The risks of ankylosis of 89 avulsed human teeth stored in saliva prior to replantation—A re-evaluation of a long-term clinical study

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Abstract

Background/Aim: The survival of an avulsed tooth highly depends on the emergency management. The aim of this study was to evaluate the risk of ankylosis for avulsed human teeth stored in saliva preceded by various dry storage conditions prior to replantation.

Material and methods: Data include 74 patients (54 male and 20 female) with 89 avulsed and replanted teeth (16 immature teeth, 73 mature teeth). Patient ages ranged from 6 to 36 years (median: 13.0 years). All teeth were stored in saliva before replantation. Treatment and follow-up were performed according to a standardized procedure. Follow-up periods ranged from 7 months to 20 years (mean 5.3 years). The risk of ankylosis over time was estimated by the Aalen–Johansen method in relation to the length of dry storage and the stage of root development. The effect of risk factors (root development and length of dry time) on the risk of ankylosis was analysed by Cox regression analysis.

Results: For mature teeth, dry storage for 5 min or less before saliva storage resulted in a 47.4% (95% confidence interval (CI): 32.8–60.7) ankylosis rate. When dry storage was >5 min and <20 min, the risk of ankylosis was 76.8% (95% CI: 45.7–91.5). When dry storage exceeded 20 min prior to saliva storage, ankylosis increased to 89.3% (95% CI: 68.0–96.7). Ankylosis also increased with increasing saliva storage time. Specifically, one additional minute of wet time increased the ankylosis hazard rate (HR) by approximately 1% (CI = [0%, 2%], p = .052). Teeth with mature root development were significantly more frequently affected by ankylosis than teeth with immature root development (HR: 2.4 (95% CI: 1.0–5.5), p = .04).

Conclusion: Temporary storage in saliva should be encouraged if an avulsed permanent tooth cannot be immediately replanted or a suitable storage medium such as milk or saline is not immediately available at the place of the accident.

Keywords
ankylosis, avulsion, dental trauma, prognosis, replacement resorption, saliva
1 | INTRODUCTION

Avulsion of permanent teeth is one of the most serious traumatic dental injuries. Avulsed permanent teeth should ideally be replanted as soon as possible,1,3 and long-term dry storage should be avoided as it will damage the periodontal ligament (PDL) cells and compromise normal healing.1 If an avulsed permanent tooth cannot be replanted at the site of accident, it is important to store the tooth in a suitable storage medium to preserve the viability of PDL cells prior to replantation.1 Numerous storage media such as saliva, saline, balanced salt solution and milk have been recommended and used in guidelines.1-8 Several studies have recommended milk as the best first choice.2,4,7,8 In addition to these storage media several alternative media such as propolis, cling film, rice water, coconut water, cell culture media and rehydration salts have also demonstrated some efficacy in preserving cell viability.9-19 A storage medium that is always available at the place of accident is the patient’s saliva. It has been recommended as a storage medium and has been included in guidelines for several decades.2 Saliva, however, does not have the same optimal osmolality as milk or saline,4,13 and it contains microorganisms that may damage the PDL in case of long-term storage. In contrast, saliva has been reported as a suitable storage medium for shorter periods of time in the patient’s mouth.4,6,9,10,11,13,16 However, order to avoid the risk of aspiration or swallowing the avulsed tooth, the patient can spit into a cup and the tooth can be placed in that cup.2-3

In vitro studies have clarified how cells react to different storage conditions in general.1,3,5-9,20 Other in vitro studies have suggested that storage in saliva may contribute to the healing of PDL cells.4,6,11,13,21 Several in vivo studies have been conducted in various experimental animals. It was found that storage in saliva for up to 2 h was as effective as storage in saline for the prevention of ankylosis.16 Other replantation studies in monkeys have reported the same protective effect.11 In another study in monkeys, 2 h storage in saliva prior to replantation resulted in PDL healing.9

Although experimental in vitro and in vitro studies are important to learn about the healing of cells and tissue, clinical studies on tooth replantation in humans are important to achieve a higher level of evidence and should be encouraged.22 Very few clinical studies have been conducted on human teeth stored in saliva prior to replantation.21,23,24 Case reports have reported that teeth stored in saliva for several hours after the accident healed without root resorption after long-term follow-up.14,15 A long-term clinical study from Copenhagen on 400 replanted teeth indicated a potential for long-term survival of teeth stored in different media.25 A recent comprehensive review showed that there is insufficient evidence to recommend saliva versus alternative solutions for temporary storage of an avulsed tooth.7 Hence, more specific clinical studies on human teeth stored in saliva prior to replantation are needed. Clinical situations are typically characterized by an initial dry storage period followed by storage in a medium, so many factors must be taken into consideration. However, healing with normal PDL is less likely when the PDL has been severely damaged - for example, due to long-term drying.1,3,17,23,28-40 In such situations, bone will grow in contact with the root, and the tooth will be fused with the alveolar bone, so-called ankylosis.1,36-40 This is a progressive condition resulting in gradual replacement of the tooth by bone, a process termed replacement resorption. Replacement resorption will progress until the tooth is completely replaced by bone. Ankylosis and replacement resorption cannot be treated, and hence, this condition cannot be stopped. For this reason, ankylosis has been shown to be the best predictor of unfavourable healing and an unfavourable outcome.22,40

The aim of this study was to evaluate the risk of ankylosis for avulsed human teeth stored in saliva.

2 | MATERIAL AND METHODS

The material for this study was extracted from an existing database at the Department of Oral and Maxillofacial Surgery, University Hospital, Copenhagen, Denmark, which included 400 replanted permanent incisors from 322 patients. Data were collected from 1965 to 1988. The permanent teeth were replanted and followed for up to 20 years.41 The methodology and results of this large material have been published elsewhere.22,41-44 In the following, a summary of the methods of relevance for the present study is presented.

The standardized clinical protocol for avulsed teeth at the University Hospital of Copenhagen was followed. The protocol stated that the avulsed teeth were to be placed in physiological saline (0.9%) as soon as the patient arrived at the emergency ward. If the tooth was obviously contaminated, it was cleansed with a flow of saline from a syringe. The tooth was then replanted into its socket by digital pressure. No effort was made to remove the coagulum before replantation. Splinting was performed with either cemented orthodontic bands united with acrylic (rigid) or acid etched labial crown surfaces united with a flexible resin (Protemp® 3 M ESPE, Germany). Splinting periods ranged from 2 to 6 weeks. Phenoxymethylpenicillin, adjusted to the weight of the patient, was administered orally for 5 days, starting on the day of the injury. In teeth with complete root formation, endodontic treatment was initiated by placing calcium hydroxide inside the root canal within 14 days after the injury and the canals were later filled with gutta-percha followed by a coronal composite filling. Teeth with immature root development were observed, and endodontic treatment was performed if there were signs of pulp necrosis and infection or infection-related (inflammatory) root resorption. One week after the injury, the patients and their parents were contacted to check and further supplement the information given during the initial emergency service to achieve the highest possible accuracy of data about the injury conditions, such as storage conditions and storage time. Exclusion criteria were previous endodontic treatment, previous trauma, destruction of the crown caused by dental caries or restorations, the presence of a concomitant crown fracture with pulp exposure, root fracture or alveolar fracture. The standard follow-up programme included clinical and radiographic reviews after 1 week, 2-3 weeks, 4 weeks, 6 weeks,
The stage of root development was determined by evaluation of radiographs from the initial examination and classified into one of the following six stages described by Moorrees et al:\textsuperscript{46}: ¼ root formation, ½ root formation; ¾ root formation; full root formation with wide open apex; full root formation with ½ closed apex; and full root formation with closed apex. The material in the present study was divided into two sub-groups: immature root development (stages 1–5) or mature root development (stage 6). Ankylosis-related resorption was diagnosed when one or more of the following clinical signs were present: high-pitch percussion sound, absence of mobility and infra-position of the tooth in growing individuals. Radiographic signs of replacement resorption later verified the clinical diagnosis of ankylosis. Mobility was measured using a modified Mühlemann periodontometer.\textsuperscript{57}

For the present study, which focused on storage conditions and ankylosis, the following inclusion criteria were applied: tooth stored in saliva prior to replantation, presence of tooth-specific clinical information and radiographs from the time of injury and the subsequent controls according to a standardized protocol. Furthermore, a minimum of 1-year follow-up was carried out unless early complications had necessitated extraction before that time. All data used in the present study were obtained in a clinical context as part of a standardized treatment regime with full acceptance from the parents (oral consent) and are fully in line with the World Medical Association's Declaration of Helsinki from 2013. By Danish law, this study is considered a ‘quality assurance follow-up study’ (i.e. all data were obtained in a clinical context and/or as part of a standardized treatment protocol), and the study thus did not qualify for evaluation by a research ethics committee. In the present data set, it was not possible to track any individual patients.

Statistical methods: Survival analysis was applied to analyse the risk of ankylosis because the follow-up period varied among patients. The risk of ankylosis was estimated using the Aalen-Johansen method\textsuperscript{48,49} accounting for the competing risk of tooth loss. The 3-year risk of ankylosis with 95% confidence limits is reported separately for teeth with immature and mature root development and in relation to the dry-storage period. It has previously been reported that the two most decisive factors for ankylosis are the length of dry time and the stage of root development. Due to the limited number of patients in the study, it was therefore decided to only include these two factors in the multivariate analysis. Risk factors for ankylosis were analysed by cause-specific Cox regression models for the hazard rate of ankylosis and the hazard rate of tooth loss without ankylosis, respectively.\textsuperscript{50} Reported were hazard ratios and 3-year risks of ankylosis according to all combinations of risk factors. Risk factors included in the analysis were the length of dry time and the stage of root development. The effect of increasing the wet storage time on the hazard rate of ankylosis was analysed in the subset of the data including only teeth for which the dry storage time was below 6 min. The level of significance was set at 5%. All analyses were performed with the statistical software RR Core Team 2020.\textsuperscript{49}

### Results

The material comprised 74 (54 male and 20 female) patients with 89 avulsed and replanted teeth that had all been placed in saliva prior to replantation. The median age of the patients was 13.0 years, ranging from 6 to 36 years. Table 1 shows the distribution of the saliva-stored teeth related to patient, age, gender and tooth type. Most teeth were maxillary central and lateral incisors (84 teeth). The period the avulsed tooth was placed in saliva (wet storage) ranged from 1 to 150 min, with a mean period of 35 min. The distribution of mature and immature teeth in relation to dry-storage period is presented in Table 2. Mature teeth comprised 82% of the material.

![Image](https://via.placeholder.com/150)

**Table 1** Distribution of patient age and gender

<table>
<thead>
<tr>
<th>Age 0–10 years</th>
<th>Male n (%)</th>
<th>Female n (%)</th>
<th>Total n (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 0–10 years</td>
<td>19 (28.4)</td>
<td>5 (22.7)</td>
<td>24 (27.0)</td>
<td></td>
</tr>
<tr>
<td>Age 11–15 years</td>
<td>21 (31.3)</td>
<td>9 (40.9)</td>
<td>30 (33.7)</td>
<td></td>
</tr>
<tr>
<td>Age more than 15 years</td>
<td>27 (40.3)</td>
<td>8 (36.4)</td>
<td>35 (39.3)</td>
<td>.7013</td>
</tr>
</tbody>
</table>

**Table 2** Distribution of teeth in relation to stage of root development and dry time period

<table>
<thead>
<tr>
<th>Dry time period</th>
<th>Immature n (%)</th>
<th>Mature n (%)</th>
<th>Total n (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5 min</td>
<td>9 (56.2)</td>
<td>44 (60.3)</td>
<td>53 (59.6)</td>
<td></td>
</tr>
<tr>
<td>6–15 min</td>
<td>0 (0.0)</td>
<td>12 (16.4)</td>
<td>12 (13.5)</td>
<td></td>
</tr>
<tr>
<td>&gt;15 min</td>
<td>7 (43.8)</td>
<td>17 (23.3)</td>
<td>24 (27.0)</td>
<td>.0952</td>
</tr>
</tbody>
</table>

**Figure 1** shows the overall risk of ankylosis over time. Overall, 40% of the teeth that had been stored in saliva prior to replantation showed healing without ankylosis. In most cases, ankylosis was diagnosed during the first year after replantation. However, some teeth were not diagnosed as having ankylosis until 2–3 years after the trauma. After 3 years, no new cases of ankylosis were diagnosed. Progress of ankylosis with replacement resorption over time was
seen in all cases where ankylosis was diagnosed and no cases were reversible.

Figures 2–4 show examples of cases where teeth which had been stored in saliva healed without ankylosis even after the teeth had been stored in saliva for long periods of time.

Table 3 shows the risk of ankylosis estimated after 3 years of observation in relation to dry-storage and stage of root development. Figure 5A shows the risk of ankylosis over time in relation to the stage of root development and Figure 5B shows the risk of ankylosis over time in relation to the dry-time period.

Table 4 shows the Cox regression analysis including the risk factors dry-storage period and stage of root development. Increasing the dry storage time from 5 min or less to 6–20 min significantly increased the risk of ankylosis (HR: 2.25 (95% CI: 1.03–4.89) \( p = .04 \)).

Increasing the dry time to more than 20 min increased the risk even more (HR: 3.40 (95% CI: 1.81–6.37) \( p < .001 \)). Furthermore, teeth with mature root development were significantly more frequently affected by ankylosis than teeth with immature root development (HR: 2.4 (95% CI: 1.0–5.5), \( p = .04 \)).

A separate analysis of the effect of wet time was conducted for 53 teeth that had been stored dry for 5 min or less before being placed in saliva. Table 5 shows the Cox regression analysis including wet time and stage of root development. A linear trend was found, showing that one additional minute of wet time increased the hazard rate for ankylosis by approximately 1% (CI = [0%, 2%], \( p = .052 \)).

Figure 6 illustrates the trend of development of ankylosis between teeth with mature and immature root development over time in this sub-group.
DISCUSSION

The present study shows that saliva is a realistic storage medium for avulsed teeth before replantation.

One strength of the present study is that the material is the largest follow-up material reported in the literature on saliva-stored human teeth prior to replantation. Another strength is that the patients included in the study were treated and followed according to a standardized protocol. To ensure that the information on storage medium and storage period was as accurate as possible, the patient was recalled, generally after 1 week, for a review of the information provided at the time of the accident. This was the responsibility of a single person. In this manner, the number of misunderstandings and amount of incorrect information were reduced. Another strength is that the healing of the replanted tooth was followed for an extended period. In most teeth, ankylosis was diagnosed during the first year, and all teeth with ankylosis were diagnosed within the first 3 years. This is in line with reports from previous studies. A weakness of a long-term study such as the present one is that the recommended treatment may have changed over time—for example, the fixation period for the traumatized tooth varied from 6 weeks at the beginning of the study period in the 1960-s and 1970-s to later recommendations of 1-2 weeks. It has been shown that functional stimulation during the first weeks of healing may influence the development of ankylosis, and short-time splinting has hence been suggested. However, this variation in splinting period affected the groups equally in this study.

The present study focused only on ankylosis. Hence, other factors such as age, splinting type and tooth type were not included in the analysis. However, these factors have been analysed and reported in other studies originating from the same database.

The clinical diagnosis of ankylosis was carried out by registering high percussion sound, absence of mobility and radiographic signs provided at the time of the accident. This was the responsibility of a single person. In this manner, the number of misunderstandings and amount of incorrect information were reduced. Another strength is that the healing of the replanted tooth was followed for an extended period. In most teeth, ankylosis was diagnosed during the first year, and all teeth with ankylosis were diagnosed within the first 3 years. This is in line with reports from previous studies. A weakness of a long-term study such as the present one is that the recommended treatment may have changed over time—for example, the fixation period for the traumatized tooth varied from 6 weeks at the beginning of the study period in the 1960-s and 1970-s to later recommendations of 1-2 weeks. It has been shown that functional stimulation during the first weeks of healing may influence the development of ankylosis, and short-time splinting has hence been suggested. However, this variation in splinting period affected the groups equally in this study.

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The clinical diagnosis of ankylosis was carried out by registering high percussion sound, absence of mobility and radiographic signs.
of replacement resorption. In the early stages, percussion sound and absence of mobility were seen. Later, radiographs revealed replacement resorption. The validity of these methods for diagnosis of ankylosis has earlier been assessed and documented. These diagnostic methods of ankylosis are used in clinical practice and have been reported in clinical studies. Progress with replacement resorption could be seen in all cases where ankylosis was diagnosed.

There may be different reasons why saliva is a good storage medium. One unique factor related to saliva appears to be its general positive effect upon wound healing. A recent experimental study showed better wound healing in extraction sockets when saliva was present. Moreover, the ability of PDL cells to form colonies (clonogenic capacity) has been studied in an in vitro study, which found that PDL cells stored in saliva showed a reduced clonogenic capacity over time. If the clonogenic capacity was higher than 3%, there was a chance of PDL healing. After 30 min, the capacity was 7.6%. At 60 min, the clonogenic capacity was 1.5% after storage in saliva.

Another factor may be a high number of bacteria which can possibly make saliva a less suitable storage medium during the extra-alveolar period for the tooth before replantation. Saliva contains four times more aerobic bacteria and two times more anaerobic bacteria than milk. In the same study, saliva-stored monkey teeth showed many adhering bacteria on the root surface, regardless of the time they were stored in saliva, while teeth stored in milk had few adhering bacteria on their periodontal ligaments. A third factor is osmolality which has been shown to be an important factor in PDL cell survival. Saliva has a higher osmolality than water but not as high as milk. In experimental in vivo studies, Blomlöf et al showed that monkey teeth stored in milk prior to replantation can heal with normal PDL when the replanted teeth were stored in milk for up to 6 h. In saliva, the time was much shorter, and Blomlöf et al suggested that saliva may serve as a storage medium for up to 2 h. The results of the present study suggest that saliva can be recommended as an immediate temporary storage medium until a better storage medium - such as milk or physiological saline - is found near the accident site. However, the findings of the present study also show that saliva has a limited ability to preserve the PDL for longer periods. Already after 5 min, the risk of ankylosis is increased. Hence, the results of this study indicate that saliva should be considered as a temporary

<table>
<thead>
<tr>
<th>Root development</th>
<th>Dry time (min)</th>
<th>Risk 3 years (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immature</td>
<td>0-5</td>
<td>23.7 [8.6;42.9]</td>
</tr>
<tr>
<td>Immature</td>
<td>6-15</td>
<td>NA</td>
</tr>
<tr>
<td>Immature</td>
<td>&gt;15</td>
<td>60.5 [29.6;81.2]</td>
</tr>
<tr>
<td>Mature</td>
<td>0-5</td>
<td>47.4 [32.8;60.7]</td>
</tr>
<tr>
<td>Mature</td>
<td>6-15</td>
<td>76.8 [45.7;91.5]</td>
</tr>
<tr>
<td>Mature</td>
<td>&gt;15</td>
<td>89.3 [68.0;96.7]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazard ratio</th>
<th>CI 95%</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet time</td>
<td>1.01</td>
<td>[1.00;1.02]</td>
</tr>
<tr>
<td>Stage of Root development</td>
<td>Immature</td>
<td>Mature 2.67 [0.61;11.72]</td>
</tr>
</tbody>
</table>

FIGURE 5 A. Risk of ankylosis (y-axis) of avulsed permanent teeth stored in saliva prior to replantation related to root development. Number of remaining teeth over follow-up time (x-axis). N = 89. B. Risk of ankylosis (y-axis) related to dry time storage (0-5, 6-15, >15 min) prior to placing the tooth in saliva. Number of remaining teeth over follow-up time (x-axis). N = 89
storage medium that should be replaced as soon as possible by a better, more physiological medium such as milk or saline. The results of the present study indicated a linear trend with ankylosis increasing by approximately 1% per minute when the tooth was placed in saliva prior to replantation. The results of this study indicate that avulsed teeth in humans have a higher risk of ankylosis than what has been reported earlier in studies of animal teeth when they were stored in saliva prior to replantation.\textsuperscript{10,16} This may be due to the studies in laboratory animals being conducted under more controlled conditions than studies conducted in human clinical settings. Factors other than osmolality that promote healing may influence the findings in replanted saliva-stored teeth. Many animals lick their wounds, and this may possibly have a positive effect on wound healing. One study suggested that saliva is the primary factor in accelerating the oral wound-healing process.\textsuperscript{52} Moreover, saliva creates a humid environment in the oral mucosa that prevents oral tissues from dehydrating, which yields improved access to nutrition and increases the survival of the cells involved in the wound healing process. All these factors together accelerate re-epithelialization. Saliva also contains many different molecules that improve healing in the oral cavity, including proteins and peptides.\textsuperscript{52} One novel discovery is that saliva contains high amounts of tissue factors that probably contribute to wound healing by speeding up blood clotting.\textsuperscript{53} Growth factors are found in saliva, (e.g. epidermal growth factor), but it has been shown that most growth factors in human saliva occur in very small amounts and sometimes in an inactive form compared with saliva in animals.\textsuperscript{51,54-56} Histatins and secretory leucocyte protease inhibitors have also been found in saliva and these help accelerate wound healing.\textsuperscript{51} Moreover, it has been shown that saliva is important for rapid healing of extraction sockets.\textsuperscript{2}

The current results show that storage in saliva prior to replantation reduces the risk of ankylosis compared to dry storage. These results are consistent with some previous experimental animal studies and in vitro studies.\textsuperscript{4,6,9,11,16} In other studies, in which teeth were stored dry for 1 h or more before replantation, ankylosis was reported.\textsuperscript{9,10,16,23,32,45} One study with replanted dog teeth showed that it did not matter if the teeth were stored dry for 20, 60 or 90 min before replantation because the PDL cells were already very damaged after 20 min, and ankylosis was reported.\textsuperscript{47} In another in vivo study with replanted monkey teeth, the results showed a clear association between ankylosis and teeth stored dry for 30 min prior to replantation.\textsuperscript{16} Hence, ankylosis must be expected in many teeth when the dry storage period is prolonged. However, a very recent study on replanted teeth stored dry for more than 60 min prior to replantation showed that ankylosis may be expected in as many as 85% of the teeth.\textsuperscript{22}

Within the limitations of this study, with a low number of teeth in the material, the results indicate that teeth with immature root development may have a lower risk of ankylosis than teeth with a closed apex. The reason for this may be that, unlike teeth with completed root development, immature teeth have a thicker PDL layer.\textsuperscript{1,22,25} Another factor may be that immature teeth have an open apex allowing more vessels to provide a better blood supply. However, a prerequisite for this is that the pulp is not infected. In cases with an infected pulp, infection-related root resorption can rapidly destroy an immature tooth due to the wider root canals and dentine tubules compared to mature teeth.\textsuperscript{1,22} Infection-related root resorption may have an influence on healing in the short term (e.g. during the first year) but can today be prevented or treated, while ankylosis is the main factor influencing the long-term prognosis and it is not possible to treat.

The dry storage time before the tooth was placed in saliva was shown to be a critical factor. Dry storage for 5 min or less before saliva storage resulted in ankylosis in 40% of cases, but when dry storage exceeded 5 min prior to storage in saliva, ankylosis was seen in 80% of the replanted teeth. This observation shows that the increased dry time for the avulsed tooth is a crucial factor even if the tooth is subsequently placed in saliva. For this reason, dry storage should be minimized as much as possible before the tooth is placed in saliva. In the clinical setting, dentists should always strive to replant the avulsed permanent tooth as soon as possible.\textsuperscript{1,3,7} If a tooth cannot be replanted, it should be stored in an optimal storage medium such as milk, saline or HBSS as the first options.\textsuperscript{4,5,9,10-12} However, in many cases, neither saline nor milk is available at the site of the accident. The advantage of saliva is that it is always available in the patient’s mouth, so quick placement of the tooth in saliva should be encouraged if the tooth cannot be replanted or stored in milk. Of note, storing the tooth in milk is a better alternative than storing it in saliva according to recent studies.\textsuperscript{7,8,52} For this reason, saliva should be regarded a temporary storage medium and used until better storage alternatives may be found near the place of the accident. Storage in saliva can best be done by placing the tooth in the vestibule of the mouth.
between the cheek and teeth. Two studies have suggested that saliva may also be contained by spitting into a container and placing the tooth there. In summary, the results of this study support the recommendations of the IADT guidelines that saliva may be recommended as an alternative way of storing the avulsed tooth in situations in which replantation is not possible and when better storage media such as milk and balanced salt solution are not immediately available at the place of the accident.

5 | CONCLUSION

Storing a tooth in saliva prior to replantation reduces the risk of ankylosis compared with dry storage. Immature teeth stored in saliva prior to replantation had less risk of ankylosis in comparison to mature teeth. Saliva may serve as a temporary medium in situations when an avulsed permanent tooth cannot immediately be replanted.

ACKNOWLEDGEMENT

The authors want to thank Dr Frances Andreasen and Mette Borum for collecting data.

CONFLICT OF INTEREST

The authors confirm that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

Josefin Albertsson carried out the literature review, participated in the design of the study, analysis of data and manuscript writing. Eva Lauridsen was active in the design of the study, analysis of data and manuscript writing. Jens Andreasen collected the original clinical material and carried out follow-up of the patients, participated in the design of the study, analysis of data and manuscript writing. Thomas Gerds was active in the design of the study, carried out all the statistical analyses and participated in the manuscript writing. Lars Andersson was active in the design of the study, analysis of data, manuscript writing and was the corresponding author with the journal.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES