Treatment of avulsed permanent teeth in children

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Structure of Guideline

The guideline is made up of the following sections:

Executive Summary
Introduction and remit of guideline
Guideline development and methodology
Outcomes/ Glossary (O)
Management (M)
Explanatory Notes (EN)
References
Appendix A: Treatment flow chart
Appendix B: A sample structured history form for recording dento-alveolar trauma and details of the electronic computer trauma record
Appendix C: Patient information for avulsion injuries
Appendix D: Telephone advice for parents or bystanders following avulsion injury
Appendix E: Poster with advice for the public following an avulsion injury
Appendix F: Guideline development and methodology

Executive summary

Traumatic dental injuries are common, with between 6-34% of children aged 8-15 experiencing damage to their permanent teeth [O'Brien, 1993; Hamilton *et al.,* 1997; Chadwick *et al.*, 2006]. One of the most severe dento-alveolar injuries is avulsion, where the tooth or teeth are completely knocked out of the mouth. This injury accounts for between 0.5 to 3% of dento-alveolar trauma to permanent teeth [Andreasen and Andreasen, 2007]. In the most severe scenarios, the tooth or teeth are lost, e.g. not replanted, or extracted due to the failure of the replanted tooth. The latest UK national survey [Chadwick *et al.,* 2006] reported a prevalence of 1.2% of fifteen-year old children with missing anterior teeth as a result of trauma. Over three quarters of all traumatic oral injuries occur in childhood [Eilert-Petersson *et al.,* 1997] and for this age group the mouth was the fourth most common site of injury, despite occupying only 1% of the body surface.

Since this document was originally published [Gregg and Boyd, 1998] there have been significant changes in our understanding of this injury and the potential outcomes of healing. The treatment options have changed little, with still very few robust clinical trials which have investigated what options the dentist or health care professional is able to provide to improve the clinical outcome [Day and Duggal, 2010]. What is presented in this guideline is the best evidence available based on human, animal and in-vitro studies.

This guideline has been updated and one of the authors has also contributed to the International Association of Dental Traumatology guideline and had a very minor role in reviewing the Dental Trauma Website (www.dentaltraumaguide.com). This guideline complements these other sources of advice. There are a number of areas where it differs and these include:

- The development of the guideline is clearly described. This includes details of the search strategy used, a narrative of how the review process was undertaken and a discussion of the literature that supports each treatment intervention and the strength of this evidence.
- The treatment and care described is for a UK audience, which allows the guideline to concentrate on national issues relevant to our population and healthcare system.
- Specifically it differs from these other two sources of guidance with respect to the cut off point when the avulsed tooth has little chance for cemental/periodontal healing (see page 22) and after this time point whether the periodontal ligament should be removed or not (see page 46). The guideline reviews the evidence and estimates that up to 10% of teeth beyond this time point may still demonstrate cemental/periodontal healing. It is therefore at the clinician's discretion whether they want to give the tooth a chance of cemental/periodontal healing beyond this time point. It should be identified that over

90% of teeth will heal unfavourably, ankylosis, and treatment which accepts this can be provided in the emergency situation which will reduce the number and length of subsequent clinic visits.

- The use of a topical antibiotic soak is not currently recommended in this guideline (see page 32) . The literature demonstrates a favourable benefit for use of an antibiotic soak. There is, however, no readily available soaking solution in the UK and insufficient evidence to recommend one particular drug, dose or duration.
- Early involvement (either discussions or referral) of specialist inter-disciplinary teams to identify the likely prognosis and treatment planning over the short, medium and long term is strongly recommended. This needs to be supplemented by clear communication between parents, children and primary and specialist care providers to ensure each is clear about the treatment required and who will provide it.

The local dentist, the accident and emergency department, dental access centre or a secondary dental care provider may provide emergency care for this injury. Such injuries require immediate access to these services as the prognosis for the tooth/teeth diminishes rapidly. It is appropriate that parents, bystanders or health care professionals replant the tooth at the scene of the accident or in a hospital setting before referring the child on to a dentist for splinting and definitive repositioning. Even at this early stage, decisions must be made with regard to the long-term outcomes for the tooth that will determine what treatments are provided. The guidelines are presented in three formats. A treatment flowchart (appendix A), management notes which give further information to clinicians (starting on page.13) and explanatory notes which review the evidence and reasoning behind each recommendation (starting page.22).

Follow up care needs good coordination between the initial provider of treatment and access to secondary care specialist services (an inter-disciplinary team – an orthodontist and a clinician with the appropriate experience and training in the holistic management of complex dento-alveolar trauma e.g. a paediatric dentist). This team will benefit from other specialists when they will be providing the longer-term care, for example a transplant or implant. What is clear is that parents and children need to be fully informed of the prognosis of the avulsed teeth **as soon as possible.** Further, the potential costs and time required with regard to the different treatment options should be openly discussed. Treatments of little proven benefit, unless requested by the child, should be avoided to prevent unnecessary additional visits or expectations. To help parents and children with avulsion injuries, a patient information sheet is provided with this guideline, Appendix C. At the emergency visit or visits parents may find verbal information difficult to remember and thus the benefit of written information is invaluable.

The cost to the health service, parents and children is considerable because long term dental care is required for this injury. Furthermore severe dental trauma almost always involves the upper anterior teeth with a considerable effect on dental and facial aesthetics. This frequently coincides with adolescence and can have a significant impact for some children on their quality of life.

There are five key areas that need improving in the current services provided for children in the UK with avulsion injuries:

- The provision of better public information so that parents, bystanders and front line medical staff are aware of the most appropriate treatment to provide, e.g. replant the tooth as best they can, or failing this, to place the avulsed tooth in milk and attend emergency dental services.
- Improve information to the public and medical staff on how to access emergency dental services quickly.
- Better provision of emergency dental care with a clinician competent in making the diagnostic decisions and delivering the appropriate treatment.
- A clinical care pathway to ensure that more complex injuries, avulsions being one, are seen soon after the injury by a specialist inter-disciplinary team to accurately predict the outcome for the tooth or teeth and plan for the short, medium and long term future.
- Finally, the need for improved research and audit using multi-centre collaborations to investigate robustly the treatment options currently used and potential treatments for the future.

Introduction and remit of guideline

The following guideline is intended to assist in the management and treatment of avulsed permanent teeth in children and adolescents until the completion of facial growth. They should be used by practitioners, in combination with their own professional judgement. Although it is impossible to guarantee a good long term prognosis or permanent retention of a tooth that has been replanted following avulsion, timely treatment of the tooth in the appropriate manner maximises the chance of success. The various definitions of success are described in the OUTCOMES section, on page 8. The MANAGEMENT section on page 13 gives a prescriptive description of treatments to be provided for an avulsed tooth or teeth. A more detailed discussion of the evidence and reasoning behind the guideline recommendations is given in the EXPLANATORY NOTES section that follows, on page 22. The level of evidence that supports each treatment is stated according to SIGN classification [SIGN 50: 2008].

Target group for guideline

The guideline has been developed for clinicians who may provide initial and follow up care for children suffering avulsion injuries. As a result of the scientific language used within the guideline, additional documents (namely Appendices C, D and E) provide information for bystanders or parents who may provide emergency care at the scene of the accident.

Clinical questions to be covered by the guideline

When should a permanent tooth be replanted?
What factors influence periodontal and pulpal healing and tooth survival?
How should the tooth be stored prior to replantation?
What techniques should be used to replant and splint the tooth?
What adjunctive medicaments and interventions influence the outcomes?
When should endodontic treatment be undertaken?
When should patients be referred for specialist opinions following initial treatment?

Guideline development and methodology

There has been some concern in the literature with regard to the development of clinical guidelines in dental trauma [Kenny *et al.*, 2003] and the lack of transparency in the process. Therefore for this guideline the search strategy is reported (Appendix F) and is taken from the Cochrane review carried out by the lead author [Day and Duggal, 2010]. The human studies identified and reviewed are listed in the same appendix. For each paper, the treatment provided and outcomes reported were reviewed. The criteria for selecting the evidence and methods used to formulate the recommendations are further described in Appendix F.

All treatment recommendations have been graded using the SIGN classification [SIGN 50: 2008] and this allows clinicians to judge the quality of evidence supporting each. Unfortunately the level of evidence to support these treatment interventions is frequently low or based on animal or in-vitro studies. This is, however, the best evidence currently available.

The guidelines developed by the American Academy of Pediatric Dentistry [2007], International Association of Dental Traumatology [Flores *et al.*, 2007] and American Association of Endodontists [2004] have been reviewed as part of this process.

Following development of this guideline by the authors, they have been circulated through the clinical effectiveness committee of BSPD to all respective groups within BSPD. In addition, external peer review has been sought from three leading external experts in the field (Professor Lars Anderson, Professor Jens Andreasen and Professor Dave Kenny). With respect to some areas complete agreement was not always possible. Therefore the guideline represents the authors considered opinion of the published evidence at the time of writing.

Reviewing and Updating
This guideline will be reviewed every three years.

No external or internal funding has been received by either author for the development of this guideline. The first author led a multi-centre randomised controlled trial examining two endodontic root canal pastes for avulsed and replanted teeth. The study was partially funded by Department of Health and Henry Schein grants. Free materials for the trial were provided by Mediartis – TTS splints, Henry Schein - Ledermix® ® and Optident – Ultracal XS®. There are no other conflicts of interests reported.

OUTCOMES (O)

Before the different treatment options are discussed the potential outcomes for the avulsed tooth should be defined. The prognostic factors which influence which of these outcomes are most likely is described in the Explanatory Notes, on page 22.

O - Periodontal healing

The root of the tooth is separated from the alveolar bone by a thin layer of connective tissue, the periodontal membrane. This consists of cementum and a periodontal ligament (fibroblasts, dense network of collagen fibres with embedded nerves and blood vessels and remnants of the epithelial root sheath).

The periodontal membrane attaches the root to the adjacent bony socket. It also prevents the adjacent bone from resorbing the tooth as part of physiological bony remodelling. An absence of the periodontal membrane results in ankylosis, a union between tooth and bone.

The types of periodontal healing following avulsion injury can be defined as:

Regeneration: The regeneration of a healthy periodontal membrane after extensive necrosis of these tissues following injury.

Likely to occur when: currently there is no technique or medication that are able to consistently facilitate the regeneration of a periodontal membrane.

Cemental/Periodontal ligament (PDL) healing: The re-establishment or repair of a vital periodontal membrane between the replanted tooth and its socket. This requires the repair of any damaged cement and the associated periodontal ligament. In the literature this has also been described as favourable healing [Trope M, 2002] and in some animal studies normal periodontal ligament and surface resorption (now also called repair related resorption) have been summated to give the proportion of the root showing favourable healing.

Likely to occur when: there is minimal damage to the periodontal membrane from the avulsion injury and the subsequent storage prior to replantation.
Outcome: the tooth can be expected to last as long as an adjacent uninjured tooth.

Bony healing (ankylosis): this occurs following significant injury to the periodontal membrane. Alveolar bone from the adjacent bony socket fuses to the root surface. With time the bone will remodel and this leads to the loss of the root as it is replaced by bone. This is known as replacement resorption.

Likely to occur when: there is significant damage to the periodontal membrane as a result of the injury or the subsequent storage prior to replantation. This type of healing will only occur if there is an absence of infection within the root canal space.

Outcome: The tooth will eventually be lost once the entire root is replaced by bone. Ankylosis is a slow process which maintains surrounding bone and allows time for clinicians to assess other treatment options as part of an inter-disciplinary team [Day *et al.,* 2008]. In a growing child over time this can give an unsatisfactory appearance as the tooth infraoccludes in comparison to an adjacent non ankylosed tooth or teeth. Where infraocclusion is detected (greater than a 1mm discrepancy in gingival margin with a contra lateral non ankylosed tooth) treatment is indicated before the clinical appearance gets worse.

Uncontrolled infection (inflammatory resorption or infection related resorption): This occurs when there is an untreated infection of the root canal space combined with damage to the periodontal membrane and cementum following avulsion and replantation.

Likely to occur when: there is a failure to extirpate the necrotic pulp tissues and eliminate the associated infection following avulsion and replantation.

Outcome: This is preventable and once established, infection related resorption can be difficult to eliminate [Andersson *et al.,* 1989; Trope *et al.,* 1995]. The loss of the tooth is rapid [Kinirons and Boyd, 1999] allowing less time to plan for its replacement and furthermore may compromise future options due to the loss of adjacent alveolar bone.

Summary of periodontal healing

The aim of treatment is to facilitate cemental/PDL healing. For many teeth that suffer avulsion and replantation as a result of the emergency care this is unrealistic and therefore the optimal outcome is ankylosis.

O - Pulpal healing

Types of pulpal healing can be defined as:

Regeneration (also called revascularisation or pulp metaplasia): This occurs where new tissue grows into the root canal space and re-establishes a biological filling of this space. The type of tissue is variable (metaplasia) and is an area of active research.

Likely to occur when: the avulsed and replanted tooth has an immature root form [Kling *et al.*, 1986; Andreasen *et al.*, 1995e] and has had a brief extra alveolar period prior to replantation.

Outcome: a variety of tissues can grow in the root canal space, furthermore on some occasions continued root growth in both length and root width occurs. If no further root growth occurs these immature teeth are at high risk of coronal crown root fracture. Therefore any further root growth is beneficial.

Controlled necrosis (with disinfection of root canal space): occurs where the chances of pulpal regeneration are small or non existent and the clinician electively removes the necrotic pulpal tissue minimising any chance of this space becoming infected and inflammatory root resorption developing.

Likely to occur when: avulsed and replanted teeth have no chance of pulpal regeneration as a result of their complete root development and the pulp has been extirpated with removal of infection. This is usually within 10 days after the injury.

Outcome: The root canal space is disinfected and at the appropriate time obturated with gutta percha.

Uncontrolled infection: pulpal necrosis and infection of the root canal space is predictable in the vast majority of avulsed teeth and if untreated can lead to the risk of infection related resorption and on some occasions pain and swelling.

Likely to occur when: there is replantation of the tooth without appropriate follow up care and failure of pulpal extirpation and disinfection at the appropriate time.

Summary of Pulpal Healing

Although pulpal regeneration is desirable especially in immature teeth, in most situations this is unrealistic and therefore elective disinfection of the root canal space is an optimal outcome. With modern day endodontic techniques and success rates, pulpal regeneration may in some occasions be sacrificed to increase the chance of periodontal healing by avoiding the chance of infection related resorption and therefore tooth survival. In the vast majority of cases uncontrolled infection, inflammatory root resorption, is predictable and an unacceptable outcome.

O - Tooth survival

Tooth survival is related to periodontal healing [Andersson *et al.*, 1989; Andreasen *et al.*, 1994]. Where cemental/PDL healing has occurred the tooth will be expected to last as long as an uninjured adjacent tooth. When periodontal repair occurs by ankylosis the root will slowly be replaced by bone. The speed of this process is governed by the age of the patient and speed of bone turnover [Andersson *et al.*, 1989; Barrett and Kenny, 1997]. In adults, replacement of the root by bone is a slow process that takes place over a longer time frame (5-20 years). In children, replacement is more rapid, especially if ankylosis occurs before puberty [Andersson *et al.*, 1989; Barrett and Kenny, 1997]. In children the consequences of ankylosis are complicated further by lack of vertical growth in this area with the consequent infraoccluded appearance [Malmgren and Malmgren, 2002]. Ankylosis must be **detected as early as possible** or assumed in clinical scenarios where there is minimal chance of cemental/PDL healing. There should be short, medium and long term planning for the loss of the tooth or teeth which should be discussed with the child and family since the management of ankylosis is complex and frequently requires an inter-disciplinary approach [Day *et al.*, 2008; De Souza *et al.*, 2010].

O - Discolouration

Discolouration is an important outcome that concerns children and their families and may necessitate further treatment. Two case series [Ravn and Helbo, 1966; Ebeleseder *et al.,* 1998] report discolouration following avulsion injury. This obviously has significant concerns for the child, especially if the colour differs significantly from the adjacent teeth. In Ebelesder *et al* [1998], thirty five percent of avulsed and replanted teeth became discoloured. However, no patient perception was reported.

Non-setting calcium hydroxide and Ledermix® were found to cause a yellow and grey discolouration respectively in one clinical randomised controlled trial [Day *et al.,* 2011]. These medicaments are recommended in this guideline in some situations but to reduce the risk of discoloration they should be placed only in the root canal. Care should be taken to remove any material from the access cavity and crown of the tooth.

O - Quality of life and health economics

Traumatic injuries invariably affect the anterior maxillary teeth [Andreasen *et al.,* 1995d], with central incisors being most frequently involved [Jacobsen and Andreasen, 2001]. The injuries may affect dental health, appearance, facial aesthetics and in some cases also have a negative psychological impact [Cortes *et al.,* 2002; Fakhhruddin *et al.,* 2008; Berger *et al.,* 2010; Rodd *et al.,* 2010]. It is unsurprising therefore that, especially during adolescence, injuries can have a harmful psychological impact on the child's social interaction with other children and adults [Cortes *et al.,* 2002; Fakhhruddin *et al.,* 2008]. It is therefore crucial to try to consider the child's concerns and achieve an optimal aesthetic appearance. Care should be child centred.

Current treatment for this injury is time-consuming with one study reporting an average 7.2 hours spent in the dental chair and the direct costs of initial treatment averaging $1780 (Canadian dollars) in the first year alone [Nguyen *et al.,* 2004]. The indirect costs, time off work and school, are considerable and are a recurring theme when patient and parent are questioned. Glendor *et al.* [2000] estimated that direct dental chair time only made up 16% of the time taken by parents and children to attend these appointments. Despite these costs and impact on parents' and children's lives, both were supportive of the treatment decisions made [Nguyen *et al.,* 2004].

MANAGEMENT (M) –

A summary flowchart is given in Appendix A

M 1. Management at Site of Accident

1.1 If telephone advice is sought, and replantation is appropriate (see section M 2.2.1., page 14), advise immediate replantation at the site of the accident. Specific advice to patients, parents, bystanders or to medical staff is given in Appendix D.

1.2 If immediate replantation is not possible, place the tooth in a vessel containing suitable storage media - in order of preference: milk, physiological saline or saliva. Advise to attend the dentist immediately.

M 2. Initial Management by Dentist

2.1 History

During examination, place tooth in fresh milk or physiological saline to prevent further damage to the root surface. If the tooth has already been replanted, leave it in situ. Elicit careful medical, dental and accident history. Thoroughly examine the head and neck and intraorally for both bony and soft tissue injuries. Be alert to concomitant injury including head injury, facial fracture or lacerations. Seek medical examination as necessary. Avoid unnecessary delays prior to replantation.

M 2.2 Determine prognosis (if tooth has not already been replanted)

If extra alveolar dry time is less than 30 minutes and extra alveolar total time is less than 90 minutes when stored in an appropriate storage medium (e.g. milk, physiological saline or saliva if neither of the others are available) then there is a chance of cemental/PDL healing. Best estimates are that this chance is greater than 10%. Then follow advice in M3, page 15. Further guidance on these prognosis factors are given in the Explanatory Notes (on page 22).

If the tooth has already been replanted follow treatment described in M3, page 15.

If the extra alveolar dry time is greater than 30 minutes or extra alveolar total time is greater than 90 minutes or stored in an inappropriate storage medium (e.g. water) then healing following replantation is likely to be by ankylosis. Best estimates are that this chance is greater than 90%. Treatment described in M4, page 20 should be undertaken prior to replantation, having first assessed the benefits and disadvantages of replanting a tooth where ankylosis is likely to occur. Where the clinician does not feel sufficiently confident, experienced or have time to make this decision please follow guidance from M3, page 15.

Bottom line: The decision to **replant is almost always the correct decision** unless one of contra indications listed in section M. 2.2.1. is met. Replantation will keep **future treatment options open** even if healing by ankylosis is expected. The tooth can always be extracted at the appropriate point following a **prompt inter-disciplinary assessment**.

M. 2.2.1 When NOT to replant

As already stated, replantation of an avulsed tooth is frequently the best treatment. In a few situations replantation is not appropriate and these include:

- Primary teeth
- Where other injuries are severe and warrant preferential emergency treatment and / or intensive care
- Where the medical history indicates that the patient would be put at risk by replantation of a tooth (such as impaired immune system as a result of active chemotherapy, taking immune-suppressant as a result of a organ transplant or a primary or secondary immunodeficiency). In these cases or with other children who have significant medical histories, for example congenital cardiac defects it is prudent to discuss the treatment options with the child's paediatrician
- For very immature permanent teeth with a short root and wide open apex, where healing by ankylosis is the only outcome. In this situation, however, clinicians may still replant the tooth and leave the further management and decisions to the specialist inter-disciplinary team.

M 3 CEMENTAL/PDL HEALING PATHWAY - Treatment for avulsed teeth with a chance of cemental/PDL healing e.g. Teeth with extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium

M 3.1 Consent

The time taken to replant the tooth or teeth is critical. Fully informed consent can be difficult to achieve prior to replantation, therefore it is appropriate to replant the tooth as quickly as possible, giving it the best chance of cemental/PDL healing and then further discussions with regard to future treatment and options can be discussed. The tooth can be extracted subsequently if the parents and child are not happy with the initial decision.

This is a traumatic situation for the parent and child and any information discussed is frequently forgotten. Written information for the parent is helpful and a sample of a patient information leaflet is provided in Appendix C.

M 3.2 Topical tetracycline soak prior to replantation

Not currently recommended, please see page 32.

M 3.3 Replantation

Local anaesthesia allows accurate replantation, reduction of any associated alveolar fractures and manipulation of the socket. Anaesthesia should include both buccal and palatal tissues. Replantation is possible without local anaesthesia where there is minimal disruption to the socket. This will also facilitate quicker replantation. The dentist must decide which option is less likely to traumatise the child further and facilitate a successful, quick and accurate replantation.

If a clot is present, gently irrigate the socket with a syringe filled with saline to remove it.

Handle the tooth by the crown NOT the root. Do not scrape or scrub the root surface. If contaminated, wash in physiological saline, and only if necessary gently dab with gauze soaked in saline to remove stubborn debris (e.g. do no further damage to the periodontal membrane).

If the tooth will not replant fully then STOP. Alveolar bone fragments can prevent replantation. Withdraw tooth and place back in saline or milk. Introduce a blunt instrument into the socket to reposition bony spicules, and once again attempt replantation.

DO NOT COMMENCE ROOT CANAL TREATMENT PRIOR TO REPLANTATION.

M 3.4 Splinting

Splint to one adjacent un-injured tooth either side using a physiological splint for 7-14 days. Acid etch/composite and flexible wire splint is recommended. Other splints such as orthodontic brackets and wire can be used as long as the wire is passive. Importantly the gingival margin should be easy to clean when the splint is in situ.

Home care advice during splinting includes a sensible diet and care when biting to avoid excessive trauma to the injured tooth. The maintenance of good oral hygiene by tooth brushing and rinsing with chlorhexidine mouthwash is ESSENTIAL. Appropriate pain control should be prescribed and/or advised.

M 3.5 Antibiotics and Tetanus

Prescription of antibiotics is at the clinician's discretion. There is limited evidence to support the use of systemic antibiotics for avulsion injuries with respect to improved pulp or periodontal outcomes. It would seem prudent to advocate the use of an antibiotic during the first few days of healing (5-7 day course) where:

- there has been additional contamination of the tooth or soft tissues.
- there is injury to multiple teeth, soft tissues or other parts of the body which may necessitate the need for antibiotics on their own or as a result of the combination of these injuries
- to facilitate the safe delivery of subsequent surgery or
- the medical status may make the child more prone to infections.

Where indicated prescribe systemic antibiotics, doxycycline (if over the age of 12, the dose and duration are given in the Explanatory Notes, on page 36) or a penicillin based antibiotic (if under the age of 12, the dose and duration are given in the Explanatory Notes, on page 36) to commence as soon as possible.

A tetanus booster may be required if environmental contamination of the tooth has occurred. If in doubt, refer to a medical practitioner within 48 hours.

M 3.6 Endodontic Treatment

Depending on the maturity of the avulsed tooth and the inter-visit medicament chosen, pulp extirpation should commence between Day 0 – 10 following the injury. The guidance for immature teeth is different if pulpal regeneration is the desired outcome.

M 3.6.1. Immature teeth

Indications where it is appropriate to see if pulpal healing by regeneration will occur are:

- the tooth is immature (where the tooth is prior to the development of a complete root length with half or more apical closure) and where pulpal extirpation will leave a weakened root at increased risk of a late stage coronal fracture
- there is a chance of cemental/PDL healing of the periodontal membrane (extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium)

At the clinician's judgement there are situations where due to the very immature nature of the avulsed tooth a longer extra alveolar dry time or total time may be accepted and the tooth is given the opportunity to see if pulpal regeneration occurs.

For immature teeth meeting this criteria, no endodontic treatment is undertaken and the tooth is carefully monitored to assess pulpal regeneration or pulpal necrosis. Clinical and radiographic signs of these healing entities are described on page 26.

If pulpal regeneration fails and pulp necrosis is diagnosed, extirpate the pulp and thoroughly disinfect the root canal. Once extirpated these teeth need an early referral to an inter-disciplinary specialist team. They will evaluate the prognosis for the avulsed and replanted tooth with respect to the type of periodontal healing and how the immature non vital incisor should be treated.

M 3.6.2. Mature teeth

In this situation there are two potential root canal medicaments that can be used. The choice lies with the clinician.

Ledermix® (a steroid and antibiotic paste)

Remove the pulp as soon as possible, ideally at the emergency appointment, Day 0. **The tooth should be replanted and splinted prior to undertaking endodontics.** If it is not possible to extirpate on the same day pulp extirpation should be commenced by day ten at the latest, but the earlier the better when using Ledermix® as the inter-visit dressing. Under rubber dam where possible and placed around the splint, a conventional access cavity is cut and the necrotic pulp is removed using a barbed broach. Thorough chemical cleaning of the canal with sodium hypochlorite is essential, combined with minimal mechanical filing. The root length is established, the canal dried and then filled carefully with Ledermix®. It is essential to remove any Ledermix® from the crown and coronal access cavity to prevent discolouration. The access cavity should be sealed with a deep coronal seal (at least 5mm thick) of glass ionomer cement, intermediate restorative material or another temporary filling material.

The steroid dressing should remain in situ for two months. This allows the medicament to influence periodontal healing which takes approximately this duration [Nasjleti *et al.*, 1982; 1987; Breivik and Kvam, 1987; Brezniak and Wasserstein, 2002]. A further visit for chemical disinfection and dressing with non-setting calcium hydroxide is recommended prior to early obturation with gutta percha of the root canal by month three. Obturation with gutta percha should only take place if no signs of infection or infection related resorption are seen, e.g. no radiolucency is seen in the bone adjacent to the tooth.

Non-setting calcium hydroxide (NSCaOH)

If the clinician chooses NSCaOH as the inter-visit intracanal medicament, a similar protocol for the application of the paste is used as described above. Extirpation and application of NSCaOH should not be

undertaken before day seven, but ideally carried out before day eleven. The duration of dressing is for four weeks prior to obturation with gutta percha if no infection related resorption or infection within the root canal is identified.

M 3.7 Splint removal and mobility of injured tooth

Remove splint between day 7- 14. Explain to patient and parents that upon removal the injured tooth will be mobile. A further week of splinting is appropriate only if excessive trauma from the opposing dentition is likely to further traumatise the tooth or if the avulsed tooth is unable to retain its vertical position.

Where the patient has suffered multiple different injuries or loss of buccal alveolar bone a longer duration of splinting is appropriate.

At follow up visits adjacent teeth should also be monitored as these may have been damaged as a result of the same accident and should not be overlooked.

M 3.8 Prompt referral (for specialist inter-disciplinary planning and treatment)

Due to the high chance of healing by ankylosis patients should be referred to a specialist inter-disciplinary team for treatment planning in case such an eventuality occurs. Even in situations where healing occurs by cemental/PDL healing, this early appointment is important to ensure the child and parents are fully aware of the possible outcomes and treatment options. In addition, many of these children will need orthodontic treatment which will be complicated by this traumatic event to their dentition [Kindelan *et al.,* 2008].

M 4 ANKYLOSIS PATHWAY - Treatment for teeth with little chance of cemental/PDL healing e.g. Teeth with extraoral time of greater than 30 minutes dry time or greater than 90 minutes total extra alveolar time even when stored in an appropriate storage medium

M 4.1 Consent

For periodontal healing by ankylosis, time taken until replantation is not as critical and therefore a fully informed decision can be made prior to replantation. Again the written information in Appendix C may help in providing information for the parents and the child.

Bottom line: Almost always the decision to replant the tooth is the appropriate decision as this keeps future treatment options open even if healing by ankylosis is highly likely. The tooth can always be extracted at the appropriate point following an early inter-disciplinary assessment.

M 4.2 Extraoral endodontics

Hold the root in saline or milk soaked gauze to prevent further unnecessary periodontal ligament damage. A conventional access cavity is cut and the necrotic pulp is removed using a barbed broach. The root length is established by direct vision. Thorough chemical cleaning of the canal is essential combined with some mechanical filing. Sodium hypochlorite or chlorhexidene are appropriate canal irrigants but care should be taken to keep either within the root canal. The canal is then dried and obturated with gutta percha and sealer. Any gutta percha extruded through the apex can be removed directly. The access cavity should be sealed with a definitive coronal seal.

M 4.3 Replantation, splinting and post operative care

The tooth is now replanted and splinted. The appropriate home care instructions have been given and antibiotics as described in sections M3.3, M3.4 and M3.5 have been prescribed. Obviously the tooth needs no further endodontic treatment but will require splint removal and prompt referral to a specialist inter-disciplinary team.

M 4.4 Review, Splint removal and endodontics if not already provided

The child should be reviewed at 7-10 days for reassessment, reinforcement of oral hygiene practice and splint removal. If the tooth is excessively mobile, at risk of further trauma or subject to a significant occlusal load from the adjacent dentition, a longer splinting period may be undertaken. A long duration of splinting can be undertaken as this will have no effect on the type of periodontal healing unless other teeth were injured and are incorporated into the splint.

If extraoral endodontics has not been undertaken at the emergency visit then intraoral endodontics should be undertaken at the 7-10 day visit following the NSCaOH methodology. Ledermix® is **not** advocated in this situation as the steroid will have no effect on the type of periodontal healing and unnecessarily risks discolouring the crown.

For the timing of definitive obturation see the Explanatory Notes, on page 43. At follow up visits adjacent teeth should be monitored as these may have been damaged as a result of the same accident and should not be overlooked.

M 4.5 Early referral for specialist inter-disciplinary planning and treatment

This is essential so that treatment planning can take place for the short, medium and long term options for a tooth that will undergo ankylosis and be lost over the medium term.

Explanatory Notes (EN)

The Explanatory Notes are graded by the SIGN classification [SIGN 50: 2008] according to the quality of the research evidence justifying each conclusion. If evidence is based on animal or in-vitro studies this is stated.

EN - Prognostic factors and diagnosis of healing outcomes

Almost all clinical studies and several review articles [Day and Duggal, 2002; Andreasen *et al.*, 2006b] have investigated the prognostic factors which influence how the periodontal and pulpal tissues heal following avulsion and replantation.

EN - Periodontal healing

This guideline has attempted to identify a cut off point beyond which the chances of cemental/PDL healing are unlikely. The two prognostic factors that have the strongest influence on the chances of cemental/PDL healing are: extra alveolar dry time and then total extra alveolar time when stored in an appropriate medium such as milk or physiological saline. On reviewing the evidence the best estimate is that over 90% of teeth/ patients outside these time points will demonstrate ankylosis. This differs from the IADT guidelines [Flores *et al.*, 2007] which uses a longer maximum dry time (60 minutes) with no reference to total time when stored in an appropriate media. Teeth replanted outside the IADT time frame are estimated to have less than 1% chance of cemental/PDL healing.

The reasons why this guideline recommends different cut off times for dry time and total time when stored in an appropriate media are:

- Patients and parents are less likely to have false hope of the tooth healing "normally" e.g. with cemental/PDL healing
- Both the parent and dentist are therefore prompted to refer for an early inter-disciplinary consultation to discuss future treatment options. Some treatment options have relatively short time periods when it is ideal to carry them out e.g. auto transplantation. Furthermore leaving referral until significant infra occlusion has developed will only complicate whichever treatment option is chosen.
- Extra alveolar endodontics has shown similar progression of ankylotic root resorption to that of conventional endodontics at 7-10 days [Giannetti and Murri, 2006; Murri Dello Diago and Giannetti, 2011]. The benefit of extra alveolar endontics is that it minimizes the number and duration of patient

visits. There is a significant treatment burden for children suffering avulsion injuries. For some children the traumatic nature of the initial injury is significant and extra alveolar endodontics minimises the amount of further acute dental treatment. Finally for some children who miss their follow up appointments, extra alveolar endodontics prevents the risk of infection related resorption where endodontic treatment is not carried out within the first ten days.

- Evidence from a multi-centre randomised controlled trial in the UK [Day *et al.*, 2012] demonstrated that around 10% of children had their tooth or teeth replanted within the inclusion criteria of the study (a maximum of 20 minutes dry time or within 60 total time where stored in an appropriate media and the dry time was not exceeded). This guideline therefore emphasises the most appropriate care for teeth that are highly likely to heal by ankylosis, extra alveolar endodontics prior to replantation, as this is relevant for the large majority of children in the UK. Furthermore early discussions and prompt referral to specialist inter-disciplinary teams in the UK are relatively easy to facilitate.
- For teeth outside these time periods where they have been replanted without extra alveolar endodontics the risk of discolouration caused by Ledermix® is prevented by following this guideline.

As with all guidelines there will be situations where these advantages may not be appropriate to an individual patient. By giving a tooth or teeth outside this cut off point a chance of cemental/PDL healing is more appropriate. In such situations the clinician should follow the cemental/PDL pathway described in the Appendix A and section 3 in the management and explanatory notes.

The cut off point beyond which ankylosis is likely is given in the sub heading of each prognostic factor.

Dry time – Maximum 30 minutes (SIGN Level of Evidence: 3 and in-vitro studies)

The time a tooth is kept dry prior to replantation has been shown in human case series to have a significant effect on whether the periodontal ligament repairs by cemental/PDL or ankylosis. This has been found to be the most important prognostic factor. In the largest human series [Andreasen *et al.*, 1995c] at five minutes there was a significant difference in cemental/PDL healing compared to a 5-20 minute group. This second group again did significantly better than teeth stored dry for greater than 20 minutes. This effect was confirmed in a clinical case series [Kinirons *et al.*, 2000] and in a multi-centre randomised controlled trial [Day *et al.*, 2012]. Chappius and Von Arx [2005] showed a significant improvement in cemental/PDL healing for teeth stored dry for less than 15 minutes compared to teeth stored longer. Andersson [1988]

identified 30 minutes as the cut off point for cemental/PDL healing. A well conducted in-vitro studies of periodontal cells stored in different storage media [Lekic *et al.,* 1996; 1998; Lin *et al.,* 2000] also reported that after " dry storage for more than 15 minutes, precursor cells on the root-side of the periodontal membrane were unable to reproduce and differentiate into fibroblasts". These studies also showed that "with 30 minutes of dry storage, virtually all root side PDL cells have died".

Storage media prior to replantation (SIGN Level of Evidence: 3, animal and in-vitro studies)

A storage medium is a liquid that the tooth is placed in by a bystander, parent or injured patient at the scene of the accident. This medium is then used to transport the tooth to the dentist or accident and emergency. Consequently these liquids have to be present either at the scene of the accident or easily accessible within a few minutes. "Conditioning or soaking" of the tooth prior to replanting the tooth refers to a liquid that the tooth is placed in on arrival at accident and emergency or the dental surgery. The role of the soaking media is discussed on page 32 in the Explanatory Notes.

Many studies have investigated the effect of different storage media. The majority are in-vitro and have used pseudo outcome measures to differentiate the effectiveness of different media. The validity of pseudo outcome measures is discussed by Kenny [2001]. In summary, milk and physiological saline are similar, with saliva and tap water providing poorer physiological storage conditions [Weinstein *et al.,* 1981; Hammarstrom *et al.,* 1986b; Andreasen and Andreasen, 2007]. Animal studies have confirmed the superiority of some storage media over others [Andreasen, 1981c; Blomlof *et al.,* 1983]. These animal studies, however, suggest storage in milk may be possible for up to six hours prior to replantation without a detrimental effect on cemental/PDL healing. Clinical studies, detailed in the next section do not support such optimism. Extra alveolar wet storage periods exceeding 20 minutes are reported to produce a significant reduction in cemental/PDL healing [Andreasen *et al.,* 1995c].

Specialised storage media are recommended by some authors, for example: Hanks balance salt solution [Lekic *et al.,* 1996; 1998; Lin *et al.,* 2000], Viaspan [Pettiette *et al.,* 1997] and Tooth Rescue Box [Chappuis and von Arx, 2005; Pohl *et al.,* 2005c]. The literature to support them, however, is either based on in-vitro, animal studies or on clinical studies with multiple interventions on few teeth, which do not allow the influence of each factor to be identified. Although the evidence suggests they are at least equivalent to milk, they are not widely available in the UK [Filippi *et al.,* 2008]. Milk is almost always available, chilled and pasteurised and therefore recommended.

Extra alveolar time – 90 minutes when stored in an appropriate storage medium (SIGN Level of Evidence - 3)

A number of studies [Andreasen and Hjorting-Hansen, 1966; Andersson and Bodin, 1990; Schatz *et al.*, 1995; Andreasen *et al.*, 1995c; Kinirons *et al.*, 2000; Chappuis and von Arx, 2005; Day *et al.*, 2012] have investigated the effect of total extra alveolar time on a proportion of teeth demonstrating cemental/PDL healing when they have been stored in an appropriate storage medium. Once the extra alveolar time when stored in milk or another physiological medium is greater than ninety minutes, the chances of cemental/PDL healing is small. This extra alveolar time includes any dry time as well.

Diagnosing periodontal healing (SIGN Level of Evidence: 3 and animal studies)

The type of periodontal healing is determined by the initial injury, the storage and management of the avulsed tooth. Consequently a detailed history of the accident is essential at first consultation with the patient, particularly if the initial treatment was provided elsewhere. The clinician should take a detailed history of various important prognostic factors (extra alveolar time, dry time, storage media, contamination) and identify when ankylosis is the likely outcome rather than waiting for these clinical and radiographic signs to become apparent. In such situations, the process of arranging an inter-disciplinary referral and treatment planning for the eventual loss of the tooth or teeth should be started promptly.

In situations where cemental/PDL healing is feasible; this diagnosis is made by exclusion (e.g. no clinical or radiographic signs to suggest ankylosis). After 12 months the chance of ankylosis subsequently developing is low [Andreasen *et al.*, 1995c; Boyd *et al.*, 2000]. The most accurate way of detecting ankylosis is if the tooth will move under orthodontic forces or with physiological growth. Frequently time or elective orthodontics to assess ankylosis are not appropriate and therefore other clinical and radiographic signs are elevated.

Clinical signs of ankylosis include: infraocclusion of the tooth in comparison to uninjured adjacent teeth, reduced mobility and a high resonant tone heard on percussion testing [Andersson, 1988]. Early radiographic diagnosis is often difficult as the site of initial replacement resorption is usually on the buccal or palatal aspects of the root surface which is difficult to image with two dimensional standard radiographic techniques [Andreasen, 1980a; Andersson, 1988]. Radiographic signs include loss of periodontal space and

lamina dura or disappearance of the normal periodontal space with replacement by bone in association with an uneven contour of the root.

Some authors [Filippi *et al.*, 2006] have suggested that the Periotest® is able to detect ankylosis before these clinical and radiographic signs become apparent, others have not found this advantage [Campbell *et al.*, 2005]. Consequently further evaluation is required before the Periotest® can be advocated for this purpose.

Recall intervals and orthodontics

Assessment of the type of periodontal healing should coincide with treatment visits in the first three months. After completion of endodontics, further reviews at six and twelve months are appropriate. After twelve months if no ankylosis is detected orthodontic treatment, if required, can be commenced or be re-started [Kindelan *et al.*, 2008].

EN - Pulpal healing

A number of studies have investigated the prognostic factors that influence the chances of pulpal regeneration. The cut off point beyond which regeneration is unlikely is described.

Root length and apical status –Complete root length with half or more apical closure (SIGN Level of Evidence: 3 and animal studies)

For the rest of this guideline teeth that have root development greater than this point e.g. complete root length with half or more apical closure will be defined as **mature teeth** and those with less as **immature teeth**.

Clinical studies have reported the chances of pulpal regeneration between 18% [Kling *et al.*, 1986] – 34% [Andreasen *et al.*, 1995b] of immature teeth (the more immature a tooth the better the chance of regeneration). In teeth with an apical width of 1mm or less, no regeneration was seen [Kling *et al.*, 1986]. The apical width and length of the pulp were also found to be significant with no pulp regeneration seen in mature roots [Andreasen *et al.*, 1995b]. These findings are confirmed histologically in animal models [Kristerson and Andreasen, 1984; Cvek *et al.*, 1990b], with Cvek reporting that regeneration did not occur when apical foramen was 0.5mm or less. These results are in contrast to Ebeleseder *et al* [1998] who found

pulp regeneration in a human case series occurred in 41% of immature teeth (mean age 8), 9% in mature teeth in adolescents (mean age 12) and 0% in adults (mean age 25).

Teeth with extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium (SIGN Level of Evidence: 3 and 4)

Human clinical case series have shown that the chance of pulpal regeneration decreases with extra alveolar time. A significant difference in the chance of regeneration was shown at 45 minutes total time whether stored wet or dry, by Kling *et al* [1986]. The study did report that a few teeth still showed regeneration beyond this time point. In contrast Andreasen *et al* [1995b] found no significant relationship between extra alveolar time or wet or dry storage with respect to pulp regeneration. Therefore to keep the guideline as simple as possible the authors have elected to use the same time frame and prognosis factors as those identified for periodontal healing e.g. teeth with extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium.

Diagnosis of pulpal healing or pulp necrosis (SIGN Level of Evidence: 3)

At recall appointments the following radiographic signs indicate pulpal regeneration: continued root growth, pulp canal obliteration (PCO) or bony ingrowth. In a case series of immature replanted teeth with half to three quarters root growth, six out of 13 teeth completed root growth and a further five showed partial further root growth [Andreasen *et al.*, 1995a]. From the same dataset [Andreasen *et al.*, 1995e] PCO was seen in 29 out of 32 cases demonstrating regeneration. They reported that PCO was visible on the radiograph between four and eighteen months. In the remaining three cases bony ingrowth precluded PCO. Bony ingrowth, although this is not strictly pulpal regeneration, requires an infection free root canal space and no treatment intervention is required.

The diagnosis of pulpal necrosis can be difficult. The only definite diagnostic indicator is radiographic signs of infection related resorption. The remaining clinical and radiographic signs may indicate but do not guarantee pulpal necrosis and should not be used in isolation to diagnose it:

- tenderness to percussion (initially care has to be taken with this symptom as this might be the result of the initial trauma or replantation of the tooth out of its original position and / or a traumatic occlusion).

- buccal or palatal sinus (highly suggestive of pulp necrosis if the sinus is related to the avulsed and replanted tooth)
- mobility (increased mobility can be as a result of a number of factors, such as the initial trauma, loss of buccal bone, traumatic occlusion, removal of splint for example)
- tooth discolouration
- coronal yellow discolouration may be a sign of PCO [Andreasen *et al.,* 1987; Robertson *et al.,* 1996].
- darkening hue may be evidence of either pulpal haemorrhage or necrosis, with blood or necrotic material taken up by surrounding dentinal tubules [Andreasen, 1988]. For pulpal necrosis to be diagnosed no improvement in colour would be expected over a three to six month period.
- radiographic periapical pathology. Periapical pathology can be misleading and care should be taken interpreting the periapical region as it may represent a failure to replant the tooth completely or relate to the acute injury.
- radiographic signs of infection related resorption. This is shown by resorption of root and adjacent bone with associated radiolucency within bone. This is a highly suggestive sign of pulp necrosis especially if seen from three weeks after the injury or later.
- sensibility tests can be misleading as they are subjective and require the child to understand what they have to do. Where regeneration did occur, positive sensibility tests were recorded after four to twenty four months with a mean of six months [Andreasen *et al.,* 1995e].

These clinical and radiographic findings should be assessed in light of the prognosis factors discussed, the response of adjacent teeth and, where available, signs and symptoms recorded at the previous appointments.

Recall intervals – for immature teeth where pulpal regeneration is the aim of treatment (SIGN Level of Evidence: 3 and animal studies)

The recall interval and justification is discussed in EN 3.6.1.1, page 38.

EN - Principles underlying treatment provided

PDL / CEMENTAL HEALING PATHWAY - Teeth with extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium – e.g. teeth with a chance of cemental/PDL healing – treatment aims to reduce inflammatory stimulus and dampen host response.

Following avulsion and replantation, an acute inflammatory response is produced by the host. The purpose of this response is to remove all necrotic tissues, foreign and infected material including bacteria and other organisms. Once this has taken place the body can then repair the damaged tissues. From animal studies a critical size of cementum damage has been identified beyond which cemental/PDL healing will not occur [Andreasen and Kristerson, 1981b; Springer *et al.,* 2005]. Consequently a major treatment aim is to prevent any iatrogenic damage and dampen the inflammatory response thereby reducing the area of periodontal damage. Treatment includes early extirpation of the pulp with an appropriate inter-visit canal dressing.

ANKYLOSIS PATHWAY - Teeth with an extra alveolar time of greater than 30 minutes dry time or total time greater than 90 minutes even if stored in an appropriate storage medium - e.g. teeth with little chance of cemental/PDL healing – treatment aims to prolong the functional use of the tooth before it is lost

For teeth replanted in this situation ankylosis is likely to occur. Consequently treatment aims to prolong the functional survival of the tooth until the appropriate timing for other treatment options to replace the tooth [Day *et al.,* 2008; De Souza *et al.,* 2010]. Treatment therefore aims to achieve the following:

- avoidance of infection within the root canal which will cause adjacent bone loss,
- to replant quickly to minimise further necrosis of the periodontal membrane and therefore reduce the area at which ankylosis can occur. The tooth will still resorb but survival of the tooth is reported to be longer.
- minimise the number of clinical visits by obturating prior to replantation

Aetiology and Prevalence

The incidence of traumatic avulsion of teeth has been reported as 0.5 - 3% of all traumatised teeth [Andreasen and Andreasen, 2007]. Upper central incisor teeth are the most frequently avulsed teeth and occur most frequently in the age group 7 - 9 years old [Andreasen *et al.,* 1995d]. .

Injury and care provided at the scene of the accident or Accident and Emergency (SIGN Level of Evidence: 3)

The damage caused directly by the injury and the time and treatment prior to arrival are beyond the control of the clinician. Only in rare circumstances is the dentist contacted prior to the child's arrival, however, if this eventuality arises, Appendix D gives an outline for what advice should be provided over the telephone. This advice should whenever possible suggest the parent, bystander or first health care provider replant the tooth as quickly as possible to minimise extraoral time and improve the chance of cemental/PDL healing. The accuracy of replantation is not essential, what is important is to restore the injured periodontal membrane to its socket. If replanted back to front or in the wrong socket this is simple to treat by the emergency dentist who sees the patient. **Dentists who encounter teeth replanted in the wrong socket or rotated should consider what is in the best interests of the periodontal membrane as in some scenarios (e.g. patient attends after a day or later) the teeth may be better left in their new position and have crown modification or be orthodontically derotated at a later stage**.

Currently public and other health care professionals' knowledge of what do with an avulsed tooth is poor. As part of this guideline a sample of a public information poster, Appendix E, is suggested.

Treatment provided by the Dentist

EN 2 History, examination and diagnosis

Minimising further damage to the periodontal membrane / tooth prior to replantation is important. Therefore, unless already replanted, the tooth should be placed in milk or physiological saline or other suitable storage media (see storage medium prior to replantation section, on page 24) during the history and examination of the patient.

A thorough history and examination is required. As with all cases of trauma it is essential to record details of the accident clearly in writing. Paper based structured histories have been shown to be the most effective method of improving the clinical records [Day, 2003; 2006]. There are a number of different structured histories used at different specialist centres [Day and Duggal, 2006] and currently an electronic trauma record is available to facilitate multiple centres recording the same clinical information. Details of a paper based structured history and electronic trauma record are provided in Appendix B.

The history should identify:
Signs of neurological injury. These can include dizziness, neck pain, amnesia, headache or other symptoms of head injury. If identified a medical assessment should be arranged immediately.
A full examination of the head and neck should include the intra and extraoral bony and soft tissue structures.
Care should be taken to note any injuries to adjacent teeth. Missing tooth fragments should be accounted for.

Dental and facial trauma may occur in non-accidental injuries. Clinicians should assess that the history of the accident and the injuries sustained are consistent. In situations where there are such suspicions prompt referral for a full examination and investigation should be arranged. Referral will follow local protocols and is outside the remit of this guideline. Further examples and information on non accidental injuries are available at www.cpdt.org.uk, www.core-info.cardiff.ac.uk and Maguire *et al* [2007].

EN 3 PDL / CEMENTAL HEALING PATHWAY - Treatment for avulsed teeth with a chance of cemental/PDL healing – e.g. Teeth with extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium

EN 3.1 Consent

EN 3.2. Conditioning/ soaking of the tooth prior to replantation (SIGN Level of Evidence 1-)

Authors have disagreed about the value of soaking and drawn different conclusions from the same literature [Andreasen *et al.,* 2005; Pohl *et al.,* 2005a]. Brief soaking of the tooth prior to replantation with an appropriate soaking solution may wash necrotic tissue and cellular debris away and reduce the chance of bacterial contamination. As yet, however, no agent has reproducibly demonstrated that it can regenerate dead periodontal membrane.

The role of soaking of the tooth prior to replantation has been demonstrated by one randomised controlled trial directly [Loo *et al.,* 2008] and another indirectly [Chen *et al.,* 2000]. Both studies investigated medicaments (thymosin α1 and gentamycin sulphate), which have not been evaluated by other researchers in either animal or clinical studies. For further discussion of these studies and problems with their design and execution readers are referred to the Cochrane review [Day and Duggal, 2010]. Therefore this guideline does not recommend either of these medicaments for soaking prior to replantation.

EN 3.2.1. Tetracycline soak prior to replantation (SIGN Level of Evidence 4 and animal studies)

Although there is reasonable evidence, described below, to demonstrate soaking teeth in a tetracycline solution prior to replantation can increase periodontal healing and pulpal regeneration, there is insufficient evidence to recommend one particular drug, dose or duration. Furthermore no preparation reported in the literature (5% tetracycline, 1mg oxytetracycline HCL is dissolved in 20ml of saline [Chappuis and von Arx, 2005] or doxycycline, 1mg dissolved in 20ml of saline using doxycycline hyclate powder [Cvek *et al.,*

1990a; Ritter *et al.*, 2004]) is commonly available to dentists in the UK or is easy to make up. Therefore this guideline is unable to recommend either of these medicaments for soaking prior to replanation.

An immature tooth avulsion model [Cvek *et al.*, 1990a] found topical doxycycline resulted in a significant reduction in ankylosis and infection related resorption compared to no soaking or systemic doxycycline. The main effect of topical doxycycline was for teeth stored wet between 30 and 60 minutes and dry for 30 minutes. This beneficial effect was not significant for teeth stored dried for 60 minutes [Ma and Sae-Lim, 2003; Bryson *et al.*, 2003]. A clinical case series of 45 teeth [Chappuis and von Arx, 2005] has shown good results for cemental/PDL healing (64%) at 12 months. All teeth in this study were soaked for five minutes in 5% oxytetracycline. The precise effect of this soaking is difficult to establish as teeth were also placed in a tooth storage medium for 30 minutes on arrival.

Animal studies of immature teeth with a chance of pulpal regeneration also suggest benefits from topical tetracyclines soaking [Cvek *et al.*, 1990a; 1990b; Yanpiset and Trope, 2000; Ritter *et al.*, 2004]. The mechanism of action has been suggested to be related to a reduction in the numbers of micro organisms thereby reducing the risk of invading the pulp space [Cvek *et al.*, 1990a].

In summary, at present no robust clinical trials have tested the effect of tetracycline application prior to replantation, but some animal models do suggest benefits, most likely associated with decontamination of the root surface. Clearly, animal models cannot replicate the true nature of an avulsed tooth being exposed to the external environment and further research is required.

EN 3.3. Replantation (animal studies)

Local anaesthesia allows accurate replantation, reduction of any associated alveolar fracture or manipulation of the socket. Anaesthesia should include both buccal and palatal tissues. Replantation is possible without local anaesthesia where there is minimal disruption to the socket. This will also facilitate quicker replantation. The dentist must decide which option is less likely to traumatise the child further and facilitate a successful, quick (e.g. minimise further extra alveolar time) and accurate replantation.

The clot within the socket should be washed out with saline to allow examination of the socket. The effect of washing the socket out has been investigated by one animal model which found no benefit in periodontal healing [Andreasen, 1980b], however, the clot may prevent repositioning into its original position.

The exact position of the tooth after replantation is reported to have no effect on the type of healing seen [Andreasen, 1981a]. This study investigated tooth transplantation, where transplanted teeth are frequently different in shape to the socket they are transplanted into. For immature teeth, where continued root growth is beneficial, the position in which teeth were transplanted did have some effect [Kristerson and Andreasen, 1984]. Therefore, where possible, teeth should be replanted in the best position to reduce any further treatment, to maximise aesthetics and, for immature teeth, to optimise further root growth.

EN 3.3.1. Debris on root surface (SIGN Level of Evidence 3 and animal study)

Clinical evidence suggests that macroscopic contamination on the root surface results in a significantly higher percentage of teeth healing by ankylosis following avulsion and replantation [Andreasen *et al.,* 1995c; Kinirons *et al.,* 2000]. An explanation for this is that any foreign material and bacteria will increase the extent and duration of the destructive phase of the inflammatory response. Interestingly, one animal study reports that washing a tooth extraorally in saline for 10 seconds enhances cemental/PDL healing compared to washing in saliva [Weinstein *et al.,* 1981]. The authors suggest that saliva introduced further bacterial contamination onto the root surface prior to replantation.

In one study almost all teeth replanted with contamination or that required rubbing to remove contamination, healed by ankylosis [Kinirons *et al.,* 2000]. Contaminated teeth, however, even when washed in saline are still more likely to present with ankylosis at an earlier time point compared to visibly uncontaminated teeth [Donaldson and Kinirons, 2001]. Therefore foreign material on the root surface increases the chances of ankylosis. When debris is resistant to removal by washing with saline this should be carefully removed with damp gauze.

EN 3.4. Splint placement and duration (SIGN Level of Evidence 3 and animal studies)

The type of splint and duration has not been shown to be a significant variable with regards to pulp or periodontal healing in human studies [Andreasen *et al.,* 1995b; 1995c; Kinirons *et al.,* 2000; Hinckfuss and Brearley Messer, 2009c]. There are many designs of splints in the literature and the most appropriate one depends on the facilities available. A cross over randomised controlled trial on ten healthy adult volunteers investigated four trauma splints (wire composite splint, a button bracket splint, a resin splint and a titanium trauma splint). All splints allowed good periodontal health to be maintained and facilitated physiological

vertical and horizontal mobility [von Arx *et al.,* 2001]. This study also looked at patient outcomes (sensitivity of splinted teeth, irritation of the gingival margin, irritation of lips, impairment of speech, eating and oral hygiene) and found the composite wire and titanium trauma splint were more acceptable to the participants [Filippi *et al.,* 2002b].

Whichever splint is chosen, it must allow some physiological movement of the injured tooth [Kahler and Heithersay, 2008] and care must be taken in application i.e. avoid impinging on gingivae or creating areas of stagnation which are inaccessible for cleaning. Poor or slow gingival healing will allow prolonged bacterial access to both denuded dentine of the root and to the clot between the root and socket [Cvek *et al.,* 1990a; 1990b]. Where the tooth is splinted in non ideal settings, e.g. outside a dental clinic setting, the splint should be reviewed in the dental setting within the first 48 hours to ensure it is still in situ and to allow modifications or reapplication using more appropriate materials. This opportunity does allow the clinician to reinforce the importance of keeping the wound clean and the appropriate mouth care instructions while the gingival tissues are still healing.

Two reviews of literature [Kahler and Heithersay, 2008; Hinckfuss and Brearley Messer, 2009c] did not identify a specific time period for the duration of splinting. From animal based studies [Andreasen, 1975; Nasjleti *et al.,* 1982; Kristerson and Andreasen, 1983; Mandel and Viidik, 1989; Hinckfuss and Brearley Messer, 2009c] these would suggest a shorter duration of splinting would lead to less ankylosis. Therefore the splint should remain in situ until the tooth is able to maintain its own position, 7-14 days. Once removed the tooth or teeth will still be mobile but cleaning of the tooth and gingival tissues is easier. Ideally splint removal should coincide with other treatment interventions e.g. pulp extirpation to minimise the number of visits patients need to make. It is for this reason that this guideline advises the use of a 7-14 day splinting duration.

While it is the intention of this guideline to minimise unnecessary visits, one randomised controlled trial, at high risk of bias, has shown regular visits with a hygienist following injury improves the plaque free score around the site of injury [Pasini *et al.,* 2006].

Home care advice:
The use of a semi-soft diet [Andersson *et al.,* 1985], chlorhexidene mouthwash and pain control would appear to be biologically appropriate; there is little evidence to support or discourage this advice.

EN 3.5. Systemic Antibiotics (SIGN Level of Evidence 3 and animal studies)

The use of systemic antibiotics has not been shown to be a significant variable with regard to pulp or periodontal healing in human studies [Andersson and Bodin, 1990; Andreasen *et al.,* 1995b; Andreasen *et al.,* 1995c; Sae-Lim and Yuen, 1997; Hinckfuss and Brearley Messer, 2009a]. From animal studies, it has been suggested that the provision of systemic antibiotics if taken promptly reduced the occurrence of inflammatory resorption [Hammarstrom *et al.,* 1986a; 1989]. This benefit was not maintained if endodontics were carried out on day one [Hammarstrom *et al.,* 1986a]. Two other studies have shown an increase in cemental/PDL healing for the use of tetracycline rather than amoxicillin in a replacement resorption [Sae-Lim *et al.,* 1998a] and in an infection related resorption model [Sae-Lim *et al.,* 1998b]. These experiments have not been repeated by other research groups and there is concern about their applicability to the clinical situation owing to the prolonged extra alveolar storage time and media. Unlike in the animal model, the tooth will have been exposed to bacterial contamination extraorally and intraorally. Thus the reduction in the bacterial inflammatory stimulus by the use of antibiotics may have some role in improving periodontal and pulpal healing.

There is no evidence from human case series of beneficial periodontal outcomes between the use of a systemic penicillin or tetracycline. Some authors and guidelines [Trope, 2002a; Flores *et al.,* 2007] have argued for the use of a systemic tetracycline (doxycycline for ten days) for patients greater than 50kg, 200mg twice a day for first day and then 100mg for next 10 days. The dose is halved if the patient is less than 50kg [Chappuis and von Arx, 2005]. The explanation given is that tetracyclines have additional benefits beyond their antibacterial effects that may enhance periodontal healing. These include a direct inhibitory effect on osteoclasts and collagenase, anti-inflammatory action by inhibiting polymorphonucleocytes activity and phosopholipase A2 and enhancement of fibroblast attachment to the root surface [Trope, 2002b]. Doxycycline is not advised for children under the age of 12 [BNF, 2011] due to the risk of intrinsic discolouration. This would, however, have a minimal effect on any discolouration of crowns of visible teeth as the anterior teeth have already completed their crown formation by the age of seven [Brown *et al*, 2007].

For this younger group an alternative antibiotic would be a penicillin such as penicillin V or amoxicillin 250mg three times a day for five to seven days. The dose for amoxicillin is 250mg three times a day for children aged five to eighteen years old. Parry *et al.,* [2003] investigated the profile of the bacteria found within the socket of avulsed teeth prior to replantation. They found that these bacteria were sensitive to penicillin-based antibiotics and therefore the use of these would appear appropriate. This area of the

literature has recently had three reviews published [Andreasen *et al.*, 2006a; Trope, 2007; Hinckfuss and Brearley Messer, 2009a] and is an ongoing debate [Shah and Ashley, 2010].

In cases of environmental contamination of the tooth a tetanus booster may be required and prompt referral to the child's general medical practitioner is required. Again this advice is based on common sense.

EN 3.6. Endodontic treatment for teeth with a chance of cemental/PDL healing – see treatment flow chart, Appendix A

Increasingly animal and clinical studies are investigating the role of medicaments placed within the root canal to encourage cemental/PDL healing. Following pulpal extirpation the root canal space is devoid of blood supply and consequently any medicament has a good chance of remaining in situ to exert its effect. The open tubules allow communication between the root canal and the periodontal membrane especially in the areas of damage [Andreasen, 1981b]. Therefore depending on molecule size [Abbott *et al.*, 1988] medicaments can pass from root canal to sites of necrotic cementum and influence the type of periodontal healing seen.

All replanted teeth, which fall outside the prognostic factors for pulp regeneration, e.g. as discussed in section EN3.6.1. below, should have endodontic treatment instigated within ten days. Following avulsion injury the pulpal tissue is severed from the supporting neurovascular tissues. Consequently, necrotic pulpal material is left within the root canal which on its own or if and when it becomes infected acts as a significant inflammatory source [Andreasen, 1981b]. It is therefore essential that the necrotic pulp tissue is removed to prevent infection related resorption becoming established resulting in a more rapid loss of the tooth [Donaldson and Kinirons, 2001; Humphreys *et al.*, 2003].

EN 3.6.1. Immature teeth – e.g. a tooth with less than complete root length with half apical closure (SIGN Level of Evidence 3 and animal studies)

Pulpal regeneration is the optimal outcome for immature teeth. This outcome provides a vital tooth and on occasions further root growth. Andreasen *et al.* [1995a] reported that six out of thirteen teeth showed complete root growth and a further five showed partial further root growth. Clinicians, however, must appreciate the risks taken by following this conservative approach. **For the majority of immature teeth, 59-82%** [Kling *et al.*, 1986; Andreasen *et al.*, 1995e; Ebeleseder *et al.*, 1998]**, pulp necrosis is the outcome**

and consequently the delay in pulpal extirpation exposes the tooth to the risk of infection related resorption [Hinckfuss and Brearley Messer, 2009b] **and the increased difficulty in its elimination** [Andersson *et al.,* 1989; Trope *et al.,* 1995]. Furthermore inflammatory resorption is reported to occur more rapidly in young patients. The suggested reason for this is that dentine tubules are more patent and readily transmit inflammatory products from the pulp to the root surface [Hammarstrom *et al.,* 1986a]. **Therefore this guideline proposes to delay endodontic treatment and allow an opportunity for pulpal regeneration only if:**

- The tooth is immature and where pulpal extirpation will leave the patient with a weakened root at increased risk of a late stage crown root fracture.
- **There is a chance of cemental/PDL healing of the periodontal membrane (**teeth with extraoral time of less than 30 minutes dry time and less than 90 minutes total extra alveolar time when stored in an appropriate storage medium).

For avulsed teeth meeting these criteria **no endodontic treatment is undertaken** unless pulpal necrosis or infection related resorption is detected , see page 27.

In situations of very immature teeth where the tooth has been replanted, the extra alveolar times and storage may be elongated further as the tooth will have a very poor prognosis if extirpation is untaken. Clinicians must be happy to diagnose and treat infection related resorption if it should occur and confident that the child will attend for frequent follow up review appointments. Furthermore it should be remembered that in these situations cemental/PDL healing, pulpal regeneration and further root growth are all needed to ensure a favourable long term prognosis. Where any of these do not occur the tooth should be considered a short-term treatment that keeps future treatment options open. Early discussion or referral to an inter-disciplinary team is essential.

EN 3.6.1.1. Timings of review appointments for assessment of pulpal and periodontal healing

Importantly early contact with the inter-disciplinary specialist team is essential to discuss and / or refer the patient. This allows the likely prognosis for the avulsed tooth or teeth to be determined, treatment planning for the short, medium and long term to be undertaken and a tailored follow-up regime to be identified. Clear communication between the parents, child, primary and specialist team are essential to ensure everybody is clear on what treatment is required and who will provide it.

The family should be advised that there is a low success rate and of the need to return for follow up. Pulpal status (clinical and radiographic) should be reviewed at 7-14 days coincident with splint removal, then at, one, two, three, four, six and twelve months. This more frequent recall regime is justified as the tooth is at a high risk of infection related resorption if pulpal regeneration does not occur which will lead to the rapid loss of the tooth [Kinirons and Boyd, 1999; Humphreys *et al.,* 2003; Stewart *et al.,* 2008]. Once established infection related resorption is difficult to eliminate [Trope *et al.,* 1995]. Unfortunately infection related resorption is frequently asymptomatic and consequently the patient is unaware of its existence. Children / parents should be advised to return to clinic sooner if they experience symptoms of pulp necrosis detailed in diagnosis of pulp necrosis, on page 27. Even if pulpal healing is detected, periodic reviews to determine periodontal healing is required as these two entities can occur independently of each other. Clinical and radiographic signs of ankylosis or cemental/PDL healing are discussed on page 25.

EN 3.6.2. Mature Teeth– e.g. tooth with complete root length and half or more apical closure and Immature teeth where regeneration is not indicated (SIGN Level of Evidence 3 and animal studies)

Clinical studies [Cvek, 1974; Kinirons and Boyd, 1999; Chappuis and von Arx, 2005] have established that when the pulp is extirpated within the specified time and the appropriate root canal dressing is placed infection related resorption is eliminated.

Histologically, infection related resorption is present by two weeks [Andreasen, 1981b]. Once established there is considerable progression of infection related resorption within a few weeks [Andreasen, 1981b]. In a series of animal studies [Trope *et al.,* 1992; Trope *et al.,* 1995] showed that a short dressing of seven days with non-setting calcium hydroxide (NSCaOH) was sufficient to control infection prior to obturation with gutta percha when extirpation was carried out 14 days after injury. When extirpation was left until 28 days a longer duration of NSCaOH (more than seven days) was required to facilitate disinfection of the root canal before definitive obturation with gutta percha. These findings have been replicated in clinical studies [Andersson *et al.,* 1989; Kinirons and Boyd, 1999; Stewart *et al.,* 2008].

Andersson [1989] showed infection related resorption was difficult to eliminate when endodontics was delayed for more than 21 days after replantation. Despite subsequent endodontics of these teeth, a higher incidence of infection related resorption was found as late as 3 years after replantation. Kinirons *et al*

[1999] showed that when root canal treatment was started at day 20 or more, infection related resorption was a more common finding. Stewart *et al* [2008] showed that pulps extirpated at later than day 10 resulted in the detection of resorption (all types of resorption were grouped together in this study) at a significantly earlier point than those extirpated at this time point or earlier. Finally a recent review of the human avulsion literature [Hinckfuss and Brearley Messer, 2009b] was unable to identify a significant benefit for pulp extirpation in reducing infection related resorption before day 14. They found no significant benefit with regard to periodontal healing or prevention of infection related resorption if pulp extirpation was undertaken before day 10. The review did not investigate which inter-visit medicament was used and found only two (total of 26 patients) and three clinical studies (total of 88 patients) with respect to periodontal healing or infection related resorption. Concern has been raised by other authors in respect of how data was summated between studies in this meta analysis and whether it was appropriate to do so [Andreasen *et al.,* 2010].

Is there any benefit in extirpating the pulp at an earlier stage than this? This depends on the medicament used. It should be noted that a medicament must be used, as leaving the root canal empty does not prevent bacterial invasion and subsequent infection related resorption in one animal model [Andreasen, 1981d].

EN 3.6.2.1. Medicament (SIGN Level of Evidence 1+ and animal studies)

The effect of Ledermix® compared to NSCaOH was investigated by a multi-centre randomised controlled trial. The study showed no significant difference between the medicaments with respect to cemental/PDL healing, however these results should be interpreted with caution as the study failed to recruit sufficient children to meet its power calculation [Day *et al.,* 2012]. Consequently the use of either medicament is currently valid. The following section discusses the benefits and disadvantages of each and the timing at which they should be applied.

Timing of placement: the most beneficial effect of Ledermix® on periodontal healing appears from animal studies to be at Day 0 following replantation. As the time between replantation and extirpation increases, the beneficial effects of Ledermix® reduce. In addition the use of Ledermix® has to be countered against its propensity to cause discolouration of the tooth. If NSCaOH is chosen it should be placed between day 7-10. If placed earlier than this point in time, it is likely to increase the chance of ankylosis of the periodontal membrane.

EN 3.6.2.1.1. Steroid dressings (Ledermix®) -This guideline advocates placement of Ledermix® as an inter-visit root canal dressing as soon after replantation as possible e.g. Day 0-10.

Ledermix® is a commercially available paste containing 1% triamcinolone and 3% demeclocycline. A number of animal studies have investigated the effectiveness of Ledermix® as a root canal medicament in an avulsion model [Pierce and Lindskog, 1987; Thong *et al.*, 2001; Bryson *et al.*, 2002; Wong and Sae-Lim, 2002; Chen *et al.*, 2008]. These studies have shown a beneficial effect of Ledermix® in comparison to the other medicaments including NSCaOH and gutta percha. This medicament has been shown to improve significantly the proportion of the root surface showing cemental/PDL healing in a number of conditions. Studies have investigated its effect with placement at day 0 [Bryson *et al.*, 2002; Wong and Sae-Lim, 2002; Chen *et al.*, 2008], day 11 [Thong *et al.*, 2001] and day 21 [Pierce and Lindskog, 1987]. In all studies Ledermix® was shown to outperform the other medicaments and **the most significant effects were seen when pulp extirpation and Ledermix® placement were carried out at day 0**. The steroid dressing should remain in situ until cemental/PDL healing has taken place. This takes approximately two months [Nasjleti *et al.*, 1982; 1987; Breivik and Kvam, 1987; Brezniak and Wasserstein, 2002].

These studies identified that one of the main effects of Ledermix® was the reduction in infection related resorption compared to the control medicaments. The explanation given was the presence of the corticosteroid in Ledermix® and its ability to dampen the inflammatory response during the healing of the periodontal membrane. The separate role of the corticosteroid and the antibiotic have been evaluated in one animal study [Chen *et al.*, 2008]. This showed equivalent results for cemental/PDL healing for the corticosteroid alone in comparison to the combination of steroid and antibiotic found in Ledermix®.

Pharmacokinetics

The pharmacokinetics of Ledermix® have been investigated in a number of studies by Abbott. They showed good diffusion and release of the constituent parts of Ledermix® through the dentinal tubules into the periodontal tissues up to 14 weeks after application [Abbott *et al.*, 1988]. In addition they estimated the potential systemic dose released from a root canal filled with Ledermix® and concluded that the steroid dose was minimal in comparison with the daily endogenous cortisol released [Abbott, 1992].

Disinfection (SIGN Level of Evidence 1+*)*

Chu *et al* [2006] investigated the efficacy of NSCaOH and Ledermix® at disinfecting root canals with established bacterial flora of non vital teeth exhibiting apical periodontitis in a randomised controlled trial. They showed no significant differences in the number of canals with bacteria growth after instrumentation, irrigation and intracanal dressing for seven days. This is important as there are concerns that the steroid antibiotic mix in Ledermix® may actually encourage bacterial growth, as a result of the steroid, and the justification for the use of the material is not primarily as a result of its abilities for disinfection of the root canal. It may well be that avulsed teeth have a reduced quantity and type of micro-organisms as there has been considerably less time for a mature flora to become established. Consequently in avulsed and replanted teeth Ledermix® would appear to be of similar efficacy for disinfecting the root canal to NSCaOH.

Intrinsic discolouration (SIGN Level of Evidence 1+ and in-vitro*)*

Two in-vitro experiments suggest that Ledermix® causes a grey brown discolouration of the crown [Kim *et al.,* 2000a; 2000b] which is exacerbated by sunlight and an immature root canal. When Ledermix® was restricted to the root and no material was allowed into the crown the degree of discolouration was significantly less. A multi-centre randomised controlled trial has confirmed this grey brown discolouration for Ledermix® [Day *et al.*, 2011].

EN 3.6.2.2. Non-setting calcium hydroxide - This guideline advocates placement of NSCaOH as an inter-visit root canal dressing between day 7-10.

This is the medicament of choice for disinfection of root canals in conventional endodontics [Spangberg and Haapasalo, 2002] because of its high pH. In addition the active hydroxyl group shows good diffusion properties allowing it to pass along the dentinal tubules into the periodontal space [Tronstad *et al.,* 1981]. These properties, however, are indiscriminate and cause damage to the host tissues resulting in a detrimental increase in ankylosis if applied at the time of replantation [Andreasen and Kristerson, 1981a; Lendgheden *et al.*, 1990; Bryson *et al.*, 2002]. This guideline advocates placement of NSCaOH as an inter-visit root canal dressing between day 7-10. This is a balance between too early which would increase the chance of ankylosis and too late, which would allow infection related resorption to become established.

Intrinsic discolouration (SIGN GRADE 1+ and in-vitro*)*

Yellow discoloration of the crown has been reported with NSCaOH in one multi-centre randomised controlled trial [Day *et al.,* 2011]. In two in-vitro studies [Kim *et al.,* 2000a; Kim *et al.,* 2000b] yellow discoloration was recorded but only one study [Kim *et al.,* 2000a] found it to be significantly different to the control group with saline in situ.

EN 3.6.2.2. Definitive obturation with gutta percha (SIGN Level of Evidence 3 and in-vitro)

Previous guidelines have advocated long term NSCaOH being left in situ for 6-12 months prior to obturation with gutta percha. Recently this has been questioned. Firstly the use of long term calcium hydroxide may be detrimental to the dentine and make it more brittle and liable to fracture [Andreasen *et al.,* 2002; Rosenberg *et al.,* 2007; Twati, 2009] . Secondly two clinical studies demonstrate that definitive obturation with gutta percha following short term application of NSCaOH prolongs the survival of avulsed and replanted teeth in comparison to long term NSCaOH even if healing was by bony replacement. [Andreasen *et al.,* 1994; Barrett and Kenny, 1997]

The increasing use of decoronation for ankylosed teeth [Malmgren *et al.,* 1984; Malmgren, 2000] showing early stages of infraocclusion requires the clinician to weigh up the benefits and disadvantages of definitive obturation. Although gutta percha can be removed from the root canal at the time of decoronation this increases the time and complexity of the procedure. There is, however, a relatively short window in which to obturate ankylosed teeth before resorption cavities involve the pulp canal space, thereby complicating the procedure. Consequently long term planning and an assessment of the chances for infra occlusion needs to be considered by the inter-disciplinary team. Furthermore the severity of infraocclusion is variable between patients which adds to the difficulty of the decision [Malmgren and Malmgren, 2002]. What is certain is that root canal space must be infection free to prevent any additional bone loss. Therefore where the decision is made to retain the potentially ankylosing tooth until it is lost to replacement resorption or if there is a low risk of infraocculsion, early definitive obturation with gutta percha is advisable.

EN 3.6.2.2.1. Gutta Percha or Mineral Trioxide Aggregate (MTA)?

There is some concern about the placement of gutta percha or MTA in a root canal of a potentially ankylosing tooth, when the root will ultimately be replaced by bone. Both materials are relatively inert and will have minimal effect on bony replacement of the root [Hauman and Love, 2003; Srinivasan *et al.*, 2009]. The preference for gutta percha rather than MTA relates to subsequent treatment options (transplant or implant) to replace the missing tooth. For both these scenarios a socket is fabricated within the bone. While gutta percha is simple to remove or drill through with an implant bur, it is unknown how MTA will behave. Consequently a local decision needs to be made at the time of long term planning with the clinician who will ultimately place the transplant or implant. Furthermore if decoronation is anticipated as a medium term treatment option, placement of MTA will increase the difficulty in apical instrumentation and bleeding into the root canal which is an essential step of this technique [Malmgren, 2000].

EN 3.6.2.2.2. Why no extraoral obturation?

Where there is a chance of cemental/PDL healing of the avulsed tooth, extraoral obturation is contra indicated as this will cause further damage to the periodontal ligament thereby increasing the chances of ankylosis [Andreasen, 1981d]. This would also prevent the use of the root canal as a vehicle for application of medicaments to influence healing, as described earlier.

EN 3.6.2.2.3 Timings of review appointments for assessment of periodontal healing and endodontic treatment

Importantly early contact with the inter-disciplinary specialist team is essential to discuss and or refer the patient. This allows the likely prognosis for the avulsed tooth or teeth to be determined, treatment planning for the short, medium and long term to be undertaken and a tailored follow-up regime to be identified. Clear communication between the parents, child, primary and specialist team are essential to ensure everybody is clear about what treatment is required and who will provide it.

The intracanal medicament will determine the follow up regime [Day *et al.*, 2012].

The steroid dressing should remain in situ for two months. This allows the medicament to influence periodontal healing which takes approximately this duration [Nasjleti *et al.*, 1982; 1987; Breivik and Kvam,

1987; Brezniak and Wasserstein, 2002]. A further visit for chemical disinfection and dressing with NSCaOH is recommended prior to early obturation of the root canal with gutta percha.

For NSCaOH, this medicament should remain in-situ for up to four weeks to ensure disinfection of the root canal prior to obturation.

On occasions the specialist inter-disciplinary team may elect not to obdurate with gutta percha. They may choose to maintain NSCaOH in situ as infra occlusion is anticipated in the short term or has already been diagnosed and decoronation is the medium term treatment option, see page 43.

Obturation with gutta percha should only be undertaken if no infection related resorption or infection within the root canal is identified. A longer duration of NSCaOH with further applications may be needed if any entities are diagnosed [Trope *et al.*, 1995].

The avulsed tooth or teeth then should be reviewed at three, six and twelve months to determine periodontal healing. Clinical and radiographic signs of ankylosis or cemental/PDL healing are discussed on page 25. Obviously other injuries or patient reported concerns may necessitate more frequent visits in addition to attending the inter-disciplinary team for treatment planning.

EN 4 ANKYLOSIS PATHWAY - Treatment for teeth with little chance of cemental/PDL healing e.g. Teeth with extraoral time of greater than 30 minutes dry time or greater than 90 minutes total extra alveolar time even when stored in an appropriate storage medium

Although ankylosis in this situation is highly likely there is clinical evidence that the longer the extra alveolar time before replantation the more rapid the onset and speed of replacement resorption [Coccia, 1980; Andersson *et al.,* 1989; Andreasen *et al.,* 1994; Donaldson and Kinirons, 2001; Humphreys *et al.,* 2003]. As extra alveolar time increases so does the extent of necrosis of the periodontal membrane that will occur and therefore more sites on the root surface are available for ankylosis to be initiated. Thus care should be taken not to unnecessarily damage the periodontal membrane further. It is a balance between minimising further damage to the membrane and reducing the treatment burden for the child and parent who will now need medium to long term treatment to replace the ankylosing tooth. **Therefore this guideline does not support the removal of the remaining periodontal membrane prior to replantation (**SIGN Level of Evidence 3)**.**

Extraoral obturation should be carried out prior to replantation to reduce the number of patient visits and reduce the risk of infection leading to further alveolar bone loss.

EN 4.2 Extraoral obturation (SIGN GRADE 1-)

Extraoral obturation still requires the periodontal ligament to be carefully handled. Therefore the root is placed in damp gauze during extraoral obturation. The root care should not however compromise the quality of the root canal obturation. The treatment is still carried out to the clinician's best ability and concentration on good disinfection of the root canal and a well condensed gutta percha filling is essential. The clinical evidence for the benefit of this treatment comes from one randomised controlled trial [Giannetti and Murri, 2006] and one well conducted case series [Barrett *et al.,* 2005]. The randomised controlled trial [Giannetti and Murri, 2006] showed similar levels of radiographic resorption at 12 months between the 10 patients treated with standard intraoral endodontics and the 10 patients treated with extraoral endodontics. At four years similar finding have been reported for a larger group of patients [Murri Dello Diago and Giannetti, 2011]. The original aim of the case series [Barrett *et al.,* 2005] was to investigate the effect of

Emdogain® for regenerating the periodontal membrane. While this was unsuccessful, an important outcome was that these teeth that had undergone extraoral obturation showed no inflammatory resorption and replacement resorption of a similar magnitude to other studies treated with intraoral endodontics.

EN 4.3. Timings of review appointments and endodontic treatment if not undertaken prior to replantation

Importantly early contact with the inter-disciplinary specialist team is essential to discuss and / or refer the patient. This allows the likely prognosis for the avulsed tooth or teeth to be determined, treatment planning for the short, medium and long term to be undertaken and a tailored follow-up regime to be identified. Clear communication between the parents, child, primary and specialist team are essential to ensure everybody is clear about what treatment is required and who will provide it.

Where endodontic treatment has not been undertaken prior to replantation then the protocol for NSCaOH should be followed (see page 42).

The avulsed tooth or teeth then should be reviewed at three, six and twelve months to determine periodontal healing. Obviously other injuries or patient reported concerns may necessitate more frequent visits in addition to attending the inter-disciplinary team for treatment planning.

EN 5. Other techniques and medicaments

Many other medicaments and techniques have been investigated and are not currently recommended by this guideline until further evidence appears. These include:

Emdogain [Bamass and Iqbal, 2001; Filippi *et al.*, 2002a; Barrett *et al.*, 2005; Schott and Andreasen, 2008] (SIGN grade 3 and animal studies)

Alendronate [Levin *et al.*, 2001] (animal study)

Calcitonin [Pierce *et al.*, 1988] and thyrocalcitonin [Barbakow, 1979] (animal studies)

Fluoride [Coccia, 1980; Selvig *et al.*, 1990; Shulman *et al.*, 1998] (SIGN grade 1- and animal studies)

Hyperbaric oxygen [Chen *et al.*, 2000] (SIGN grade 1-)

Thymosin alpha 1[Loo *et al.*, 2008] (SIGN grade 1+)

Titanium posts as an alternative to conventional root canal treatment [Pohl *et al.*, 2005b; Pohl *et al.*, 2005c; Pohl *et al.*, 2005d] (SIGN grade 3)s

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