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Results after replantation of avulsed permanent teeth. III. Tooth loss and survival analysis

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Abstract – Avulsed permanent teeth were replanted following immediate extraoral endodontic treatment by insertion of posts from a retrograde direction. Some teeth were rescued in a physiologic environment (tissue culture medium contained in a tooth rescue box), and in some cases antiresorptive-regenerative therapy (ART) was used. The aim of the study was to identify variables that influence the incidence of tooth loss and the survival of avulsed and replanted permanent incisors. Twenty-eight permanent teeth in 24 patients aged 7–17 years were investigated. In all teeth extraoral endodontic treatment by retrograde insertion of posts was performed. All nine teeth with functional healing (FH) were *in situ*. Of the 19 teeth with non-FH, seven were removed to allow transplantations. Two teeth were removed due to severe infrapositions. One tooth was lost following a new trauma. No tooth was lost due to acute infections. In descriptive statistics the incidence of tooth loss was significantly related to healing ($P = 0.0098$, Fisher's exact test), to treatment planning, i.e. consecutive replantation of premolars and primary canines ($P = 0.0001$, Fisher's exact test) and to immediate physiologic rescue ($P = 0.0394$). ART was related to tooth loss when tested in teeth with a compromised periodontal ligament ($P = 0.0389$). No influence could be found for the parameters maturity, age and all other factors. In a regression analysis treatment planning was the only factor left which had a significant influence ($P = 0.0002$). The estimated mean survival time (Kaplan–Meier analysis) for all teeth was 57.3 months. The survival was significantly reduced ($P = 0.0002$, log rank test) when consecutive transplantations were intended and performed. No influence could be found for maturity, age and all other factors. The different findings to previous studies can be explained by the prevention of complications related to conventional endodontic treatment approaches. Statistics have to be carefully interpreted due to case preselection which is determined by the treatment guidelines and actual treatment options of the individual treating dentist.

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Tooth loss following avulsion and replantation is a common problem. Avulsed and replanted teeth may be lost as early as 2 months after replantation (1, 2) or survive for many years (1). According to the progression of root resorption in replanted teeth – as measured on radiographs – a complete resorption of

the root substances takes 3–7 years in patients aged 8–16 years and 'decades' in older patients (3). These findings were later confirmed with the same method by other authors (4). The mean observation periods were 4.8 and 2.5 years respectively. Replanted teeth may be lost long before complete resorption (2, 4), and beyond calculations clinical long-term studies are necessary. Mean and even median values for observation periods or survival rates are unsatisfactory and survival analysis was demanded (5, 6). However, only very few clinical studies gave reasons for the loss of avulsed and replanted teeth and/or presented a real survival analysis or at least data and graphs.

In a clinical study on 110 avulsed and replanted teeth no tooth was lost that had functionally healed (functional healing, FH). About 55% of the teeth that exhibited infection-related resorption (IRR) were lost within the first year after replantation, teeth showing replacement resorption (RR) were lost to a lower extent. The differences were significant for the first year (1). In total, 51 teeth were lost. In the second part of that study, 22 of the extracted 51 teeth were further analyzed. Data were given on the endodontic treatment (extraoral, postponed, none) as well as on the healing types and the retention period. With postponed or without endodontic treatment 10 of 11 teeth showed IRR and also 10 of 11 teeth were removed within the first year, and one tooth after 2 years (median: 3 months). With immediate (extraoral) endodontic treatment six of 11 teeth showed IRR and all teeth had an observation period of at least 24–144 months (median: 45 months) (7).

In a clinical study of 46 avulsed and replanted permanent teeth five teeth were lost due to chronic apical infection, progressive root resorption, secondary infection leading to loss of marginal alveolar bone support (two teeth) and caries destruction at the palatal access cavity. The retention periods were given with 2 months (three teeth), 20 and 82 months but not related to the given reasons for tooth loss. Survival analysis was not performed (2).

In a study on 400 avulsed and replanted teeth with a mean observation period of 5.1 years the overall periodontal healing rate was significantly better in immature teeth (36%, root stages 2–4) than in mature teeth (22%, root stages 5 and 6). However, the rate of IRR was higher in immature teeth (38%) than in mature teeth (28%), but no test on significance was given. A higher rate of tooth loss was found in immature teeth (44%) than in mature teeth (27%), the difference being significant. In total, 30% of the investigated teeth were extracted. The yearly survival rates were given graphically. From these figures it can be estimated that the survival rate 10 years after replantation is about 55% for mature teeth and about 45% for immature teeth. The given healing complications were not put into a relation to tooth loss, and no survival analysis was performed (8).

Fifty-two avulsed and replanted teeth with an extended extra-alveolar duration (more than 5 min) were analyzed. The mean observation period was 30 months (12–70 months). Only teeth with a minimal observation period of 12 months were included. Teeth with additional injuries (crown or root fractures, alveolar fractures) were excluded. Thirteen replants (25%) were lost. The majority failed within the first 2 years but more precise data were not given. Statistics including survival analysis revealed that teeth with a completed endodontic treatment had a higher survival expectation than teeth with a temporary endodontic treatment and that immature teeth had a lower survival expectation than mature teeth. Neither healing types nor distinct reasons for tooth loss were given, and no survival analysis was performed stratifying these factors (5).

In a clinical study on 103 permanent teeth with a mean observation period of 2.5 years 23 teeth were lost. The reasons given were primary epithelial downgrowth (three teeth), cervical resorption (seven teeth), resorption by erupting canine (three teeth), endodontic failure (two teeth), orthodontic considerations (three teeth), new trauma (two teeth), intracoronal resorption after complete RR (three teeth). No data were given on the timing of the occurrence of these complications or on the timing of the tooth loss, and no survival analysis was performed (4).

In a clinical study 24 immature front teeth with pulp necrosis were intentionally replanted. In all teeth extraoral endodontic treatment was performed by retrograde insertion of posts. Eleven teeth (45.8%) were extracted or were in need of extraction after a mean observation period of 62.0 months (max. 170 months). Survival analysis revealed a significant dependence on the presence or absence of a preoperative endodontic infection (9). These findings were confirmed later with a higher number of replants ($n = 40$). Without infection ($n = 12$) all teeth exhibited FH. Two failures were recorded: in one case the inserted ceramic post fractured apically to the plane of resection 105 months after replantation due to a second trauma, and one tooth was removed after 170 months to exclude it as a potential focus in a systemic illness. The mean observation period was 72 ± 51.9 months (15–170 months), and the survival estimation was 148.3 months. The failure rate in teeth with a preoperative endodontic infection was 15 of 28 (53.6%), the mean observation period was

53.6 ± 37.5 months (10–142 months). The estimated survival (75.7 months) was significantly shorter ($P = 0.0132$, log rank test) (10).

Aim

The aim of this study was to identify parameters related to loss and survival expectation of permanent incisor teeth that were avulsed and replanted following an extraoral retrograde insertion of posts.

Material and methods

The standard treatment protocol concerning the endodontic and periodontal treatments of avulsed and replanted teeth is described in detail in the first two parts of this publication (11, 12). The treatment comprised extraoral endodontic treatment by retrograde insertion of posts in all teeth and the use of antiresorptive-regenerative therapy (ART) in some teeth.

All recorded parameters related to trauma, the patient, the treatment, the healing and the loss of the avulsed and replanted teeth (11, 12) were subjected to the analysis.

Descriptive statistics (cross-tabulations), linear regression and survival analysis were performed (SPSS for Windows 10, SPSS Inc., Chicago, IL, USA). Some desirable analyses were not computed due to too less or lacking data in subgroups.

Results

The evaluated 28 teeth had a mean observation period of 31.2 months. Ten teeth were removed after a mean observation period of 33.0 months (±25.0 months). The estimated survival according to a Kaplan–Meier analysis was 57.3 months (Table 1, Fig. 1).

Six teeth were rescued in a physiologic environment (tooth rescue box), and none of these teeth was lost (mean observation: 27.0 months). In contrast, 10 of 22 teeth not immediately rescued

Table 1. Observation periods and survival estimates according to Kaplan–Meier analysis

		Loss		Survival							Observation					
	No. teeth	Extr. teeth	$\chi^2 P$	Surv. mean	SE	95% CI	Surv. median	SE	95% CI	log rank P	Observ. mean	SD	Observ. median	Min	Max	First loss/ extrac.
Total data	28	10	–	57.3	8.8	40.0–74.5	53.4	15.5	23.1–83.7		31.2	24.1	23.8	5.1	100.2	5.1
Healing																
Functional	9	0	0.0098[3]	–[1]	–[1]	–[1]	–[1]	–[1]	–[1]	0.1220	23.1	16.8	16.9	6.6	62.1	–
Complic.	19	10		51.0	9.1	33.1–68.9	44.6	10.1	24.8–64.5		35.0	26.5	25.2	5.1	100.2	5.1
Functional	9	0	0.0216	–[1]	–[1]	–[1]	–[1]	–[1]	–[1]	0.2799	23.1	16.8	16.9	6.6	62.1	–
RR	16	8		51.9	10.7	30.8–73.0	53.4	18.2	17.7–89.2		32.3	27.1	24.1	5.1	100.2	5.1
IRR	3	2		49.5	9.9	30.2–68.8	44.6	10.7	23.7–65.6		49.5	20.9	44.6	31.5	72.5	31.5
Storage																
Physiol.	6	0	0.0394	–[1]	–[1]	–[1]	–[1]	–[1]	–[1]	0.1572	27.0	19.3	16.9	12.4	62.1	–
Unphysiol.	22	10		51.7	9.1	33.9–69.5	44.6	10.1	24.9–64.3		32.3	25.6	24.1	5.1	100.2	5.1
ART																
No	14	7	0.1147	60.6	9.7	41.6–79.5	53.4	16.3	21.6–85.3	0.4145	43.6	28.2	31.2	10.3	100.2	22.0
ART	14	3		28.8	4.0	21.0–36.6	–	–	–		18.8	9.2	17.6	5.1	37.1	5.1
PDL comprom.																
No	8	5	0.0389	49.1	10.7	28.1–70.2	44.6	7.5	29.9–59.3	0.9018	42.4	25.5	31.2	22.0	100.2	22.0
ART	8	1		27.9	2.7	22.6–33.2	24.1	–	–		20.7	7.2	21.9	6.6	31.7	22.0
ART																
No	10	5		62.3	11.5	39.7–85.0	53.4	27.5	0.0–107.3		45.6	31.9	31.2	10.3	100.2	24.1
Box	4	2	0.2881	45.5	8.2	29.4–61.6	44.6	17.3	10.7–78.5	0.6833	38.5	18.7	34.9	22.0	62.1	22.0
ART	14	3		28.8	4.0	21.0–36.6	–	–	–		18.8	9.2	17.6	5.1	37.1	5.1
Consec.																
Transpl.[2]	7	7	0.0001[3]	24.6	6.3	12.2–37.0	24.1	2.8	18.6–29.7	0.0002	24.6	16.8	24.1	5.1	53.4	5.1
No transpl.	21	3		78.8	10.3	58.6–99.0	89.6	33.7	23.5–155.7		33.4	26.1	23.4	6.6	100.2	24.1
Maturity																
Immature	13	6	0.2831	48.3	11.7	25.4–71.2	44.6	13.6	18.0–71.2	0.2740	26.4	24.2	17.8	5.1	89.6	5.1
Mature	15	4		67.2	12.5	42.7–91.8	–	–	–		35.3	24.2	24.1	16.6	100.2	22.0
Healing complic.																
Immature	10	6	0.4977	45.9	12.0	22.4–69.4	44.6	19.5	6.5–82.8	0.5317	30.7	26.1	24.7	5.1	89.6	5.1
Mature	9	4		56.4	14.6	27.9–85.0	31.5	0.6	30.3–32.7		39.8	27.6	30.9	22.0	100.2	22.0

RR, replacement resorption; IRR, infection-related resorption; ART, antiresorptive-regenerative therapy.
[1]No losses, no survival calculation possible.
[2]Only losses in this group; survival = observation.
[3]Fisher's exact test.

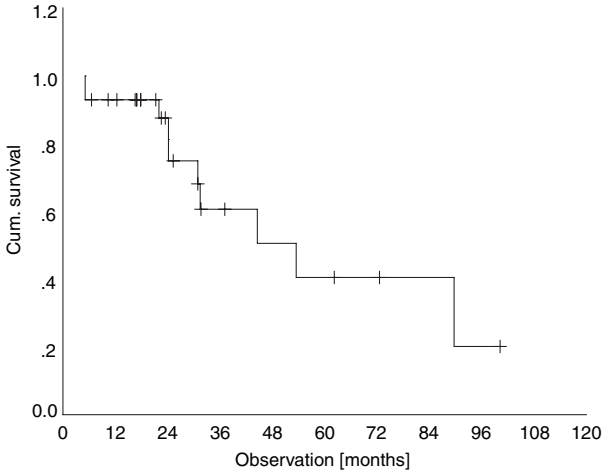

Fig. 1. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. All data.

in physiologic conditions were removed. There was a significant correlation between storage and tooth loss ($P = 0.0394$). As there was no loss in the group with physiologic rescue, no survival expectation could be calculated. Teeth with unphysiologic storage had a mean survival expectation of 51.7 months (Fig. 2).

None of the nine teeth showing FH was lost, the mean observation period was 23.1 months. Nineteen teeth exhibited non-FH (complication). Sixteen teeth showed RR and eight teeth were removed. Two of three teeth with IRR were removed. There were no clinical signs of infection, and the primary reasons for the removal were the infraposition and the planned transplantation of a premolar. Healing (FH vs. complication as well as FH vs. RR vs. IRR) had a significant impact on the removal of teeth ($P = 0.0098$ and $P = 0.0216$ respectively). The mean observation period of teeth exhibiting IRR was longer (49.5 months) than that for teeth with RR (32.3 months). The first loss of teeth with IRR was 31.5 months after replantation, that for teeth with RR was 5.1 months. The survival expectation for both groups was similar (49.5 and 51.9 months, respectively) (Figs 3 and 4).

On 14 teeth ART was used, and three of these were removed. Seven of 14 teeth without ART were lost. The observation periods were 18.8 and 43.6 months respectively. ART seemed to have a positive healing effect when teeth with a compromised but not hopeless periodontal ligament (PDL) were investigated (12). The evaluation of teeth with a compromised PDL revealed that five of eight teeth without ART (mean observation period:

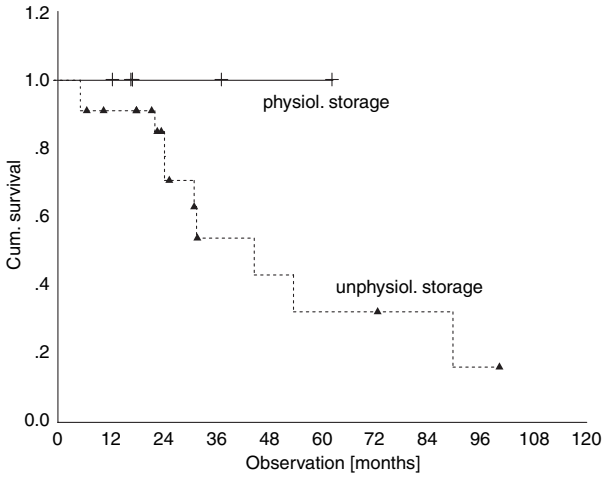

Fig. 2. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for storage conditions: physiologic storage (tooth rescue box) versus unphysiologic storage.

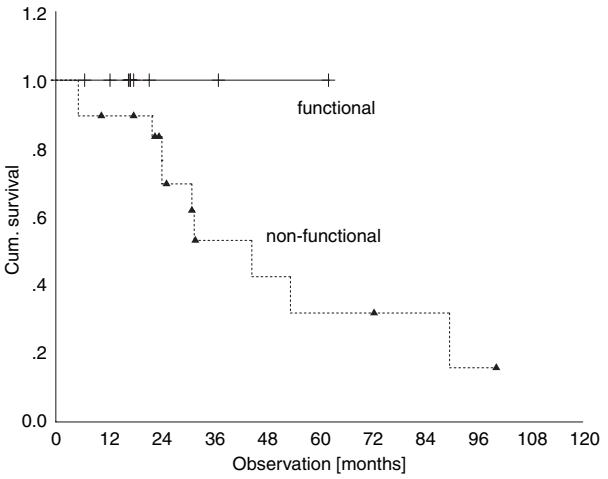

Fig. 3. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for healing type: functional healing versus complication.

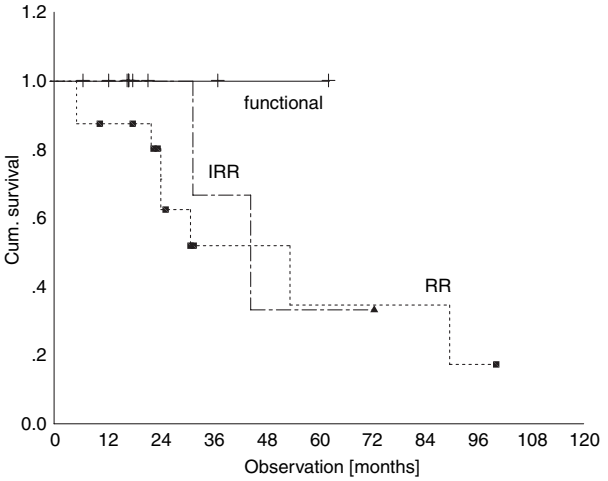

Fig. 4. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for healing type: functional healing versus replacement resorption (RR) versus infection related resorption (IRR).

42.4 months) and one of eight teeth with ART (mean observation period: 20.7 months) were lost. In these teeth with a compromised PDL, ART had a significant influence on tooth retention ($P = 0.0389$).

Six of 13 immature teeth [root stages 2–4 (13)] were lost, and four of 15 mature teeth (root stages 5 and 6). There was a preselection concerning immature teeth. Until recently, immature teeth were only subjected to extraoral endodontic treatment when they were rescued in non-physiologic conditions (11, 12). Therefore, statistical calculations were also performed for teeth only exhibiting non-FH. Six of 10 immature teeth were lost, and four of nine mature teeth. There was no significant correlation between maturity and tooth loss, and the log rank test revealed no difference for the survival expectation, either for all data or for teeth with healing complications (Fig. 5 and 6).

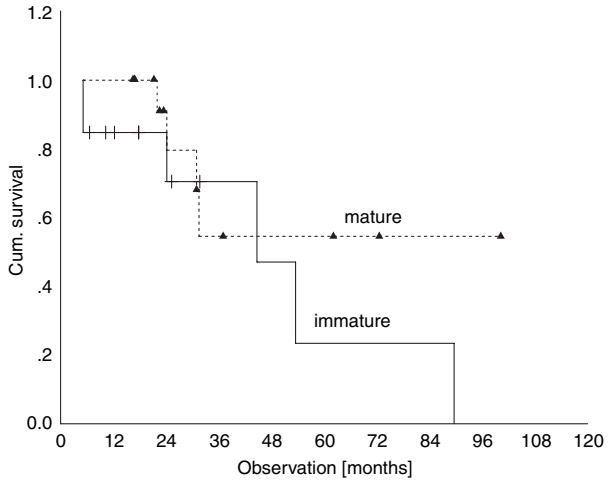

Fig. 5. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for maturity: immature roots (stages 2 to 4) versus mature roots (stages 5,6).

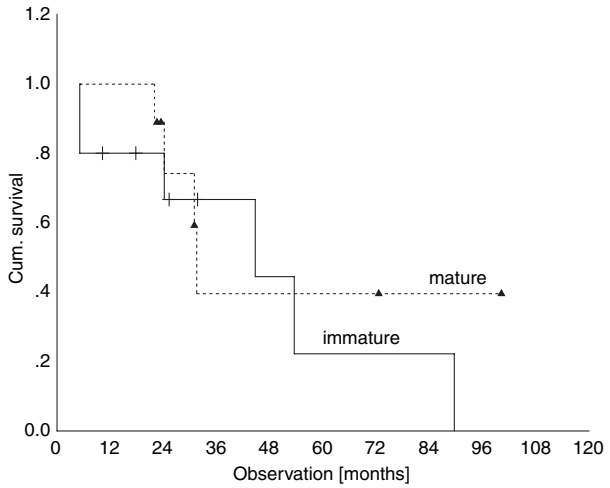

Fig. 6. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Only teeth whixh exhibited non-functional healing. Stratified for maturity: immature roots (stages 2 to 4) versus mature roots (stages 5,6).

To allow transplantations of primary canines or premolars, seven of the lost teeth were removed after 24.6 months (±16.8). Two teeth were removed after survival periods of 44.6 and 89.6 months due to severe infrapositions connected with esthetic and functional problems. One ankylosed tooth was lost after 24.1 months following a severe trauma with a complicated crown-root fracture and dislocations and fractures of two adjacent teeth. No further tooth was lost due to acute or external causes. Transplantation as a consecutive treatment was significantly related to tooth loss, for all teeth as well as for teeth exhibiting non-FH ($P = 0.0001$, Fisher's exact test). The survival expectation for teeth without consecutive transplantation was 78.8 months, that for teeth which were replaced by transplants was 24.6 months (Fig. 7). The log rank test revealed a significant difference ($P = 0.0002$).

There were no other factors related to tooth loss except the use of postoperative antibiotics (cross-tabulation, Fisher's exact test, $P = 0.0410$). No statistical difference in the log rank test was found when the data were stratified for rescue, healing, ART, root maturity and age at replantation (segregating age set to 10, 11, 12, 13, or 14 years, either for all data or for teeth with healing complications alone) or all other factors.

The parameters antibiosis, storage, ART, healing and transplantation were subjected to a linear regression analysis. Only the factor transplantation was left with a significant influence on tooth loss

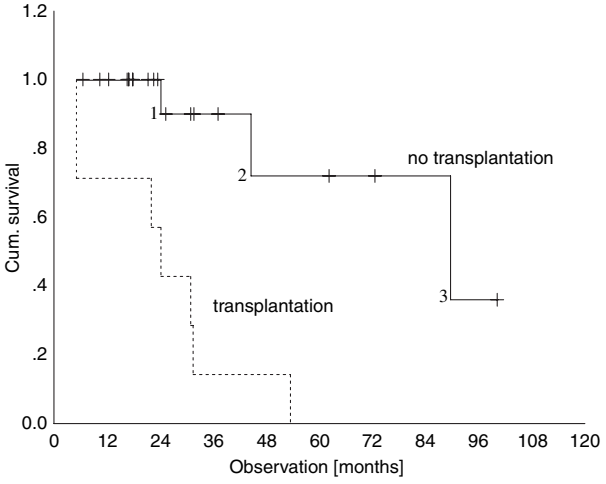

Fig. 7. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for consecutive therapy: transplantation of premolars and primary canines versus no transplantation ($p = 0.0010$). 1: new trauma 2, 3 infraposition.

($P = 0.0002$). Transplantation was significantly related to non-FH (chi-square, $P = 0.0355$).

Discussion

Time has a basic impact on the observation of healing or complication, retention or loss. It takes several days until an IRR gets obvious, and several weeks to months to diagnose RR. Teeth may be lost as early as 2 months after replantation (1, 2) or may be retained for many years even when they exhibit RR (1, 3, 4). Mean and even median values of observation periods or survival rates are inadequate, and survival analysis is requested (5, 6). Unfortunately, in dental traumatology very few studies present a survival analysis, and despite the obviously dramatic impact of healing on tooth loss/tooth removal only one clinical study investigated and documented the negative influence of an endodontic infection on the survival expectation of replanted teeth (9, 10).

Healing

In the present study healing following avulsion and replantation correlated with the removal of teeth on a significant level in descriptive statistics. No teeth exhibiting FH were lost, while 10 of 19 teeth with healing complications were removed. This finding is basically consistent with the data presented in a study of Andreasen and Hjörting-Hansen (1). In that study all teeth with FH were retained, while 61% of the teeth with healing complications were removed or lost. However, in that study distinct reasons for tooth loss were not given. The results are also consistent with the data from a long-term clinical study on intentional replantation of immature teeth with pulp necrosis in which the same extraoral endodontic treatment by insertion of posts was performed (10). There were two losses out of 12 teeth exhibiting FH. However, these losses were due to external reasons and occurred 8 and 14 years after replantation. In contrast, teeth exhibiting healing complications were lost to a rate of 53% in connection with much shorter observation periods. No other studies present in the literature analyzed the correlation of healing and tooth loss or presented data for a reevaluation.

In the present study no teeth exhibiting FH were lost. However, they had shorter mean observation periods than teeth exhibiting complications. This is due to the fact that FH is predominantly dependent on physiologic rescue, i.e. on the availability of the tooth rescue box. Teeth with long observation periods were replanted before the development and distribution of the rescue box. It may also be speculated that teeth with FH may get lost with longer observation periods. This is basically true, and in fact in a study on teeth treated with the same endodontic method but in the indication 'intentional replantation' losses were observed. However, they were related to 'external' reasons and occurred very late. In that study the teeth exhibiting FH had quite long mean observation periods (72 months) and survival estimations (148 months). We conclude that avulsed and replanted teeth which show FH for 6–12 months will have a good prognosis for long-term retention but of course will be at risk for a traumatic injury or caries like a sound tooth.

The type of complication has impact on the loss and survival of avulsed and replanted teeth. In the study by Andreasen and Hjörting-Hansen (1) more than 50% of the teeth exhibiting IRR were removed within the first year after replantation while the loss rate was <10% for teeth with RR, and tooth loss was significantly related to healing in this first year. In contrast, in the present study, few teeth showed IRR, and the first loss was after more than 30 months. Mean and median observation periods of teeth with IRR were even higher than those for teeth with RR, and in a chi-square test there were no differences between RR and IRR when tested against tooth loss. This emphasizes that IRR may be seen as an end point of a preceding RR in certain cases. There are different entities of IRR and it is very important to prevent the establishment of an early occurring IRR (11). This conclusion is supported by data from the second part of the study of Andreasen and Hjörting-Hansen (7). Avulsed teeth replanted after extraoral endodontic treatment and showing IRR were extracted later than teeth treated in the same way but showing RR (discussed in 11).

In the present study no further differentiation into the types of IRR (e-IRR, t-IRR, cRR-CR) was performed for statistical evaluation due to the shortage of cases. However, with higher case numbers such a calculation would be of interest. When healing was tested in a survival analysis the log rank test revealed no significant differences. This may be due to the low case number and the different observation periods in the subgroups. Furthermore, teeth exhibiting complications, especially RR and cRR-CR, may be retained for many years. Much longer observation periods may be needed to establish significant differences in survival analysis for teeth with FH and with infection-free complications.

Healing was significantly related to physiologic rescue and the use of ART in the present study (12). These factors also had a significant impact on the retention of teeth. However, there was no significant relation to the survival expectation which also may be due to different observation periods in subgroups, low case numbers, and too short observation periods.

Treatment planning – transplantation

In growing patients RR/ankylosis results in a specific 'consecutive' or 'follow-up complication'. The teeth get into a progressive infraposition which leads to functional and esthetic problems. To prevent these complications the early removal of ankylosed teeth at a time when root substances are still present and eventually the transplantation of premolars or primary canines are an option. In our clinics seven ankylosed teeth were removed as soon as a transplantation was possible according to orthodontic considerations, predictability of success (root stages) and compliance of patients and their parents. Two teeth were removed due to progressive infrapositions but without consecutive transplantations. In most cases the teeth were removed when the root substances were not yet completely resorbed. With the focus just on the teeth a further retention would have been possible, and the removals may then be seen as early or premature. No studies to date have addressed this premature removal or related it to tooth loss and survival. However, in the present study the decision toward a consecutive treatment, i.e. transplantation of premolars or primary canines, was of overwhelming impact on the removal of teeth. According to the regression analysis and survival statistics, this decision was the only factor with a significant influence on tooth loss and survival expectations. With a more frequent use of some new methods like decoronation (14, 15), intentional replantation with the use of emdogain (15, 16) and the transplantation of primary canines (15, 17) the impact of a decision concerning the consecutive treatment of ankylosed teeth in growing patients will even increase. Survival is therefore profoundly influenced by available treatment options. This will have to be considered in statistical evaluation in future studies and in the comparison of studies from different centers or different periods.

Ankylosing teeth in grown-up patients will not get into infrapositions, and therefore there is no indication for a premature removal. Thus the end of growth must be seen as one important borderline and should be considered in evaluations.

Only one tooth was removed in a more or less acute situation following another trauma. No removal was necessary due to acute infection-related complications which would dictate an immediate treatment. Nine of ten teeth were removed in planned operations. A statistical evaluation seemed to be pointless because of the single case with an 'acute' loss. However, with higher case numbers descriptive as well as survival statistics should be performed stratifying for acute or planned tooth loss and stratifying the acute cases for 'internal' (endodontic-related = infection-related) and for 'external' (new trauma) factors.

Besides the named reasons several other factors may result in tooth loss: epithelial downgrowth is another primary healing complication but rare (4). There are some additional 'external' reasons such as resorption by erupting neighboring teeth or caries (2, 4, 18). In the present study none of these were observed.

Maturity

In clinical studies avulsed and replanted immature teeth were lost more often and had a lower survival expectation than mature teeth (5, 8). This was shown when immature teeth were compared with mature teeth in adolescents and adults (8) and also when the comparison was restricted to the more homogenous group of growing patients (5). In these studies teeth were subjected to conventional endodontic treatment methods, or revascularization was awaited. No distinct reasons for the losses were given. However, in teeth without immediate (extraoral) endodontic treatment, IRR had a higher incidence (8) in immature compared with mature teeth, and IRR was significantly related to early tooth loss (1). Additionally, apexification, the standard endodontic treatment protocol in immature teeth that exhibit pulp necrosis, is a long-lasting procedure. Temporary endodontic treatments are significantly related to a shorter survival expectation compared with completed endodontic treatments (5). The incidence of cervical root fractures is very high in 'luxated' immature teeth compared with mature teeth, and these fractures occur very early (18). The progression of RR is significantly faster in immature teeth than in mature teeth in adults, however comparable with that of mature teeth in adolescents (4). This again emphasizes that the end of growth seems to be a borderline that should be considered.

In the present study no differences could be found between teeth with immature and mature roots concerning the rate of tooth loss or survival expectation. This is even more embarrassing when taking into account that immature teeth rescued in physiologic environment were mostly not subjected to extraoral endodontic treatment and therefore excluded from the present study (12). Because of this negative preselection of immature teeth the statistics were calculated for teeth exhibiting healing complications, and again there were no differences.

The different results in the literature and in the present study can be explained by the different endodontic treatment protocols. In contrast to the conventional approach, the immediate definite endodontic treatment prevented an early occur-

rence of IRR (11) and therefore the reason for early tooth loss. The incidence of (late occurring) IRR was equally low in immature and mature teeth (12). No cervical root fractures were observed (11).

The results of the present study indicate that immature teeth do not show a higher incidence of tooth loss or shorter survival expectation *per se* compared with mature teeth in growing patients. However, typical complications (IRR, cervical fractures) result to a higher extent when immature teeth are subjected to conventional endodontic treatments.

Statistics stratifying for maturity, and also for age, have some basic restrictions. Since 1997 in our clinics transplantations of primary canines are used to replace permanent front teeth that are lost or show non-FH. Primary canines are suitable in the age of about 6–10 years. Therefore, immature permanent front teeth can always be replaced by a transplant immediately or delayed. In elder patients premolars might be used as transplants. However, premolars have an optimal root stage and immediate transplantation is not always sensible or transplantations may not be possible at all due to orthodontic considerations. These reflections have some implications: (i) Instead of replanting an immature incisor with bad PDL conditions the transplantation of a primary canine can be performed. In fact this is the treatment option that is preferred in our clinics – a process carried out in six cases to date. In contrast, the decision toward the transplantation of premolars needs a thorough orthodontic examination as well as the consideration of the root stages. Therefore, when the transplantation of a primary canine is not possible (already lost, extensive root resorption), in our clinics the replantation of incisors is performed even when RR/ankylosis is predictable to immediately restore esthetics, to maintain the tissues and thereby facilitate a possible premolar transplantation later. Hence there may be a preselection toward the replantation of immature teeth with better PDL conditions than mature teeth, and this may give better healing results and possibly longer survival periods of immature teeth. (ii) If RR/ankylosis in avulsed and replanted immature teeth is observed an immediate extraction and consecutive transplantation of a primary canine is always possible, while ankylosed mature teeth may be retained for longer periods before a transplantation of premolars is possible or a removal due to a progressive infraposition gets necessary. This will result in shorter observation periods and shorter survival expectations of immature teeth. In fact in the present study the first removal of immature teeth to be replaced by primary canines was as early as 5.1 months after replantation, while the first removal to enable premolar transplantations was after 22 months. (iii) Within the group of mature teeth there may be grown-up patients, growing patients after and before the growth peak. This means that the degree and progression of infrapositions will be very different. Besides medical aspects, the individual attitude toward (compromised) esthetics may indicate the necessity for extraction. The attitude itself may depend on age, gender, and also on the visibility of the compromised 'red esthetics', i.e. on the level of the lip line. Immature teeth will always be replanted before the growth peak, resulting in extreme infrapositions. In the present study all replanted and ankylosed immature teeth were removed due to their infraposition about 7 years at the latest, while an ankylosed mature tooth was still *in situ* beyond that observation period.

In summary, the timing of removal and therefore the survival of replanted teeth seem to be much more dependent on 'external' factors rather than on maturity. Especially the survival of ankylosed teeth free of infection-related complications is primarily dependent on patient-related factors (growth pattern, attitude to esthetics) as well as dentist-related factors (individual guidelines for replantation and transplantation, operative options). Stratifying tooth loss for the factor maturity may, however, be helpful in the evaluation of endodontic treatment methods in replanted immature teeth concerning the prevention of early occurring complications that are related to early tooth loss (e-IRR, cervical root fractures). The criterion would be the rate of tooth loss during the first 1 or 2 years after replantation. Teeth exhibiting FH and teeth that were removed due to 'external' reasons (i.e. consecutive transplantation) should be excluded due to their predominant and significant influence. Under these conditions, no tooth was lost during the first 2 years in the present study, either mature or immature. The used extraoral insertion of posts sets a high standard especially in immature teeth. The results of other new treatment methods (temporary endodontic filling with i.e. Ledermix® (Lederle Pharmaceuticals, Wolfratschausen, Germany) paste instead of calcium hydroxide, one-step-apexification with i.e. MTA) will be of interest.

Conclusion

Following avulsion and replantation in children and adolescents the incidence of tooth loss was significantly determined by the healing type. Having significant impact on healing (12), physiologic rescue and ART were also significantly related to tooth retention. Of predominant influence on tooth removal was the factor consecutive transplantation,

which was itself related to non-FH. It was the only factor with significant relation to tooth loss in a regression model and in survival analysis. FH should be supported by physiologic tooth rescue (tooth rescue box) and by ART (glucocorticoids, tetracyclines, enamel matrix derivative). Complications related to conventional endodontic protocols should be prevented by predictably successful endodontic therapy (immediate extraoral insertion of posts). The maturity of teeth was not a predictor for tooth loss or survival *per se* which is in contrast to the findings in other studies. The difference seems to be related to the different endodontic treatment protocols.

It is claimed that future publications should give survival analyses beyond descriptive statistics. Data stratification should include healing types and distinct reasons for tooth loss ('internal', i.e. endodontic infection; 'external', i.e. consecutive treatment, new trauma). The end of growth and possibly the individual growth peak should be variables, the maturity of teeth may be considered additionally. Factors influencing healing – rescue modalities, treatment variations – need to be tested. Multicenter studies are necessary to establish a sufficient data basis.

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