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How successful is re-implanting avulsed anterior teeth in children

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Abstract

The following report is a review of literature and clinical trials conducted, to assess the efficacy of replantation of avulsed permanent teeth in children and factors influencing the success rate thereof.

Evidence for review has been obtained from different sources which include- Internet databases, Pubmed, Ovid, Textbooks in Endodontics and Paedodontics and Expert opinion. 14 articles relevant to the topic and satisfying the minimum score requirements on the “Evidence of efficacy of therapy or Prevention” checklist were further critically appraised to formulate Evidence based tables and establish Strength of Evidence for the respective interventions being studied. Clinical trials include those started in 1965 with a mean observation period of 5.1 years for various interventions to ones as recent as 2005 with observation periods ranging from 3-5 years, primarily on children within age range of 6 to 19 years.

The factors responsible for failures of replanted teeth have been thoroughly evaluated. The various Interventions studied with positive outcomes as seen on their survival curves [Appendix 4], include:

Replantation following extra-oral Post insertion following endodontic treatment ; Immediate Endo Tt. {7-10 days} following replantation as opposed to delayed endodontic treatment.[13,14,15]; Use of physiologic storage medium [3,14] vs. non-physiologic storage medium[2,13,14]; Minimizing dry/extra-oral storage time to < 15-30 mins. vs. > 30 mins.[4,11,13,14]; Studies were further stratified to evaluate healing in terms of functional healing as opposed to non-functional healing including Replacement resorption and infection related root resorption[3,6,7]; Effect of stage of root development at the time of injury on pulpal and periodontal healing[7,8,9] and closed vs. open apices on survival rates[15]. Promising results have been observed with the use of ART employing Emdogain, dexamethasone, Doxycycline; Post-op antibiotic coverage with Tetracycline and employing time limited non-rigid splinting [2,14]. However, evidence for use of $Ca(OH)_2$ paste in teeth with immature apices and fluoride treatment of roots prior to replantation is not adequately substantiated.

The reported success rate of replanted avulsed teeth has varied. Success ranges between 4% to 50% have been reported [5]. It could be as high as 70, 90, 100% in 3 years after replantation [3,6,15]. This variety in numbers can be explained by the fact that many different factors influence final outcome – survival of the replanted teeth .This research clearly shows that many procedures can be used to increase success rate. Evidence strongly emphasizes need for minimizing extra-oral time of avulsed tooth; use of physiologic storage medium with impetus on maintaining vitality of

periodontal ligament cells and initiating early endodontic treatment as being key factors in increasing success of replantation procedures [1,2, 11,13,14,15].

Introduction

Avulsion is the complete displacement of traumatized tooth from its socket. The avulsion of permanent teeth is relatively rare and its incidence rates have been changed over time. For instance, the incidence rate of avulsed teeth accounted for only 0.5 % of injuries to teeth in school children in Copenhagen schools during 1967-72 years [12, 34]. The most recent studies (1997-2005) showed the avulsion incidence rate as high as 8-9% among all dento-alveolar trauma in children (Columbus USA and Innsbruck Austria respectively) [17, 32]. However, when it occurs, it has serious consequences. The adverse psychological impact of a lost tooth on a child and the fear of being mocked at by peers is one of the first. The resulting empty site is not aesthetically pleasing and is difficult to fill and replace. Long-term sequelae include shifting of remaining teeth with resulting misalignment and periodontal disease.

Also, most permanent teeth are avulsed in children between ages 8-10 yrs, a time when the anterior permanent dentition is erupting. The tooth most commonly affected being the first upper permanent incisor. This could create problems of space management, especially if the lateral incisor erupts into the space.

This problem can be overcome if the avulsed tooth is replanted, for it acts as an ideal space maintainer and even in the event of subsequent loss, it would have served its purpose by lasting through the growing period.

The primary goal of rapid reimplantation is to preserve the periodontal ligament, not the tooth. The avulsed tooth inevitably requires a root canal; however, if the periodontal ligament survives, the degree and timeliness of root resorption is improved and ankylosis is decreased. Modern emergency departments focus on reimplanting teeth as soon as possible, minimizing periodontal damage, and preventing infection of the pulp tissue. [11]

The biologic consequence of avulsion is damage to the attachment apparatus (i.e. periodontal ligament, cemental layer) in addition the drying damage that occurs to the periodontal ligament, when the tooth is out of the mouth has extremely detrimental effects on healing . Pulp necrosis

always occurs after an avulsion injury but revascularization is possible in teeth with immature apices. Therefore complications after avulsion injury can be divided in two groups:

- **Inflammatory root resorption** which is due to damage to periodontal ligament and depends on an infected necrotic pulp.[4]
- **Replacement resorption** occurs when damage to the periodontal ligament cells and cementum has caused the area of resorption that is not healed by the secondary cementum. This kind of resorption is believed not to be connected with the presence of necrotic pulp tissue. [4]

The prevalence of dental injuries is high, including tooth avulsion [27].

Frequency:

In the US:

- Data from a consecutive series of patients in an urban paediatric department in the United States showed that 37% of children treated, had dental injuries [26]
- One study showed that injuries to hard dental structures included tooth **avulsions (8%)** [32]
- Prevalence of avulsion from traumatic injury of primary dentition is 7-13%. In permanent teeth, the prevalence is 1-16% [16]
- There are over two million teeth accidentally knocked out in the United States each year [13]

Internationally:

- A study conducted in **Sweden** showed approximately 5 % of all physical injuries involved the oral cavity. [20].
- The records of other **Swedish** study showed that 35% of the children on one or more occasions had sustained injury to their primary or permanent dentition. [21]
- 50 % trauma of all maxillofacial injuries - sustained dentoalveolar trauma. (**Austria**) [17]
- Avulsion accounts for **9% of all dentoalveolar trauma** .(**Austria**) [17]
- The highest risk of sustaining oral injuries was in the ages 0-12 years, where the annual incidence was 18 per 1000 per year, making oral injuries the third most common form of injury. (**Sweden**) [22]
- In patients aged 0-19 years, 9% of all injuries involved the oral cavity. (**Sweden**) [16]

- A prospective research design study carried out in **Denmark**, one of the few of this type, has shown that half of all children are likely to experience at least one dental injury before leaving school [28].
- Recently, a carefully carried out retrospective research design using reliable dental records from **Sweden** showed that 35% of 16-year-old children studied had on one or more occasions sustained dental injury [29].
- A total of 11.7 to 30% children in the conducted studies had experienced dental injuries. (**Sweden**) [19, 23]
- The prevalence of injuries of permanent incisors was 7.3%. (**Italy**) [30]
- Traumas of permanent incisors involving periodontal ligament constituted nearly 40% of the total. (**Italy**) [30]
- In patients aged 0-19 years, 9% of all injuries involved the oral cavity. (**Sweden**) [16]
- Child abuse is an **international** problem and over 50% of all physical injuries from child abuse occur in the head and neck region. [16, 17].
- **35.8%** total number of facial injuries was **in acts of violence**.(Austria) [31]
- In boys, 10% of all dental injuries were caused by violence. (**Sweden**) [19]

Sex: Male-to-female ratio is 1.2-3:1 [19, 21, 23, 24, 25].

Dental clinics and hospital-based studies have reported that falls and collisions, sporting activities, violence and traffic accidents are the main causes of injury to permanent incisors.

One study in Austria showed that the incidence of dental injuries with respect to the total number of facial injuries was as follows: 57.8% in play and household accidents, 50.1% in sports accidents, 38.6% in accidents at work, 35.8% in acts of violence, 34.2% in traffic accidents, and 31% in unspecified accidents [31].

The purpose of this report is to review the success rate and factors that affect it since studies show they can be preserved and replanted with good long term retention prognosis.

A note is made of the fact that the nature of the subject does **not allow for a true control group to be employed**, which is evident from investigation of studies wherein either previous literature has been employed as a control or outcomes of different interventions employed within the study have been compared.

Target population

The problem outlined in this report is based on the needs of children population to evaluate the success rate of avulsed tooth replantation. Based on the studies the target population is the children in school age specifically in the age range from 6 to 19 years old.

Method

A systematic literature search was employed to identify, select, critically appraise and utilize relevant studies.

Search Strategy

Internet based research was conducted through three different websites: PubMed(1966-present) OVID medline (1966-present), Cochrane - by using the keywords : children , tooth, avulsion. Our search yielded 738-50-0 relevant articles respectively. In addition to using online database textbooks in Endodontics and Pediatrics Dentistry were used.. Besides, the Endodontics departments were approached for the expert opinion and the unpublished faculty research information. These articles were deemed irrelevant as the studies were conducted on animals.

On the next stage the search was limited to studies that looked relevant based on the title. At the abstract stage the search were limited to studies dealt with human subjects and permanent avulsed teeth in children. Then the attempt was carried on to retrieve the articles which were available at the faculty. By utilizing the above strategies a total yield of 14 articles were identified to be relevant to our topic and were used in the final report.

Review of evidence	number
Abstracts matching search terms: <i>Teeth, Avulsion, Children</i>	738
Articles identifies through alternative means	50
Articles rejected at the title stage	440
Articles rejected at abstract stage	392
Articles retrieved and copied for review	34
Articles rejected at first reading	5
Articles scored	29
Articles meeting cutoff's criteria	14

Definition of MeSH Key Words

Success , anterior teeth , children, replantation , avulsion.

1-Success: Following the examination, the success of treatment of the replanted incisor was classified as either complete, acceptable, uncertain. Loss of success was considered as failed results .

- **Completely successful** treatment was recorded when the tooth was present with no clinical signs of ankylosis, infra-occlusion or infection and no radiographic signs of root resorption or periapical pathology.
- An **acceptably successful** treatment was recorded when the tooth was still present (either vital or root filled), there were no clinical signs of infection and any infra-occlusion was acceptable , radiographically there were no signs of periapical infection and any root resorption was arrested.
- The treatment of a replanted tooth was classified as **uncertain** if it was still undergoing root canal therapy for root resorption or apical pathology, or if it was undergoing active orthodontic treatment for infra-occlusion .

A **failure** of treatment was recorded when the replanted tooth had been lost.[10]

2-Teeth: In this evidence-based report we have considered permanent teeth.

3-Anterior teeth: Maxillary and mandibular incisors and canines. [35]

4-Replantation : Replacement of a tooth that has been removed from the alveolus either intentionally or unintentionally , as in an accident.[35]

5-Avulsion: Complete displacement of a tooth from its alveolus as a result of a traumatic episode. That can cause damage to some or all of the dental and surrounding tissues. [35]

6-Children: age between 6 and 20.

Inclusion and exclusion criteria

During the process of elimination, each article had to fulfill the predetermined inclusion and exclusion criteria in order to be considered for use in answering the problem. The title of the article had to be relevant to our question. For the abstract phase, the publication had to be in English, treat only human subjects, be a primary article, be ethical and be accessible via the University of Toronto database in order for it to be printed online or copied from a reserved journal in the campus library. The full article was then reviewed to ensure its applicability to our topic as well as its strength of research design and findings. Finally, two independent individuals of the team were asked to critically score the remaining articles by using the appropriate checklist (see Critical Appraisal Criteria below). Disagreements were resolved by consulting other group members in the team, using the same criteria.

Due to specificity of the problem, all included studies don't have a control group. The results in some studies have been compared to the average success rate, results from the previously conducted studies. Consequently, randomization wasn't used. In some studies patients have been assigned to the different treatment groups and results have been compared.

Exclusion of articles from research

These 20 articles were excluded because of the following reasons:

	Article	Reason for exclusion
1	Evaluation of 71 replanted teeth , Kemp WB, Grossman LI, Phillips J., J Endod. 1977 Jan;3(1):30-5	Poor design , old technology had been evaluated
2	Replntation of avulsed teeth after long extra-alveolar periods A Heimdahl, L.Von Konow & G. Lundquist, 1983	Age range was not consistent with the criteria
3	Tooth replantation after traumatic avulsion: A report of 10 cases Kinoshita S, Kojima R, 2002	Poor design , just case report
4	11 year follow up of tooth replantation Carmelo J. Todaro, 1979	Just one case report
5	Replantation : An analysis of 29 teeth Fumihiko Gunda, 1990	Intentional replantations were considered
6	Root resorption in dental trauma: 45 cases followed for 5 years A. Majorana, E. Bardellini, 2003	Age range was not consistant with criteria and luxation was also included
7	Tooth avulsion and replantation review Hammarstorm L., Pierce L., 1986	Animal and experimental studies
8	Dental trauma: 4.Avulsion and replantatio n of immature incisor teeth, Iain C.Mackie and Anthony S.Blinkhorn Dent Update. 1996 Jun;23(5):201-3, 208.	Poor design, insufficient evidence
9	Variations in the presenting and the treatment features in re implanted permanent incisors in children and their effect on the prevalence of root resorption M.J.Kinirons,T.A.Gregg,R.R.Welbury R.and B.O.ICole, 2000	Unethical (intentional replantation of tooth with visible contamination on root surface)

10	Factors affecting the time of onset of resorption in avulsed and replanted incisor teeth in children M.Donaldson,M.J.Kinirons, 2001	Inadequate follow up period
11	External inflammatory and replacement resorption of luxated , and avulsed replanted permanent incisors a review and case presentation David Finucane,Martin J.Kinirons, 2003	Poor design, just one case report
12	Inflammatory and replacement resorption in re implanted permanent incisor teeth : a study of characteristics of 84 teeth M.J.Kinirons,D.H.Boyod,T.A.Gregg,1999	Inadequate follow up period
13	Treatment of Tooth Avulsion in the Emergency Department. Paul R. Krasner, 1990	Rejected because this article is qualified as clinical guidance for treatment
14	Effect on periodontal healing of saline irrigation of the tooth socket before replantation Matsson L., Klinge B, Hallstrom H, 1987	Rejected because: study was done on beagle dogs.
15	Self-replantation of an avulsed tooth: 30-years follow-up, Abbott PV, Int Endod J. 1991 Jan;24(1):36-40.	Case-report
16	New philosophy for the treatment of avulsed teeth P.Krasner, H. Rankow, 2000	As a report of an expert group it belongs to the <u>grade III of design rating</u>
17	Progression of root resorption following replantation of human teeth after extended extra oral storage. L. Andersson et al, 1998.	Since title was inappropriate for purpose of our study since failure of replantation following <u>extended</u> extra-oral storage is well documented.
18	Preserving Avulsed Teeth for Replantation. Paul Krasner, DDS; Phillip Person,S, 1992.	Since poor design of study, and follow up period not uniform for entire sample with loss to follow up being greater than 20%.
19	P.Krasner, H. Rankow, New philosophy for the treatment of avulsed teeth <i>Oral Surg Oral Med Oral Path Oral Radiol Endod, 1995: 79: 616-623</i>	It's just guidelines for the clinicians
20	M. Tsukiboshi, Autotransplantation of teeth ;requirements for predictable success, Dental traumatology, 2002;18:157-180	Even though the survival analysis was performed in this study, it was excluded because some teeth were intentionally extracted and then replanted; some cases included molars and premolars.

Summary of findings

In the study on 28 avulsed incisors [1] parameters related to loss and survival expectation were identified. [2005]

Extraoral endodontic Tx by retrograde insertion of posts prevents early and minimizes the overall incidence of IRR. This method doesn't negatively influence periodontal healing. As the further advantages(no discoloration, no root fracture, pt not involved, less radiographs, less time consuming, less cost). The method is recommended in isolated teeth before replantation.

The existence of vital PDL cells with proliferative capacity is decisive for periodontal healing following replantation. Predominant influence on healing results-the immediate physiological rescue of avulsed teeth (P=0.0001) in physiologic storage - special cell culture media –

commercially available the tooth rescue box (**Dentosafe®**, Medice, Iserlohn, Germany; and **EMT Tooth saver**, Smartpractice.com, Phoenix, AZ, USA)

Media like **Milk and Saline should not be consider as “physiologic”**, since death of PDL cells stored in these media is slowed down compared with the dry storage but progressive and inevitable.

The use of **ART- antiresorptive-regenerative therapy**- seems to support FH (functional healing) in teeth with compromised PDL, but not in hopeless conditions.[1]

Survival analysis was performed. The estimated survival according to a Kaplan–Meier analysis was 57.3 months ([Fig 1](#)). 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. 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](#)). ART seemed to have a positive healing effect when teeth with a compromised but not hopeless periodontal ligament (PDL). In these teeth with a compromised PDL, ART had a significant influence on tooth retention ($P = 0.0389$). 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](#)). 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](#)). There were no other factors related to tooth loss except the use of postoperative antibiotics (cross-tabulation, Fisher's exact test, $P = 0.0410$).

In the study on 50 avulsed permanent incisors [4] it has been found that the best predictor for overall resorption was **total time of dryness** and that of replacement resorption **was total extra-oral time** ($P=0.017$). Both total extra-oral time and time stored dry appear to be important for the occurrence of resorption in replanted avulsed teeth in children. Survival free of any resorption with dry storage times of less than 30 min 49% vs. 10% when time of greater than 30 min ([Fig 10](#)). Survival free of replacement resorption with extra-oral times of less that 90 min 60% vs. 25 % when time is greater than 90 min[4] (2000) ([Fig 11](#)).

Regarding the diagnosis of healing complications, the results of the study on 400 teeth with mean observation period of 5,1 years indicated a high risk for all type of complications, with many of them being related to stage of root development at the time of replantation. Tooth loss was slightly more frequent in teeth with incomplete root formation.

With respect to healing, three aspects were analyzed: **pulpal healing, root growth and PDL healing.**

Pulpal healing was influenced by:

- 1- **pulp length**, which was the most important predictor of pulp survival (increased pulpal healing with decreased pulp length);
- 2- **wet extra-alveolar period** had a threshold effect, with immediate replantation (wet storage less than 5 min) having an optimal effect upon healing;
- 3- **dry extra-alveolar period** had increasingly negative effect on pulpal healing.

Root growth development subsequent to replantation was found to be significantly related to pulpal revascularization, being rare in cases with pulp necrosis and frequent after pulpal healing.

PDL healing was strongly influenced by the four following factors, in decreasing order of significance: stage of root development, length of the dry extra-alveolar storage period, immediate replantation and length of the wet storage period.

The overall periodontal healing rate was significantly better in **immature teeth (36%**, root stages 2-4) than in **mature teeth (22%**, root stages 5-6). 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 investigated teeth were extracted.** The yearly survival rates were given graphically (see Fig 8). From these figures it can be estimated that the survival rate 10 years after replantation is about 70 % for mature teeth and about 45 % for immature teeth (Fig 12, appendix 4). The given healing complications were not put into relationship with the tooth loss, and no survival analysis was performed.

In the study only 46 teeth **no significant difference** could be demonstrated for teeth **replanted within 30 minutes** as opposed to **more than 30 minutes**, between **the state of root development** and the **success** of treatment., and also between the **success** of treatment or root resorption when the pulp was **extirpated in the first 2 weeks** following replantation **compared** with those teeth where the **pulps were left until there were obvious signs of loss of vitality.** There was a **statistically significant increase in root resorption** that had been **stored dry** compared with those that had been stored in saliva, milk or saline.

However, even when teeth were stored dry, some were still treated successfully, showing that dry storage is not an absolute contra-indication to replantation. Teeth replanted under ideal conditions can fail and those replanted under conditions unfavourable may be successful [10].

The study on 21 teeth confirms that

1-a tooth replanted after a **short extraoral time (less than 15 min)** will **heal with no or limited root resorption**. If root resorption occurs the resorption will be limited to a small area and only in a few instances be progressive.

2-Most of the **teeth without resorption** were either **replanted immediately or within 10min**. in contrast teeth that had been subjected to **15min extraoral storage showed sign of root resorption**.

3- **Root resorption rate was found to be low compared with teeth replanted after 60min dry storage** (based on root resorption index* and regression analysis).

4- **Age seemed to have no influence on the rate of root resorption**. It was in contrast with teeth replanted after 60min extraoral storage which showed a rate of root resorption highly dependent on the age of patient.(slower with increase of age) .

5-This **study failed** to demonstrate a **meaningful relationship** between rate of **root resorption** and **splinting time** or **onset of endodontic treatment** (5%level)[11].

The study on **49** teeth lends further support to the evidence that most permanent teeth are avulsed in **children between ages 8-10 years** (the time the anterior permanent dentition is erupting and loss of a central incisor tooth can present problems of space management). **60% of children had their avulsed tooth stored dry** and this shows lack of knowledge about how to handle avulsed teeth after accident. **There was no relationship between places or personnel planted avulsed tooth. The most common avulsed tooth is central incisor** [12].

The other study looked on **129 avulsed and replanted teeth in children**. The authors concluded that **extra socket time is of paramount importance** in cases of replantation of avulsed teeth. Teeth which were replanted within 7 hours after accident showed much less resorption (replacement, inflammatory) than teeth after 7 hours following avulsion. **Overall success rate for 5 year follow up period was 78% with 22% failure**. Moreover, the pulpectomy should be done as early as possible. Age had no influence on outcome or success of replantation. There was a relationship between fluoride treatment of the root and rate of replacement resorption In addition, study showed that Ca(OH)_2 paste placed in root canal may decrease rate of inflammatory resorption [13].

45 avulsed teeth in 34 patients were followed for a **1 year period** in this paper which focused on pulpal and periodontal healing and efforts to minimize complications such as pulp necrosis and external root resorption. In consideration of earlier published data

- 1-The **strict endodontic treatment protocol** utilized in the present study, kept risk of infection related root resorption to a low 6.7%, **with tooth survival at 1 yr. being 95.6%.**
2. **Critical limit of <15 min dry storage** reduced replacement resorption to 9.5% from 38.5% for 16-60 mins.
3. Post replantation systemic Tetracycline was prescribed in addition to soaking teeth in 5% tetracycline prior to replantation, rationale being that tetracycline has direct inhibitory effect on collagenase activity and osteoclasts. Since all pts. were treated with tetracycline, its inherent could not be determined.
4. Teeth with prolonged or non-physiologic extra-oral storage were treated with Emdogain. This unfavorable precondition probably resulted in no beneficial effect with EMD.
5. **Ankylosis /Replacement resorption** was the **most prevalent** type of post-traumatic **external root resorption** at 28.9% [14].

52 avulsed and replanted teeth with an extended extra-alveolar duration (more than 5 min) were analyzed [15]. The mean observation period was 30 months (12–70 months). 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 expectations than teeth with temporary endontic treatment and that immature teeth had a lower survival expectations than mature. Neither healing types nor distinct reasons for tooth loss were given, and no survival analysis was performed stratifying these factors.

1. Apical development at the time of replantation was found to be significantly related to the survival. Incisors with **open apices exhibited lower survival as compared to incisors with closed apices.** Teeth with **open apices had relative risk of failure 4.2 greater than the teeth with closed apices.**
2. Reimplanted **incisors that required prolonged treatment for with Calcium hydroxide were found to be 10 times more likely to fail than those obturated with gutta perca and sealer.** The reason for limited success in the teeth with open apices was **that they require prolonged root canal completion time (calcium hydroxide for apical closure).**
3. A trend towards decreased tooth survival was found for patients younger than 11 years old at the time of replantation (P=0.09, relative risk 2.8) [15].

Final Conclusion

Tooth loss following avulsion and replantation is a common problem. Avulsed and replanted teeth may be lost as early as 2 months after replantation or survive for many years.[5]. The success rate is influenced by many different factors, but the incidence of tooth loss was significantly determined by the healing type. Having significant impact on healing, immediate physiological rescue and ART (antiresorptive-regenerative therapy) were also related to the tooth retention. [2,3,14]. Of predominant influence on tooth removal was the factor consecutive transplantation, which was itself related to non-functional healing [2,3], (see Fig .7).

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 (see appendix 4). Survival analysis shows different factors impacts survival rate and expectation of implanted tooth.

Success of the replantation depends on:

1. Extra socket time:

Minimizing extra oral time is of paramount importance. Teeth replanted after a **short extraoral time (less than 15 min) heal with no or limited root resorption. [11] (Level B)** . If all avulsed teeth were replanted immediately, a PDL healing rate of 85-97% (according to root development). will be achieved [6], (Level A). Both total extra-oral time and time stored dry appear to be significantly important for the occurrence of resorption in replanted avulsed teeth in children. [4],(2000). Survival free of replacement resorption with extra-oral times of less than 90 min 60% vs. 25 % when time is greater than 90 min[4] (2000, Fig 11).

2. The existence of vital PDL cells with proliferative capacity is decisive for periodontal healing following replantation and PDL healing was strongly influenced by the four following factors, in decreasing order of significance: stage of root development, length of the dry extra-alveolar storage period, immediate replantation and length of the wet storage period.

3. Medium of storage and method of transportation is crucial to maintain the vitality of the PDL cells[1], (Level A),

Avulsed teeth can be stored for long period of time without deleterious effect. Root PDL cells that have been extraoral for more than 15 min can have depleted cell metabolites replenished. For a good prognosis avulsed teeth should be stored immediately in a cell compatible medium. [5]

The best, physiological storage media are:

- **Hank's solution (highly purified collagen solution, [14,] (Level A)**
- **Eagle's medium, [14,] (Level A)**
- **Dentosafe® (Germany) –[1], (Level of evidence A)**
- **EMT Tooth saver (USA)-[1], (Level of evidence A)**

Usage of milk and saliva has controversial results.

- **Against - Milk and Saline should not be consider as “physiologic”, since death of PDL cells stored in these media is slowed down compared with the dry storage but progressive and inevitable. [1]2005, (Level A)**
- **In support of milk, saliva and saline use:**
 - a) **Milk** has been shown to be the best medium because it has an osmolaity and PH compatible with the survival of periodontal membrane cells. [12],1993, (Level B) -
 - b) In cases where immediate replantation cannot be carried out, the present study indicates no preference for storage in the oral cavity (**saliva**) or in **saline**. [6] 2000, (Level A)

Critical limit of <15 min dry storage reduced replacement resorption to 9.5% from 38.5% for 16-60 min [14]. Survival free of any resorption with dry storage times of less than 30 min 49% vs 10% with time of greater than 30 min [4], (Fig 10),(Level A).

4. Employing non-rigid splinting limited to 7-10 days helps to minimize the risk of development of replacement resorption / ankylosis. [14], (Level of evidence B)

5. Inconclusive evidence regarding use of Calcium hydroxide paste

- **Against [1]-2005,(Level A), [15]-1997 (Level A)**
- **In favour of CA(OH)₂ [13], 1980, (Level B)**

6. Studies revealed 2 different approaches towards the time of initiation of endodontic treatment with some differences in the success rate:

- **Initiation of endodontic treatment particularly within 7-10 days after replantation [11,13,14], (Level A)**
- **Extra oral endodontic treatment by retrograde insertion of posts before the implantation. [1], (Level A) .**

The total incidence of IRR with endodontic treatment before the reimplantation was 10,7% [1] total IRR while the other studies with a delayed endodontic treatment the rate was around 30-35%. [4,6,33] Moreover, endodontic treatment before the reimplantation has other advantages: no discoloration, no root fracture, pt not involved, less radiographs, less time consuming, less cost.

7. Controversial results about influence of the age:

- **Age seems to have NO influence on the root resorption. [13] 1980-(Level B); [2] 2005-(Level A)**
- A trend towards decreased tooth survival was found for patients younger than 11 years old at the time of replantation [15],1997, (Level A). PDL healing was found significantly less frequently in older age group (above 16 years of age) [9],1995, (Level A)

8. Antiresorptive-regenerative therapy employing dexamethasone, EMD, doxycycline - seems to support functional healing in teeth with compromised PDL, but not in hopeless conditions [1], (Level A).

Correlation between maturity and tooth loss is controversial. Periodontal healing rate was better in immature teeth, yet the rate of IRR was higher in immature teeth [6,9]. In clinical studies avulsed and replanted immature teeth were lost more often and had lower survival expectation rate than mature teeth. Here is the results of the different survival rate over the time after replantation in the different clinical trials [3,6,15] (see graphs in the Appendix 4) :

	Mature teeth	Immature teeth
1 year	100 %	85-90 %
2 years	80-90 %	55-72 %
3 years	70-90 %	55 %
4 years	58-65 %	50-55 %
5 years	60-65 %	25-55 %
10 years	70 % [6] (Fig. 12 Appn.4)	45 % [6] (Fig 12 Appn.4)

If physiological rescue solution is used immediately for the tooth storage, the success rate could be as high as 100% in 3 years [3]. Much longer observation period may be needed to establish significant differences for teeth with FH and with infection –free complications.

Functional healing (FH) is predominantly dependent on the availability of the tooth physiological rescue solution. If avulsed and replanted teeth show FH for 6-12 months, they will have a good prognosis for long term retention [3].

Survival analysis revealed that teeth with a completed endodontic treatment had a higher survival expectations than teeth with temporary endodontic treatment [15].

Recommendations

1-It is appropriate to recommend that avulsed teeth be immediately replanted at site of injury (Level A). At the same time current technology allows avulsed teeth to be stored for long period of time without deleterious effect (Level A). [1,5,13]

2-If immediate replantation is not possible because of the risk of aspiration

- in cases of serious injuries or
- unconscious patients

an extraoral storage medium should be recommended until replantation can be performed (Level B), [11,13]

3-It's important to educate the community and distribute physiological medium storage at locations with a high risk of traumatic tooth injuries

- schools, kindergartens,
- public pools, sporting facilities,
- at emergency units, and
- in families with children

(Level A), [1, 14].

4-Physiological storage media are:

- Hank's solution (highly purified collagen solution) (Level A)
- Eagle's medium (Level A)
- Dentosafe® (Germany) [1], (Level A)
- EMT Tooth saver (USA) [1], (Level A)

5-Media like Milk and Saline should not be consider as “physiologic” since death of PDL cells stored in these media is progressive and inevitable. They can be used only as a next best available

alternative if physiological medium storage is not available and immediate implantation is not possible[1] (Level A).

6-Non-physiologic storage in tap water, home made saline, chloramines, alcohol are not acceptable [14], (Level A)

7- Dry storage >15 min will inevitably lead to the failure of reimplantation [14], (Level B)

8-Endodontic Treatment is recommended:

- on 7-10 days after replantation (Level A) or
- Extraoral endodontic Tx by retrograde insertion of posts before the replantation (Level A) , [1].

9-In children a replanted tooth acts as the ideal space maintainer. [10,12] **Avulsed permanent incisor teeth in children should be replanted even though the prognosis may seem poor,** unless there are specific contra-indication to this treatment, such as marked anterior crowding or the patient is seriously medically compromised [10].

10-The successful prognosis of avulsed replanted teeth cannot be guaranteed since different factors influence final outcome.

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Appendix 2 Checklist to Assess Evidence of Efficacy of Therapy or Prevention

1. Was the study ethical? (1 point)
2. Was a strong design used to assess efficacy? (1)
3. Were outcomes (benefits and harms) validly and reliably measured? (1)
4. Were interventions validly and reliably measured? (1)
5. What were the results?
 - Was the treatment effect large enough to be clinically important? (1)
 - Was the estimate of the treatment effect beyond chance and relatively precise? (1)
 - If the findings were “no difference” was the power of the study 80% or better? (1)
6. Are the results of the study valid?
 - Was the assignment of patients to treatments randomized? (1)
 - Were all patients who entered the trial properly accounted for and attributed at its conclusion?
 - 1) Was loss to follow-up less than 20% and balanced between test and controls?(1/2)
 - 2) Were patients analyzed in the groups to which they were randomized? (1/2)
 - Was the study of sufficient duration? (1)
 - Were patients, health workers, and study personnel “blind” to treatment? (1)
 - Were groups similar at the start of the trial? (1)
 - Aside from the experimental intervention, were the groups treated equally? (1)
 - Was care received outside the study identified and controlled for? (1)
7. Will the results help in caring for your patients? (1)
 - Were all clinically important outcomes considered? (1)
 - Are the likely benefits of treatment worth the potential harms and costs? (1)

Appendix 3 Evidence Table of included studies

	Study	Population	Intervention/Tx	Outcome	Clinical Appraisal	Strength of evidence, classification
1	Pohl Y, Filippi A, Kirschner H. Results after replantation of avulsed permanent teeth, I. Endodontic considerations, 2005 [1]	Subjects 24 pts with 28 avulsed permanent teeth, <u>age</u> - 7-17 y <u>sex</u> - both F-6(9 teeth)& M-18(19 teeth), <u>Location</u> : Germany -2 sites	Cohort (prospective) analytical study Aim- to evaluate the clinical and radiographic results replanted after extra-oral endodontic Tx by retrograde insertion of ceramic or Ti posts Inclusion criteria:	-Prevention of early IRR and minimizes the overall incidence of IRR - infection related resorption -IRR- 15.8% of the healing complications vs 45% in other studies -As the further advantages: No discoloration, no root fracture, no need for bleaching, veneers, crowns, pt not involved, less radiographs, less time consuming, less cost -This method doesn't negatively influence periodontal healing. Results were compared with delayed endodontic Tx results of other studies	<u>Strength</u> : - Long observational period -no teeth were excluded from the study, -detailed classification and evaluation of post-operative healing <u>Weaknesses</u> : -small sample size, -no control -much longer observational period will be needed for survival analysis for teeth with FH** -statistical evaluation was not performed for dif. Types of IRR (due to shortage of cases)	<u>Check list score (efficacy)</u> :13/16 <u>CTFPHE</u> : Level A evidence, Grade-II-2
2	Pohl Y, Filippi A, Kirschner H. Results after replantation of avulsed permanent teeth, II.. Periodontal healing and the role of physiologic storage and antiresorptive-regenerative therapy, 2005 [2]	Subjects 24 pts with 28 avulsed permanent teeth, <u>age</u> - 7-17 y <u>sex</u> - both F-6(9 teeth)& M-18(19 teeth), <u>Location</u> : Germany -2 sites <u>Length</u> : 1990-2000	Cohort (prospective) analytical study Aim- to evaluate if applications of medicaments may enhance the periodontal healing. Up to 1995-teeth were kept moist and stored in physiologic saline; since 1995- in the tissue culture medium of the tooth rescue box; since 1998-additional Tx were used- ART*** antiresorptive-regenerative therapy (dexamethasone for rinsing, on root surface and into alveolus - Emdogain, doxycyclin- systemic use)	-Predominant influence on healing results- the immediate physiological rescue of avulsed teeth (P=0.0001) in physiologic storage -The use of ART-antiresorptive-regenerative therapy seems to support FH (functional healing) in teeth with compromised PDL - Media like Milk and Saline should not be consider as "physiologic" since death of PDL cells stored in these media is progressive and inevitable	<u>Strength</u> : - Long observational period -no teeth were excluded from the study, -detailed analysis and classification of the condition of PDL at the time of placement tooth in phys. storage <u>Weaknesses</u> : -small sample size, -no control	<u>Check list score (efficacy)</u> :15/16 <u>CTFPHE</u> : Level A evidence, Grade-II-2

3	Pohl Y, Filippi A, Kirschner H. Results after replantation of avulsed permanent teeth, III. Tooth loss and survival analysis, 2005 [3]	<p><u>Subjects</u> 24 pts with 28 avulsed permanent teeth, <u>age</u>- 7-17 y <u>sex</u>- both F-6(9 teeth)& M-18(19 teeth), <u>Location</u>: Germany - 2 sites <u>Length</u>: 1990-2000</p>	<p>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.</p> <p>Survival analysis was performed.</p>	<p>- The estimated survival according to a Kaplan–Meier analysis was 57.3 months. - 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. - None of the nine teeth showing FH was lost, the mean observation period was 23.1 months. - 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). - ART seemed to have a positive healing effect when teeth with a compromised but not hopeless periodontal ligament (PDL). In these teeth with a compromised PDL, ART had a significant influence on tooth retention ($P = 0.0389$). - There was no significant correlation between maturity and tooth loss. The survival expectation for teeth without consecutive transplantation was 78.8 months, that for teeth which were replaced by transplants was 24.6 months - There were no other factors related to tooth loss except the use of postoperative antibiotics (cross-tabulation, Fisher's exact test, $P = 0.0410$).</p>	<p><u>Strength</u>: - Long observational period - no teeth were excluded from the study, - detailed survival analysis for parameter tah might be related to tooth loss and survival expectations</p> <p><u>Weaknesses</u>: - small sample size, - no control group</p>	<p><u>Check list score (efficacy)</u>: 15/16</p> <p><u>CTFPHE</u>: Level A evidence, Grade-II-2</p>
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4	D.Boyd et al, A prospective study of factors affecting survival of replanted permanent incisors in children 2000, [4]	<u>Subjects</u> 42 pts with 50 avulsed incisors, <u>age</u> - 6-16, <u>sex</u> - Both F-22& M-20, <u>Location</u> : UK -1 site <u>Length</u> : 1990-95	Cohort (prospective) analytical study Prospective recording of timing of injury & replantation, storage media, degree of root dev and contamination. Completion of root canal Tx	- Freedom from resorption is the outcome. Best predictor for overall resorption was total time of dryness and that of replacement resorption was total extra-oral time (P=0.017). -Survival free of replacement resorption with extra-oral times of less than 90 min 60% vs 25 % when time is greater than 90 min. -Survival free of any resorption with dry storage times of less than 30 min 49% vs 10% when time of greater than 30 min	<u>Strength:</u> -Min follow-up period 2 years, -several factors that may effect the prognosis were evaluated, -good statistical analysis of results <u>Weaknesses:</u> -small sample size, -no control -only 1 clinical site	<u>Check list score (efficacy):</u> 13/16 <u>CTFPHE:</u> Level A evidence, Grade-II-2
5	E.J.Barrett, D.J.Kenny, Survival of avulsed permanent maxillary incisors in children following delayed replantation The Hospital for sick children, Toronto, Canada, 1997 [15]	N-38 pts.(25 males,13 females) 52 replanted permanent maxillary incisor teeth. Follow up time period: 1988-1993 Age range- 11+ years Hospital of sick children, Toronto, Canada	Survival analysis was used to identify variables that significantly influence the retention of replanted incisor teeth Survival was defined as a time lapse between the replantation of avulsed teeth and the time it was finally lost The mean extraoral duration for the sample was 123 min	1. Apical development at the time of replantation was found to be significantly related to the survival. Incisors with open apices exhibited lower survival as compared to incisors with closed apices 2. Teeth with open apices had relative risk of 4.2 greater than the teeth with closed apices 3. Replanted incisors that required prolonged treatment with Calcium hydroxide were found 4.2 times more likely to fail than those obturated with gutta perca and sealer. 4. The reason for limited success in the teeth with open apices was that they require prolonged root canal completion time (calcium hydroxide for apical closure).	<u>Strengths:-</u> -Appropriate age group. Radiographic and Clinical follow up , 3-6 weeks periapical radiographs.3 months examination and radiograph, 6month and at 1 year Examination, radiograph, repl cement of calcium hydroxide if required -5.5 year follow up of the study -In order to ensure that the bias was minimized validated scales for root resorption and root development were used and kappa score was calculated <u>Weakness:-</u> -The study included only delayed replanted cases -No true control group utilized.	<u>Check list score (efficacy):</u> 14 / 16. <u>CTFPHE:</u> Level of evidence-A, Grade II-2

6	Andreasen J, et al, 1995 [6]	<u>Subjects</u> 322 pts, with 400 avulsed teeth <u>age</u> - 5-52 y <u>sex</u> - both F- & M- <u>Location</u> : Copenhagen, Denmark <u>Length</u> : 1965-1988	Replantation of 400 avulsed permanent incisors. 1. Diagnosis of healing complications Replantation of 400 avulsed permanent incisors, in 322 patients and observation of factors related to pulpal healing. The effect of various clinical factors was examined, such as sex, age, type of tooth replanted, stage of root formation, type and length of extra-alveolar storage, clinical contamination of the root surface, type and length of splinting and the use of antibiotics	The results of this study indicated a high risk for all types of complications: <u>PULPAL HEALING</u> : 32 teeth(8%); the chance of pulpal healing appeared to decrease with increasing root development. <u>INTERNAL ROOT RESORPTION</u> : only one case. It was followed by invasion of bone into the root canal and developed into ankylosis. <u>PERIODONTAL LIGAMENT HEALING</u> : PDL healing without any signs of resorption was seen in 96 teeth(24%) and it was significantly related to stage of root development. Teeth with completed root formation and a constricted apical foramen demonstrated the lowest rate of PDL healing. <u>EXTERNAL ROOT RESORPTION</u> : the predominant resorption type was ankylosis, followed by inflammatory resorption and surface resorption. Inflammatory resorption primarily affected teeth with incomplete root formation, whereas the opposite was found for ankylosis. <u>GINGIVAL HEALING</u> : was the usual finding(93%). <u>TOOTH LOSS</u> : 30% of all replanted teeth were later extracted. The more mature stages of root development showed a significantly higher survival rate than teeth with immature root development.	<u>Strength</u> : 1. large sample size 2. strong design : prospective study 3. long period of the study, from 1965 to 1988, with mean observation period 5.1 years 4. standardized patient records were used through the entire period in order to obtain valid data <u>Weaknesses</u> : 1. no control 2. sample patients included adult patients 3.assignment of patients was not randomised	<u>Check list score (efficacy)</u> : 13/17 <u>CTFPHE</u> : Level B evidence, Grade-II-2
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7	Andreasen J.O., Borum M.K., Andreasen F.M. 1995, [7]	<p><u>Subjects</u> 322 pts, with 400 avulsed teeth</p> <p><u>age</u>- 6-9 y <u>sex</u>- both F- & M- <u>Location</u>: Copenhagen, Denmark</p> <p><u>Length</u>: 1965-1988</p>	<p>Replantation of 400 avulsed permanent incisors. 2. Factors related to pulpal healing</p>	<p>in 110 teeth, the apical foramen was either open or half open. In 16 teeth pulps were extirpated prophylactically. Thus, pulpal revascularization was considered possible in 94 teeth. Revascularization occurred in 32 teeth. Three factors were found to be significantly related to pulpal healing: pulp length and extra-alveolar dry and wet period.</p> <p>PULP LENGTH : was the most important predictor for pulp survival: increased pulpal healing with decreased pulp length.</p> <p>WET EXTRA-ALVEOLAR PERIOD: appeared to have a threshold effect, with immediate replantation (wet storage for less than 5 min.) having an optimal effect upon healing.</p> <p>DRY EXTRA-ALVEOLAR PERIOD: increasing periods of dry storage have increasingly negative effect on pulpal healing</p>	<p><u>Strength</u>:</p> <ol style="list-style-type: none"> 1. large sample size 2. strong design: prospective study 3. long period of the study, from 1965 to 1988, with mean observation period 5.1 years 4. standardized patient records were used through the entire period in order to obtain valid data <p><u>Weaknesses</u>:</p> <ol style="list-style-type: none"> 1. no control 2. sample patients included adult patients 3. assignment of patients was not randomised 	<p><u>Check list score (efficacy)</u>: 13/17</p> <p><u>CTFPHE</u>: Level B evidence, Grade-II-2</p>
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8	<p>Andreasen J.O., Borum M.K., Andreasen F.M. 1995, [8]</p>	<p><u>Subjects</u> 322 pts, with 400 avulsed teeth</p> <p><u>age</u>- 6-9 y <u>sex</u>- both F- & M- <u>Location</u>: Copenhagen, Denmark</p> <p><u>Length</u>: 1965-1988</p>	<p>Replantation of 400 avulsed permanent incisors. 3. Factors related to root growth</p> <p>Replantation of 400 avulsed permanent incisors, in 322 patients and observation of factors related to root growth. The present study deals with 30 teeth which were replanted at a stage of incomplete root formation. and the effect of clinical factors influencing completion of root development.</p>	<p>in 30 teeth root formation was incomplete at the time of injury. Two teeth were excluded due to non-physiological extra-alveolar storage (homemade saline). Of 28 remaining teeth, 7 showed subsequently completed root formation, 8 partially completed root development and 13 arrested root development. Completed root development subsequent to replantation was found to be significantly related to pulpal revascularization, being rare in cases with pulp necrosis and frequent after pulpal healing. It also occurred slightly more frequently when the dry period was less than 45 min. The explanatory factor for these findings appeared to be damage to the Hertwig's epithelial root sheat (HERS). The finding that full root length was achieved in 7 cases irrespective of pulpal status (revascularization/necrosis) indicates that HERS can tolerate trauma of avulsion and replantation plus damage due to extra-alveolar storage and sometimes even infection in the root canal.</p>	<p><u>Strength</u>: - large sample size -strong design : prospective study - long period of the study, from 1965 to 1988, with mean observation period 5.1 years -standardized patient records were used through the entire period in order to obtain valid data</p> <p><u>Weaknesses</u>: - no control -sample patients included adult patients -assignment of patients was not randomized</p>	<p><u>Check list score (efficacy)</u>: 13/17</p> <p><u>CTFPHE</u>: Level B evidence, Grade-II-2</p>
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9	Andreasen J.O., Borum M.K., Andreasen F.M. 1995, [9]	<p><u>Subjects</u> 322 patients, with 400 avulsed teeth, with 272 teeth selected for the multivariate statistical analysis.</p> <p><u>Length:</u> 1965-1988</p>	<p>Replantation of 400 avulsed permanent incisors. 4. Factors related to periodontal ligament healing</p>	<p>In the total material of 400 teeth, PDL healing was found in 96 teeth (24%). Of 272 cases selected for the multivariate statistical analysis, 69 teeth (25%) showed PDL healing. The 272 teeth revealed 9 factors significantly related to PDL healing, but the 4 following factors had the strongest impact upon PDL healing, in decreasing order of significance :</p> <ul style="list-style-type: none"> -stage of root development, -length of the dry extra-alveolar storage period, - immediate replantation -length of the wet storage period. <p>The material was divided into the following healing categories:</p> <ol style="list-style-type: none"> 1-normal periodontal healing; 2-surface resorption; 3-inflammatory resorption; 4-ankylosis; 5-combinations of 2-4 <p><u>Normal periodontal healing</u> without any signs of resorption was seen in 96 teeth.</p> <p><i>Surface resorption</i> was found in 18 of the 400 teeth and was usually diagnosed no later than 12 months after replantation.</p> <p><u>Inflammatory resorption</u> was found in 120 of the 400 cases and could usually be diagnosed within the first 6 months. In cases with late appearance inflammatory resorption, it was usually secondary to the progression of ankylosis along a deficient root filling.</p> <p><u>Replacement resorption (ankylosis)</u> was found in 243 of the 400 cases and was usually first diagnosed by clinical changes (high metallic percussion sound and lowered or absent mobility values), which usually became evident after 1 to 2 months. Radiographic signs of ankylosis could only be seen in 212 cases and usually became apparent after 1 year.</p> <p>The present study indicates that the single factor which might most efficiently improve PDL healing would be immediate replantation. In cases where immediate replantation cannot be carried out, the present study indicates no preference for storage in oral cavity (saliva) or in saline.</p>	<p><u>Strength:</u></p> <ul style="list-style-type: none"> -large sample size - strong design: prospective study - long period of the study, from 1965 to 1988, with mean observation period 5.1 years - standardized patient records were used through the entire period in order to obtain valid data <p><u>Weaknesses:</u></p> <ul style="list-style-type: none"> -no control -sample patients included adult patients -assignment of patients was not randomized 	<p><u>Check list score (efficacy):</u> 13/17</p> <p><u>CTFPHE:</u> Level B evidence, Grade-II-2</p>
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10	Cester T. Coccia., A Clinical investigation of root resorption rates in reimplanted young permanent incisors: a five – year study 1980, [13]	9-14 82 children	129 avulsed teeth. Reimplanted within 12 h after accident. Teeth are fully developed. No fractures or cracks on teeth, intact socket.	22% failure 78% success. 27 teeth were lost in 5 years. Root resorption: less than 7h before replantation—2.7—4.7mm Root resorption: more than 7h before replantation 3.6-6.13mm Teeth with early (immediate, 48h) pulpectomy showed less resorption. Teeth with late (1-4 weeks) showed more resorption. Teeth were fluoride treated vs. no fluoride treatment had less resorption	<u>Strengths:</u> Long follow-up period. Acceptable sample size <u>Weakness:</u> Weak design Insufficient data about extra oral time and storage medium in which teeth were stored prior to replantation. Time b/n avulsion, reimplantation is very important. Early pulp ectomy may reduce inflammatory resorption. Fluoride may reduce the rate of resorption. Design is weak.	<u>Check list score (efficacy):</u> 11/17 <u>CTFPHE:</u> Level of evidence B Grade-II-2
11	I.C.Mackie, H.Worthington, Avulsed human teeth replanted within 15 minutes, long-term clinical follow-up study. 1992, [10]	-36 pts -24 male 12 female -mean age : 9 (6-12) -University dental hospital of Manchester	Information from 46 replanted avulsed incisor teeth was collected from the pt's records regarding length of the time the tooth was dry, storage medium, condition of pulp, state of root development, personnel responsible for treatment, type of splint used and the splinting period. These teeth were re-examined between 1-6 years.	-Significant increase in root resorption in teeth that has been stored dry compared with those that had been stored in saliva, milk or saline. (p<0.05) -no relationship between the time the avulsed tooth was out of the mouth and success. -no significant relationship between the state of root development and the success of treatment. -no significant difference between the success of tx when the pulp was extirpated in the first 2 weeks compared with those the pulp were left until obvious signs of loss of vitality.	<u>Strengths:</u> -Long review period (mean length of time was 3 yrs (1-6 yrs) -all study group except one were re-examined. -all were treated in trauma clinic according to a standard treatment protocol, usually the direct supervision of one of the authors.(I.C.M). <u>Weakness:</u> -information was collected retrospectively from the patients' hospital notes and by telephone -small sample group	<u>Check list score (efficacy):</u> 10/17 <u>CTFPHE</u> Level:B (fair) Grade II-2 retrospective
12	Lars Andersson ,Ingrid Bodin Avulsed human teeth replaced within 15 min-a long term clinical follow up study, 1990, [11]	21 teeth/18 pt Aged 7-29 Central incisors (maxillary & mandibular) Stockholm 1990	Replantation Teeth with extraoral time less than 15 min	-No resorption after immediate or within 10min replantation -Some resorption not necessarily progressing after 15 min replantation -Root resorption rate lower than tooth replanted after long term replantation (after 60 min) -No meaningful relationship between rate of root resorption and splinting time or onset of endo treatment	<u>Strengths:</u> long-term clinical follow up average follow up 5yrs <u>Weaknesses:</u> information collected only through radiographs not considering all possible outcomes such as ankylosis	<u>Check list score (efficacy):</u> 11/15) <u>CTFPHE</u> level of evidence :B Grade II-2:prospective follow up

13	I.C.Mackie, H.Worthington, Investigation of the children referred to a dental hospital with avulsed permanent incisor teeth. Authors: Endodont Dent Traumatol 1993; 9: 106-110, [12]	-46 teeth/36 patients, -Age range between 6 and 14 years old, -University dental hospital of Manchester 1993	Retrospective study on a group of 49 children between the ages of 6 and 14. They were assessed for ankylosis, infraocclusion, root resorption, apical pathology and the state of root development	The mean age when the teeth were avulsed was 9 years old. The most common teeth are upper incisors. The majority of teeth were kept dry (60%). The time between the avulsion and replantation was 113 minutes on the average.75% of the children received treatment at first contact and 25% were referred. for them the average time was 263 minutes. The boys were twice the number of the girls. At review time 41 replanted teeth were still present, 5 of them being vital, 23 root filled and 13 had root canal dressings of calcium hydroxide. Five cases had failed because of chronic apical infection, root resorption, loss of marginal bone support due to infection, and caries. No relation between the place and personnel involved in the replantation and the success was found.	<u>Strength:</u> -Long review period - good defined criteria of success - proper age range of study <u>Weaknesses:</u> -Some information was gathered by telephone -There is no specific timetable to show for how long after the initial replantation the teeth were successful.	<u>Check list score (efficacy):</u> 10/17 <u>CTFPHE:</u> Level of evidence: B (fair) Grade II-2 (retrospective)
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14	<p>Replantation of 45 avulsed permanent teeth -1 yr follow-up.</p> <p><i>Vivianne Chappuis, Thomas von Arx. Oct. 2005. [14]</i></p>	<p>N-34 pts. 45 avulsed permanent teeth.</p> <p>Age range- 6-48 yrs, mean-21 yrs with 74 % < 16 yrs.</p> <p>University of Berne, Switzerland</p>	<p>1. Avulsed teeth soaked for 30 mins. in Dentosafe (special storage medium) upon arrival in clinic;</p> <p>2. Soaked prior to replantation in 5% tetracycline;</p> <p>3. EMD applied to socket and root surface where dry storage time > 30 mins.(N-10)</p> <p>4. Teeth stabilized with non-rigid splint.</p> <p>5. Teeth with closed apices endo treated in 7-10 days.(N-27) Ledermix paste dressing used.</p> <p>6. Teeth with open apices and ideal storage following avulsion not endo treated.</p> <p>7. Post-op systemic tetracycline regimen prescribed for 10 days.</p>	<p>Survival rate at 1 yr. re-exam - 95.6% (43/45).</p> <p>1- Pulpal Healing: - Teeth that were not root canal treated showed signs of pulp necrosis at 1 yr follow up. One with closed apex developed progressive infection related external root resorption, the other endo-perio lesion, both necessitating extraction. Three teeth with open apices showed pulp canal obliteration.</p> <p>2-Periodontal Healing: - 26 teeth (37.7%) - Normal healing.</p> <p>a. Pd. Healing more common in teeth with open apices (62.5% compared to 55.2%).</p> <p>b. Replacement resorption (ankylosis) seen in 13 teeth; less frequent in teeth with open apices-25%, compared to 31%.</p> <p>d. Dry storage time < 15 mins.had 9.5% replacement resorption compared to 100% in teeth with >60 min. dry storage time.</p> <p>e. Replacement resorption was found in 50% of EMD treated teeth compared to 22.8% without.</p> <p>No true control employed. However within the study, 2 teeth with closed and 3 with open apices were not endo treated (declined by either pt. or private dentist) (N-5).</p>	<p>Strengths:- Appropriate age group. Radiographic and Clinical follow up including- Inspection, Palpation, Percussion, Perio-test measurements ,pulp sensitivity using Co2-snow, pulp vitality testing with laser Doppler flowmetry, of all patients done.</p> <p>Weakness:- -Results based on short follow up period. -No true control group utilized.</p>	<p><u>Check list score (efficacy):</u> 12 / 17.</p> <p><u>CTFPHE:</u> Prospective Therapeutic clinical trial.</p> <p>Level of evidence-B, grade II-1.</p>
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Appendix 4 Survival curves

Fig. 1. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. [3]

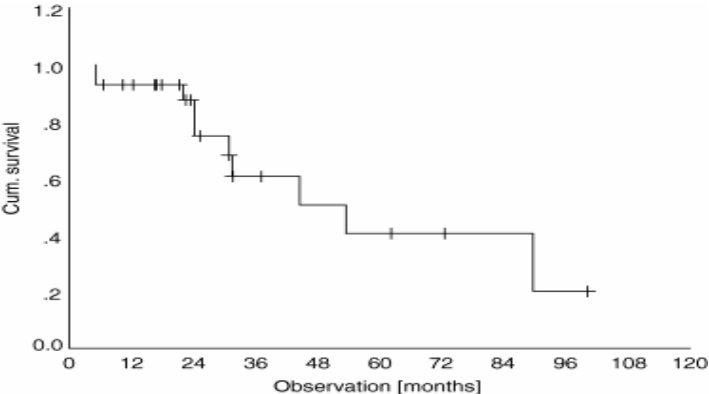


Fig. 2. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for storage conditions: physiologic storage (tooth rescue box) versus unphysiologic storage.[3]

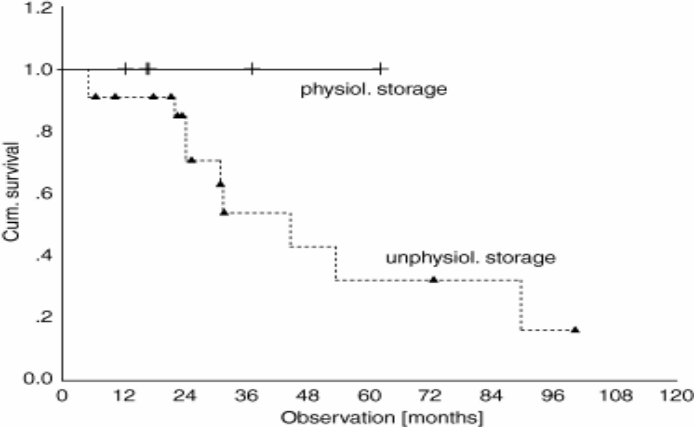


Fig. 3. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for healing type: functional healing versus complication. [3]

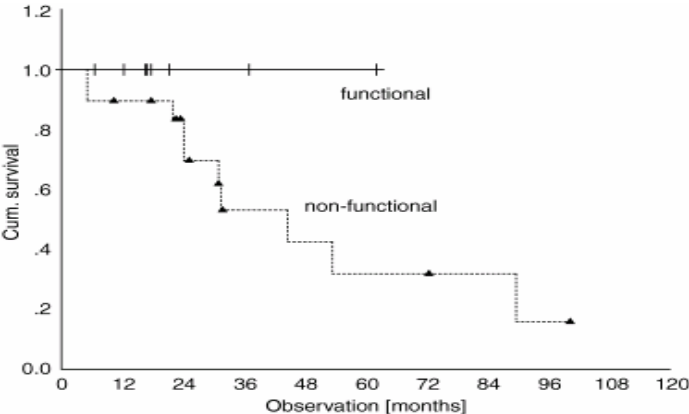


Fig. 4. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts . Stratified for healing type: functional healing versus replacement resorption (RR) versus infection related resorption (IRR).[3]

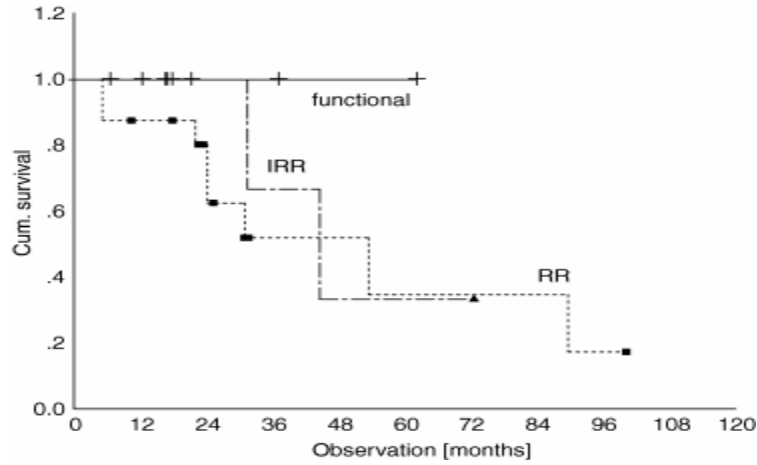


Fig. 5. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for maturity: immature roots (stages 2 to 4) versus mature roots (stages 5,6). [3]

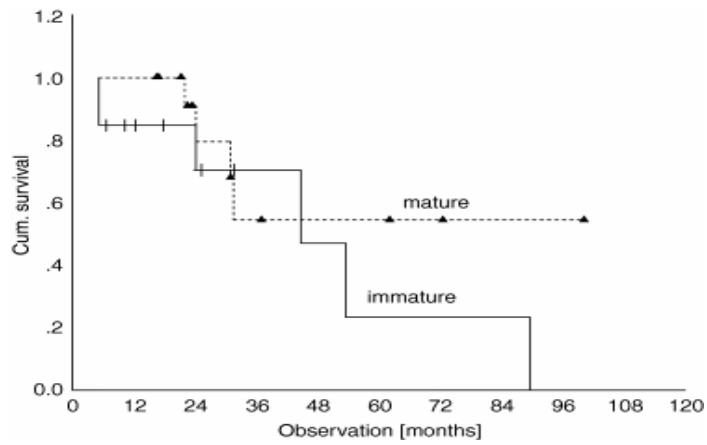


Fig. 6. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Only teeth which exhibited non-functional healing. Stratified for maturity: immature roots (stages 2 to 4) versus mature roots (stages 5,6).[3]

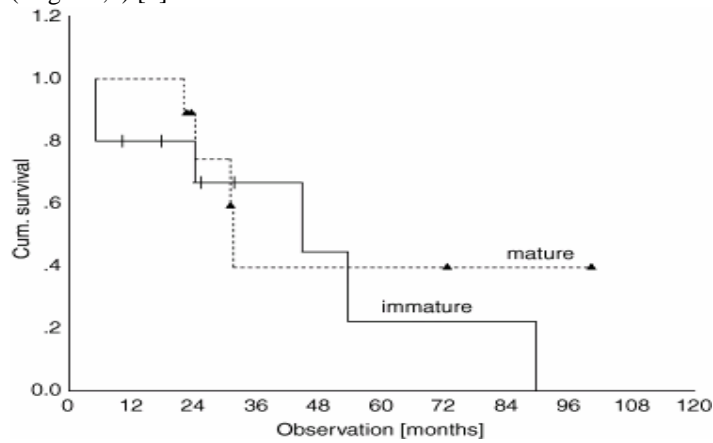


Fig. 7. Survival curve for avulsed teeth replanted in growing patients following extraoral insertion of posts. Stratified for consecutive therapy: transplantation of premolars and primary canines versus no transplantation ($p = 0.0010$). 1: new trauma 2, 3 infraposition. [3]

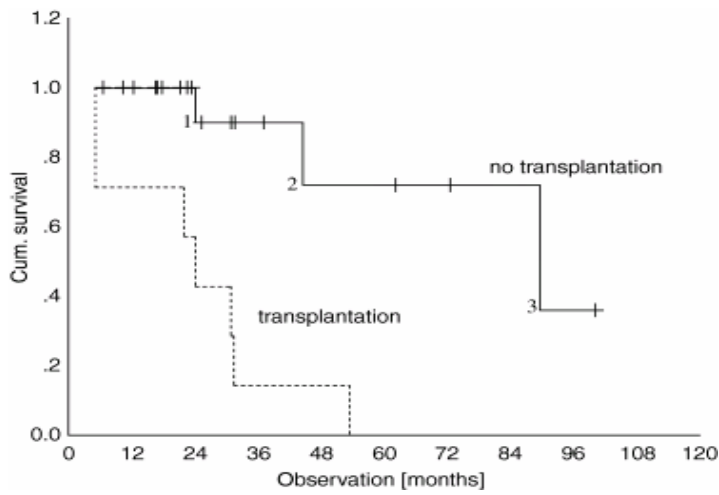


Fig. 8 Pulp and PDL healing and tooth survival related to stage of root development at the time of injury. PDL healing represents clinical healing, i.e. without signs of progressive resorption. [6]

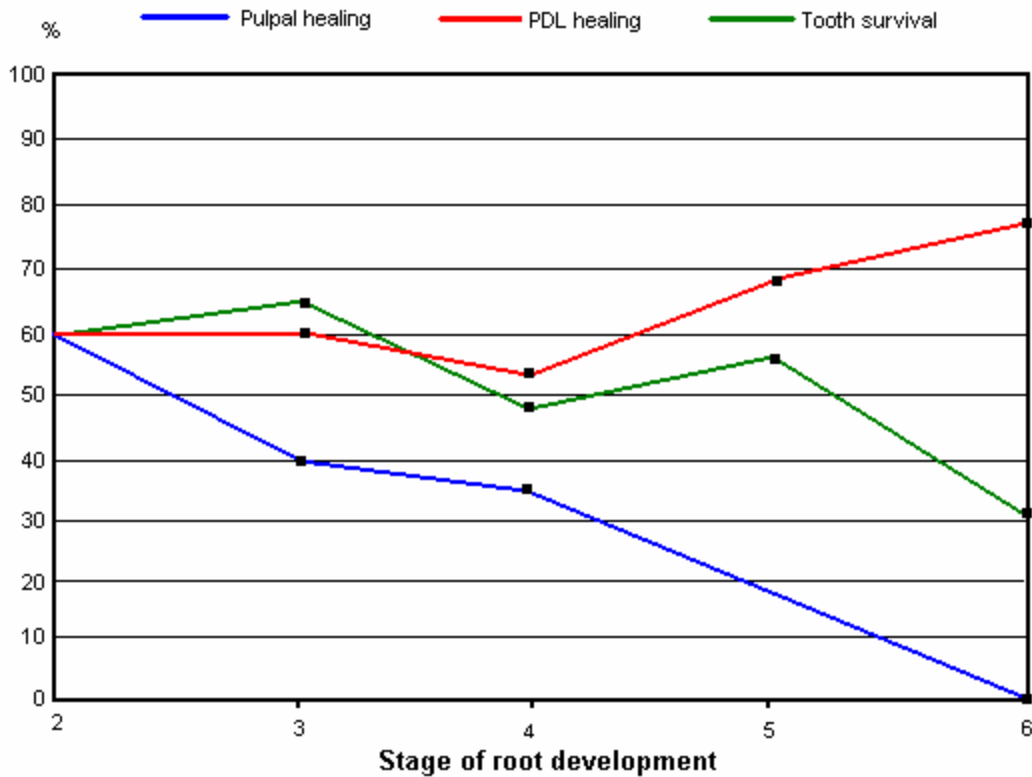


Fig 9. Survival rates of the incisors implanted with closed apices and the incisors with the open apices . [15]

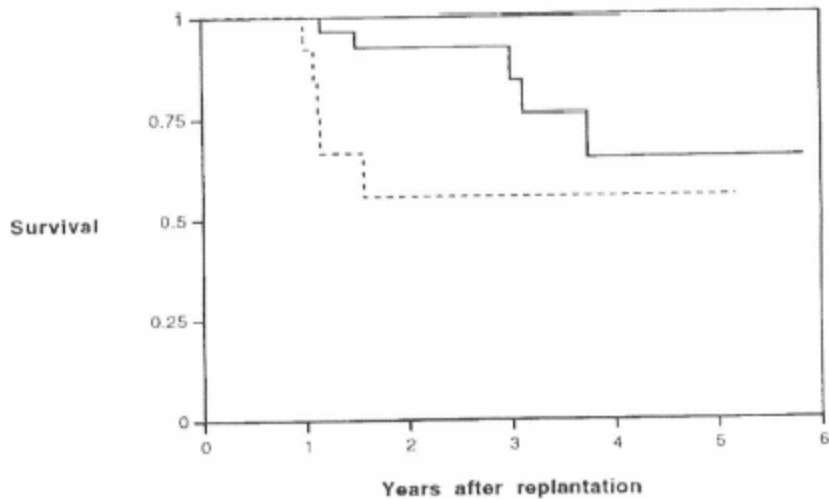


Fig. 2. Survival curves for the 'worst' case data stratified on the basis of apical development at the time of replantation. The two curves differed significantly from each other ($P=0.008$). The solid line represents incisors replanted with closed apices and the dotted line incisors with open apices.

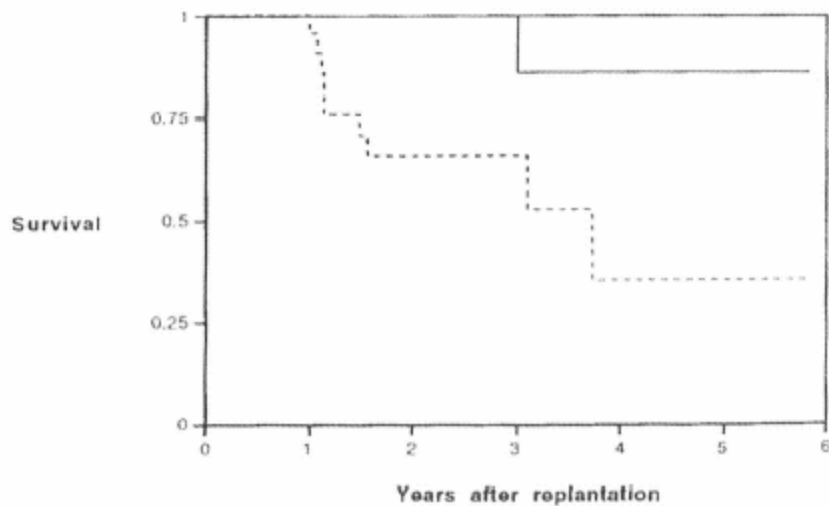


Fig. 3. Survival curves for the 'worst' case data stratified based on the completion of endodontic treatment. The two curves differed significantly from each other ($P=0.005$). The solid line represents teeth with completed endodontic treatment and the dotted line those without completed endodontic treatment.

Figure 10. Survival free of any resorption for avulsed teeth with dry storage times of less than 30 mins (upper curve) and of greater than or equal to 30 mins (lower curve). [4]

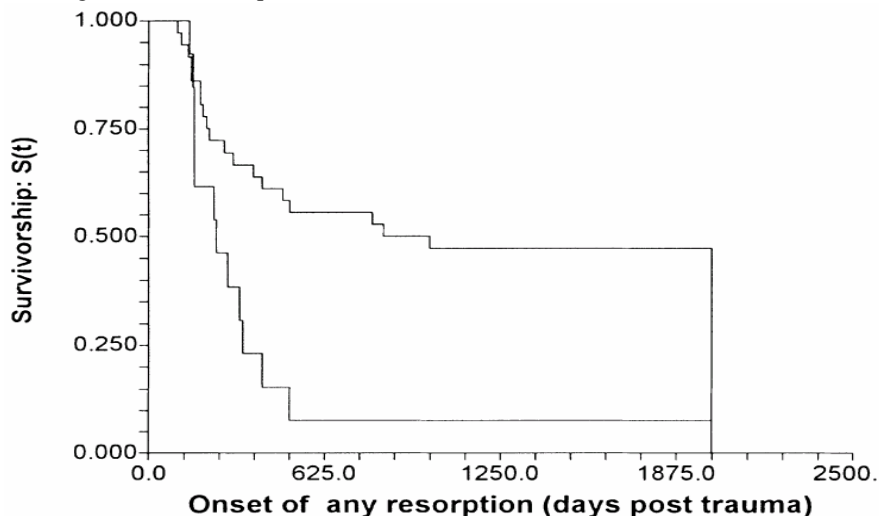


Fig 11. Survival free of replacement resorption for avulsed teeth with extra-oral times of less than 90 mins (upper curve) and of greater than or equal to 90 mins (lower curve).

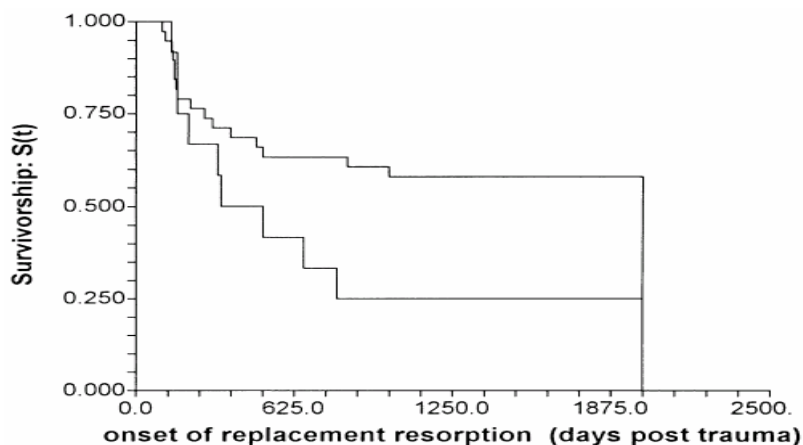


Fig 12. Tooth survival related to stage of root development at the time of replacement. [6]

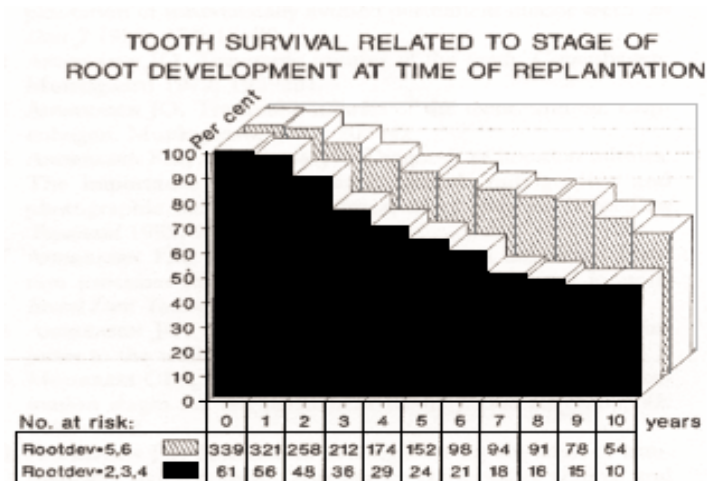


Fig. 4. Tooth survival related to stage of root development at time of injury.