

Current developments in interim transport (storage) media in dentistry: an update

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VERIFIABLE CPD PAPER

IN BRIEF

- Discusses various suggested and available interim transport (storage) media and their potential to maintain the viability of periodontal ligament cells.
- Provides an overview of the recently introduced, promising and tested interim transport media for an avulsed tooth.
- Highlights the pros and cons of the various interim transport media and based on this provides their suggested clinical usage and application.

GENERAL

Healing following avulsion and replantation is dependent on the extent of pulpal and periodontal ligament (PDL) tissue damage. Therefore, immediate replantation is the recommended treatment of choice for an avulsed permanent tooth. To achieve a more favourable prognosis following tooth replantation, use of an appropriate interim transport medium is usually advocated. Numerous studies have researched and advocated the use of media like saliva, milk, Hank's Balanced Salt Solution (HBSS) and ViaSpan. However, current research has indicated the use of few newer media as promising interim transport media for an avulsed tooth. This review summarises the current developments regarding the introduction of newer interim transport media for the treatment of avulsed teeth.

INTRODUCTION

Tooth avulsion is a complex traumatic injury characterised by the rupture of the neurovascular bundle and periodontal ligament (PDL) exposing the tooth to the outer environment.¹ The reported incidence of tooth avulsion is approximately 0.5–16% of traumatic injuries in the permanent dentition.^{1–3} It occurs most often in the age group of 7–10 years, when the alveolar bone is resilient and offers minimal resistance to extrusive forces.^{1,4} As immediate replantation is not always practically possible at the trauma site,^{2,5} an 'interim transport' media is often required to maintain the vitality (clonogenic and mitogenic capacity) of periodontal ligament cells during the extra-alveolar time period.^{6–8} The type of transport media used and the storage period play a significant influential role on the successful clinical outcome of replanted avulsed teeth.^{1,2,9–12} A variety of media like saliva, milk, Hank's Balanced Salt Solution (HBSS)^{6,13} and ViaSpan¹⁴ have been advocated as

interim storage media for avulsed teeth. However, current research and studies have proposed few newer media in this context (eg propolis,¹⁵ culture media and growth factors,^{16,17} egg albumen,¹⁸ milk powder¹⁹). This review summarises, in brief, the newly proposed interim transport media and current developments in this milieu.

FACTORS INFLUENCING SUCCESS OF REPLANTATION

Age

PDL healing is found to be significantly less in older as compared to younger age groups.^{1,2,5}

Width and length of the root canal

An increased apical diameter provides a larger interface between the pulp and PDL which better facilitates the revascularisation process and more frequent pulpal healing.^{1,5} However greater the distance to be revascularised, the greater the chances of infection.

Mechanical damage during avulsion and replantation

In the processes of avulsion and replantation, maximal damage occurs to the convex buccal and lingual root surfaces, where physical contact occurs with the bone socket during rotary movement.^{10,20}

Splinting of the replanted tooth

Semi-rigid fixation permits physiological jiggling movements of the tooth which result in a low incidence of ankylosis as compared to rigid fixation.^{1,2,5}

Effect of mastication

Masticatory stimulation has been shown to have a positive effect in reducing the extent of ankylosis. A hard diet has shown to result in significantly low incidence of ankylosis and a higher incidence of normal PDL compared to a soft diet.¹⁰

Extra-alveolar duration

Extra-alveolar periods can be wet (if the tooth is stored in an interim medium until replantation) or dry (if no interim transport medium is used until replantation). The longer the exposure of an avulsed tooth to dry storage, the worse the prognosis. A wet extra-alveolar period is always better and more conducive to healing than dry storage. The best results following replantation are obtained when extra-alveolar time does not exceed five minutes.^{2,5} Also, prolonged extra-alveolar time reduces the clinical efficacy of the medium.

STORAGE MEDIA

Immediate replantation of avulsed teeth maximises the vitality of the PDL and minimises the probability of root resorption following replantation.^{2,9} Dry storage

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(up to 30 minutes) can elicit a higher frequency of root resorption and is more detrimental to the preservation of a normal PDL as compared to wet conditions.^{9-11,19-22} Thus it is desirable to have an interim transport media with compatible pH and osmolarity and of the required characteristic properties (Table 1) at the accident site.¹⁹ The three main parameters that can influence the clinical efficacy of media are: extra-alveolar duration, osmolarity (pH) and temperature of the media.^{19,24-32} An extended time period before replantation is positively associated with a decreased incidence of PDL healing and a higher incidence of root resorption.²³⁻²⁵ An extra-alveolar dry storage exceeding five minutes duration can be detrimental to the regeneration of a normal PDL^{19,26,27} with a decrease in clonogenic and mitogenic capacity of PDL cells.²⁸⁻³¹ A medium of correct (physiologic) osmolarity and pH is critical for its optimal clinical performance for the survival of PDL cells.^{9,12,19,32} There is also a strong evidence in the literature indicating a significant improvement in the clinical performance of transport media when used in a chilled state or at lower temperatures (0°C, 4°C).^{13,28-30} Thus these key factors play an important role in determining the overall efficacy of an interim transport medium, and hence should be given due consideration.

Conventional media

A variety of media have been used traditionally (tap water, saline, saliva) and recommended conventionally (milk, HBSS, ViaSpan) to be used as *interim transport media* for an avulsed tooth.

Tap water

This is not advocated due to its hypotonic osmolarity leading to cell lysis and higher rates of replacement resorption.^{9,12}

Saline

The use of isotonic saline solution does not have any significant effect on healing PDL and is only acceptable for a short time period^{21,33} (less than ten minutes).^{2,5,23}

Saliva

Though readily and most easily available, saliva is not considered as an effective interim transport medium. Recent literature indicates that saliva may not be

a suitable transport medium for avulsed teeth due to its non-physiologic osmolarity and the presence of microorganisms.^{6,12,28,34}

Milk

Due to its physiologic osmolarity and nutritive value milk is considered an acceptable interim transport medium for avulsed teeth. Its clinical efficacy is considered equivalent to HBSS for maintaining the vitality of the PDL cells of an avulsed tooth for an extended period of time (up to six hours).^{12,13,27-30,34-36} Low fat content milk and chilled milk has shown better results in maintaining the viability of PDL and for a longer time period.^{13,28,30,35,37} The main drawback is the presence of antigens that may interfere with the reattachment process.

Hank's Balanced Salt Solution

HBSS is considered as the gold standard and is often used as a comparison reference medium to deduce the clinical efficacy of other media. It is a sterile, physiologically balanced isotonic salt solution. The American Academy of Endodontics has accepted HBSS as an acceptable medium for avulsed teeth because of its capability to maintain vitality and proliferative capacity of PDL for an extended period of time (up to 48 hours).¹² It is superior to other media in preserving the vitality and viability of PDL cells^{13,14,29,30} and has shown the highest mitogenicity for PDL cells after eight hours and 24 hours.^{37,38}

ViaSpan

ViaSpan is a cold organ transplant storage medium that can effectively maintain the viability of human fibroblasts¹⁴ and is considered as a superior long-term medium^{27,29} for avulsed teeth. However, it is neither an easily available nor an accessible media.

CURRENT DEVELOPMENTS

Propolis

Propolis is a sticky resin obtained chiefly from the buds of some conifer trees. It consists of flavonoids (45-55%), waxes and fatty acids (23-35%), essential oils (10%), pollen-proteins (>1%), vitamins and sugars (5%), other organics (ketones, lactones, quinones, steroids) and trace minerals (iron and zinc).³⁹ The main active ingredients of propolis are flavonoids.⁴⁰ At least 38

Table 1 Ideal characteristics of Interim Transport (Storage) Media

Maintain viability of periodontal fibres
Clonogenic and mitogenic capacity
Physiological osmolarity and pH
No antigen antibody reactions
Less risk of root resorption
Effective under different conditions
Antimicrobial

different flavonoids have been found in propolis, including galangin, kaempferol, quercetin, pinocembrin, pinostrobin and pinobanksin. The chemical composition of propolis is highly variable because of the broad range of plants visited by honey bees when collecting the substance. Propolis is a substance capable of preserving cellular viability⁴¹ and has demonstrated better clinical efficacy than HBSS and milk.^{15,42} A recent study by Mori *et al.* showed that propolis is an appropriate medium for the avulsed tooth and can maintain the viability of PDL for an extended duration (six hours).⁴³

Culture media

Culture media such as Eagle's medium, alpha-Minimum Essential Media (MEM) and α MEM-S (supplemented with foetal calf serum and antibiotic) have been shown to maintain the viability and proliferative activity of PDL cells for an extended period of time (48-53 hours) with a reduced rate of inflammatory resorption.^{16,29,30,38,44} This can be attributed to the availability in the culture medium of all the required essential nutrients for the growth and proliferation of PDL cells. Supplementation and the addition of growth factors (platelet derived growth factor, insulin-like growth factor, epidermal growth factor, recombinant human platelet-derived factor-AB, natural human platelet-derived growth factor, transforming growth factor, synthetic human insulin-like growth factor-I, polypeptide growth factors etc) in a culture medium has also been shown to increase the mitogenic and clonogenic capacity of PDL cells for as long as 24 hours.^{17,38} As potent biologic mediators they are proposed to aid in regeneration of PDL.⁴⁵ Similarly the addition of antioxidant-like, catalase supplementation to a medium have shown beneficial effects on PDL

Table 2 Comparison of various interim transport media

Interim medium	Characteristics
Tap water	Hypotonic osmolarity. Cellular lysis
Saline	Isotonic Not conducive to periodontal ligament cell metabolism
Saliva	Readily available. Non-physiologic osmolarity and contamination
Milk	Efficacy equivalent to Hanks Balanced Salt Solution Longer duration of storage (chilled milk) Presence of antigens
Hank's Balanced Salt Solution (HBSS)	Considered as gold standard Physiologic-isotonic solution Maintain cellular vitality for extended period of storage
ViaSpan	Long-term media Inaccessible
Propolis	Maintain cellular viability for extended duration
Culture media	Maintain cellular viability for extended period Aid in periodontal ligament regeneration Can be supplemented with growth factors
Coconut water	Biological-isotonic fluid. Contrasting results regarding efficacy
Powdered milk	High protein content and water Lack of microbial contamination Maintain viability only up to four hours
Egg albumin	Equivalent cellular viability as HBSS
<i>Salvia officinalis</i>	Natural substance. Antioxidant Short-term storage
<i>Morus rubra</i>	Natural substance. Antioxidant and anti-bacterial Extended storage
Emdogain	Doubtful efficacy in replanted and auto-transplanted teeth

cells and a reduced rate of surface resorption.⁴⁶ Recent experimental research has advocated the use of a special cell culture medium (SCCM), especially composed for storing avulsed teeth, that can maintain pulp cell viability better than HBSS and for an extended duration (24 hours).⁴⁷ Thus, supplementation of growth factors and use of special cell culture media can be beneficial in cases of tooth avulsion.

Coconut water

Coconut water is a biologically pure, sterile and natural isotonic fluid that is mainly available in tropical countries. It is rich in amino acids, proteins, vitamins and minerals and thus is readily consumed to replenish lost body fluids, electrolytes and sugars. Recent investigation by Gopikrishna *et al.* has proposed coconut water as a promising medium for avulsed teeth and has shown it to be superior to HBSS and milk in maintaining the viability of PDL cells.^{48,49} However, some other studies have reported contrary results, showing coconut water as worse than milk in maintaining

human fibroblast cell viability.⁵⁰ Thus more research studies are required before it can be recommended as an acceptable transport medium for avulsed teeth.

Powdered milk

This is the recent addition in milk substitutes and/or products that have been demonstrated to maintain the viability of PDL cells and has been proposed as a favourable transport medium.^{19,51} Powdered milk is one of the presentation forms of bovine milk and is considered as a feasible medium in cases of delayed tooth replantation. It has shown similar results to long shelf-life (ultra high temperature) whole milk in relation to the healing process after delayed replantation of avulsed teeth.¹⁹ However, the powdered form is more effective than pasteurised milk as a medium only up to four hours, following which these substitutes perform worse than whole milk.⁵¹

Egg albumin

Egg albumin is considered as a good choice because of its high protein content,

vitamins, water, lack of microbial contamination and easy accessibility. It has shown better cell viability and significantly higher incident of PDL healing as compared to milk and equivalent cell viability as HBSS.⁵² It is observed to be an excellent medium for up to ten hours with the principle advantage being its availability.⁵³

Salvia officinalis

Use of *Salvia officinalis* has been proposed as an alternate option for clinicians to transport (store) avulsed teeth until reimplantation. It belongs to the family of Labiatae and is native to the Mediterranean region. Essential oil obtained from it has some antimicrobial and antioxidant properties. These properties vary with the chemical composition of oil that is dependent on parameters like technique of extraction, geographical origin of the plant and the part of the plant analysed.⁵⁴ The major constituents are α - and β -thujone (>50%) and camphor (<20%).⁵⁴ Other components include manool, ledene, viridiflorol, 1-8 cineole, limonen, and trans-caryophyllene. The oxygenated component represents more than 80% in the essential oils. Ozan *et al.* observed that PDL cells' viability at 1-3 hours is similar for 2.5% *S. officinalis* and HBSS, whereas at 24 hours, the efficacy of 2.5% *S. officinalis* is significantly better than HBSS.⁵⁵ Thus, *S. officinalis* can be recommended as a suitable transport medium for avulsed teeth.

Morus rubra

Recently the juice of the fruit of *Morus rubra* (red mulberry) has been recommended as a suitable transport medium for avulsed teeth.⁵⁶ *Morus alba* L (mulberry) is a natural therapeutic belonging to the Moraceae family. They are rich in flavonoids, alkaloids and polysaccharides components which are the most potent active constituents.⁵⁷ The flavonoids present in mulberry leaves include rutin, quercetin, isoquercitrin and quercetin.⁵⁷ At 4% concentration, *M. rubra* is found to be more effective than HBSS up to 12 hours, in maintaining the PDL cells' viability.⁵⁶

Emdogain (Enamel Matrix Derivative, EMD)

Emdogain (Biora, Malmo, Sweden) is a commercial Enamel Matrix Derivative

(EMD) extracted from developing embryonic enamel of porcine origin and contains several matrix proteins. Studies have shown that it can influence the migration, attachment, proliferative capacity and bio-synthetic activity of PDL cells.⁵⁸ It has also been used in antiresorptive-regenerative therapy along with topical glucocorticoids and systemic doxycycline. Thus, it is a recommended therapeutic agent for the management of avulsed permanent teeth. However, no firm conclusion regarding the efficacy of EMD application on healing of replanted⁵⁹ and autotransplanted permanent teeth can be drawn because of a lack of randomised controlled trials and clinical controlled trials.⁶⁰

Tooth rescue box

A tooth rescue box containing Special Cell Culture Medium (SCCM) including amino acids, vitamins and glucose has been developed. In Europe it is marketed as Dentosafe (Dentosafe GmbH, Iserlohn, Germany) and in the USA as EMT Tooth Saver (SmartPractice.com, Phoenix, AZ, USA). An unopened box can have a shelf-life up to three years. Avulsed teeth stored in a rescue box for 15 minutes have exhibited functional healing irrespective of storage duration.⁶¹ This medium has shown to maintain the vitality and viability of PDL cells at room temperature for at least 48 hours. The usage of the tooth rescue box is self-explanatory and plausible to lay people (teachers, pupils). Avulsed teeth can be stored in the tooth rescue box for a longer duration and its early availability can result in an excellent healing prognosis after replantation.⁶² Since their introduction and distribution in Germany, the rate of functional healing after replantation of avulsed teeth has increased to 50%. Thus it is advised to distribute tooth rescue boxes at locations prone to tooth traumas (schools, kindergartens, sporting facilities, public pools) and at emergency units (hospitals, ambulances) to enhance the prognosis of avulsed teeth.⁶¹

CONCLUSION

Though performed rarely, immediate replantation is the treatment of choice for an avulsed tooth, which can at least temporarily re-establish the aesthetics and function. The combination of delayed replantation and unphysiological storage

is usually followed by low survival of PDL cells and a poorer prognosis of reimplantation.⁶³ Thus to minimise the adverse effects of the extraoral dry storage period, an interim transport (storage) medium is considered crucial for the preservation of PDL cells' vitality and viability (Table 2). So far current research considers HBSS as the most optimal interim transport medium for avulsed teeth, followed by milk. However, a variety of new media like propolis, tender coconut water, powdered milk and egg albumin have also been proposed as potential alternatives to HBSS. However, further clinical and/or *in vitro* studies are required before considering their usefulness and clinical effectiveness in the case of an avulsed tooth. Tooth preservation kits/systems (Tooth Rescue Box, Emergency Tooth Preserving System) have also been introduced in schools, sporting facilities and hospitals, to enhance the prognosis of avulsed teeth and reimplantation.

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Corrigendum

Research article and research summary (*BDJ* 2011; **210**: E15 and *BDJ* 2011; **210**: 420):

'Delivering alcohol screening and alcohol brief interventions within general dental practice: rationale and overview of the evidence'

In the above online-only research article and in the associated research summary, which appeared both in print and online, the job title and grade stated for Dr Christine A. Goodall were inaccurate. Dr Christine A. Goodall is a Senior Clinical Lecturer (Honorary Consultant) in Academic Oral Surgery, Lead Clinician Oral Surgery and Head of BDS Admissions at Glasgow University Dental School.