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Burak BULDUR

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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.

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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

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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.

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Influence of root canal instrumentation file systems and obturating materials on the success of pulpectomized teeth: A secondary analysis from a randomized controlled trial

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Highlights

This study evaluates the impact of different root canal instrumentation systems and obturating materials on the success of pulpectomized primary molars.

Rotary file systems yielded superior obturation quality compared to manual files, though obturating material type did not significantly affect the outcome.

The type of instrumentation system used may enhance clinical success rates, but obturating material choice has less impact on pulpectomy success.

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Abstract

Aim: This study aimed determine the influence of the type of root canal instrumentation file systems and obturating materials on the success of pulpectomized teeth. **Methods:** Two hundred eighty-eight primary molars from children aged 4–7 years were selected and divided into three groups of 96 teeth each. In the first, second, and third groups, root canal instrumentation was performed using Kedo-SG pediatric rotary files (KS), HERO Shaper rotary files (HS), and manual Ni-Ti K-files (MF), respectively. Following instrumentation, these three groups were subdivided into three subgroups of 32 teeth each and obturated using zinc oxide eugenol, Endoflas®, and DiaPex Plus®. The quality of the root filling was assessed immediately and evaluated clinically and radiographically over two years. The Chi-Square Test was used to analyze the data, with the level of significance set at $P<0.05$. **Results:** The quality of obturation was superior in root canals instrumented with rotary file systems compared to manual files. No significant difference in obturation quality was noted among the obturating materials used. The clinical success rate after two years was 100%. Radiologically, success rates were 97% for Kedo-SG, 94% for HERO Shaper, and 89% for manual file systems. For obturating materials, the success rates were 90%, 96%, and 94% for zinc oxide eugenol, Endoflas®, and DiaPex Plus®, respectively. **Conclusions:** The success of pulpectomized teeth was not significantly influenced by the type of root canal instrumentation file systems or the choice of obturating materials.

Keywords: Pulpectomy; Root Canal Filling Materials; Root Canal Preparation; Zinc Oxide

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INTRODUCTION

Using rotary file systems has demonstrated better predictability and helps prevent iatrogenic and procedural errors. Further, using these file systems has demonstrated superior clinical efficiency, with improved quality of obturation, reduced instrumentation and obturation time, less apical debris, decreased post-operative pain, and less stress for both the child and the operator during the procedure.[1-7] Additionally, the obturating materials that are currently available are effective against resistant root canal microflora due to their antimicrobial properties, and they also provide an impervious hermetic seal.[8] The effectiveness of these materials has been observed with a wide range of success, varying from 53% to 100%.[8-11]

The enhanced physical characteristics of rotary files and the chemical and biological qualities of the obturating materials are anticipated to affect the outcome of root canal treatments favourably. However, recent systematic reviews have not found conclusive evidence favouring rotary instruments over manual files for clinical and radiographic success in pulpectomized teeth.[13,14] Further, the influence of the filling material used after canal shaping with rotary instruments on the success of pulpectomized teeth remains largely unexplored. In light of this, the earlier phase of this report assessed the combined effects of instrumentation types and obturating materials on success of pulpectomy. The results indicated that the outcome of pulpectomized teeth is not significantly influenced by the combined effect of advanced physical characteristics of rotary files and the chemical and biological qualities of the obturating materials.[15] Consequently, additional analysis was deemed necessary as previous studies that have independently evaluated and compared the success of pulpectomized teeth according to the type of instrumentation and obturating materials have shown varying results.[5-16]

Thus, this report aims to analyze further (secondary analysis) the primary data and determine the influence of either the type of instrumentation or the obturating materials on the success of pulpectomized molars. This involved reorganizing the data of the primary study to group all pulpectomized teeth based on the type of instrumentation or obturating materials used, irrespective of the other variables. The null hypothesis was that the kind of root canal instrumentation file systems and obturating materials do not influence pulpectomized primary molars' outcome.

METHODS

The research protocol was approved by the Institutional Ethics Committee and conducted in line with the World Medical Association's Declaration of Helsinki and the Consolidated Standards of Reporting Trials (CONSORT) guidelines for clinical trials in Pediatric Endodontics. Informed consent was obtained from parents or guardians, and permission from children over 6 years.[16] This report represents a secondary data analysis from a randomized controlled trial that investigated the combined effect of different instrumentation file systems and obturating materials on the outcome of pulpectomized primary molars.[15]

A detailed description of the methodology can be found in the primary study.[15] Figure 1 represents the CONSORT flow chart followed during clinical trial. To explain briefly, the co-operative children aged 4 to 7 years requiring pulpectomy were selected. Standardized intraoral periapical radiographs were taken for teeth potentially needing a pulpectomy. Normal, healthy children without systemic diseases were included based on criteria such as teeth with carious pulp exposure, vital or non-vital molars without sinus

tracts, absence of pathological root resorption, and presence of sufficient root length.[3,5-7] Exclusion criteria included teeth with abscesses, non-restorability, pulpal floor perforation, significant root resorption, or excessive bone support loss.[3,5-7] The pulpectomy procedure was done by anaesthetizing the teeth with 2% lignocaine (2% lignocaine, Lignox, Bangalore, India). The procedure involved removing dental caries and establishing access to the pulp chamber, followed by the extirpation of radicular pulp tissue using H-files. Root canal patency was checked, and the working length was determined to be 1–2 mm short of the radiographic apex.[3,5]

The 288 selected teeth were randomized into three groups [(Kedo-SG Blue files (KS), HERO Shapers files (HS), and Manual files (MF)] using a block randomization technique and SNOSE for unbiased allocation. Root canals were instrumented with Kedo-SG Blue pediatric rotary files (Reeganz Dental Care Pvt. Ltd., India), HERO Shaper rotary file system (Micromega, Geneva, Switzerland), and manual NiTi K-files (Dentsply, Switzerland) for the KS, HS, and MF groups, respectively. In the KS and HS groups, root canals were enlarged in the coronal third with an Endoflare® file (Endoflare® file-Micromega, Geneva, Switzerland), then the rotary files were used up to the working length as per the manufacturer's instructions.

The rotary file systems were operated with an endodontic motor (X-Smart, Dentsply Maillefer, OK, USA) at 300 rpm and 2.2-Ncm torque with a lateral brushing motion.[3,17] In the MF group, canals were instrumented with manual NiTi K files using the quarter-turn-and-pullback technique.[3,5] All root canals underwent intermittent irrigation with saline and a 17% EDTA gel (RC Help, Prime Dental Products, Pvt. Ltd.) as a lubricant.[3,16] After final irrigation, the canals were dried with paper points.

The primary molars were further divided into three subgroups for obturation. The first two subgroups were obturated using zinc oxide eugenol cement (Zinc Oxide BP, Eugenol BP, Associated Dental Products Ltd) and Endoflas® (Sanlor Laboratories S.A.S, Cali-Colombia), respectively. A #25 lentulospiral on a slow-speed handpiece was used for obturation. In the third subgroup DiaPex Plus® (DiaDent Group International, Korea), a pre-mixed iodoform paste, was used for obturation.[10] After obturation, the access cavity was sealed with type II glass ionomer cement. The treated teeth were restored with stainless steel crowns (3M ESPE, St.Paul, MN, USA).[5-7] The stainless steel crowns were placed within a week to ensure comfort for the young patients and to maintain consistency in the treatment process. A skilled operator performed all pulpectomies in a single session, strictly adhering to aseptic protocols and the manufacturer's guidelines to ensure consistent results.

Quality of Obturation Evaluation

Two pediatric dentists (PK and AS) blinded for the specific instruments and materials used, evaluated the radiographs and graded the obturation as underfilled, optimally filled and overfilled.[18,19] Discrepancies were resolved by defaulting to the lower classification of obturation quality.

Evaluation of Pulpectomized Teeth

Pulpectomized teeth underwent clinical and radiographic assessments every three months for two years. High kappa scores indicated strong examiner agreement, with disagreements resolved through discussion or marked as failures. A pulpectomy was considered clinically successful if there were no symptoms such as pain, tenderness to percussion, gingival swelling, sinus tract formation, or abnormal tooth mobility.[20,21] Similarly, a pulpectomy was considered

radiographically successful if there was no increase in the size of preoperative furcal or periapical radiolucency, development of new radiolucency on subsequent follow-ups, or development of internal or external root resorption, changes in lamina dura/width of periodontal ligament space, and deviation in the path of succedaneous tooth eruption.[20,21] Further, the radiographic examination also included the resorption of intraradicular material and extraradicularly extruded materials.[21]

The clinical and radiographic success was determined independently as not all radiographic failures are associated with clinical symptoms and vice versa.[5,20]

To maintain the study's integrity, all participants, guardians, outcome assessors, and data analysts were blinded to the types of instrumentation systems and obturating materials used. The operator, however, could not be blinded due to the recognizable nature of the intervention materials.

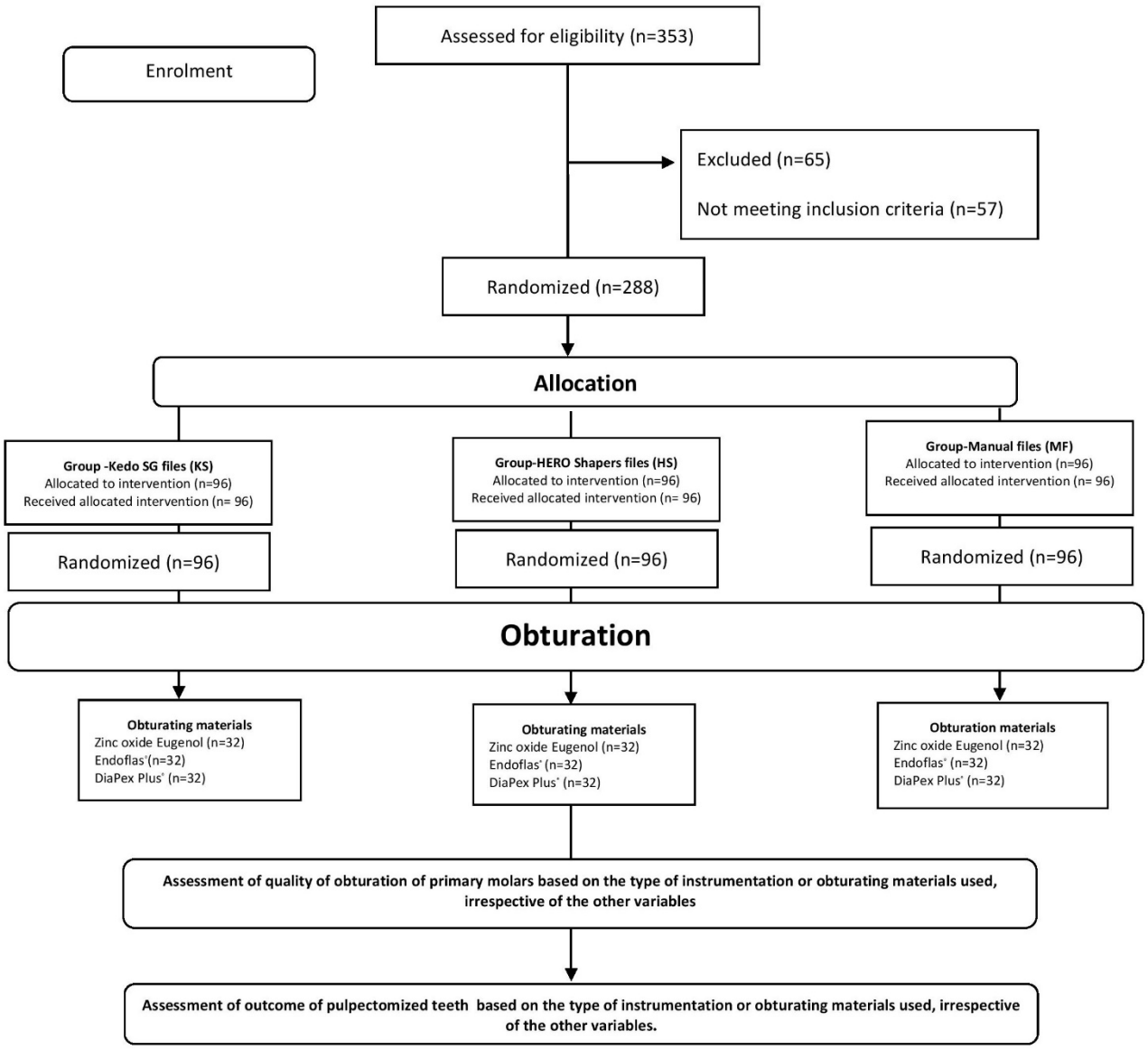

Figure 1. CONSORT flow chart followed during clinical trial

RESULTS

The research included 288 children, with a gender distribution of 102 males and 186 females, aged 4-7 years, averaging 5.31±1.09 years. An equal number of maxillary and mandibular first and second molars were treated, with no dropouts.

Quality of Obturation

About the type of instrumentation, in the KS group, 8.3% of teeth were underfilled, 77.1% were optimally filled, and 14.6% were overfilled. In the HS group, 5.2% of teeth were underfilled, 72.9% were optimally filled, and 21.9% were overfilled. In the MF group, 32.3% were underfilled, 54.2% were optimally filled, and 13.5% were overfilled. There was a statistically significant difference ($p \leq 0.001$) in the quality of obturation on comparison of the three groups (Figure 2).

The quality of obturation was significantly superior in the KS and HS groups compared to the MF group, but there was no significant difference between the KS and HS groups (Table 1).

Regarding the type of obturating materials, 16.7% of teeth filled with zinc-oxide eugenol were underfilled, 65.6% were optimally filled, and 17.7% were overfilled. For teeth filled with Endoflas®, 14.6% were underfilled, 72.9% were optimally filled, and 12.5% were overfilled. For teeth filled with DiaPex Plus®, 14.6% were underfilled, 65.6% were optimally filled, and 19.8% were overfilled. In the comparison of the three obturating materials, there was no statistically significant difference ($p \leq 0.68$) in the quality of obturation (Figure 2 and Table 1).

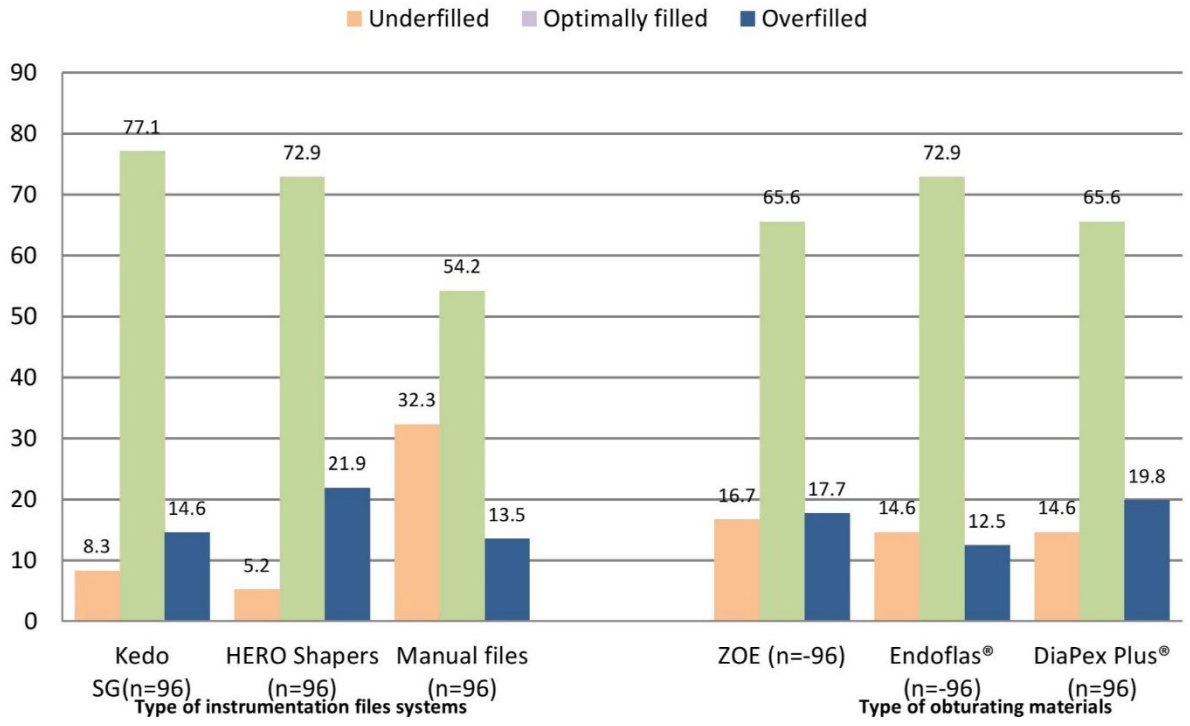

Figure 2. Comparison of obturation quality in primary molars by instrumentation file systems and obturating materials

Table 1. Multiple comparisons of obturation quality by instrumentation file systems and obturating materials

	Instrumentation file systems			Obturating materials		
Groups	**Kedo-SG vs HERO Shapers**	**Kedo SG vs Manual files**	**HERO Shapers vs Manual files**	**ZOE vs Endoflas**	**Endoflas vs DiaPex Plus**	**DiaPex Plus vs ZOE**
p-value	0.33	<0.001*	<0.001*	0.63	0.68	0.59

After the end of two years, the clinical success rate was 100% regardless of the type of instrumentation and obturating materials used. The radiological success rates varied depending on the kind of instrumentation, with rates of 97%, 94%, and 89% for groups KS, HS, and MF, respectively. When considering the type of obturating materials, the success rate was 90% for teeth filled with zinc oxide eugenol and 96% and 94% for those filled with Endoflas® and DiaPex Plus®, respectively.

Although not statistically significant, a slightly higher success rate was observed in the KS and HS groups compared to the MF group and in teeth filled with Endoflas® and DiaPex Plus® compared to those filled with zinc oxide eugenol. However, when comparing the clinical and radiographic success over 24 months, no statistically significant difference was found among the types of instrumentation or obturating materials (Table 2 and Figure 3).

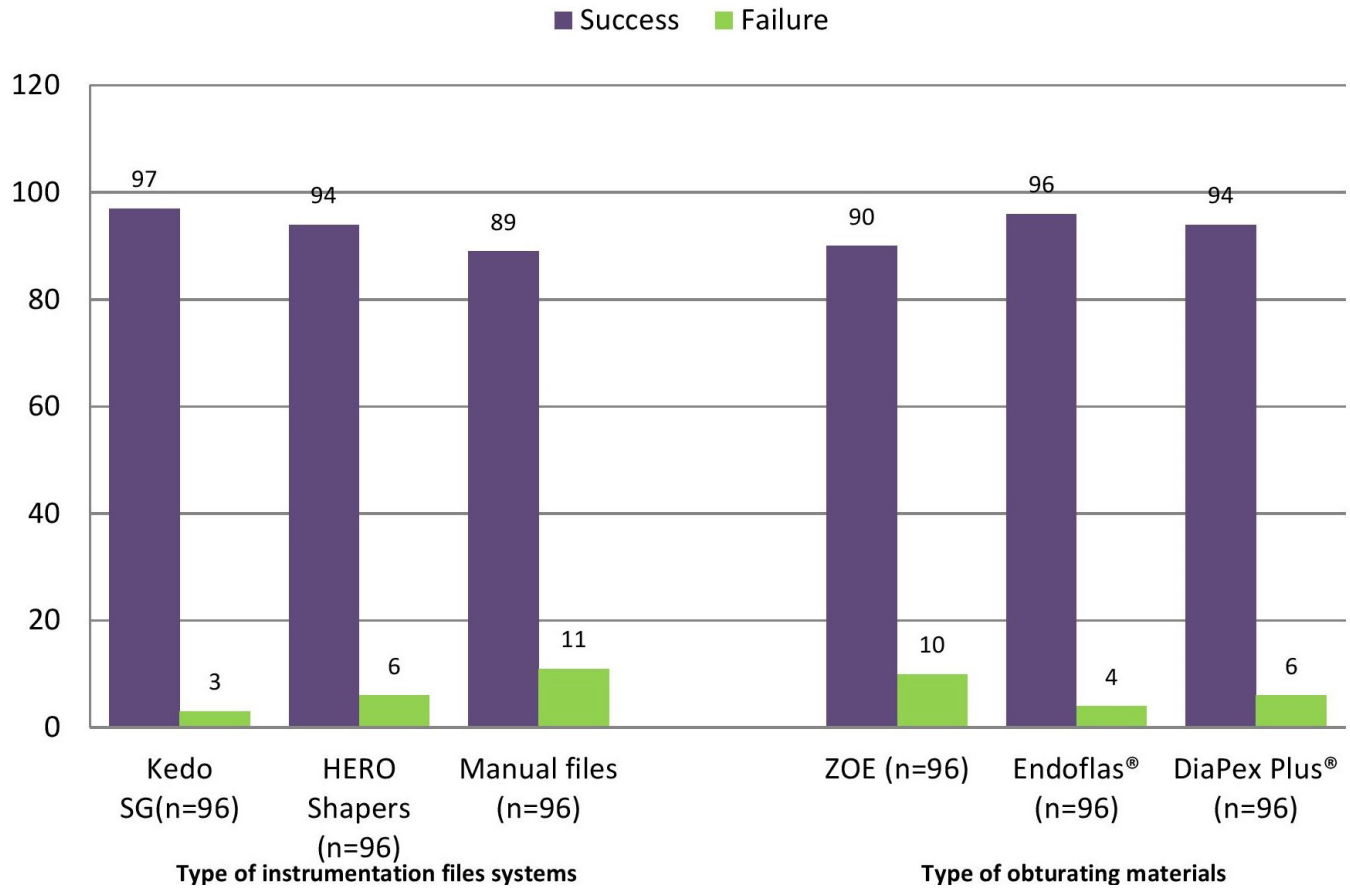

Figure 3. Outcomes of pulpectomized teeth by instrumentation file systems and obturating materials

Table 2. Success rates of pulpectomized teeth by instrumentation file systems and obturating materials

	Instrumentation file systems						Obturating materials					
	Clinical success			Radiographic success			Clinical success			Radiographic success		
	Kedo-SG	HERO Shapers	Manual files	Kedo-SG	HERO Shapers	Manual files	ZOE	Endoflas	DiaPex Plus	ZOE	Endoflas	DiaPex Plus
Evaluation period	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)	(n=96) n (%)
3-month	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)
6-month	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)
9- month	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)
12- month	96 (100)	96 (100)	96 (100)	96 (100)	96 (100)	**95 (99)**	96 (100)	96 (100)	96 (100)	**95 (99)**	96 (100)	96 (100)
15- month	96 (100)	96 (100)	96 (100)	**95 (99)**	96 (100)	**92 (96)**	96 (100)	96 (100)	96 (100)	**93 (97)**	**95 (99)**	**95 (99)**
18- month	96 (100)	96 (100)	96 (100)	**94 (98)**	**93 (97)**	**89 (92)**	96 (100)	96 (100)	96 (100)	**89 (92)**	**94 (97)**	**93 (97)**
24- month	96 (100)	96 (100)	96 (100)	**93 (97)**	**90 (94)**	**86 (89)**	96 (100)	96 (100)	96 (100)	**87 (90)**	**92 (96)**	**90 (94)**
P value		-			0.13			-			0.42	

Correlation Between the Quality of Obturation and the Outcome of Pulpectomy

Regarding the type of instrumentation, the correlation between the quality of obturation and the outcome of pulpectomy showed that the optimally filled (66.3%) primary molars had a higher success rate compared to underfill (14.2%) or overfilled teeth (12.8%) at the end of the evaluation period. This difference was statistically significant ($p \leq 0.001$) (Table 3). Similarly, with obturating materials, a statistically significant success rate was observed in optimally filled primary molars (66.3%) compared to underfilled (13.8%) and overfilled teeth (13.1%) (Table 4). A 100% success rate was observed in the KS group using Endoflas.

Type of Radiographic Failures

After 24 months, in the KS group, 3 teeth had furcal radiolucency. The HS group had 3 teeth with furcal radiolucency, 2 with periapical radiolucency, and 1 with increased periodontal ligament space. The MF group showed radiographic failure in 10 teeth: 3 with furcal radiolucency, 4 with periapical radiolucency, and 4 with increased periodontal ligament space. Zinc oxide eugenol was associated with 9 failures: 5 with furcal radiolucency, 3 with periapical radiolucency, and 1 with increased periodontal ligament space. Endoflas had 4 failures: 3 with periapical radiolucency and 1 with increased periodontal ligament space. DiaPex Plus® showed 6 failures: 2 with furcal radiolucency, 1 with periapical radiolucency, and 3 with increased periodontal ligament space (Table 5).

Table 3. Correlation between instrumentation file systems and pulpectomized teeth outcomes based on obturation quality

Instrumentation file systems	Outcome	Underfilled n (%)	Optimally filled n (%)	Overfilled n (%)	P value
Kedo-SG (n=96)	Success	7 (97)	74(100)	12(85.7)	0.003*
	Failure	1(3)	0	2(14.3)	
Hero Shapers (n=96)	Success	4(97)	69(98.6)	17(82.2)	0.03*
	Failure	1(3)	1(1.4)	4(18.3)	
Manual files (n=96)	Success	30(96.8)	48(92.3)	8(61.5)	0.001*
	Failure	1(3.2)	4(7.7)	5(38.5)	
Total (n=288)	Success	41 (14.2)	191(66.3)	37(12.8)	0.001*
	Failure	3(1)	5(1.7)	11(3.8)	

Table 4. Correlation between obturating materials and pulpectomized teeth outcomes based on obturation quality

Obturating materials	Outcome	Underfilled n (%)	Optimally filled n (%)	Overfilled n (%)	P value
ZOE (n=96)	Success	14(87.5)	61(96.8)	12(70.6)	0.001*
	Failure	2(12.5)	2(3.2)	5(29.4)	
Endoflas (n=96)	Success	13(92.8)	70(100)	9(75)	<0.001*
	Failure	1(7.1)	0	3(25)	
DiaPex Plus (n=96)	Success	13(92.9)	60(95.2)	17(89.5)	0.65
	Failure	1(7.1)	3(4.8)	2(10.5)	
Total (n=288)	Success	40(13.8)	191(66.3)	38(13.1)	0.001*
	Failure	4(1.38)	5(1.7)	10(3.4)	

Table 5. Radiographic evaluation of pulpectomized teeth by instrumentation file systems and obturating materials

Follow-up	Radiographic findings	Type of instrumentation			Type of obturating materials		
		Kedo-SG n=96 n (%)	HERO Shapers n=96 n (%)	Manual file n=96 n (%)	ZOE n=32 n (%)	EF n=32 n (%)	DP n=32 n (%)
12-Mon	FR	-	-	-	-	-	-
	PR	-	-	-	-	-	-
	PDL	-	-	1(3)	1(1)	-	-
15-Mon	FR	1(1)	-	1(1)	2(2)	-	-
	PR	-	-	1(1)	-	1(1)	-
	PDL	-	-	1(1)	-	-	1(1)
18- Mon	FR	1(1)	2(2)	1(1)	3(3)	-	-
	PR	-	1(1)	1(1)	2(2)	1(1)	1(1)
	PDL	-	-	1(1)	-	-	1(1)
24-Mon	FR	1(1)	1(1)	-	-	-	2(2)
	PR	-	1(1)	2(2)	1(1)	1(1)	-
	PDL	-	1(1)	1(1)	-	1(1)	1(1)
Total	**Failures**	**3(3)**	**6(6)**	**10(10)**	**9(9)**	**4(4)**	**6(6)**
	Success	**93(97)**	**90(94)**	**86(90)**	**87(91)**	**92(96)**	**90(94)**
	p-value	**0.37**			**1.00**		

FR: Furcal Radiolucency; PR: Periapical Radiolucency; PDL: increase in the width of periodontal ligament space; ZOE: Zinc Oxide Eugenol; EF:Endoflas®; DP: DiaPex Plus®

Radiographic evaluation of obturating materials' longevity

Both intraradicular resorption and the resorption of extruded materials were first noticed during the 9-month and persisted until the end of the 24 months. Intraradicular resorption of the obturating materials was seen in three teeth, each in the KS, HS, and MF groups. All of these teeth were filled with DiaPex Plus®. The other obturating materials, Endoflas® and zinc-oxide eugenol were not associated with intraradicular resorption. The resorption of extruded materials was observed in 9 teeth in the KS group, 13 in the HS group, and 6 in the MF group. Extruded materials were absorbed in 12 teeth filled with Endoflas® and 19 teeth filled with DiaPex Plus®, but not in any teeth filled with zinc oxide eugenol (Table 6).

DISCUSSION

The secondary analysis revealed that the primary molars instrumented with rotary file systems resulted in superior obturation quality compared to those treated with manual NiTi file systems. Further, after a 2-year follow-up, there was no significant difference in the success rate between primary molars instrumented with rotary or manual file systems. Furthermore, the choice of obturation materials did not significantly affect the overall success rate.

Table 6. Radiographic evaluation of obturating materials' longevity

Evaluation period (month)	Type of instrumentation Intraradicular resorption of obturating material			Resorption of extruded material (Overfilled teeth)			Type of obturating materials Intraradicular resorption of obturating material			Resorption of extruded material (Overfilled teeth)		
	KS (n=96)	HS (n=96)	MF (n=96)	KS (n=96)	HS (n=96)	MF (n=96)	ZOE (n=96)	EF (n=96)	DP (n=96)	ZOE (n=96)	EF (n=96)	DP (n=96)
3	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
9	Nil	01	01	2	3	2	Nil	Nil	2	Nil	2	5
12	01	Nil	Nil	4	4	2	Nil	Nil	1	Nil	5	5
15	01	01	Nil	2	5	4	Nil	Nil	2	Nil	3	8
18	01	Nil	01	1	1	1	Nil	Nil	2	Nil	2	1
24	Nil	01	01	-	-	-	Nil	Nil	2	Nil	Nil	Nil
TOTAL	03	03	03	09	13	06	Nil	Nil	09	Nil	12	19
	09			**31**			**09**			**31**		

KS: Kedo-SG; HS: HERO Shapers; MF: Manuel files; ZOE: Zinc Oxide Eugenol; EF: Endoflas®; DP: DiaPex Plus®

The observation of more optimally filled root canals using rotary files can be attributed to their design. The unique design of rotary file systems, featuring elastic memory and radial land, helps them stay centered in the canal, leading to more uniformly conical canal shapes than those formed by manual files. This conical configuration, achieved by rotary files, is conducive to improved obturation quality.[1-7] Additionally, pre-flaring the coronal third of the canal with instruments like the Endoflare® removes any obstructions at the canal entrance, ensuring unimpeded access to the canal's apical part.[2,4-7] The larger rotary file taper also shapes the canal into a more conical form, facilitating a smoother flow of the obturating material to the apex. These aspects are believed to enhance the density, uniformity, and overall quality of the obturation.[5-7,20] This finding is consistent with prior research indicating that rotary files are more effective at cleaning the irregular surfaces of primary root canals, thereby achieving better obturation quality than manual files.[1,3-7] Consistent with previous research, this study found no significant difference in obturation quality between molars treated with pediatric or adult rotary file systems, supporting that rotary file systems improve obturation quality in primary teeth, regardless of the file system type.[3,5-7] However, some studies have found no difference in obturation quality between rotary and manual files, suggesting that further investigation is needed.[20,22]

In alignment with the previous studies, the occurrence of underfilled root canals was more frequent with the use of manual NiTi files.[3,5-7] The limited taper of these manual files may result in narrow and uneven canal shapes, obstructing the proper distribution of the filling material.[23] It's crucial to recognize that underfilled canals are susceptible to infiltration by tissue fluids, which can stagnate and possibly cause infection, a situation referred to as the 'Hollow Tube Effect.[8]

Teeth treated with the adult rotary file system exhibited a higher incidence of overfilling. As the adult rotary file system is primarily designed for permanent teeth, its use in primary teeth would have led to over-instrumentation due to their increased length and taper, causing overfilling.[5] Additionally, incorrect maintenance of the working length of the file or lentulospiral could also lead to overfilling.[5,23] In contrast, using the pediatric rotary file system resulted in fewer overfilled root canals

than the adult rotary file system. This could be because it is an exclusive pediatric file system that causes minimal apical enlargement, thus preventing over-preparation and extrusion of the obturating material.[3] The least number of overfilled canals were observed using manual files. This could be due to under preparation of the root canals that have resulted in fewer overfilled canals.[23] Despite this, some studies have reported a higher incidence of overfilling with manual files, suggesting that preexisting conditions of the primary roots may play a role.[8,24]

In terms of obturation materials used, no marked difference in obturation quality was noted, aligning with previous studies.[8,10] Endoflas® had a marginally higher rate of optimally filled canals, yet comparable to Zinc Oxide Eugenol and DiaPex Plus®. The obturation technique and material consistency may influence these results.[10] Both Endoflas® and DiaPex Plus® had equivalent underfilled canals, with Zinc Oxide Eugenol showing a slightly higher rate. Underfilling typically results from incomplete chemo-mechanical preparation, imprecise working length determination, or insufficient canal irrigation. Underfilling may occur if the working length is based on average anatomical measurements rather than the actual apical foramen, leading to voids that could cause reinfection.[5,8,23,25]

Overfilling occurred with all the obturating materials used. This may be due to the rotary lentulospiral ability to carry low-viscosity materials like Zinc Oxide, Eugenol, and Endoflas® deeper into the canal.[23] Some studies did not find a higher rate of overfilling with Endoflas®, attributing it to specific techniques used.[10,24] The thinner consistency of DiaPex Plus® might explain its higher incidence overfilling. The application of this technique could also influence this, where the material is actively pushed into the canal.[10] Overfilling may sometimes be an inevitable consequence of the delicate and fragile dentinal walls near the developing permanent tooth, which may collapse during the procedure.[5,20]

The success of a pulpectomy is measured by the tooth's ability to function properly until it naturally exfoliates without any clinical or radiographic signs of failure. Clinically, all teeth demonstrated a 100% success rate after two years, irrespective of the instrument type used for root canal preparation. This is in accordance with Babu et al., who found a 100% clinical success rate over 24 months using both adult and pediatric rotary file systems and manual files.[5] Similarly, comparing three pediatric rotary file systems with manual files showed a 100% clinical success rate after two years.[16] Amorim et al. reported a 100% clinical success rate at 12 months for primary molars treated with rotary and manual techniques.[22] Elheeny et al. observed a higher clinical success rate for rotary instruments than manual ones after 12 months.[26] However, an Indian study indicated lower clinical success rates for rotary techniques than manual ones after 24 months.[20]

In the current study, a 100% clinical success rate was observed regardless of the chosen material for obturation. This means that the type of material did not affect the clinical outcome of the treated teeth. This finding aligns with an Indian study which reported a 100% success rate in teeth filled with Endoflas®, Metapex®, and zinc oxide eugenol.[10] Similarly, Pramila et al. observed a 100% success rate using RC Fill®, Pulpdent®, and Vitapex® after 30 months.[21] Previous studies have also reported a 100% success rate with zinc oxide eugenol over a 24-month follow-up.[5,16] Ozalp et al. noted a 100% success rate at 18 months using zinc oxide eugenol and Vitapex®.[27] Chen et al. found success rates of 92.2% with zinc oxide eugenol and 71.4% with Vitapex®.[11] In contrast, Pandranki et al. reported a higher success rate with Endoflas® compared to zinc oxide eugenol cement.[8] Ramar et

al. documented success rates of 96.8% with Metapex® and 100% with Endoflas® at 9 months,[9] while Fuks et al. reported a 70% success rate with Endoflas®[24] and Nakornchai et al. reported a high success rate of 96% with Vitapex®.[28]

By the end of the study, teeth treated using rotary file systems exhibited a marginally higher radiographic success rate than those treated with manual file systems. However, the difference was not statistically significant. The enhanced success rate of rotary file systems could be attributed to the minimized extrusion of apical debris.[2] Conversely, the increased failure rates for manual files might be due to the accumulation of dentinal shavings in the periapical area, a problem potentially exacerbated by the rhizolysis in primary teeth.[22] While this study supports the notion of rotary files achieving better outcomes,[5,17,26] other research has indicated the opposite, with hand files sometimes showing superior radiographic success compared to rotary instruments. [20,22]

In this study, Endoflas® had a higher success rate, followed closely by DiaPex Plus® and zinc oxide eugenol. This finding is in consistent with previous studies.[10,27,21] Contrasting these results, lower radiographic success rates have been observed with Endoflas®, zinc oxide eugenol, and iodoform-based materials like Vitapex® (53%) and Metapex®.[8,9,11]

Previous studies have documented an overall success rate of 95% to 100% for teeth treated with rotary and hand files over various follow-up periods.[5,12,16,17,26] Similarly, success rates for teeth filled with different obturating materials have been reported to range from 53% to 100%.[8-11,21,27,28] It is important to highlight that these studies presented their findings as a combined success/survival rate without distinguishing between clinical and radiographic success or sorting the results by specific groups (rotary vs. hand files).

The discrepancies in success rates can be linked to multiple factors. One key issue is the difference between clinical and radiographic outcomes, where silent radiographic failures, clinically asymptomatic, are counted as radiographic failures.[20] Other variables affecting success rates include individual immune response, the pre-treatment pathological state of the tooth, independent assessments of clinical and radiographic outcomes, the inclusion of pathological root resorption and radiological alterations in furcal or periapical regions as radiographic failures, and the criteria used to select primary molars for treatment. Additionally, the instrumentation method, the type of irrigation solutions, the obturating materials used, the practitioner's skill and expertise, post-treatment restorations, and the length of the follow-up period are significant contributors.[12,19,26,29] The healing process, which may require more time to be detectable radiographically, is another vital aspect. Moreover, interpreting furcal and radicular radiolucencies can be highly subjective, potentially leading to 'observer bias', even when the same observer conducts subsequent evaluations.[22,26]

The present study's findings align with previous studies that reported no marked difference in the success rates of pulpectomized primary molars, regardless of whether they were prepared using rotary or hand file systems or filled with various materials.[5,8-10,16,17,20,22,26,29,30] This might be because the variation in root canal instrumentation was only in terms of the technique or type of instrumentation and filling materials, while all other factors remained constant.[20] This uniformity likely contributed to the similar clinical and radiographic outcomes observed after 24 months.

The correlation between the obturation quality and the success of pulpectomized teeth indicates that rotary file systems may lead to a higher proportion of optimally filled teeth, thereby

enhancing the overall success rate. This improvement could be attributed to the diminished presence of apical debris, which correlates with decreased radiographic failures and an increase in adequately filled root canals.[2,5,16] Regarding the filling materials, teeth obturated with Endoflas® have demonstrated a higher success rate, potentially due to Endoflas®'s robust antibacterial properties associated with its alkaline pH.[8,10] Moreover, Endoflas® is known to facilitate healing in the periapical area and support bone regeneration.[8] Further, the superior success rate could also be attributed to the higher number of optimally filled teeth and the resorption of only extraradicularly extruded material.

The success rate for optimally filled canals was notably higher, corroborating prior research findings.[5,8-10,16,24,30] In consistent with previous studies, the overfilled canals had a lower success rate.[24,30] Failures in overfilled canals may be associated with preoperative conditions like radiolucency or root resorption, adversely affecting prognosis. Yet, some studies have reported high success rates even for overfilled root canals.[18,31]

The underfilled canals may foster bacterial proliferation within the narrow channels, potentially leading to reinfection and a consequent increase in failure rates.[8] Earlier studies have substantiated this trend.[8,10] Intriguingly, Moskovitz et al. [32] observed a high success rate in underfilled canals treated with Endoflas®, surpassing even flush-filled and overfilled canals. They posited that discrepancies between the radiographic and anatomical apex, resulting from physiological or pathological root resorption in primary teeth, could cause misinterpretations of 'flush fill' and 'failure' as 'over-fill'.[32]

In summary, the secondary analysis suggests that the success of pulpectomized molars is not significantly affected by the choice of instrumentation file systems or obturating materials. Nonetheless, observations indicate a trend where the use of rotary file systems, particularly those designed for pediatric use, and obturation with Endoflas® correlate with higher success rates. This could be attributed to their role in achieving a greater proportion of optimally filled root canals, a key factor in treatment success. Dental practitioners must enhance their proficiency in rotary endodontics, given its emerging importance in pediatric dentistry, and deepen their knowledge of obturating materials chemical and biological properties.

The study acknowledges limitations, such as a limited sample size, reliance on two-dimensional radiographic imaging, and the challenge of blinding the operator due to the instruments and materials distinct nature. Future research should incorporate more sophisticated imaging modalities, like cone beam computed tomography (CBCT) or micro-CT, expand the sample size, and extend the follow-up period until natural exfoliation of the teeth.

CONCLUSIONS

Primary molars treated with rotary file systems demonstrated better obturation quality than those treated with manual NiTi file systems. However, there was no significant difference in obturation quality between the Kedo-SG pediatric rotary and HERO Shaper rotary file systems. The choice of obturation materials did not markedly impact obturation quality. After two years, the clinical success rate was 100%. Radiologically, success rates were 97% for Kedo SG, 94% for HERO Shaper, and 89% for manual file systems. Primary molars with optimal filling demonstrated higher success rates than underfilled or overfilled cases. Using rotary file systems and Endoflas® resulted in more optimal fillings and better outcomes, although statistical significance was not observed. Thus, it can conclude that the success of pulpectomized teeth is not significantly influenced

by the type of root canal instrumentation file systems or obturating materials offering operators a wide range of choices for pulpectomy procedures based on individual preferences and clinical considerations.

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Emergency endodontic care for permanent teeth in children: Patterns, treatment outcomes, and challenges in Trinidad, West Indies

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Highlights

- Data on patterns and outcomes of emergency treatment for pulpally involved permanent teeth in children is limited. This information is essential for guiding clinicians on potential issues in endodontic care.
- The majority of cases involving emergency endodontic treatment of permanent teeth in children remain untreated.
- This study highlights the need for timely treatment of endodontically involved permanent teeth following emergency management to improve tooth retention.

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Abstract

Aim: The aim of this study was to assess the patterns and treatment outcomes of permanent teeth requiring emergency endodontic care in children and to highlight the challenges encountered in obtaining this care at the Child Dental Health Unit, School of Dentistry, University of the West Indies, St. Augustine, Trinidad. **Methods:** This study was conducted through a retrospective analysis of pediatric patients requiring emergency endodontic treatment of permanent teeth at the Child Dental Health Unit clinic from January 2016 to December 2019. Data were collected via file record reviews and telephone interviews with the patients' parents or caregivers, using standardized questions. The collected data included the patient's age, sex, tooth involved, reasons for endodontic treatment, type of treatment provided, stage of endodontic treatment attained, and completion time. The data were then formatted and analyzed using descriptive statistical methods. **Results:** A total of 6887 patients attended the Child Dental Health Unit for emergency care, of which 5% required endodontic treatment in permanent teeth. Among these, 60.5% of cases were female and 39.5% were male, with a mean age of 12.1 years. The majority of cases (77.3%) were due to caries, while 22.7% were due to trauma. Molar teeth were the most commonly treated, but only 42.9% of all emergency endodontic treatments on permanent teeth were completed. The primary reason for the non-completion of endodontic treatment was lengthy patient wait times for follow-up appointments. **Conclusions:** The majority of emergency endodontic cases were not completed, primarily due to delays or lack of recall by dental students and vocational trainees. Lengthy waiting times resulted in an increased need for tooth extractions. Existing services require evaluation to ensure prompt treatment, preventing delayed care, recurrent pain, infection, and tooth loss.

Keywords: Emergency Treatment; Pediatric Dentistry; Permanent Dentition; Root Canal Therapy; Treatment Outcomes

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INTRODUCTION

Endodontic therapy is a viable and successful treatment option for the preservation of severely compromised permanent teeth due to decay and trauma.[1,2] This therapy helps limit the need for the extensive and expensive restorative and orthodontic treatment required to correct the resultant problems.[3] This is particularly significant in the growing patient, as early loss of permanent teeth can lead to problems with masticatory function, occlusion and facial disharmony.[4]

In Trinidad and Tobago, dental care for children is provided through the public health system and at private dental clinics. Services within the public health system are offered at no cost to the patient but are often limited to preventive measures, simple operative treatment and exodontia. Emergency management for permanent teeth typically involves the prescription of analgesics, antibiotics, and, when applicable, exodontia.

The University of the West Indies School of Dentistry, Child Dental Health Unit, receives and treats patients up to the age of 16 years. These patients are often self-referred, referred by local dental clinics in the public health system or private dental offices, as there are either minimal or no costs attached to the dental treatment received and the Unit offers a wider range of treatment services than in the public health system. There is however limited access to specialist treatment and adjunctive services like sedation or general anesthesia.

The patients attending for emergency care at the Child Dental Health Unit are usually treated by either first year dental vocational trainees or senior dental undergraduate students who subsequently arrange for the continuity of care for these cases. It was observed however, that cases needing permanent tooth root canal therapy following emergency treatment, remained incomplete and patients often re-attended with repeat infection or required extraction of the affected teeth.

A previous study[5] done at the Unit revealed a significant percentage of children attended for emergency treatment related to caries and dental trauma. Many of the cases were in the mixed dentition, from lower socio-economic backgrounds and required complex treatment.

There is no information available to date about the pattern of emergency endodontic treatment and the treatment outcomes of these patients once they were seen. This study aimed to highlight the patterns and treatment outcomes of permanent teeth requiring emergency endodontic care in children and examine the challenges encountered in obtaining this care at a dental school clinic in Trinidad. This information can guide clinicians in optimizing emergency endodontic treatment strategies and improving oral health outcomes for pediatric patients. The null hypothesis is that most of the emergency endodontic treatment of permanent teeth in children is completed within 6 months of initiation.

METHODS

The study was approved by the University of the West Indies, Campus Research Ethics Committee (Ref: CREC-SA.1000/05/2021) and was carried out in the Child Dental Health Unit, School of Dentistry, Eric Williams Medical Sciences Complex, from June 2021 to December 2021. The study approval also included the obtaining of consent via telephone from the parent/guardian following the provision of information about the study.

Study Design

This study was conducted through a retrospective analyzis of pediatric patients who required emergency endodontic treatment of permanent

teeth at the Child Dental Health Unit clinic from January 2016 to December 2019. The research involved reviewing file records and conducting telephone interviews with the patient's parent or guardian using standardized questions. The data obtained was formatted using Excel and later analyzed for frequencies using SPSS.

Data Collection

The Child Dental Health Unit clinical logbook which records all cases attending for emergency treatment, was used to identify potential patients. The inclusion criteria included patients aged 6 to 16 years at the time of treatment, who required endodontic treatment in permanent teeth between January 2016 and December 2019.

The corresponding paper-based patient records were requested, evaluated, and analyzed for patient demographics, including age and gender. The type of tooth was categorized as anterior (central incisor, lateral incisor, canine) or posterior (premolar, molar), and its location was identified as either upper or lower. The reasons for endodontic treatment were documented, with cases classified as due to caries or trauma. The stage of root canal treatment attained was noted, whether it involved sedative dressing, pulp extirpation, cleaning and shaping, or obturation with or without final restoration. The time taken to complete the root canal was recorded, and it was determined whether apexification or extraction was required.

This was followed by telephone interviews with the parent/guardian of the qualifying subjects and the co-investigator (KB) of the study. Once informed consent for participation in the study was obtained, a series of open-ended and close-ended questions were asked including the type of treatment sought elsewhere if any and the reasons given for non-continuance of care. The various reasons were categorized based on parent responses during the interview and file documentation. From parent interviews, reasons included the cost being too expensive to obtain treatment privately, still awaiting an appointment with no follow-up received, the patient losing interest in treatment due to the absence of pain, a preference for extraction due to the numerous visits required for root canal therapy, difficulties with scheduling and attending offered appointments, and reinfection or pain leading to tooth extraction. From the file documentation, additional reasons included the tooth becoming unrestorable and root canal treatment not being considered ideal, with enforced loss recommended after an orthodontic assessment.

Statistical Analysis

The data obtained was formatted using Excel and later analyzed for frequencies using SPSS version 29.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were employed to provide a summary of the variables within the dataset. Chi-square test was used to test associations involving discrete data with the level of significance set at $p<0.001$.

RESULTS

From January 2016 to December 2019, there were 345 emergency cases for endodontic treatment in permanent teeth. This made up 5% of all 6887 recorded emergency patients in the Child Dental Health Unit during this period. 79 (22.9%) case files however could not be located, and 46 patients (13.3%) could not be reached using the given contact information. 220 cases were therefore used for this study.

60.5 % of cases (133/220) were female and 39.5% (87/220) were male. The mean age was 12.1 years. 77.3% (170/220) of cases were due to caries, while 22.7% (50/220) were due to trauma. The teeth involved are shown in Figure 1. Most of the anterior teeth were upper central incisors, 80% (52/65).

The posterior teeth comprised lower molars 69% (107/155), upper molars 26.5% (41/155) and upper premolars 4.5% (7/155).

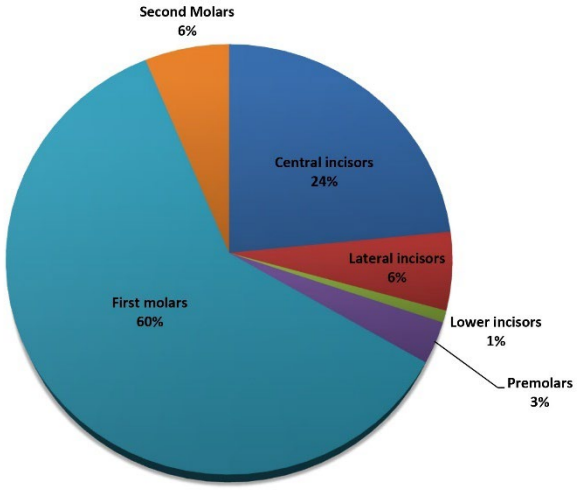

Figure 1. Endodontic treatment received according to tooth type

28.6 % (63/220) of cases continued treatment at the university's clinics with dental students and vocational trainees, 3.6% (8/220) sought care with private general dental practitioners and the remaining 67.7% (149/220) were still awaiting follow-up care with either students or vocational trainees, at the time of audit.

Of the 220 cases included, 33.6 % (74) only received a sedative dressing i.e. LEDERMIX™ (Oz Dent Dental Products Australia) or ODONTOPASTE® (Australian Dental Manufacturing) and an interim temporary restoration for pain relief. 4.5% received pulpectomy only and 31.9% were obturated. 57 (25.9%) cases did not proceed with endodontic treatment and later received extractions. 2.3 % (5/163) of cases required apexification treatment and these were all on anterior teeth (Table 1 and Figure 2).

The cases that proceeded with endodontic treatment (n=163) comprised 38% (62/163) anterior teeth (central and lateral incisors), 2.5% (4/163) premolars and 59.5% (97/163) molars. Only 42.9% (70/163) of all cases were completed. Most of the completed endodontic cases were anterior teeth 60% (42/70). There was statistical significance noted between anterior and posterior teeth and their endodontic treatment completion. ($p<0.001$) (Table 2). The majority of posterior teeth that required endodontic treatment were lower molars. Only 27.8% (27/97) of all molar cases were completed and there was no statistical difference between root canal completion in upper molar and lower molar teeth.

Table 1. Different stages of root canal therapy obtained in the study

Stage of treatment obtained	**(N = 220) (%)**
Sedative dressing with Ledermix/ Odontopaste	74 (33.6 %)
Pulp extirpation, calcium hydroxide and IRM	10 (4.5%)
Canal cleaning and shaping	4 (1.8%)
Obturation with no final restoration	14 (6.4%)
Obturation with final restoration	56 (25.5%)
Apexification	5 (2.3%)
Did not want endodontics - Extraction preferred	57 (25.9%)

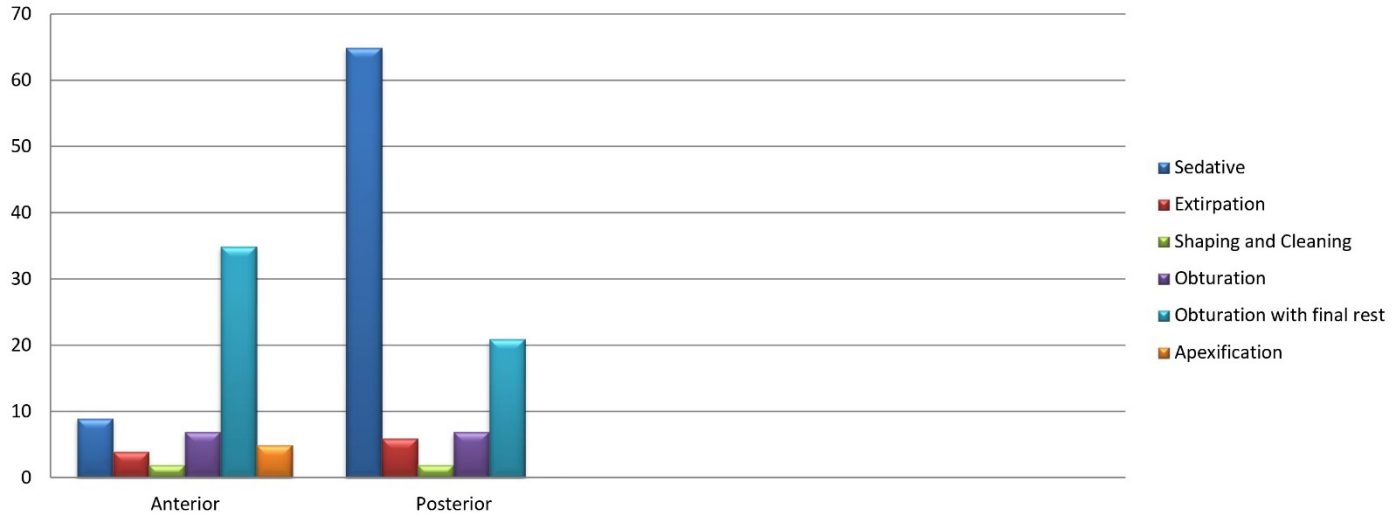

Figure 2. Stages of root canal therapy attained by anterior versus posterior teeth

10% (7/70) of emergency cases sought follow up endodontic care with private general practitioners. All of the endodontic cases completed privately were molars.

The main reasons reported for non-completion of endodontic treatment in this study were the prolonged wait time for follow up appointments and re-infection that led to tooth extraction (Table 3).

The mean waiting time for uncompleted emergency endodontic cases was 3.9 years. However once continued, molar root canal treatment had an average completion time of 3.9 months whereas the average completion time for anterior teeth was 28 days.

Table 2. Pattern of completion status of root canal therapy by tooth type

	Completion Status			
Tooth Type	**Incomplete**	**Complete**	**Total**	**p value**
	(n = 93)	**(n = 70)**	**(n = 163)**	
Anterior	20	42	62	*<0.001*
Posterior	73	28	101	
Tooth Type	**Incomplete**	**Complete**	**Total**	**p value**
	(n =70)	**(n = 27)**	**(n = 163)**	
Upper Molar	23	5	28	0.162
Lower Molar	47	22	69	

Table 3. Reasons for non-completion of root canal therapy

Reason	No of cases (%) (n = 150)
Cost	8 (5.3 %)
Still awaiting appointment with student/vocational trainee	88 (58.7 %)
Reinfection/pain – tooth extracted	19 (12.7%)
Tooth became unrestorable	12 (8%)
RCT not considered ideal-enforced loss recommended	12 (8%)
No pain, patient is no longer interested in treatment	1 (0.7 %)
Too many visits- patient preferred extraction	8 (5.3%)
Unable to attend appointments – problems with scheduling	2 (1.3%)

DISCUSSION

Emergency dental services provide immediate pain relief for patients with endodontic problems resulting from caries and dental trauma. Endodontic therapy allows for preservation of teeth that would otherwise be extracted due to pulpal pathology.[6] Early tooth loss of permanent teeth in a pediatric patient can lead to problems with tipping and supra-eruption of teeth which can require either expensive orthodontic treatment or prosthodontics to correct in the future.

This study makes known information on the pattern of emergency endodontic treatment in permanent teeth of pediatric patients and the treatment outcomes. It also highlights potential challenges faced in providing this care to young patients to mitigate problems associated with early tooth loss.

The prevalence of endodontic treatment reported in several studies[7,8] ranged from 2% to 21%. Five percent of emergency patients who presented to the Child Dental Health Unit from January 2016 to December 2019 required permanent tooth endodontic treatment. This study's findings are comparable to the study[9] conducted at the endodontic clinic of the University of Pennsylvania on patients between the ages of 6 to 12 years old, during the period of June 2017 to June 2020 where 6.7% of patients required endodontic treatment in permanent teeth. This was a significant demand for this nature of treatment. Although not a statistically significant finding, there appeared to be a predominance of females in this study (60.5%) who required endodontic treatment. This was noted to be similar to that found in other studies.[10]

In this study most of the cases that required emergency endodontic treatment were due to carious involvement of the pulp. The molar teeth were most affected by caries and anterior teeth were affected by trauma. The caries prevalence in this population in the 6 – 15 year old age group is considered to be high (33%-62%) which can contribute to the significant demand for emergency endodontic services.[11]

The most frequently affected tooth type was the mandibular first permanent molar and caries was found to be the main etiological factor. This is consistent with the findings of Ajayi et al.[12] who explored the pattern of endodontic therapy in children below the age of 16 years at a teaching hospital and concluded that permanent mandibular molars were more commonly affected compared to permanent maxillary molars and any other tooth type. Specifically, the permanent mandibular first molar required more treatment than the maxillary first molars and mandibular second molars.

There are several factors that can contribute to the high caries susceptibility and risk of pulpal involvement of mandibular first permanent molars. When transitioning to mixed dentition, the mandibular first permanent molars are the first teeth to erupt at the age of 6 years. They therefore have an early exposure to the oral cavity compared to any other permanent tooth counterpart. Parents may also fail to recognize them as permanent teeth as they are not succedaneous. Additionally, their morphology facilitates plaque retention, and these teeth can be found to be affected by hypomineralization. These factors, perhaps coupled with limited preventive measures, particularly fissure sealant use in this population, make them prone to caries development.

The mean age of the patients was found to be 12.1 years. This is significant as, at this age, any consideration for enforced loss of molars specifically the first permanent molars produces less than ideal results in preserving the occlusion and retention of these teeth becomes a more crucial factor to consider.

The finding that more posterior teeth needed endodontic treatment due to caries compared to anterior teeth needing endodontic treatment due to dental trauma in this study, was interestingly opposite to that seen in the Popoola et al.[6] study. This may be explained by the prevalence of reported dental trauma being generally lower in this country (9.5%-13%).[13,14]

The students and vocational trainees completed more emergency endodontic treatment in anterior teeth than in posterior teeth. The average completion time for anterior teeth was 28 days compared to 3.9 months for molar teeth. This disparity could be attributed to the shorter duration and lesser technical complexity involved in treating anterior teeth compared to multi-rooted teeth with more intricate anatomy. It could also be due to the influence of anterior teeth on aesthetics thereby motivating both parent and clinician to ensure treatment completion.

"Delayed treatment" as defined by Wong et al.[15] is incomplete root canal therapy (never obturated) or completion of root canal therapy in a period greater than four months (delayed root canal filling). The mean waiting time for uncompleted emergency endodontic cases in this study was 3.9 years. The main reasons reported for non-completion of endodontic treatment in this study were the prolonged wait time for follow up appointments and re-infection that led to tooth extraction.

Several factors could explain these findings. In the comprehensive care model used at the dental school, stabilization of disease may be required before completing complex treatment. This could delay the completion of root canal therapy by senior undergraduate students and vocational trainees who may have limited availability of clinical treatment sessions.

Root canal therapy is also technique sensitive, and its overall success is dependent on the accuracy of multiple individual steps.[16] During root canal procedures, as reported by Almutairi et al.[17], students experience challenges reaching profound anesthesia, placing rubber dam, taking periapical radiographs using the mesial and distal shift method, access cavity preparation and calculating working length. Each of these steps can ultimately affect the completion of the endodontic therapy.[15,18]

Lengthy wait times can be associated with endodontic flare-ups and inter-appointment emergencies when compared to cases where follow up treatment was received in a prompt manner. Lengthy wait times can lead to the breakdown of interim restorations, causing re-infection, recurrent decay, tooth fracture and questionable restorability that could complicate case management and ultimately lead to tooth loss.

Patient non-compliance with dental treatment together with the absence of pain also increases the likelihood of clinical complications.[19] This study showed that several cases had issues with attendance, length of the procedures or were no longer interested in completing treatment after receiving palliative endodontic care. Several studies[15,20] have shown that an increase in the duration of the procedure and in the number of patient visits are both associated with incomplete endodontic treatment.

Successful endodontic therapy can also be compounded by additional challenges in managing patient behavior in this age group.[20] The need for pharmacological behavior management, including nitrous oxide, conscious sedation and general anesthesia may be crucial to attaining patient cooperation and facilitating treatment by alleviating fear and anxiety in young patients.[9] The limited access to such adjunctive services as well as specialist or postgraduate endodontic services at the dental school facility, add to the myriad of challenges that students and vocational trainees may face in providing and completing emergency endodontic treatment in permanent teeth in children with minimal delay.

Twenty five percent of children who had emergency endodontic treatment of their permanent teeth later required extraction. This outcome is not considered ideal and can reflect a less than adequate use of resources by the dental school unit to provide this type of emergency service. A closer review of the services provided and treatment protocols at the unit should be done. More robust patient selection criteria and associated treatment counseling should be considered.

In this setting, given the numerous challenges, perhaps vital pulp therapy (VPT) can also be considered as an alternative to non-surgical root canal therapy. In recent times, there have been notable progressions in the use and application of bioactive hydrophilic calcium silicate cements, including Biodentine, mineral trioxide aggregate, calcium-enriched mixture, and bioceramics, for utilization in VPT procedures. These materials have also been reported to have a clinical success rate of over 85% when used as the medicament of choice even in irreversibly inflamed permanent teeth.[21]

Pulpotomy procedures are comparatively simpler, cost-effective and entail fewer dental appointments than conventional non-surgical root canal therapy. The latter can be particularly advantageous for pediatric patients especially where resources are limited to provide timely emergency endodontic treatment.

There were several limitations in this study. Over one third of cases who attended for emergency endodontic treatment were excluded due to unavailability of case files or inability to contact the patients which could have impacted significantly on data findings. Given the length of time elapsed in many cases, there may have been recall bias by parents. The etiology of the tooth's pulp status i.e. symptomatic irreversible pulpitis, symptomatic periapical periodontitis, was not always recorded in the patient files so any association between pulp status and likelihood of root canal completion could not be obtained.

Given the paucity of completed emergency endodontic treatment of permanent teeth in this study and the unfavourable treatment outcomes, a review of the services provided and treatment protocols at this clinic are required. Consideration can be given to the use of vital pulp therapies where applicable. These strategies could decrease treatment complexity, completion time and treatment cost as well as improve long-term tooth retention.

CONCLUSIONS

The prevalence of emergency endodontic treatment on permanent teeth among the children examined in this study was 5% and dental caries was found to be the main etiological factor. Anterior teeth endodontics were completed by student and vocational trainees more than posterior teeth. Long waiting times for completion of emergency endodontic treatment by students and vocational trainees, particularly molars, are likely to lead to an increase in unfavorable outcomes especially tooth extraction.

To improve treatment outcomes greater consideration should be made in patient selection, parent education and the chosen endodontic therapy. The use of VPT in permanent teeth and more robust patient recall systems may reduce waiting times for treatment. These approaches can limit the problems associated with delayed endodontic care and increase tooth retention.

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Case Report
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Conservative aesthetic management of dental fluorosis using microabrasion with two different acidic compounds in pediatric patients: A report of two cases

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Highlights

- Dental fluorosis can severely impact the aesthetics and social life of pediatric patients. Effective management is crucial for improving the confidence and overall well-being of affected children.
- Microabrasion using two different acidic compounds demonstrated significant improvement in the aesthetic appearance of teeth affected by dental fluorosis.
- This study provides comparative insights into the efficacy of two acidic compounds in treating dental fluorosis, aiding clinicians in choosing best treatment for pediatric patients.

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Abstract

Dental fluorosis is a subsurface hypomineralization condition, characterized by yellow to dark brown stains, with or without enamel porosity and pitting. Due to aesthetic concerns, children with discolored anterior teeth often experience negative impacts on their psychological, emotional, and social development. Treatment options include porcelain laminates or veneers, direct resin restorations, and crowns. However, these methods are invasive and require significant enamel reduction, making them unsuitable for children due to their enlarged pulp chambers. Microabrasion is the least invasive and safest treatment for children with fluorosis. This technique involves using a combination of 37% phosphoric acid gel with extra fine grain pumice, 18% hydrochloric acid in pumice, or 6.6% and 10% hydrochloric acid with silica carbide particles. The mixture is applied with a slowly rotating rubber cup to the areas of discoloration or white opacities. An additional benefit of microabrasion is that it leaves the enamel surface highly polished, reducing the growth of cariogenic bacteria and increasing resistance to demineralization. This case report describes two instances of dental fluorosis treated with microabrasion using different acidic compounds in two pediatric patients, resulting in clinically acceptable and aesthetically pleasing outcomes.

Keywords: Dental Fluorosis; Enamel Microabrasions; Esthetics; Preventive Dentistry

INTRODUCTION

Dental fluorosis (DF) is a developmental disorder of enamel caused by a prolonged intake of excessive fluoride during enamel formation, causing pathological alterations in ameloblasts, preventing the development of normal hydroxyapatite crystals clinically characterized by exterior hypermineralization and subsurface hypomineralization. [1] Despite the well-known fact that water fluoridation is a safe and effective public health strategy for lowering the incidence of dental caries, excess fluoride in drinking water, above a concentration of 0.5-1.5 mg/l, can cause metabolic changes in ameloblasts, resulting in a defective matrix and insufficient calcification of teeth, known as dental fluorosis.[2,3]

Several treatments have been proposed to improve the appearance of DF, including the use of veneers or full crowns, composite restoration, microabrasion, bleaching, and/or resin infiltration.[1] The severity of the condition determines which techniques are to be used. As most DF patients are young, prosthetic therapy like full coverage crowns are invasive procedures that causes excessive sacrifice of tooth material, that may lead to complications like pulpal exposure.[4] A less invasive aesthetic procedure, such as microabrasion, is therefore more appropriate for mild-moderate DF management. However, if the depth of the defect is greater, microabrasion in conjunction with bleaching or bonded restorations can be used to provide optimal aesthetics.[3,5] Although bleaching, a non-abrasive technique, is widely accepted for removal of stains, bleaching agents impacts the tooth surface chemically because of their low pH and chelating agents, creating surface topographic enamel irregularity , such as depressions, surface porosity, and surface abnormalities rendering the dentin more vulnerable to post-operative teeth sensitivity.[6,7] This can worsen in cases of dental fluorosis due to presence of subsurface hypomineralization and thereby deeper penetration of the bleaching agents.[8,9]

The microabrasion technique is a minimally invasive and definitive technique that involves the application of a mixture of 37% phosphoric acid gel in extra fine grain pumice, 18% hydrochloric acid in pumice, or 6.6% and 10% hydrochloric acid with silica carbide particles to areas of discoloration using a rubber cup in a slow rotating motion.[10]

In the present case report, two patients with Dean's fluorosis score of 4 (moderate DF) were treated with the minimally invasive esthetic technique of microabrasion, using 34% H_3PO_4 and 18% HCl respectively, followed by fluoride application; and subsequent composite application on the labial surface of anterior teeth.

CASE REPORT

CASE 1

A 9-year female reported to the Department of Pediatric Dentistry with a chief complaint of discoloration of the upper front teeth. Her father noticed this discoloration since she was seven years of age, affecting her appearance and smile. On recording history, it was noted that she lived in Agra, Uttar Pradesh, a fluoride endemic region.[11,12] Further exploration of family history revealed that her elder brother had more severe discoloration of front teeth. On examinations her teeth displayed irregular chalky white and brown spots in the permanent maxillary and mandibular incisors. The patient had good oral hygiene with no signs of gingivitis or caries found. There was no pain or other sign / symptom present in any teeth. The distribution of chalky, opaque white and brown spots on anterior teeth and her area of residence supported a diagnosis of moderate DF (Figure 1).

Figure 1. Preoperative photograph of Case 1 illustrating pitted and diffuse discoloration of the anterior teeth

Because the patient was young, wanted less invasive treatment, and the DF fell in the range of moderate, it was decided to perform microabrasion on the incisors, followed by 2% sodium fluoride and composite application on the labial surface.

Oral prophylaxis followed by rubber dam placement was done on the anterior teeth. A slurry mixture of 37% H_3PO_4 gel (Smart Etch, SafeEndo Pvt Ltd., Ahmedabad, India) and pumice powder (to achieve toothpaste like consistency) was coated on the labial surfaces of approximately 1mm thickness. The outer surface of the enamel was abraded with the use of a polishing cup (Prophy cups, Cotisen Ltd, China) at low speed using contra-angle handpiece (Figure 2). After 40 to 50 seconds of performing the abrasion, the paste was rinsed off and the enamel surface was re-evaluated. This procedure was repeated four times to achieve desirable aesthetics.

After microabrasion procedure, a 2% sodium fluoride gel (Fluocal Gel, Septodont®, France) was applied for 4 minutes to prevent postoperative sensitivity. After one week on the next visit, restorative composite (shade A1, Te-Econom Plus, Ivoclar, India) was applied on the labial surface of the anterior to enhance the aesthetics. For shade selection of the composite, after choosing a shade from the guide, 1mm^2 of composite ball of that shade was cured on the affected tooth surface without bonding, to find the definitive shade match for the patient, which was then removed. The patient was pleased with the aesthetics achieved (Figure 3,4).

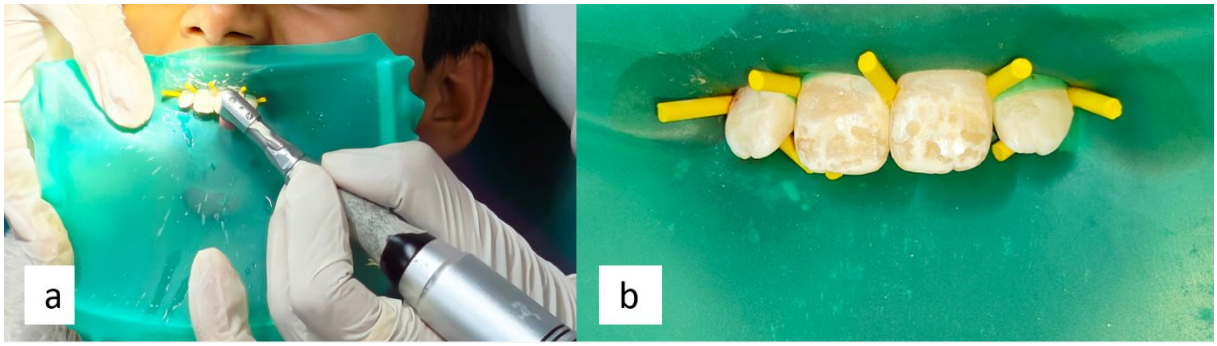

Figure 2. Intraoperative photographs. (a) Polishing of the enamel surface using a rubber cup with a latch-type handpiece; (b) Application of a rubber dam on the anterior teeth

Figure 3. Postoperative photographs of Case 1 following microabrasion and composite application

Figure 4. Comparative preoperative and postoperative photographs of Case 1, highlighting the changes in appearance

CASE 2

An 11-year-old male reported to the department with complaint of discolored anterior teeth and wanted aesthetic correction of the same. On recording the demographic data, it was noted that he lived in Unnao, a high fluoride belt region.[11] On examination, opaque white and brown discoloration (mottling) was observed on anterior teeth; pertaining to the clinical diagnosis of moderate fluorosis (Figure 5).

Minimally invasive treatment of microabrasion with 18% HCl and pumice slurry, followed by composite application was decided. After performing oral prophylaxis, rubber dam was placed on the anterior teeth and the patient was made to wear protective eye wear for safety from acid pumice slurry. One mm thickness of the slurry was coated on labial surface of teeth, and rubber cup attached on contra-angle handpiece was used for microabrasion (Figure 6).

Figure 5. Preoperative photographs of Case 2 showing brown and opaque white patchy discoloration of the anterior teeth

A total of three cycles of 30-40 seconds each were required to attain desirable esthetics, this was followed by application of 2% sodium fluoride for four minutes on the labial surface (Fluocal gel, Septodont®, France). After one-week, restorative composite was applied after shade matching to improve esthetics (shade A1, Te-Econom Plus, Ivoclar, India).

The shade matching was done as explained earlier for case 1. The patient was satisfied with the results and looked pleased with his look (Figure 7,8).

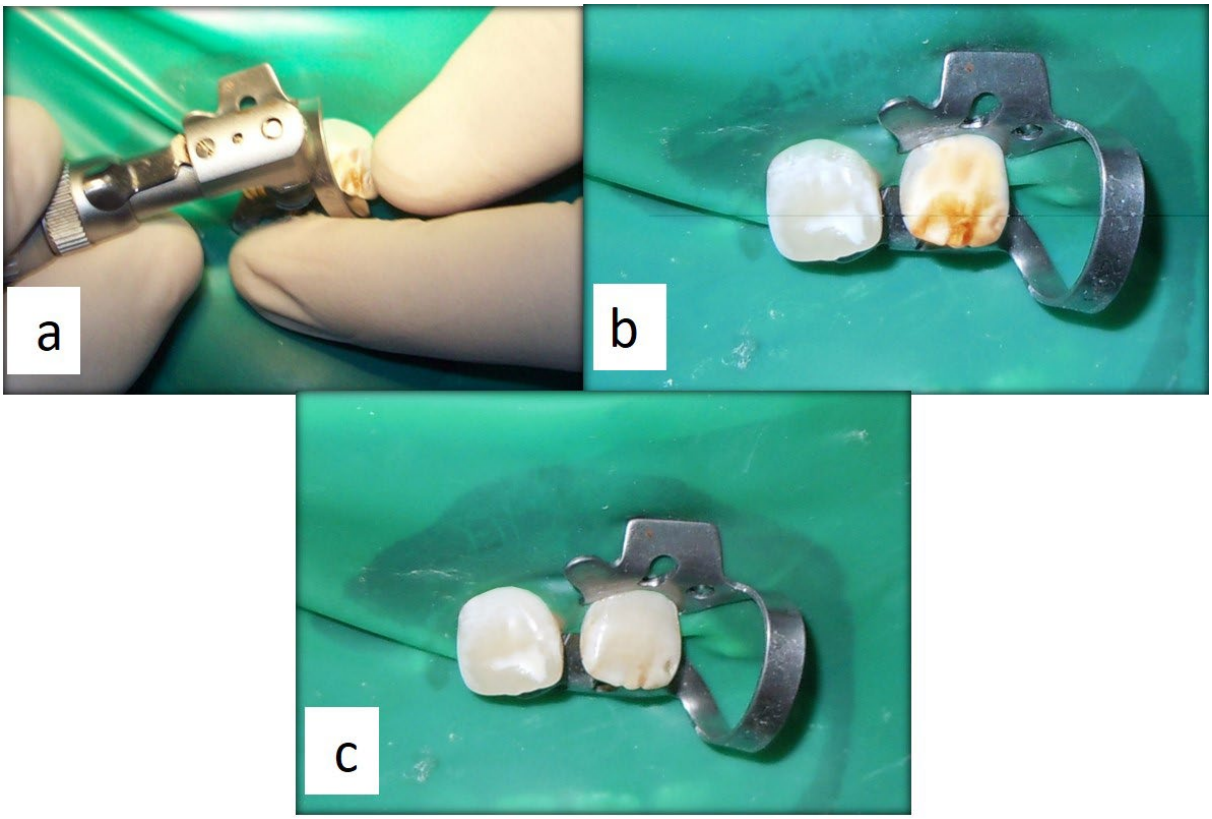

Figure 6. Intraoperative photographs. (a) Application of a rubber cup with a handpiece on the anterior teeth; (b) Post-microabrasion on tooth #11; (c) Post-microabrasion on teeth #11 and #21

Figure 7. Postoperative photographs of Case 2 following microabrasion and composite application

Figure 8. Comparative preoperative and postoperative photographs of Case 2, highlighting the changes in appearance

DISCUSSION

Dental fluorosis is a condition induced by chronically high fluoride intake during development of tooth. The degree of severity of dental fluorosis is determined by the amount of fluoride intake, their concentration and duration of exposure, degree of tooth bud development, genetic susceptibility, and environmental influences.[13] It ranges from opaque white to brown to even blackish stains, causing serious aesthetic challenge in some cases.[12] Based on reports of 2017, a whopping 62 million people, including 6 million children were affected by fluorosis in India. Residence of both the above cases belonged to the state of Uttar Pradesh, of which the ground level water of Agra is 0.1 to 14.80 mg/L and that of Unnao is 0.8–13.9 mg/L.[11,12] The differential diagnosis of dental fluorosis includes molar incisal hypomineralization, enamel hypoplasia, white spot lesion.

A surge in demand for improved dental aesthetics has resulted in several scientific and technological advancements in numerous fields of dentistry. The minimally invasive microabrasion technique has demonstrated excellent results in the treatment of intrinsic stains, particularly those caused by fluorosis, due to its several advantages.[10] Firstly, this is less invasive and conservative technique, requiring removal of only the outermost thin layer of enamel. Mild to moderate fluorotic lesions typically occur in the outer 80-100 μm of enamel and microabrasion process removes the

first 25-200 μm of surface enamel, depending on acid concentration and application time. [10] Furthermore, with utilizing adequate precautions, it does not cause postoperative discomfort or sensitivity, even when a young permanent tooth is treated. It is also a single-sitting procedure, being both permanent and cost-effective, leaving the enamel polished and lustrous.[15] Keeping the benefits in mind, we chose the microabrasion technique followed by composite application to attain desired aesthetic.

In the present case, two different acidic compounds were incorporated. When comparing their efficacy, it was found that both acids produced desirable aesthetic results; however, the duration and cycles required to achieve the results were lesser in HCl-pumice slurry than in H_3PO_4-pumice slurry. This could be due to the more corrosive and potent character of HCl. Meireles et al.[16] and Mendes et al.[17] reported a larger and deeper region of demineralization with HCl than with H_3PO_4, which could explain why this molecule required less time and fewer applications in the current cases too. In both the present patients, 2% sodium fluoride gel was applied at the end of microabrasion procedure. Fluoride acts by formation of calcium fluoride which transforms hydroxyapatite into fluorapatite through the remineralization process.[18]

The clinical effectiveness of these two microabrasion compounds was compared for degree of stain removal and improvement in appearance and appearance improvement and stain removal degree. [10] The results showed that HCl proved more clinical effectiveness than H_3PO_4, but the difference between the two was not statistically significant. Similarly, in a study conducted by Bassir and Bagheri[19], they proposed using 18% HCL for cases of moderate to severe fluorosis to reduce the overall time and number of applications, hence minimizing enamel loss and therefore yellowish staining. Therefore, microabrasion can be accomplished with both chemicals in an efficient manner; however, HCl required relatively less time and applications to complete the microabrasion treatment than H_3PO_4 pumice.

CONCLUSIONS

In the present report, both HCl and H_3PO_4 gave desirable and satisfactory results in aesthetic treatment of mild to moderate dental fluorosis; however, it was observed that HCl required lesser time and cycle in bringing out similar results as H_3PO_4 in comparable cases of fluorosis. Therefore, HCl can be opted to save time and carry out the procedures more efficiently. Nevertheless, excessive precautions should be maintained while handling HCl, especially with children due to its corrosive nature.

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Pediatric dentistry approach in a child with Aicardi-Goutières Syndrome type 2: A case report and literature review

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Highlights

- Aicardi-Goutières Syndrome is a rare congenital disorder with limited documentation on dental management strategies for pediatric patients.
- This case report is the first to document delayed primary teeth eruption in Aicardi-Goutières Syndrome Type 2.
- Pediatric dentists should monitor patients with Aicardi-Goutières Syndrome for early caries and guide parents on oral hygiene to support healthy dental development.

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Abstract

Aicardi-Goutières Syndrome is a rare autosomal recessive disorder characterized by a triad of partial or complete agenesis of the corpus callosum, infantile spasms, and chorioretinal lacunae. The condition predominantly affects females, as males often do not survive the embryonic period. Intellectual disability associated with the syndrome ranges from mild to moderate. There is limited information in the literature regarding the oral manifestations of this syndrome. This case report aims to provide insights into the development of primary dentition in patients with Aicardi-Goutières Syndrome and to raise awareness about the oral and dental health needs of these rare pediatric patients, particularly during early childhood. In this case report, it was observed that the primary teeth of a 2-year-5-month-old patient had not yet erupted. Notably, even at 3 years and 1 month old, the patient's primary dentition remained incomplete despite continued monitoring during follow-up examinations. These patients often have limited ability to cooperate with dental treatments due to their intellectual disability, which complicates the process. Furthermore, due to the respiratory risks associated with the syndrome, dental treatments under general anesthesia are generally not preferred. In this context, maintaining the oral health of these patients and implementing preventive strategies, including topical fluoridation, along with appropriate oral hygiene instructions and dietary modifications, are crucial in managing patients with Aicardi-Goutières Syndrome. Pediatric dentists are responsible for educating families on these matters, and caregivers play a vital role in maintaining the oral health of these patients by collaborating closely with dental specialists.

Keywords: Aicardi Syndrome; Preventive Dentistry; Tooth Eruption

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INTRODUCTION

Aicardi-Goutières Syndrome is an X-linked autosomal recessive neurodegenerative disease first described in 1984. Although the exact gene responsible for the disease remains unidentified, it is not inherited in a traditional manner, as almost all cases result from new gene mutations (de novo mutations).[1-4] This syndrome is encountered in approximately 1 in 100,000 to 150,000 live births and predominantly affects females, as the disease typically causes embryonic lethality in males.[5]

The diagnosis of Aicardi-Goutières Syndrome is based on clinical and radiological findings. The classical triad associated with the syndrome includes partial or total agenesis of the corpus callosum, infantile spasms, and chorioretinal lacunae.[2] In addition to this classical triad, diagnostic criteria for major and supporting findings have also been established (Table 1).[1] Infantile spasms, the most characteristic seizure type, usually begin around the third month of life and are often the first symptoms prompting clinicians to recommend further investigation.[2,6]

Although oral findings in Aicardi-Goutières Syndrome are limited, reported case studies indicate an increase in gingival inflammation and the prevalence of early childhood caries, likely due to patients' dietary habits, medications, and inadequate oral hygiene.[4,7]

Type I interferons play a significant role in the pathogenesis of Aicardi-Goutières Syndrome, with their expression upregulated, leading to increased production.[8] Consequently, one of the classic laboratory findings in these patients is elevated interferon alpha levels in the cerebrospinal fluid, pleocytosis, and similarly elevated levels of neopterin and biopterin.

The potential utility of assessing the expression levels of interferon-stimulated genes in peripheral blood as a diagnostic marker is currently under investigation, as there is evidence that these levels remain elevated beyond the encephalopathic phase, a phenomenon referred to as the "interferon signature."[8-10] Another key diagnostic feature is the detection of neuroimaging abnormalities, such as calcifications in the basal ganglia and changes in the white matter.

To date, mutations in seven genes have been identified that can lead to the upregulation of the interferon signaling pathway: *ADAR, RNASEH2A, RNASEH2B, RNASEH2C, SAMHD1, TREX1,* and *IFIH1*. Heterozygous mutations have been identified in the *TREX1, ADAR,* and *IFIH1* genes, while all other reported mutations are homozygous.[11] Mutations in the *IFIH1* gene were identified in 2014[12] and are the least common pathogenic variants, whereas mutations in the *RNASEH2B* and *TREX1* genes account for the highest proportion of diagnosed Aicardi-Goutières Syndrome cases.

Homozygous mutations in the *RNASEH2B* gene, one of the most frequent variants associated with Aicardi-Goutières Syndrome, typically result in a phenotypic expression that closely aligns with the syndrome's classic presentation.[12]

While previous studies in the literature have outlined dental treatment strategies for patients with Aicardi-Goutières Syndrome, we found no reports specifically highlighting delayed tooth eruption in pediatric patients with this condition. Accordingly, the aims of this case report and literature review are (1) to provide general information about Aicardi-Goutières Syndrome to dental healthcare professionals and (2) to guide oral and dental health procedures for children with this syndrome.

Table 1. Criteria for the Diagnosis of Aicardi Syndrome [1]

Classic Triad
Agenesis of the corpus callosum (may be partial)
Chorioretinal lacunae
Infantile spasms
Major Features
Cortical malformations (mostly microgyria)
Cysts around the 3d ventricle and/or choroid plexuses
Periventricular and subcortical heterotopia
Papillomas of choroid plexuses
Optic disc/nerve coloboma
Supporting Features
Vertebral and costal abnormalities
'Split-brain' EEG (dissociated suppression-burst tracing)
Microphthalmia and/or other eye abnormalities
Gross hemispheric asymmetry

CASE REPORT

Based on the medical history obtained from the family of a 2-year-old girl diagnosed with Aicardi-Goutières Syndrome Type 2 (OMIM #610181), it was determined that the mother conceived at an advanced age, underwent a monitored pregnancy, and delivered at 38 weeks gestation and the parents were seen to be related within the third degree of consanguinity. It is known that there is no inherited metabolic disease in the family. The patient has been exhibiting frequent fevers and failure to thrive since birth. During a previous physical examination, the patient's head circumference was measured at 37 cm, consistent with microcephaly. Deep tendon reflexes were noted to be more pronounced or increased compared to normal. The patient exhibited poor head control, hypotonia, lack of eye contact and object tracking, congenital glaucoma, facial dysmorphic features, spasticity throughout the body, and a simian crease on the hands (Figure 1).

Brain MRI revealed hypoplasia of the brainstem and inferior vermis, increased distance in the retrocerebellar cerebrospinal fluid space, decreased white matter at the level of the centrum semiovale, and increased signal intensity in the remaining portion. Other findings included corpus callosum atrophy and atrophy of the cortical sulci in the hemispheres. Genetic analysis conducted on the patient at 1 year of age at the Medical Genetics Clinic of Gülhane Training and Research Hospital, University of Health Sciences, confirmed a diagnosis of Aicardi-Goutières Syndrome Type 2 with a homozygous autosomal recessive c.511G>T variant (Table 2).

Figure 1. Typical appearance of Aicardi-Goutières Syndrome

Table 2. Genetic analysis result of the patient

Gene/ Transcript	Exon	Variant	Variant Type	Zygosity	Classification	Diseases	Inheritance
RNASEH2B NM_024570.4	Exon 7	c.511G>T (p.V171F)	Splicing	Homozygous	Likely Pathogenic	Aicardi-Goutières Syndrome Type 2	Autosomal Recessive

The patient, a 2-year-5-month-old female, was brought by her guardian to the University of Health Sciences, Gulhane Faculty of Dentistry, on 17 January 2022, with the chief complaint of delayed tooth eruption. According to the medical history provided by the guardian, the patient, diagnosed with Aicardi-Goutières Syndrome, was prescribed Baclofen (Lioresal, Novartis, Basel, Switzerland) and Levetiracetam (Keppra, London, England) for the management of infantile spasms. Clinical examination revealed developmental delay and severe mental retardation. The patient was unable to hold her head up independently and required support to sit (Figure 1). Intraoral examination showed that none of the primary teeth had erupted. Due to the patient's age and limited cooperation, periapical or panoramic radiographs could not be obtained. Oral hygiene and dietary recommendations were provided to the patient's parents, and a follow-up appointment was scheduled for 6 months later.

At the 6-month follow-up (2 years 11 months), the parents reported a white lesion on the underside of the patient's tongue. Intraoral examination revealed the eruption of teeth 51, 61, 71, and 81 according to the FDI World Dental Federation notation system.[13] Trauma from the lingually erupted tooth 71 had led to the development of Riga-Fede disease. Occlusal adjustment of tooth 71 was performed, and fluoride varnish (Polimo, Imicryl, Konya, Türkiye) was applied. A subsequent follow-up session was planned for 3 months later.

At the next follow-up appointment (3 years 2 months), intraoral examination revealed the eruption of teeth 54, 55, 64, 74, 84, and 85. The erupted teeth were noted to be covered with dental plaque, likely due to a lack of mastication and increased intake of sweetened liquids. Complete healing was observed on the underside of the tongue, which had previously been affected by Riga-Fede disease. Oral hygiene instructions were reiterated, emphasizing the need for improved oral hygiene practices. Intraoral photographs and periapical radiographs were obtained according to the patient's level of compliance (Figures 2 and 3).

Figure 2. Intraoral photographs of the patient during the last follow-up session (3 years 2 months)

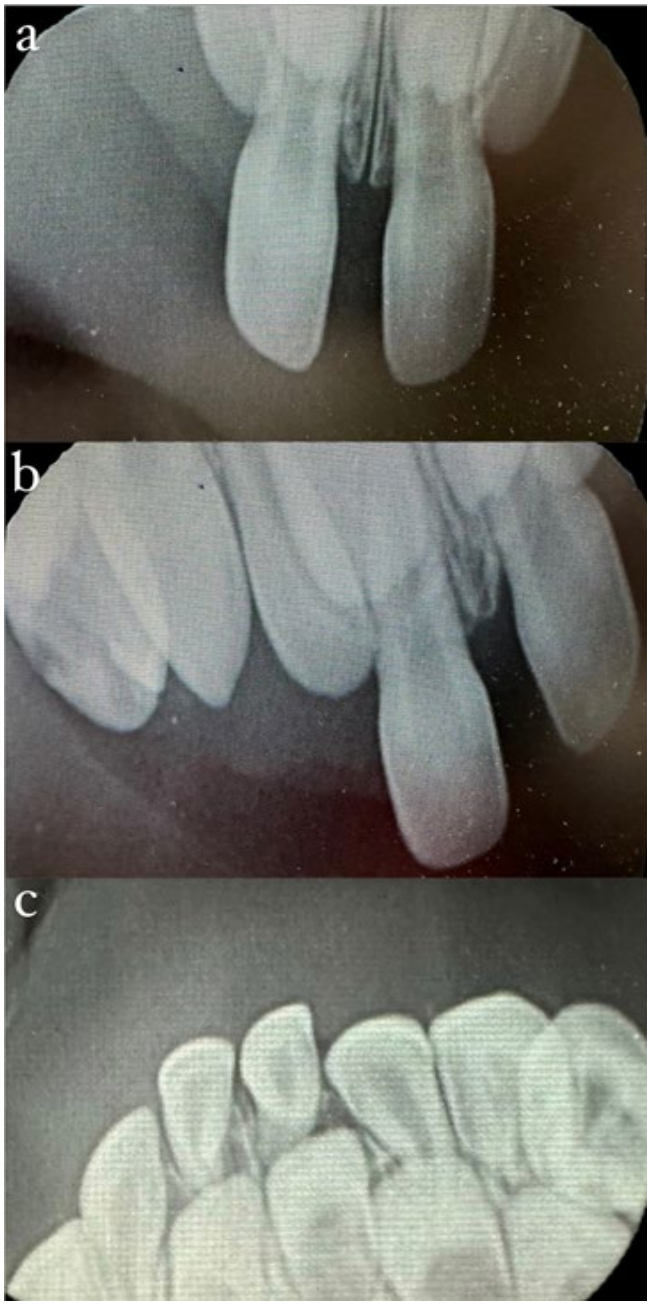

Figure 3. Periapical radiographs taken from the patient: a) Periapical radiograph of teeth 51-61; b) Periapical radiograph showing the presence of teeth 52-53; c) Periapical radiograph of the patient's anterior mandible

DISCUSSION

Aicardi-Goutières Syndrome is extremely rare, with an estimated prevalence of 1 to 5 cases per 10,000 live births.[14,15] Aicardi-Goutières Syndrome manifest in two forms: early-onsets: early-onset and late-onset. Diagnosis is based on typical clinical findings, characteristic abnormalities on cranial CT (calcifications of the basal ganglia and white matter), MRI (leukodystrophic changes), or the identification of mutations in one of seven genes (*ADAR, RNASEH2A, RNASEH2B, RNASEH2C, SAMHD1, TREX1, IFIH1*).[16,17] In the present case, homozygous mutations in the *RNASEH2B* gene, one of the most frequent variants associated with Aicardi-Goutières Syndrome, closely aligned with the classic triad of the syndrome.[12] The c.511G>T variant detected in the *RNASEH2B* gene has not been previously reported in various databases containing information on the frequency and clinical significance of genetic variants, such as dbSNP, gnomAD, ExAC, 1000G, and CLINVAR, suggesting it is likely a rare and novel mutation. Furthermore, based on a review of the literature, this is the first case report detailing the oral manifestations associated with delayed tooth eruption in a child with Aicardi-Goutières Syndrome Type 2.

Aicardi-Goutières Syndrome is a rare genetic disorder characterized by varying degrees of developmental delay and mental retardation.[18,19] Behavioral management of these patients is challenging due to their lack of cooperation. Dental treatments under general anesthesia are not recommended, given the risks associated with respiratory management and the potential for epileptic seizures.[20] These patients are often fed with liquids for prolonged periods, and factors such as hypotonia of the masticatory muscles, poor oral hygiene, and the effects of medication further compromise oral and dental health. The primary goal in managing the dental care of these patients should be the prevention of oral and dental diseases through routine intraoral examinations during early childhood and by raising parental awareness about oral health through appropriate oral health instructions.

Iwamoto et al.[21] reported a syndromic infant patient with cleft lip and palate, providing information on dental treatment approaches in this context. Another case report[4] described a 4-year-old patient with Aicardi-Goutières Syndrome who presented with acute dental pain. Intraoral examination revealed that the primary dentition was complete, but early childhood caries were observed, likely due to poor nutrition and inadequate oral hygiene. It was also noted that children with this syndrome may experience gingival inflammation, possibly as a result of medications used to manage seizures. Pathak et al.[7] documented a 3-year-old patient with Aicardi-Goutières Syndrome Type 3 who had been suffering from painful oral ulcers for over two months. Intraoral examination revealed complete primary dentition but severe early childhood caries. Literature reviews indicate that oral findings in children with Aicardi-Goutières Syndrome are limited. In these patients, it is believed that the prevalence of gingival inflammation and dental caries is increased due to the consumption of soft and liquid foods, inadequate oral hygiene habits, and the effects of medications used for seizure control. However, the recent case report differs from previous studies by offering an opportunity to evaluate the development of primary dentition in early childhood.

The eruption of primary teeth typically starts between 4 to 10 months of age. This process progresses with the appearance of approximately one new tooth each month, culminating in the near completion of all 20 deciduous teeth by the time a child is around 30 months old.[22] However, in the present case, none of the primary teeth were detected in the oral cavity at the first examination of the patient, who was 2 years and 5 months old. Although this phenomenon has not been previously reported in the literature, the delay in primary tooth eruption may be related to the developmental deficiencies observed in these syndromic patients. This paper is the first to report delayed primary tooth eruption in patients with Aicardi-Goutières Syndrome, thereby highlighting an additional aspect of the oral findings associated with this syndrome.

CONCLUSIONS

Pediatric dentists frequently encounter children who require special healthcare. The most crucial step in managing these patients is educating their guardians on oral and dental health. Ensuring the continuity of oral and dental health necessitates early and regular dental check-ups, along with strict adherence by the guardian to the dentist's oral hygiene instructions. In the present case, due to the patient's early admission, our primary goal has been to maintain oral and dental health from the moment the primary teeth erupted. The guardian has been instructed on plaque removal, which is essential due to the patient's consistent consumption of soft foods, and routine fluoride applications are repeated at each check-up session. The patient continues to attend follow-up appointments every three months. In conclusion, it is essential to recognize that pediatric dentists play a significant role in maintaining overall health in patients who require special healthcare.

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