Contemporary Pediatric Dentistry

Review
Contemp Pediatr Dent 2024:5(2):53-70
DOI: 10.51463/cpd.2024.6

Storage medium for avulsed teeth: A narrative review

Rutuja Shinde[1], Dinesh Rao[2] ✉, Sunil Panwar[3], Remi RV[4]

Highlights

- Immediate replantation is essential for achieving optimal treatment success and a favorable prognosis in avulsed permanent teeth.
- The biological properties of storage mediums are critical for preserving the viability, clonogenic capacity, and mitogenic potential of periodontal ligament cells.
- Milk is a preferred storage medium due to its satisfactory performance, widespread availability, and cost-effectiveness in emergency situations.

[1] Postgraduate Student, Department of Pediatric Dentistry, Pacific Dental College and Hospital, India
[2] Professor, Department of Pediatric Dentistry, Pacific Dental College and Hospital, India
[3] Professor, Department of Pediatric Dentistry, Pacific Dental College and Hospital, India
[4] Senior Lecturer, Department of Pediatric Dentistry, Pacific Dental College and Hospital, India

Correspondence:
Department of Pediatric Dentistry
Pacific Dental College and Hospital
E-mail address:
pedodinesh2003@yahoo.co.in

Abstract

Dental avulsion is the most severe type of traumatic tooth injury, resulting in the complete displacement of the tooth from its socket in the alveolar bone. Immediate replantation of an avulsed permanent tooth is recommended for successful treatment and a good prognosis. However, replantation is not always feasible. The biological properties of the storage medium, which must preserve the viability, clonogenic capacity, and mitogenic potential of the periodontal ligament (PDL) cells, are crucial for successful reimplantation. If the root surface dries out excessively due to prolonged extraoral time before replantation, the damaged PDL cells can trigger an inflammatory response across the root surface, leading to ankylosis. There are various types of storage media, both synthetic and natural. Therefore, selecting the appropriate storage medium in an emergency is critical for improving the outcome of teeth that cannot be immediately replanted. This review examines research on various storage media for avulsed teeth, focusing on their properties and effectiveness, based on articles from electronic databases.

Keywords: Dental Trauma; Periodontal Ligament; Storage media; Tooth Avulsion; Traumatic Dental Injuries

Received: 23 Feb 2024
Accepted: 11 May 2024
Online First: 25 May 2024

INTRODUCTION

Trauma to the teeth can result in crown or root fractures, luxation injuries, or avulsions. An avulsion is the complete exarticulation of a tooth from the socket.[1] Immediate replantation is recommended for an avulsed permanent tooth, to minimize the risk of post-replantation resorption of either an inflammatory or a replacement nature.[2] However, immediate repositioning of teeth is not always possible in conditions such as a person's conscious state or lack of knowledge. In these kinds of situations, keeping the tooth in a sufficiently moist media is essential for a better prognosis of replantation because it can prolong the life of the periodontal ligament cells that are still present on the root surface.[3] To maintain periodontal ligament (PDL) cell viability, a variety of storage media can be employed.[4] Determining an appropriate storage medium is crucial to maintaining the highest possible PDL cell survival rate before replantation.[5]

The ideal storage medium should be capable of preserving the feasibility of the cellular periodontal ligament such that the cells can go through mitosis and form clones of the damaged fibroblasts of the periodontal ligament and its generating cells.[6] This is essential so that the root surface with no cells or any damaged fibroblasts of PDL cells attached to it can be repopulated by fibroblasts, avoiding the adherence of osteoclasts in this area So ideal storage media should have the following properties: it should be easily available and economical[7]; it should have a good shelf life; to produce new cells, the cellularity of the remaining PDL should be maintained[8]; the adherence of osteoclasts to the PDL fibers should be minimized; it should produce an antigen-antibody reaction[8]; it should reduce inflammatory reactions and root resorption[7]; it should preserve the feasibility of the cellular periodontal ligament, enabling cells to undergo mitosis and form clones of the damaged fibroblasts and their progenitor cells[7]; it should be capable of removing toxic products[9]; it should have antioxidant properties[8]; it should have a compatible pH and physiological osmolarity[8]; and it should wash off extraneous materials and toxic waste products.[10]

There are quite a few review articles already published elsewhere.[7, 8, 11-17] These studies have included limited varieties of storage media, without proper classification methods. Adan et al.,[8] explained more than 20 storage media with their ideal properties, Khinda et al.,[7] and Poi et al.,[11] explained natural as well as synthetic media, Udoye et al.,[12] explained each storage media based on properties such as maximum storage period, nutrient content, refrigeration requirement, cost-effectiveness, bacterial content, viability of PDL, and clonogenic and mitogenic capacity. Thus, the current review article focuses on a wide variety of storage media with their properties and effectiveness. Also, the different storage media have been explained in a well-classified manner. Thus, the main purpose of this paper is to review available storage media for avulsed teeth and discuss the properties and effectiveness of different storage mediums that have been tried and tested.

METHODS

Using the keywords 'storage medium', 'transportation medium', 'avulsion', 'tooth avulsion', 'tooth replantation', and 'Natural storage media', PDL cells viability. PubMed/Medline, Lilacs, BBO, and SciELO electronic databases were searched for research articles, reviews of literature, animal laboratory studies, and laboratory studies involving cell counting in human teeth assessing the PDL cell viability after storage of avulsed teeth in different substances, which had been published in English between 2000 and 2024. Regarding the features, effectiveness, and

accessibility of the storage media, 77 publications were chosen and subjected to a critical evaluation process. Each paper was evaluated regarding the effectiveness of maintaining PDL cells, the properties of media, the accessibility and cost of storage media, etc.

Classifications of storage media

The different storage media for an avulsed tooth can be classified into three categories based on their constituents.[18]

Physiologic Storage Media

These are solutions that closely mimic the composition of the fluids in the human body and are isotonic, meaning they have a similar osmolarity to bodily fluids. These solutions help maintain the viability of periodontal ligament cells on the root surface of the avulsed tooth. e.g.: Hank's balanced salt solution (HBSS), Save-A-Tooth® system, and Viaspan®.

Hypertonic Storage Media

These are solutions that have a higher concentration of solutes than the fluids in the human body and can prevent the swelling of the periodontal ligament cells, thereby reducing the risk of damage. Hypertonic solutions like 10% dextrose or 20% sucrose have been suggested for preserving organs for transplantation due to their dehydrating effect, they are not ideal for storing avulsed teeth. Placing an avulsed tooth in a hypertonic solution can lead to dehydration and damage to the periodontal ligament cells, reducing the chances of successful reimplantation.

Non-Physiologic Storage Media

These are solutions that are not meant for long-term storage but can be used as a temporary measure until a suitable physiologic storage medium is available, e.g., saline solution, and tap water (as a last resort). It is important to note that the storage medium should be used as soon as possible after the avulsion to improve the chances of successful reimplantation. Tap water can cause damage to periodontal cells due to its hypotonic nature, while milk and saliva lack the necessary components to support cell viability over an extended period. Additionally, the tooth should be handled gently to the crown structure and not on the root surface, and not scrubbed or cleaned before storage, as this can damage the periodontal ligament cells.

Research has shown that storing avulsed teeth in a physiologic solution significantly improves the chances of successful reimplantation by preserving the vitality of PDL cells and promoting periodontal healing.[18, 19] Using hypertonic solutions for prolonged storage of avulsed teeth is not recommended as it can compromise the viability of PDL cells and decrease the chances of successful reimplantation. Storing avulsed teeth in non-physiologic solutions can lead to rapid deterioration of PDL cells, increasing the risk of ankylosis and root resorption upon reimplantation.[18, 20]

Another classification based on origin is shown in Table 1.

Natural storage media

Tap water

Tap water is a non-physiologic storage medium and has non-physiological pH and osmolality, bacterial contamination, and hypotonicity that promote the lysis of PDL cells, it is not a suitable medium for keeping avulsed teeth.[21, 22] Its hypotonic nature causes the periodontal ligament to rapidly lyses cellularly, similar to how dry storage does, even though it helps to prevent dehydration. For this reason, it is not a suitable method for preserving avulsed teeth.[22, 23]

Table 1. Classification of storage media based on origin

Natural	*Synthetic*
Tap water[21,22]	Normal saline[90]
Saliva[21,26]	HBSS[91,92]
Milk[27,28]	Eagle's medium[94,95]
Egg white[25,31]	Dubelco's storage media[96]
Propolis[40]	Gatorade[97]
Coconut water[44,45]	Tooth rescue box[100]
Camellia sinensis (Green tea extract)[46]	Contact lens solution[101]
Saliva officinalis extract[54]	L-DOPA[102,103]
Morus rubra fruit (red mulberry)[58]	ViaSpan[105]
Emdogain®[60-62]	Ricetral[106]
Soy milk[63]	Minimal essential medium[107]
Honey milk[67,68]	Cling film[108]
Punica granatum (Pomegranate juice)[73]	Euro-COLLINS[111]
Aloe vera[75,76]	Cryoprotective agents[112]
Rice water[77]	Catalase supplementation[113]
Dragon's blood sap[35]	Custodial[90]
Cranberry[79]	Conditioned medium[114]
Mimusops Elengi (Bakul)[81]	Probiotics[117]
Prunus domestica (Plum)[79]	Casein phospho-peptides[118]
Psidium guajava (Guava)[79]	Oral rehydration solution[119]
Basil (Tulsi)[85]	Growth factors[121]
Ice apple (*Borassus flabellifer)*[87]	Cornisol[121]
Curcuma longa *(turmeric)*[88]	Placentrex[122]
Neem (Azadirachta indica)[88]	
Castor oil[89]	

Saliva

Human saliva (buccal vestibule) is used as a storage medium due to its availability, but it has unfavourable characteristics, such as non-physiological pH and osmolality (60-70 mOsm/kg), high microbial contamination, and hypotonicity.[21] It has been suggested that saliva can be used as an interim storage medium for up to 4 hours.[24] Though it is readily available, avulsed teeth should not be stored for longer than 30 minutes in saliva. It contains potentially harmful substances, such as enzymes, bacteria, and their by-products.[23, 25] On the other hand, in an animal study, Andreasen et al.,[26] reported that saliva and

saline were appropriate storage media to prevent root resorption for brief extra-alveolar intervals.

Milk

Milk is a physiologic storage medium that closely mimics the composition of the fluids in the human body. It satisfies the requirements for a short-term storage medium such as it is physiologically pH balanced, capable of maintaining PDL cell viability, and bacterial count is low and widely accessible.[27] as well as the advantages of milk as a preservative fluid are that it is nearly isotonic and relatively free of bacterial contamination.[27] It is the most practical transport medium for the short-term storage of avulsed teeth because of its ready availability in almost all situations.[28] It is a compatible short-term storage medium for teeth if placed in it within 15 to 20 minutes of being avulsed. Milk can maintain the viability of PDL fibroblast, and it is superior to saliva, water, or air drying, but not as good as HBSS[27] and coconut water.[29, 30]

Egg white

Egg albumin is composed mainly of 76.15% water, 12.56% proteins, 0.72% carbohydrates, 9.51% total fats, minerals (Ca, Fe, Mg, Ph., Po, Na, and Zn), vitamins (A, C, B complex, and E), and sugars. The pH of egg albumin is about 6.6-7, and its osmolality is about 251-298 mOsmol/kg.[31] So it is considered a good choice as a storage medium for teeth undergoing delayed replantation due to its high content of proteins, vitamins, and water, absence of microbial contamination, and easy access.[21, 23] No significant difference between egg white and HBSS at storage times of 1, 2, 4, 8, and 12 hours has been established, and egg white was more suitable than water and milk as it preserved the PDL cell viability.[25]

Propolis

Propolis is a physiologic storage medium that closely mimics the composition of the fluids in the human body. It is a natural, non-toxic resinous substance that has been collected from several types of plants by bees for covering and protecting the hive.[32] It has anti-inflammatory,[33] antiseptic,[34] antibiotic, antibacterial, antifungal, antiviral, antioxidant, anti-carcinogenic, anti-thrombotic, and immunomodulatory properties.[35] Along with these properties, propolis also inhibits the osteoclastic resorption of teeth, which is a common sequela of replantation of teeth.[36] Propolis is one step ahead of milk,[35, 37] HBSS,[35] Dulbecco's modified Eagle's medium[38], or saline in maintaining PDL cell viability. 10% Propolis is more efficient than 20% in maintaining PDL viability.[38] It may be helpful as an intracanal medication to reduce the resorption of damaged teeth as it can prevent the final stages of osteoclast growth.[39] Propolis's major drawback is its limited availability to the general public, which makes it not useful as a tooth avulsion storage solution.[40]

Coconut water

Coconut water is a physiologic storage medium that closely mimics the composition of the fluids in the human body. It is biologically pure, sterile, and rich in amino acids, proteins, vitamins, and minerals. It possesses regenerative[41] and antioxidant properties.[42] storage media having antioxidant properties can be more effective in maintaining the viability of PDL. But it has a pH of 4.1 that causes harmful effects on cell metabolism until sufficiently neutralized. Avulsed teeth that are left dry for more than 30 minutes may benefit from soaking in 100% mature coconut water.[43] Gopikrishna et al.,[44] reported that coconut water has a greater capacity to maintain cell viability when compared to propolis, HBSS, and milk. On the other hand, Pearson et al.,[22] and Thomas et al.,[45] observed that inflammatory resorption was

more frequent when the tooth was maintained in coconut water compared with milk.

Camellia sinensis (Green tea extract)

Epigallocatechin-3-gallate [EGCG] is a major polyphenol in green tea, having antioxidant, anti-inflammatory, and antibacterial properties and good anticarcinogenic effects.[46-48] The commercially available green tea is easily available at the site of the accident. Therefore, it is tested as a storage media. Hwang et al.,[46] and Jung et al.,[49] found positive results with green tea in minimizing the infections following tooth replantation, maintaining PDL cell viability, and reducing root resorption and ankylosis, with the maintenance of 90% of cell viability for up to 24 hours, comparable to the HBSS control.[46, 49] However, on the other side, it has low osmolality which may lead to the death of the PDL cells and therefore, is not suitable for storage of avulsed teeth.[50]

Salvia officinalis

Salvia, the largest genus of *Lamiaceae*, includes approximately 900 species widespread all over the world.[51] It has antimicrobial,[52] antiviral, antitumoral,[53] and anti-inflammatory properties. Ozan et al.,[54] observed that the viability of PDL cells is similar for 2.5% *S.officinalis* and HBSS at intervals of 1-3 hours, but the effectiveness of 2.5% *S.officinalis* is noticeably higher than that of HBSS at a 24-hour interval. So, it has been confirmed as a storage medium as it has antioxidant effects due to the presence of its phenolic components (rosmarinus acid, camosic acid, and salvianolic acid).

Morus rubra fruit (red mulberry)

The mulberry belongs to the genus Morus of the family *Moraceae*.[55] Mulberry fruits can be used as a worming agent, as a remedy for dysentery, and as a laxative, odontalgic, expectorant, hypoglycemic, and emetic.[56] The methanolic extract of red mulberry shows antimicrobial properties.[57] Özan et al.,[58] observed that 4.0% and 2.5% *M. rubra* solutions showed better results than HBSS at all hours, except at 24 hours in maintaining the PDL cells' viability. However, storage media containing *M. rubra* are not yet available.[58]

Emdogain®

Emdogain® is a commercial name for Enamel matrix derivative (EMD) is prepared from an acidic extract of homogenized extracellular matrix from tooth buds of swine, and contains predominantly the protein amelogenin as well as other enamel matrix proteins and growth factors such as transforming growth factor-beta.[59] EMD acts selectively on periodontal ligament fibroblasts and stimulates attachment, proliferation, extracellular matrix synthesis, autocrine growth factor expression, and cellular differentiation.[60, 61] Fridström et al.,[62] mentioned Emdogain® gives more favourable conditions regarding extra-oral time, storage medium, and systemic antibiotics.

Soy milk

Soymilk, the water extract of soybeans, is a rich source of high-quality protein and amino acids. It contains no cholesterol or lactose and very small amounts of saturated fatty acids.[63] It has been identified as an excellent culture medium for cell growth and biochemical activities as it has a pH of 7.3 and 267 mOsmol/kg of osmolarity.[64] It has been able to maintain cell viability at similar levels as whole milk[65, 66] and, HBSS.[66]

Honey milk

It is 8% non-fat solid milk, 3 gm protein, 11 gm carbohydrate, 0.1 gm calcium, 0.6 gm minerals & 0.12gm phosphorous and natural honey (5%). It has a pH of 6.07 and 280 mOsmol/kg of osmolarity. The storage capacity is at least 6 months without the need for a refrigerator. After 9

hours the long shelf life of honey milk showed better results than fresh milk and comparable results to HBSS.[67, 68] and easily available than expensive commercial solutions.

Punica granatum (pomegranate juice)

Pomegranate is the fruit of *Punica granatum (Punicaceae),* which has been extensively used in the folk medicine of many cultures.[69] It is a rich source of polyphenolic flavonoids; which possess direct and indirect antioxidant, anti-inflammatory, and antibacterial properties.[70-72] Along with these properties, it also promotes strong cell attachment. While pomegranate polyphenols have antioxidant and antiviral properties, which may result in higher viability of PDL cells.[69] Tavassoli-Hojjati et al.,[73] observed that *Punica granatum* is equally effective as HBSS. They further suggested that a 7.5% concentration of pomegranate juice is more effective, and cell viability increases with increased concentration. Since research conducted to assess its efficacy is very limited, further research is needed.

Aloe vera

Aloe vera is a physiologic storage medium that closely mimics the composition of the fluids in the human body. The inner gel of aloe vera contains more than 75 active ingredients. It has anti-inflammatory, antibacterial, antioxidant, immune-stimulating, and hypoglycemic effects among its pharmacological actions.[74] At doses of 10%, 30%, and 50%, aloe vera preserved cell viability above 90%. Fulzele et al.,[75] observed that indigenously prepared pure aloe vera gel has exhibited PDL cell viability comparable to HBSS. It was observed that periodontal fibers near the cementum of the tooth stored in Aloe vera were thick and intact, however, the periodontal fibers associated with teeth stored in milk and HBSS were loose.[76] Due to its easy availability and low cost, it can be used as a storage medium for avulsed teeth.

Rice water

Rice water has low sodium content, and useful quantities of potassium, Vitamin B, thiamine, and niacin. It also has anti-inflammatory properties. The iron and zinc in its composition help in the synthesis of collagen.[77] Sharma et al.,[77] mentioned that rice water may be able to maintain PDL cell viability better than egg white or milk. Since research conducted to assess its efficacy is very limited, further research is needed.

Dragon's blood sap (Croton Lechleri)

Dragon's blood sap is a medicinal plant with anti-inflammatory, healing, anticancer, antimycotic, antiviral, antifungal, antibacterial, and antioxidant properties. It can induce osteogenesis mineralization, and bone formation, as reported.[35] Martins et al.,[35] evaluated the efficacy of the sap to maintain PDL cell viability.

Cranberry (vaccinium macrocarpon)

Cranberry is regarded as a superfruit. It is a rich source of phytochemicals, vitamins, and phenolic compounds (e.g, amthocyanins, proanthocyanidins, phenolic acids, and flavonols).[78] It has antibacterial and antiviral properties.[79] Anegundi et al.,[79] observed that the cranberry can preserve viable cells even in prolonged extra-alveolar time.

Mimusops Elengi (bakul)

Bakul has antimicrobial, anti-inflammatory, analgesic, and antipyretic properties.[80] Kumar et al.,[81] observed that *Mimusops elengi* (bakul) can maintain 70% PDL cell viability, but the pH and osmolality were not favourable for the growth of the PDL cells. Hence, its use as a storage medium was dismissed.

Prunus domestica (plum)

Plums are phenolic-rich fruits that contain a mixture of polyphenolic compounds that can exert several biological effects, including antibacterial,[82] antioxidant,[83] and anti-inflammatory properties.[84] Anegundi et al.,[79] observed that *prunus domestica* increases cell viability at 15 minutes to 30 minutes and 1-3 hours' time intervals.

Psidium guajava (guava)

Guava or *Psidium guajava*, is a fruit that is also said to have therapeutic qualities. Guava leaves showed cell proliferative capacity and also maintained viable PDL cells.[79] Since research conducted to assess its efficacy is very limited, further research is needed.

Basil leaves (tulsi) (ocimum sanctum)

Basil leaves have been used for centuries as a medicinal plant. It contains high phenolic compounds, and phytochemicals such as flavonoids, tannins, terpenoids, and saponins in the leaves and stems. It has antioxidant, anti-inflammatory, antifungal, and antibacterial properties due to the presence of anion radicals. Because of these properties, basil can be used as a storage medium.[85] Since research conducted to assess its efficacy is very limited, further research is needed.

Ice apple (*Borassus flabellifer)*

Botanically, ice apple (*Borassus flabellifer*), a locally available fleshy, juicy fruit in coastal regions of India, has a similar composition as coconut water.[86] The fresh pulp of ice apple fruit is rich in vitamins A and C, several phytochemicals that possess strong antioxidant and anti-inflammatory properties, dietary fiber, and minerals, which are positive factors in the nourishment and viability of the cells and it has a pH of 5.3-5.4.[87] Bijlani et al.,[87] observed that 10% ice apple fruit pulp has the maximum capacity to maintain PDL cell viability.

Curcuma longa (turmeric)

Turmeric (*Curcuma longa*) is a popular antiseptic in the *Zingiberaceae* family. The anti-inflammatory, antioxidant, antibacterial, antiseptic, and antimutagenic qualities of curcumin have been demonstrated. Curcumin can preserve the viability of PDL cells and can be used as a suitable natural storage medium.[88] Since research conducted to assess its efficacy is very less, further research is needed.

Azadirachta indica (neem)

It has been established that neem leaf and its components have antiviral, antifungal, antihyperglycemic, antimutagenic, anticarcinogenic, and immunomodulatory qualities. With a pH balance of 7-7.5 and an osmolality of 270 mOsmol/kg. Dhimole et al.,[88] observed that neem maintains the PDL cell viability as comparable to milk.

Castor oil

Castor oil as a vegetable oil has several advantages, such as antimicrobial and antioxidant properties, low toxicity, glutathione preservation capability, low cost, and high availability. It has a pH of 6.0-8.1 and 260 to 320 mOsmol/kg. But Nabavizadeh et al.,[89] observed that castor oil was not able to preserve the viability of PDL cells efficiently, comparable to HBSS and milk.

Synthetic storage media

Normal saline

Saline has an osmolality of 280 mOsmol/kg and a pH of 7, which is favourable for PDL cells. While readily accessible, it is deficient in important nutrients that the cells require, such as glucose and ions. It can be stored for up to 30 minutes, and if left out longer, it begins to degrade PDL cells. Although saline is an insufficient medium, it can be utilized momentarily due to its ease of availability.[90]

Hank's balanced salt solution (HBSS)

HBSS is a physiologic storage medium that closely mimics the composition of the fluids in the human body. Because of its osmolality of 320 mOsmol/kg and pH of 7.2, HBSS is regarded as the gold standard media for avulsion. Ingredients present in it, including glucose, calcium, and magnesium ions, can replenish and maintain the depleted biological components of the PDL cells.[91] It was the most successful medium for maintaining the survival, mitogenicity, and clonogenic potential of periodontal ligament cells for up to 24 hours at 4°C, according to Ashkenazi et al.,[91] and Pillegi et al.,[92] It is commercially available as Save-A ToothTM. It has been recommended as the storage medium of choice for avulsed teeth by the American Association of Endodontics.[93] Unfortunately, HBSS is not commonly used in India since it is not readily available.

Eagle's medium

Eagle's Minimal Essential Medium is a physiologic storage medium that closely mimics the composition of the fluids in the human body. It contains L-glutamine, penicillin, streptomycin, nystatin, calf serum, amino acids, vitamins, and bicarbonates. It has a pH of 6.8-7.2 and 310-360 mOsmol/kg osmolarity. As reported by Ashkenazi et al.,[94] Eagle's medium exhibited a comparatively high level of viability, mitogenicity, and clonogenic capability for up to eight hours at 4° C in storage. The Eagle's medium at 37° C is a recommended storage medium as it can preserve the PDL for extended periods before reimplantation.[95]

Dubelco's storage medium

Dubelco's Modified Eagle's Medium (DMEM) is a physiologic storage medium that closely mimics the composition of the fluids in the human body. It is a variation of Eagle's Modified Essential Medium (EMEM) that contains approximately four times more vitamins and amino acids than the regular EMEM formula, as well as 2-4 times more glucose, iron, and phenol red. DMEM is suitable for use with most types of cells. However, it is not accessible to the general public, making it useless as a storage medium for avulsed teeth.[96]

Gatorade®

Gatorade® is a physiologic storage medium that closely mimics the composition of the fluids in the human body. It is a non-carbonated sports drink, consumed by non-athletes for rehydration. Sigalas et al.,[97] evaluated Gatorade as toxic to the cells at 37° C, but this may be an alternate medium to HBSS and milk when used ice cold and for a short time. Since the low pH (3) and high osmolarity (280-360 mOsmol/kg) are unfavourable to cell development or survival.[98] Chamorro et al.,[99] found that it mildly damages cell membranes, which triggers apoptosis in human PDL cells. Whereas Gatorade preserves more viable cells than tap water. It only serves as a storage medium if other media are not available as it is easily available at sporting events.[95]

Tooth Rescue Box (Dentosafe)

It has a growth medium with salts, amino acids, glucose, and vitamins in it, just like the one used for islet cell transplantation. The unopened box is good for three years at room temperature. It has been demonstrated to sustain PDL cell viability *in vitro* for up to 48 hours at room temperature.[100] The unopened box is good for three years at room temperature. Pohl et al.,[100] recommended that Dentosafe be a common item in first aid kits after showing in human studies that all teeth placed in the Dentosafe solution shortly after avulsion healed with physiologic function. Since research conducted to assess its efficacy is very limited, further research is needed.

Contact lens solution

Contact lens solutions are fatty acid monoester composites with an antimicrobial cationic component. Preservative-containing buffered, isotonic saline solutions are found in contact lens solutions, which may help maintain PDL cell viability. It has antimicrobial activity. It preserves significantly more viable cells than tap water and Gatorade but is not as effective as HBSS and milk.[101] The advantage of contact lens solutions as storage mediums is it readily available at homes, schools, and centers of physical activities. Since research conducted to assess its efficacy is very limited, further research is needed.

L-DOPA

L-DOPA (levodopa; Sigma Chemicals, Perth, WA, Australia) is a drug with possible mitogenic effects. In the human body, L-dopa changes to dopamine, which stimulates the anterior part of hypophysis to secrete growth hormone which is a promoter of the healing process.[102] Partovi et al.,[103] studied levodopa's impact on human PDL fibroblasts. They found that the drug may have a local impact on cell proliferation, including PDL cells, and may be utilized as a preservation agent for avulsed teeth. Due to the presence of all nutrients, pH, and osmolarity for cellular growth L-Dopa contributes to the mitogenic activity of these viable PDL cells.[104]

ViaSpan

ViaSpan is a medium used for the transportation of organs. It is clear to a light yellow sterile, non-pyrogenic solution with an osmolality of 320 mOsmol/kg and a pH of 7.4 at room temperature. After eighteen hours of storage, it yielded results better than milk and comparable to HBSS, making it the finest storage medium ever seen.[105] Its high cost and unavailability make it difficult to find and use this storage medium.[101]

Ricetral

Ricetral is an oral rehydration solution that contains essential cells and nutrients like glucose and vital salts in concentrations considered adequate for cell metabolism and can be used as storage media for avulsed teeth. Ricetral was shown to be superior to milk and comparable to the HBSS control in a study conducted by Rajendran et al.[106] Since research conducted to assess its efficacy is very limited, further research is needed.

Minimum Essential Medium (MEM)

MEM cell culture medium contains L-glutamine, penicillin, streptomycin, Nystatin, bovine serum, and nutrients for cell growth and proliferation.[107] Souza et al.,[107] have reported its efficacy in preserving the viability of PDL cells and have indicated it as a storage medium before tooth replantation. Since research conducted to assess its efficacy is very limited, further research is needed.

Cling Film

It is a recent alternative transport medium with a storage period of up to 6 hours. According to Zeissler et al.,[108] cling film storage medium shows a probability of cell growth at the withdrawal time of 2 hours and 86% cell growth, so it can be used as a storage medium for avulsed teeth. It retains the thin fluid film on the root surface can create the physiologic environment necessary for cell survival.[109].

Euro-Collins

It is used for preserving organs to be transplanted. It has a physiologic pH of 7.4 and an osmolality of 420 mOsmol/kg to maintain PDL cell viability. It contains potassium, sodium, and chlorine.[110] Electrolytes and phosphate present in Euro-collins have a buffering capacity that prevents PDL cell acidosis. Whereas a high concentration of

potassium decreases the intracellular cation loss and the presence of essential nutrients for the growth and proliferation of PDL cells.[105] When Sottovia et al.,[111] evaluated the avulsed dog teeth kept in the Euro-Collins solution histologically and historically, they found outcomes that were identical to those seen following immediate replantation, including good supporting tissue repair, vessel and PDL collagen fiber repair, and cementum formation. But their lack of availability and high cost make their routine use unviable.

Cryoprotective Agents

Cryoprotective agents are generally used to protect biological tissue from freezing damage. Cryoprotective compounds, such as 10% glycerol and 5% and 10% dimethyl sulfide (DSMO), were examined by Schwartz et al.,[112] for their impact on PDL. Their findings indicate that using cryoprotectants in conjunction with carefully regulated freezing temperatures down to -196°C can help maintain the pulp of restored teeth to varying degrees.

Catalase Supplementation

Catalase is an antioxidant enzyme that converts H_2O_2 to water and oxygen. Surface resorption was shown to be significantly reduced upon catalase supplementation, according to Buttke et al.,[113] It is hypothesized that roots preserved with antioxidants have reduced surface resorption levels. PDL cells may benefit from including an antioxidant such as catalase because some storage media contain hydrogen peroxide, which may harm PDL cells.

Custodial

Custodiol is a potassium-free histidine-tryptophan ketoglutarate solution, it has excellent flow characteristics and is utilized as an organ transplant preservation solution. Its composition, with an osmolality of 310 mOsmol/kg, is comparable to that of extracellular fluid.[85] According to Alaçam et al.,[90] it is comparable to HBSS for cell preservation. Since it is not accessible to the general public, its usefulness as a storage medium has been limited.

Conditioned Medium

The culture-grown supernatant of human gingival fibroblasts is the source of conditioned media. These growth factors may have a stimulatory effect on the remaining cells on the root surface because they may contain stimulatory factors released by the gingival fibroblast cells. An animal study[114] observed that roots immersed in a conditioned medium had reduced healing rates compared to roots soaked in HBSS and ViaSpan. On the other hand, placenta-derived mesenchymal stem cells showed better inhibition of apoptosis of PDL cells and promoted the proliferation of PDL cells.[115]

Probiotic Solution

Probiotics are living microorganisms that are administered or taken to improve health. probiotic milk to maintain PDL cell viability comparable to that of HBSS.[116] considered almost comparable to that of HBSS. Cagler et al.,[117] reported that because *Bifidibacterium animalis DN 173010* has a high percentage of viable PDL cells, it appears to be a promising option for the temporary storage of avulsed teeth. To assess its efficacy in clinical practice, further research is needed.

Casein Phosphopeptides

Casein phosphopeptide is a non-fluoridating remineralizing agent. It contains 80% of milk proteins and growth factors. The osmolarity and pH are physiologic; they also have a low bacterial content due to pasteurization and, hence, can be efficient as a storage medium.[118] Since research conducted to assess its efficacy is very limited, further research is needed.

Oral rehydration solution (ORS)

ORS is a simple, inexpensive glucose and electrolyte solution that has been widely used in the treatment of dehydration. It is a glucose-electrolyte solution whose compositions maintain the optimal osmolality as well as pH and can even provide nutrients. Mousavi et al.,[119] observed that by using ORS, the viability of the PDL cells was maintained for at least 12 hours and was similar to HBSS. Whereas, the 100% concentration of ORS was considered the worst concentration, which might be because of the hyperosmotic situation.

Cornisol

Cornisol is a corneal storage solution for human corneas and can be preserved for up to 14 days. Supplements include trace elements, vitamins, ATP precursors, chondroitin sulphate, recombinant human insulin, dextran, stabilized L-glutamine, gentamycin, and streptomycin. According to a study conducted by Singh et al.,[120] Cornisol showed promising results in preserving the periodontal ligament cell viability for an extended period of up to 96 hours and was considered superior to HBSS. Since research conducted to assess its efficacy is very less, further research is needed.

Growth factors

It has been demonstrated that polypeptide growth factors encourage PDL regeneration. Short-term administration of a combination of insulin-like growth factor (IGF) and platelet-derived growth factor (PDGF) has been shown by Lynch et al.,[121] to promote the healing of the periodontal attachment apparatus. It has been noted that fibroblasts exposed to growth factors enhanced the cells' ability to proliferate.

Placentrex

Each ml of Placentrex is resultant from 0.1 gm. of fresh, sterilized, infection-free human placenta. It has wound-healing, anti-inflammatory, anti-oxidant, and analgesic properties. Thoyalil et al.,[122] mentioned that Placentrex is a better alternative storage medium for avulsed teeth. Since research conducted to assess its efficacy is very limited, further research is needed.

In this review article, the evidence-based articles have been given more focus rather than opinion-based articles. The cost of each material is not mentioned accurately. The cost of individual storage media, which can be used for carrying avulsed tooth, can vary depending on region, availability type of media, etc. However, low cost is one of the main interests of dental trauma research. Certain natural media like egg whites, saliva, normal saline, milk, coconut water, etc., can be economical. However, most of the research points towards the HBSS solution being the best of all the available media. However, in developing countries, this type of media and its storage in schools or any community area can be a challenging factor.

In future, animal studies or *in vivo* studies of efficacy of newer materials such as certain cell growth media or organ transplanting solutions, etc. should be carried out to evaluate better efficacy in dental clinical practice.

CONCLUSIONS

The selection of an appropriate storage medium for avulsed teeth is critical in preserving their viability and enhancing the chances of successful re-implantation. By understanding the characteristics and benefits of different types of storage media, dental professionals can make informed decisions to optimize treatment outcomes and improve patient care. Based on the detailed analysis of the literature it's important to recognize that no storage media is perfect while physiologic solutions like Hank's Balanced Salt Solution (HBSS) offer advantages in mimicking the body's natural environment and supporting cell

viability, they still have limitations as they may not always be readily available in emergencies, and their effectiveness can diminish over time. However, more research is needed to find the storage media that matches all ideal properties along with readily available storage media at accident sites.

REFERENCES

1. Yadav S, Sisodia N, Jha V, Yadav M. Dental exarticulation. Niger J Clin Pract 2015;18:426-428
2. Hamilton F, Hill F, Mackie I. Investigation of lay knowledge of the management of avulsed permanent incisors. Dent Traumatol 1997;13:19-23
3. Moazzami F, Asheghi B, Sahebi S. Effect of four different media on periodontal ligament cells viability of dry-stored dog teeth. J Dent 2017;18:24
4. Osmanovic A, Halilovic S, Kurtovic-Kozaric A, Hadziabdic N. Evaluation of periodontal ligament cell viability in different storage media based on human PDL cell culture experiments—A systematic review. Dent Traumatol 2018;34:384-393
5. Lee W, Stover S, Rasoulianboroujeni M, Sherman K, Fahimipour F, Dashtimoghadam E et al. The efficacy of commercial tooth storage media for maintaining the viability of human periodontal ligament fibroblasts. Int Endod J 2018;51:58-68
6. Ashkenazi M, Sarnat H, Keila S. In vitro viability, mitogenicity and clonogenic capacity of periodontal ligament cells after storage in six different media. Dent Traumatol 1999;15:149-156
7. Khinda VI, Kaur G, Brar GS, Kallar S, Khurana H. Clinical and practical implications of storage media used for tooth avulsion. Int J Clin Pediatr Dent 2017;10:158
8. Adnan S, Khan FR. Storage media for avulsed teeth: a review. J Pak Dent Assoc 2014;23:54-60
9. Kaur A. Storage Media for Avulsed Tooth: A Brief Review of Literature. Journal of MAR Dental Sciences 2023;7:1-9
10. Khan M, Sharma M. Comparison of efficacy of different storage media for an avulsed tooth. Int J Appl Dent Sci 2020;6:528-531
11. Poi WR, Sonoda CK, Martins CM, et al. Storage media for avulsed teeth: a literature review. Braz Dent J 2013;24:437-445
12. Udoye CI, Jafarzadeh H, Abbott PV. Transport media for avulsed teeth: a review. Aust Endod J 2012;38:129-136
13. de Borba MG, de Alencar AHG, de Figueiredo JAP, Estrela C. Storage media for avulsed teeth: review of literature. Rev Odonto Ciência 2014;29:63-67
14. Mabudi A, Hoshyari N. Different Storage Medium for Avulsed Teeth: A Literature Review. J Mazandaran Univ Med Sci 2019;29:117-129
15. Venugopal M. Recent advances in transport medium for avulsed tooth: A review. Amrita J Med 2022;18:37-44
16. Surana P, Doifode D, Gopal R, Aafreen S. Recent Advances in Storage Media for Avulsed Tooth-A review. Int J Clin Prev Dent 2018;5:73-78
17. Navin H, Veena A, Rakesh C, Prasanna K. Advances in storage media for avulsed tooth: A review. Int J Prev Clin Dent 2015;2:41-47
18. Andersson L, Andreasen JO, Day P, Heithersay G, Trope M, Diangeliset AJ et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 2. Avulsion of permanent teeth. Dent Traumatol 2012;28:88-96
19. Blomlöf L, Otteskog P, Hammarström L. Effect of storage in media with different ion strengths and osmolalities on human periodontal ligament cells. Scand J Dent Res 1981;89:180-187
20. Gomes MCB, Westphalen VPD, Westphalen FH, Silva Neto U, Fariniuk LF, Carneiro E. Study of storage media for avulsed teeth. Braz J Dent Traumatol 2009;1:69-76
21. Goswami M, Chaitra T, Chaudhary S, Manuja N, Sinha A. Strategies for periodontal ligament cell viability: An overview. J Conserv Dent 2011;14:215-222
22. Pearson RM, Liewehr FR, West LA, Patton WR, McPherson III JC, Runner RR. Human periodontal ligament cell viability in milk and milk substitutes. J Endod 2003;29:184-185

23. Malhotra N. Current developments in interim transport (storage) media in dentistry: an update. Br Dent J 2011;211:29-33

24. Lekic P, Kenny D, Barrett E. The influence of storage conditions on the clonogenic capacity of periodontal ligament cells: implications for tooth replantation. Int Endod J 1998;31:137-140

25. Khademi A, Saei S, Mohajeri M, Mirkheshti N, Ghassami F, Torabi nia N et al. A new storage medium for an avulsed tooth. J Contemp Dent Pract 2008;9:25-32

26. Andreasen J, Borum M, Andreasen F. Replantation of 400 avulsed permanent incisors. 3. Factors related to root growth. Dent Traumatol 1995;11:69-75

27. Courts FJ, Mueller WA, Tabeling HJ. Milk as an interim storage medium for avulsed teeth. Pediatr Dent 1983;5:183-186

28. Hammarström L, Pierce A, Blomlöf L, Feiglin B, Lindskog S. Tooth avulsion and replantation—a review. Dent Traumatol 1986;2:1-8

29. Huang S-C, Remeikis NA, Daniel JC. Effects of long-term exposure of human periodontal ligament cells to milk and other solutions. J Endod 1996;22:30-33

30. Kokkali V, Bendgude V, Sharangpani G. Comparative evaluation of post-traumatic periodontal ligament cell viability using three storage media. Eur Arch Paediatr Dent 2017;18:209-214

31. Abdallah A, Gamal A, Elyazeed G, Hamid M. Egg White-Milk Mixture as a Novel Biological Storage Media for Avulsed teeth Periodontal Ligament Cells: An In-Vitro Study. J Dent Oral Care Med 2017;3:101-110

32. Burdock G. Review of the biological properties and toxicity of bee propolis (propolis). Food Chem Toxicol 1998;36:347-363

33. Kujumgiev A, Tsvetkova I, Serkedjieva Y, Bankova V, Christov R, Popov S. Antibacterial, antifungal and antiviral activity of propolis of different geographic origin. J Ethnopharmacol 1999;64:235-240

34. Al-Shaher A, Wallace J, Agarwal S, Bretz W, Baugh D. Effect of propolis on human fibroblasts from the pulp and periodontal ligament. J Endod 2004;30:359-361

35. Martin MP, Pileggi R. A quantitative analysis of Propolis: a promising new storage media following avulsion. Dent Traumatol 2004;20:85-89

36. Pileggi R, Antony K, Johnson K, Zuo J, Holliday LS. Propolis inhibits osteoclast maturation. Dent Traumatol 2009;25:584-588

37. Casaroto AR, Hidalgo MM, Sell AM, Franco Sl, Cuman RKN, Moreschi E et al. Study of the effectiveness of propolis extract as a storage medium for avulsed teeth. Dent Traumatol 2010;26:323-331

38. Abdelbaseer N, Khattab N, Mahmoud M. Evaluation of the efficacy of propolis as storage media for avulsed teeth. Egypt Dent J 2022;68:2115-2121

39. Özan F, Tepe B, Polat ZA, Er K. Evaluation of in vitro effect of Morus rubra (red mulberry) on survival of periodontal ligament cells. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:66-69

40. Mori GG, Nunes DC, Castilho LR, Moraes IG, Poi WR. Propolis as storage media for avulsed teeth: microscopic and morphometric analysis in rats. Dent Traumatol 2010;26:80-85

41. Nwangwa EK, Aloamaka CP. Regenerative effects of coconut water and coconut milk on the pancreatic β–cells and cyto architecture in alloxan induced diabetic wistar albino rats. Am J Trop Med Public Health 2011;1:137-146

42. Mantena SK, Jagadish, Badduri SR, Siripurapu KB, Unnikrishnan MK. In vitro evaluation of antioxidant properties of Cocos nucifera Linn. water. Food Nahrung 2003;47:126-131

43. Ali SA-H, Al-Jundi S, Mhaidat N, Awawdeh L, Naffa R. Effect of coconut water concentration on survival of bench-dried periodontal ligament cells. Int J Clin Pediatr Dent 2011;4:9-13

44. Gopikrishna V, Thomas T, Kandaswamy D. A quantitative analysis of coconut water: new storage media for avulsed teeth. Oral Surg Oral ed Oral Pathol Oral Radiol Endod 2008;105:e61-e6545. Thomas T, Gopikrishna V, Kandaswamy D. Comparative evaluation of maintenance of cell viability of an experimental transport media "coconut water" with Hank's balanced salt solution and milk, for transportation of an avulsed tooth: In vitro cell culture study. J Conserv Dent 2008;11:22

46. Hwang JY, Choi SC, Park J-H, Kang SW. The use of green tea extract as a storage medium for the avulsed tooth. J Endod 2011;37:962-967

47. Dreosti IE. Bioactive ingredients: antioxidants and polyphenols in tea. Nutr Rev 1996;54:51-58

48. Elbling L, Weiss R-M, Teufelhofer O, et al. Green tea extract and (−)-epigallocatechin-3-gallate, the major tea catechin, exert oxidant but lack antioxidant activities. FASEB J 2005;19:1-26

49. Jung IH, Yun JH, Cho AR, Kim CS, Chung WG, Choi SH. Effect of (-)-epigallocatechin-3-gallate on maintaining the periodontal ligament cell viability of avulsed teeth: a preliminary study. J Periodontal Implant Sci 2011;41:10-16

50. Jain D, Dasar PL, Nagarajappa S. Natural products as storage media for avulsed tooth. Saudi Endod J 2015;5:107-113

51. Anačkov G, Božin B, Zorić L, et al. Chemical composition of essential oil and leaf anatomy of Salvia bertolonii Vis. and Salvia pratensis L.(Sect. Plethiosphace, Lamiaceae). Molecules 2008;14:1-9

52. Masaki H, Sakaki S, Atsumi T, Sakurai H. Active-oxygen scavenging activity of plant extracts. Biol Pharm Bull 1995;18:162-166

53. Sivropoulou A, Nikolaou C, Papanikolaou E, Kokkini S, Lanaras T, Arsenakis M. Antimicrobial, cytotoxic, and antiviral activities of Salvia fructicosa essential oil. J Agric Food Chem 1997;45:3197-3201

54. Ozan F, Polat ZA, Tepe B, Er K. Influence of storage media containing Salvia officinalis on survival of periodontal ligament cells. J Contemp Dent Pract 2008;9:17-24

55. Kim D, Kang K-H. Anti-inflammatory and anti-bacterial potential of mulberry leaf extract on oral microorganisms. Int J Environ Res Public Health 2022;19:4984

56. Tîrziu I, Lautaru A, Rabontu AG, Popescu GS, Ienciu A, Manea D. Biochemical contents of mulberry fruits 2020

57. Dimitrijevic D, Kostic D, Paunovic D, et al. Antimicrobial activity and the quantitative analyses of phenolic compounds and heavy metals of red mulberry extracts (Morus rubra L.) from Serbia. Stud Univ Babes-Bolyai Chem 2022;67:195-208

58. Ozan F, Tepe B, Polat ZA, Er K. Evaluation of in vitro effect of Morus rubra (red mulberry) on survival of periodontal ligament cells. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:e66-e69

59. Kawase T, Okuda K, Momose M, Kato Y, Yoshie H, Burns DM. Enamel matrix derivative (EMDOGAIN®) rapidly stimulates phosphorylation of the MAP kinase family and nuclear accumulation of smad2 in both oral epithelial and fibroblastic human cells. J Periodontal Res 2001;36:367-376

60. Gestrelius S, Andersson C, Lidström D, Hammarström L, Somerman M. In vitro studies on periodontal ligament cells and enamel matrix derivative. J Clin Periodontol 1997;24:685-692

61. Van der Pauw MT, Van den Bos T, Everts V, Beertsen W. Enamel matrix-derived protein stimulates attachment of periodontal ligament fibroblasts and enhances alkaline phosphatase activity and transforming growth factor β1 release of periodontal ligament and gingival fibroblasts. J Periodontol 2000;71:31-43

62. Fridström M, Schollin J, Crossner CG. Evaluating Emdogain® and healing of replanted teeth using an intra-individual experimental–control study design. Dent Traumatol 2008;24:299-304

63. Wang YC, Yu RC, Chou CC. Growth and survival of bifidobacteria and lactic acid bacteria during the fermentation and storage of cultured soymilk drinks. Food Microbiol 2002;19:501-508

64. Scalabrini P, Rossi M, Spettoli P, Matteuzzi D. Characterization of Bifidobacterium strains for use in soymilk fermentation. Int J Food Microbiol 1998;39:213-219

65. Côvre LM, Caliente EA, Sonoda CK, Brandini DA, Poi WR. The effect of soy and whole milk as a means to store avulsed teeth: A histometric study. Dent Traumatol 2021;37:81-89

66. Silva EJ, Rollemberg CB, Coutinho-Filho TS, Krebs RL, Zaia AA. Use of soymilk as a storage medium for avulsed teeth. Acta Odontol Scand 2013;71:1101-1104

67. Trope M, Friedman S. Periodontal healing of replanted dog teeth stored in Viaspan, milk and Hank's balanced salt solution. Dent Traumatol 1992;8:183-188

68. Babaji P, Melkundi M, Devanna R, SB S, Chaurasia VR, VP G. In vitro comparative evaluation of different storage media (hank's balanced salt solution, propolis, Aloe vera, and pomegranate juice) for preservation of avulsed tooth. Eur J Dent 2017;11:71-75

69. Vidal A, Fallarero A, Peña BR, et al. Studies on the toxicity of Punica granatum L.(Punicaceae) whole fruit extracts. J Ethnopharmacol 2003;89:295-300

70. Seeram NP, Adams LS, Henning SM, et al. In vitro antiproliferative, apoptotic and antioxidant activities of punicalagin, ellagic acid and a total pomegranate tannin extract are enhanced in combination with other polyphenols as found in pomegranate juice. J Nutr Biochem 2005;16:360-367

71. Chidambara Murthy KN, Jayaprakasha GK, Singh RP. Studies on antioxidant activity of pomegranate (Punica granatum) peel extract using in vivo models. J Agric Food Chem 2002;50:4791-4795

72. Aggarwal BB, Shishodia S. Suppression of the nuclear factor-κB activation pathway by spice-derived phytochemicals: reasoning for seasoning. Ann NY Acad Sci 2004;1030:434-441

73. Tavassoli-Hojjati S, Aliasghar E, Babaki FA, et al. Pomegranate juice (Punica granatum): a new storage medium for avulsed teeth. J Dent (Tehran) 2014;11:225-232

74. Fani M, Kohanteb J. Inhibitory activity of Aloe vera gel on some clinically isolated cariogenic and periodontopathic bacteria. J Oral Sci 2012;54:15-21

75. Fulzele P, Baliga S, Thosar N, Pradhan D. Evaluation of Aloevera gel as a storage medium in maintaining the viability of periodontal ligament cells-An in vitro study. J Clin Pediatr Dent 2016;40:49-52

76. Pattamapun K, Ruchikeeratikul P, Handagoon S, Chaiyasuk K, Bovonratanavait A. Effect of aloe vera gel on periodontal tissue after avulsion Available from:
https://iadr.confex.com/iadr/2006Brisb/techprogram/abstract_81583.htm

77. Sharma M. In vitro periodontal ligament cell viability in different storage media. Braz Dent J 2016;27:408-411

78. Diarra MS, Hassan YI, Block GS, Drover JC, Delaquis P, Oomah BD. Antibacterial activities of a polyphenolic-rich extract prepared from American cranberry (Vaccinium macrocarpon) fruit pomace against Listeria spp. LWT 2020;123:109056

79. Anegundi RT, Paritosh SN, Tavargeri A, Patil S, Trasad V, Battepati P. Novel herbal storage media for exarticulated teeth. Int J Contemp Med Res 2016;3:729-732

80. Purnima A, Koti B, Thippeswamy A, et al. Antiinflammatory, analgesic and antipyretic activities of Mimusops elengi Linn. Indian J Pharm Sci 2010;72:480-490

81. Kumar KN, Kumar CS, Rao VVN. The use of herbal extracts of Ocimum sanctum and Mimusops elengi as a novel storage media for the avulsed tooth. J Adv Med Dent Sci Res 2018;6:1-9

82. Sójka M, Kołodziejczyk K, Milala J, et al. Composition and properties of the polyphenolic extracts obtained from industrial plum pomaces. J Funct Foods 2015;12:168-178

83. Michalska A, Wojdyło A, Łysiak GP, Figiel A. Chemical composition and antioxidant properties of powders obtained from different plum juice formulations. Int J Mol Sci 2017;18:176

84. Hooshmand S, Kumar A, Zhang JY, Johnson SA, Chai SC, Arjmandi BH. Evidence for anti-inflammatory and antioxidative properties of dried plum polyphenols in macrophage RAW 264.7 cells. Food Funct 2015;6:1719-1725

85. Vyas T, Sood P, Kaur M. Antioxidants in oral diseases and future prospects and their application in dentistry. J Adv Med Dent Sci Res 2018;6:53-62

86. Bijlani S, Shanbhog R, Godhi BS, Talwade P, Tippeswamy H. An in vitro evaluation of ice apple water, Aloe vera, and propolis as a storage medium to preserve viability of human periodontal ligament fibroblasts. J Indian Soc Pedod Prev Dent 2022;40:195-200

87. Bijlani S, Shanbhog RS. An in vitro evaluation of ice apple as a novel storage medium to preserve the viability of human periodontal ligament fibroblasts. Int J Clin Pediatr Dent 2022;15:699-705

88. Dhimole P, Bhayya DP, Gupta S, Kumar P, Tiwari S, Pandey S. Evaluation of the efficacy of

neem (Azadirachta indica) and turmeric (Curcuma longa) as storage media in maintaining periodontal ligament cell viability: An in vitro study. J Indian Soc Pedod Prev Dent 2019;37:140-145

89. Nabavizadeh M, Abbaszadegan A, Khodabakhsi A, Ahzan S, Mehrabani D. Efficiency of castor oil as a storage medium for avulsed teeth in maintaining the viability of periodontal ligament cells. J Dent 2018;19:28-35

90. Alacam T, Görgül G, Omürlü H, Can M. Lactate dehydrogenase activity in periodontal ligament cells stored in different transport media. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;82:321-323

91. Ashkenazi M, Marouni M, Sarnat H. In vitro viability, mitogenicity and clonogenic capacities of periodontal ligament fibroblasts after storage in four media supplemented with growth factors. Dent Traumatol 2001;17:27-35

92. Pileggi R, Dumsha TC, Nor JE. Assessment of post-traumatic PDL cells viability by a novel collagenase assay. Dent Traumatol 2002;18:186-189

93. Krasner P, Person P. Preserving avulsed teeth for replantation. J Am Dent Assoc 1992;123:80-88

94. Ashkenazi M, Marouni M, Sarnat H. In vitro viability, mitogenicity and clonogenic capacity of periodontal ligament cells after storage in four media at room temperature. Dent Traumatol 2000;16:63-70

95. Khan M, Sharma M. Comparison of efficacy of different storage media for an avulsed tooth. Int J Appl Dent Sci 2020;6:528-531

96. Chandha MH. Extra alveolar storage media for tooth autotransplants and replants. J Med Nus 2006;27:64-67

97. Sigalas E, Regan JD, Kramer PR, Witherspoon DE, Opperman LA. Survival of human periodontal ligament cells in media proposed for transport of avulsed teeth. Dent Traumatol 2004;20:21-28

98. Franklin S. Weine endodontic therapy. 1st ed. Auflage: Mosby, St Louis 2004

99. Chamorro MM, Regan JD, Opperman LA, Kramer PR. Effect of storage media on human periodontal ligament cell apoptosis. Dent Traumatol 2008;24:11-16

100. Pohl Y, Tekin U, Boll M, Filippi A, Kirschner H. Investigations on a cell culture medium for storage and transportation of avulsed teeth. Aust Endod J 1999;25:70-75

101. Bazmi BA, Singh AK, Kar S, Mubtasum H. Storage media for avulsed tooth-A review. Indian J Multidiscip Dent 2013;3:1-10

102. Pritchett JW. L-dopa in the treatment of nonunited fractures. Clin Orthop Relat Res 1990:293-300

103. Partovi M, Sadeghein A, Azizi E, Ostad SN. Mitogenic effect of L-dopa on human periodontal ligament fibroblast cells. J Endod 2002;28:193-196

104. Ebenezar AV, T M, Priya J. Addition of L-dopa to HBSS in enhancing the maintenance of cell viability of Periodontal Ligament (PDL) cells: An In-Vitro Study. J Clin Diagn Res 2014;8:ZC79-80

105. Trope M, Friedman S. Periodontal healing of replanted dog teeth stored in Viaspan, milk and Hank's balanced salt solution. Endod Dent Traumatol 1992;8:183-188

106. Rajendran P, Varghese NO, Varughese JM, Murugaian E. Evaluation, using extracted human teeth, of Ricetral as a storage medium for avulsions–an in vitro study. Dent Traumatol 2011;27:217-220

107. Souza BDM, Lückemeyer DD, Felippe WT, Simões CMO, Felippe MCS. Effect of temperature and storage media on human periodontal ligament fibroblast viability. Dent Traumatol 2010;26:271-275

108. Zeissler-Lajtman A, Connert T, Kühl S, Filippi A. Cling film as storage medium for avulsed teeth. An in vitro pilot study. Swiss Dent J 2017;127:954-959

109. Nabi S, Kavikumar V, Tahir A. Storage media for avulsed tooth–A review. Eur J Biomed Pharm Sci 2018;5:130-133

110. Poi WR, Sonoda CK, Martins CM, et al. Storage media for avulsed teeth: a literature review. Braz Dent J 2013;24:437-445

111. Sottovia AD, Sottovia Filho D, Poi WR, Panzarini SR, Luize DS, Sonoda CK. Tooth replantation after use of Euro-Collins solution or bovine milk as storage medium: a histomorphometric analysis in dogs. J Oral Maxillofac Surg 2010;68:111-119

112. Schwartz O, Andreasen J. Cryopreservation of mature teeth before replantation in monkeys:(I) Effect of different cryoprotective agents and freezing devices. Int J Oral Surg 1983;12:425-436

113. Buttke TM, Trope M. Effect of catalase supplementation in storage media for avulsed teeth. Dent Traumatol 2003;19:103-108

114. Pettiette M, Hupp J, Mesaros S, Trope M. Periodontal healing of extracted dogs' teeth air-dried for extended periods and soaked in various media. Dent Traumatol 1997;13:113-118

115. Ji LL, Song G, Jiang LM, et al. Evaluation of conditioned medium from placenta-derived mesenchymal stem cells as a storage medium for avulsed teeth: An in vitro study. Dent Traumatol 2021;37:73-80

116. Saini D, Gadicherla P, Chandra P, Anandakrishna L. Coconut milk and probiotic milk as storage media to maintain periodontal ligament cell viability: an in vitro study. Dent Traumatol 2017;33:160-164

117. Caglar E, Peker S, Durhan MA, Kulan P, Kuscu OO, Pisiriciler RA et al. Quantitative Analysis of a Probiotic Storage Media for Avulsed Teeth. Acta Stomatol Croat 2015;49:21-26

118. Cehreli SB, Gurpinar AO, Onur AM, Dagli FT. In vitro evaluation of casein phosphopeptide-amorphous calcium phosphate as a potential tooth transport medium: viability and apoptosis in L929 fibroblasts. Dent Traumatol 2008;24:314-319

119. Mousavi B, Alavi SA, Mohajeri MR, Mirkheshti N, Ghassami F, Mirkheshti N. Standard oral rehydration solution as a new storage medium for avulsed teeth. Int Dent J 2010;60:379-382

120. Singh S, Kini S, Pai S, HR R, Purayil TP. Survival of human periodontal ligament fibroblast cells in Cornisol and HBSS for transportation of avulsed teeth: a comparative ex vivo study. Acta Odontol Scand 2021;79:112-117

121. Lynch SE, Williams RC, Polson AM, et al. A combination of platelet-derived and insulin-like growth factors enhances periodontal regeneration. J Clin Periodontol 1989;16:545-548

122. Thoyalil M, Belchada DK, Devi KB, Ravi RV, Uchummal MM, Parikkal R. The Comparative Analysis of the Effectiveness of Four Different Storage Media (Placentrex, Propolis 10%, Pomegranate Juice 5%, and Hank's Balanced Salt Solution) in Preserving the Viability of Periodontal Ligament Cells: An In Vitro Study. Cureus 2023;15:1-10

How to cite this article:

Rutuja Shinde, Dinesh Rao, Sunil Panwar, Remi RV. Storage medium for avulsed teeth: A narrative review. Contemp Pediatr Dent 2024:5(2):53-70.

Declarations

Acknowledgements: *Not applicable.*

Conflict of Interest Statement: *Authors disclose no potential conflicts of interest.*

Ethics Statement: *The study was approved by the Institutional Ethical Committee of Pacific Dental College and Hospital, Udaipur (Ref. No.STU/IEC/2022/159).*

Informed Consent: *Not applicable.*

Author contributions: *Conception and design: All Authors; Acquisition of data: RS, DR, SP; Interpretation of data: RS, DR; Drafting article: RS, DR, SP; Revision artice: RS; Final approval: All Authors.*

Funding: *Not applicable.*

Data Availability: *The data used to support the findings of this study can be made available upon request to the corresponding author.*

Peer-review: *Externally double-blinded peer-reviewed.*