: The noted availability times were dependent on the distance between storage location of the rescue box and the location of the accident, as one would expect. 11.7% of the questionnaires were filled out incompletely. Thus, the total number of rescued teeth is at least 219 (201 teeth in 154 boxes + X teeth in 18 boxes). Questionnaires may not have been sent back despite the use of the box. Thus, the quote of usage of 8.2% (172 of 2100 displayed boxes) is a minimal quote.

Only injuries that had been documented by the questionnaires were evaluated. It is unknown how many avulsions/crown fractures occurred and the rescue box was not used despite it was available. This comprises situations where it was unknown that a rescue box was stored nearby, or the box was available but the fragments or teeth could not be found. The necessity of the rescue of fragments or teeth was judged by lay persons. It is understandable that the loss and the rescue of a complete tooth is regarded as more important than a small fractured fragment which additionally is more difficult to find. Thus, no calculations of prevalence or incidence of accidents or tooth injuries are possible and also the ratio of avulsed teeth and crown fragments cannot be compared with other epidemiologic data.

Availability time

About two-thirds of avulsed teeth/crown fragments were rescued in the tooth rescue box within 10 min after the accident, and additionally 20% between 11 and 20 min. As expected, there were significant differences when the data were stratified for the distance between location of accident and storage location of the rescue box. When

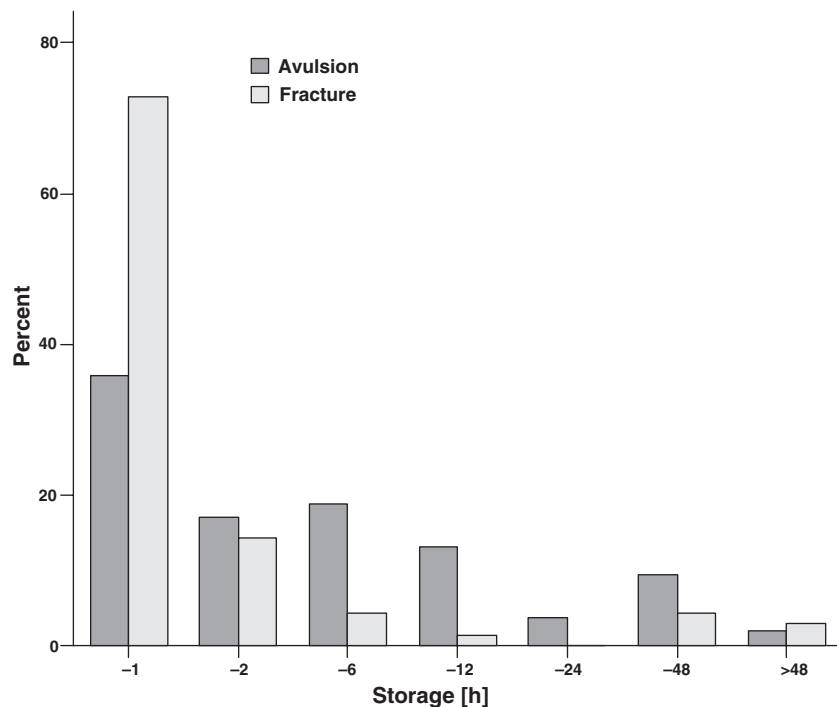


Fig. 5. Duration of storage of rescued avulsed teeth ($n = 53$) and fractured crown fragments ($n = 70$) in the tissue culture medium of the tooth rescue box until commencement of dental treatment (123 rescued teeth/fragments).

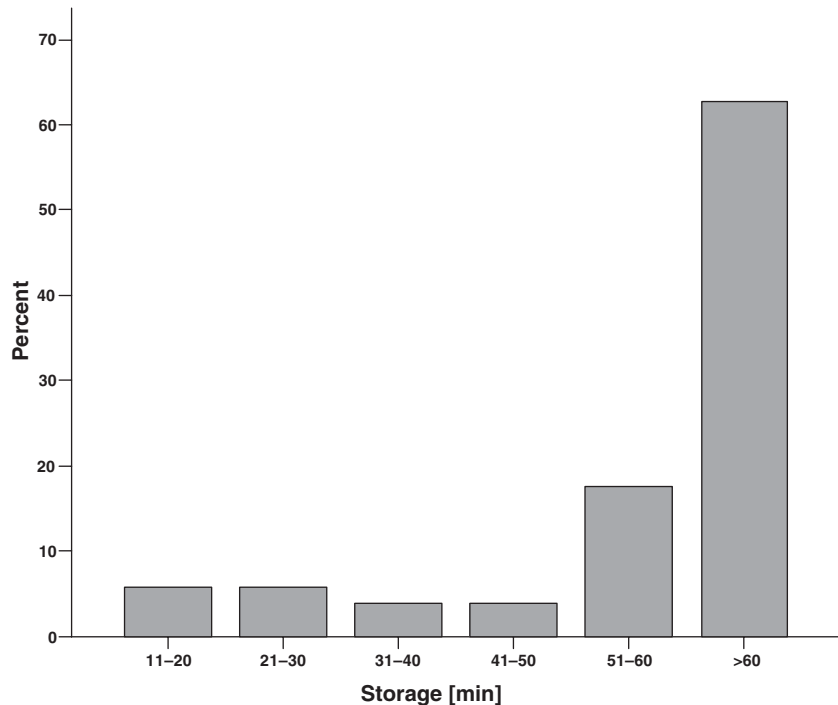


Fig. 6. Duration of storage of rescued avulsed teeth in the tissue culture medium of the tooth rescue box until commencement of dental treatment (32 rescue actions).

the accident occurred near a stored box, more than 72% of the rescue actions were carried out within 10 min, and more than 92% within 20 min. When an additional detailed time was noted on the questionnaires, 60% of the rescue actions were carried out within 5 min, and 80% within 10 min. In few cases, the availability time was longer. This comprised some unlucky situations: Boxes were stored near the accident (here: sporting facility of a school) but not accessible in a training session after official school hours. The housekeeper had to be searched who then opened the locked rescue kit. In another situation it took a lot of time to find a fragment in the pool.

The very short availability time of mostly less than 5 min gives excellent chances for FH when rescue boxes are stored at potential accident sites. The probability of FH for teeth replanted immediately within 5 min after avulsion had been calculated to be 85–97%, depending on the root development stage [Table 1 (25)]. It may be speculated that the storage in optimal conditions for some time before replantation may increase the healing results compared with immediate replantation: while microorganisms and deleterious cell metabolites are kept within the PDL of immediately replanted teeth these substances may be washed out by soaking in the medium. A reconditioning effect may result, and the PDL cells may recover from the initial damage (36, 37, 41, 42). In a long-term clinical study, all teeth that were rescued and stored in the tooth rescue box within 15 min after avulsion exhibited FH after replantation, irrespective of the root development stage and irrespective of the storage duration that was up to 53 h (36). However, the avulsed teeth were treated according to a special concept including extraoral endodontic therapy and ART, and it cannot be definitely decided whether the storage in the rescue box alone could have enhanced the results.

When the boxes were stored distant to the accident, the availability times were much longer. The by far longest were noticed when the avulsed teeth were transported to a dentist where the teeth were put into the rescue box. With storage times of more than 20 and 30 min in unphysiologic circumstances (dry) there are only minimal chances of FH, even with the use of modern ART (36). When an ambulance was called, the teeth were always rescued within 11–20 min, which gives at least some chances of healing. The PDL of these teeth is damaged, but not in a hopeless condition. The use of ART resulted in better healing prognosis in such cases (36). In some instances a tooth injury occurred on the way to the school/kindergarten or on the way home, i.e. at the bus station. The affected children or companions remembered the availability of a tooth rescue box at school, and relatively short availability times resulted.

The very short availability times set focus on the fact that the reactions must have been very fast and correct. Obviously, a short information to teachers on the delivery with rescue boxes resulted in a good transmission of information and a remembrance in case of a tooth trauma – in some instances even pupils of primary schools reacted correctly. The naming ‘tooth rescue box’ seems to be self-explaining and the usage plausible to lay persons. No professional help or even assistance by telephone had been necessary, thus valuable and important minutes could be spared.

Storage time

Predominantly, the duration of storage of fragments/ avulsed teeth was less than 1 hour. When stratified the storage time was much longer for avulsed teeth. Repeatedly, the primarily visited dentists rejected the treatment and sent the patients to dental clinics or surgeons.

Obviously, the dentists judged themselves to overcome the problems with fractured tooth crowns but felt overcharged or uncomfortable with avulsed teeth. Whether they would have reacted in another way when the teeth would have been stored in unphysiologic rather than in optimal conditions remains unknown. The fact is that about two-thirds of the avulsed teeth were stored for more than 1 h, and the median was at 2 h. Storage for these long periods in other media like saline or saliva results in extensive death of PDL cells and deteriorates dramatically the healing chances (25).

Conclusion

Tooth rescue boxes were distributed predominantly at schools; at least 8.2% were used for storage of avulsed teeth or fractured crown fragments. The availability times were significantly dependent on the distance between storage location of the boxes and the location of the accident. With a short distance, very short availability times of mostly less than 5 min were noticed. Thus, an excellent prognosis for the healing after replantation of avulsed teeth can be anticipated. When the accidents occurred distant to the stored boxes, the availability times were much longer and the prognosis deteriorates dramatically. The observed storage periods of avulsed teeth exceeded by far periods that are acceptable for alternative but unphysiologic media (saline, saliva, milk). Tooth rescue boxes should be prophylactically stored at locations prone to tooth traumas: schools, kindergartens, sporting facilities, public pools. Emergency units (hospitals, ambulances) should be equipped with tooth rescue boxes as well as every dentist. Tooth rescue boxes are recommended for families with children.

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