

Silver Diamine Fluoride: Overcoming the Traditional Drill and Fill Technique in Children

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Abstract

Dental caries is a chronic, bacterial, multi-factorial dynamic process and remains a significant public health problem in children. The treatment of dental caries can be very challenging for the dentist especially in young children. Silver Diamine Fluoride (SDF) offers a non-invasive alternative for managing dental caries in children, revolutionizing traditional drill and fill technique. Its unique properties, including antimicrobial activity, remineralization potential, and desensitizing effects, make it a versatile and effective agent for addressing carious lesions and improving oral health outcomes. Plenty of clinical evidence is available including many in-vivo and in-vitro studies that have demonstrated the successful use of SDF in preventive and curative aspects of clinical dentistry. While SDF offers significant benefits, dental professionals should carefully weigh the potential risks and benefits and adhere to recommended protocols to ensure safe and effective use. With the ongoing research and advancements in SDF, it continues to hold promise as a key component of preventive and restorative dentistry strategies aimed at improving oral health and reducing the burden of dental caries worldwide.

Keywords: Dental caries, Oral health, Minimally Intervention Dentistry, Silver Diamine Fluoride, SMART, Pediatric dentistry, Drill and fill technique, Non-invasive treatment.

Introduction

Dental caries is a chronic, bacterial, multi-factorial dynamic process. An individual is never free of caries as mineralization and re-mineralization is always occurring side by side. It is only when the net mineral loss is more than mineral gain, caries is evident clinically.^[1] Dental caries remains

a significant public health problem in children. By early 1990, a completely new approach of non-operative management of dental caries was introduced which led to the development of a new term "Minimal treatment" given by Mount which was later elaborated and published as "Minimal Intervention Dentistry" by Dawson and Makinson.

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The Minimal Intervention Dentistry (MID) is a more acceptable alternative to the traditional drill and fill technique of dental caries management in children. MID focuses at maintenance of sound tooth structure using non-invasive techniques, that has replaced the conventional methods.^[2]

The treatment of dental caries can be very challenging for the dentist especially in young children with limited adaptive ability, that will require highly developed skills of the dentist and high cost of instrumentation as well. Arresting Caries Treatment (ACT) which has been proposed in the recent years to manage the untreated dental caries in children.^[3] Numerous innovative approaches and treatment modalities utilizing various silver-based products for managing dental caries in primary dentition have been introduced in dentistry, ranging from the traditional technique where the carious tissue is removed completely on the one hand and, on the other hand is a minimally invasive approach where the carious lesion is not removed at all or removed selectively.^[4]

Silver Diamine Fluoride (SDF) though not new, has made its way to a wealthy list of fluoride-based caries-preventive agents, which basically aims at controlling the activity of microorganisms present in the biofilm on the tooth and lesion surface that remains the root cause for the progression of dental caries.^[5] Silver diamine fluoride Modified Atraumatic Restorative Technique (SMART) is a special approach that combines the caries-arresting ability of the SDF and the ability of a well-placed and well-maintained high viscosity Glass Ionomer Cement (GIC) restoration to effectively seal the carious lesion, which ultimately leads to remineralization of the demineralized dentine (affected dentine). The limited co-operation of the children pertaining to their age, behaviour and disabilities makes this approach quite practical and beneficial to the dentist in arresting the advancement of an active carious lesion, which allows the dentist to buy time for more definitive treatment alternative until the child grows older. Ultimately helping the apprehensive child to cope with the dental treatment and at the same time instils a positive attitude in the child and as well as in his/her parents towards dentistry.^[6] Such treatment methods can be implemented at community level

regularly to halt the progression of dental caries to reduce its burden.

The present review is an evidence-based understanding of the use of SDF in Minimal Intervention Dentistry to manage dental caries in children and provides a comprehensive overview of its composition, mechanism of action, efficacy and safety, and its clinical significance based on the published literature.

Silver Diamine Fluoride

Silver diamine fluoride (SDF) has emerged as a promising topical agent in Minimal Intervention Dentistry due to its non-invasive nature, cost-effectiveness and unique properties in preventing and arresting caries.^[6]

SDF was first developed by Yamaga et al. at Osaka University in Japan in the 1960s. It was primarily used as a cavity liner to protect the tooth's pulp and reduce tooth sensitivity. In the 1990s and early 2000s, researchers began conducting clinical trials to investigate the efficacy and safety of silver diamine fluoride for caries management and discovered promising results, demonstrating its ability to halt the progression of cavities, particularly in primary teeth.^[7] In the United States, SDF received clearance from the U.S. Food and Drug Administration (FDA) in August 2014 for using it as a desensitizing agent. However, it was widely adopted by dentists during the 2020s and they began to use it off-label to arrest caries without the need for cavity preparation. This was particularly beneficial for young children, elderly patients, and individuals with dental anxiety. Its ease of application and cost-effectiveness further contributed to its widespread adoption. Over time, dental associations and organizations including the American Dental Association (ADA) began to recognize the potential of silver diamine fluoride in caries management. In 2021, the World Health Organization (WHO) recognized SDF as an "Essential Medicine" to treat caries. Guidelines were developed for its use in various settings, including pediatric dentistry, geriatric dentistry, and public health programs targeting underserved populations.^[8]

SDF is a colorless alkaline solution that contains silver ions, fluoride ions, and ammonia, in a liquid base of water which works synergistically to inhibit

the progression of cavities by remineralizing tooth structure and reducing bacterial activity. The typical composition of commercially available silver diamine fluoride solutions is as follows: Silver Nitrate (AgNO_3) – It is highly soluble in water and dissociates into silver ions (Ag^+) and nitrate ions (NO_3^-) when dissolved. Silver ions are believed to play a significant role in the antimicrobial properties of silver diamine fluoride; Ammonium Fluoride (NH_4F) – Ammonium fluoride serves as the source of fluoride in SDF. Fluoride ions are well-known for their ability to remineralize tooth structure and inhibit the progression of dental caries by promoting the formation of fluorapatite, a more acid-resistant form of tooth enamel; Water (H_2O) – Water is the solvent used to dissolve silver nitrate and ammonium fluoride and form SDF solution. It serves as the carrier for the active ingredients and facilitates their application to the tooth surface. Additionally, some commercial preparations may contain other minor components or stabilizers to enhance shelf-life or improve application properties.^[9]

A wide range of concentrations (w/v) of SDF are available that varies depending on the manufacturer and formulation including 10%, 12%, 30%, and 38%.^[9] Out of these the best efficacy is obtained with 38% SDF.^[11] Studies have found that post-application of 38% SDF, *Streptococcus mutans* levels reduced about 95% in 24 hours in saliva with highest reduction of about 99.95% was observed after 30 days.^[12] A high variability regarding SDF application protocol was observed i.e. from annual to bi-annually or no second application at all. Yasmi and Richard in their study have mentioned that biannual application is more effective than annual application, though for children with poor oral hygiene, the frequency of application can be increased from annual to semiannually to reduce the caries rate.^[13] In India, SDF is commonly available in 38% (w/v) concentration in a 5ml bottle under various brand names such as Caries Stop, Dengen caries arrest, Fagamin, and e-SDF.^[9]

The mechanism of action of SDF involves several processes that contribute to its effectiveness in preventing and arresting dental caries. The primary mechanisms of action of SDF include: Antimicrobial Activity^[13] – Silver ions (Ag^+) have potent antimicrobial properties as they disrupt the cell

membrane of the bacteria, inhibit bacterial enzyme function, promote dextran induced agglutination and interfere with bacterial DNA replication, ultimately leading to the death or inhibition of cariogenic bacteria such as *Streptococcus mutans* that helps to control and prevent the progression of dental caries; Inhibition of Matrix Metalloproteinases^[12]– 38% SDF has an inhibitory effect on MMP-2, MMP-8 and MMP-9 and helps in arresting caries progression; Remineralization^[14] – Fluoride ions penetrate up to 50-100 microns in dentin, interact with hydroxyapatite crystals and form calcium fluoride (reservoir for fluorapatite) and fluorhydroxyapatite that prevent decalcification of dentin and enhance its remineralization; Chemical Plugging of dentinal tubules^[15] – Silver ions released from SDF can interact with the organic matrix of dentin and form insoluble silver salts, that obturate the dentinal tubules, preventing acid invasion and diffusion. The silver ions also effectively reduce *Streptococcus mutans* in tubules due to the oligomeric action; pH Modulation^[16] – SDF can modulate the pH of the oral environment by neutralizing acids produced by cariogenic bacteria. By raising the pH and buffering acidic conditions, SDF helps to create a less favorable environment for bacterial growth and acid demineralization of tooth enamel. These properties make SDF a valuable tool for managing dental caries, particularly in population with limited accessibility to dental care or in cases where traditional restorative treatment may not be immediately feasible. Overall, the multifaceted mechanism of action of SDF makes it a versatile and effective agent for preventing, controlling, and treating dental caries in various clinical settings.^[17]

SDF has specific indications and contraindications for its use in dental practice. SDF is primarily indicated for the prevention, arrest, or treatment of active carious lesion, particularly in cases of primary teeth, teeth with limited access to restorative treatment, anxiety-prone patients, elderly patients, individuals with a high risk of tooth decay such as those with poor oral hygiene, young children, individuals with special needs, individuals with limited access to dental care, or certain medical conditions; and to alleviate tooth hypersensitivity. The various contraindications

include individuals with a known allergy or sensitivity to silver metal; ulcerative gingivitis or stomatitis due to the potential for increased discomfort or irritation; pulp and peri-radicular diseases or deep carious lesions that require immediate conventional treatment; anterior teeth as SDF causes staining of the tooth surface and can compromise the esthetic appearance. Dental professionals need to conduct a thorough examination, including clinical and radiographic assessments, to evaluate the extent and severity of dental caries before deciding on SDF application. Additionally, patient education are essential aspect of the decision-making process and informed consent/assent should also be obtained before proceeding with the application.^[16]

The SMART approach involves several steps to ensure effective and safe treatment (Figure 1). A general outline of the steps involved in the application of SDF as per the SMART approach is as follows: Firstly, isolate the tooth using cotton rolls, dental dams, or other isolation techniques and ensure moisture control. A barrier is also formed by applying petroleum jelly on the perioral area to prevent staining. Then clean the tooth surface using a toothbrush or cotton swab to remove debris, plaque, and biofilm followed by drying thoroughly with an air syringe or cotton pellet to ensure optimal adhesion of the SDF solution. Secondly, scrub the SDF solution gently and evenly onto the affected tooth surface using a microbrush or applicator tip so that all areas of the carious lesion are covered. After application, the SDF solution is allowed to remain in contact with the tooth surface for 1-3 minutes. Lastly, when a well arrested shiny dark lesion is visible, the tooth is restored with a high-viscosity Glass Ionomer cement restoration.^[6]

The patient is provided with post-treatment instructions, including recommendations for oral hygiene, dietary habits, and avoiding eating or drinking for a specified period after treatment. If necessary, additional applications of SDF may be performed during follow-up visits to maintain the effectiveness of treatment and prevent the recurrence of dental caries. The frequency of application of SDF ranges from a single application or annual application or twice per year to three times per year.^[6]

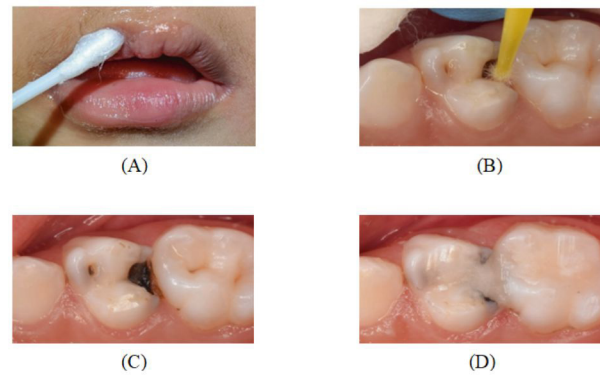


Figure 1: Illustrating the step by step application process of SDF. (A) Application of petroleum jelly to create a barrier. (B) Scrubbing SDF using a micro applicator tip on carious lesion. (C) Arrested shiny dark lesion. (D) Glass ionomer restoration post SDF application.

SDF is biocompatible with oral tissues, including enamel and dentin. Studies have demonstrated that SDF is well-tolerated when applied topically to teeth and does not typically cause significant adverse reactions or tissue damage when used appropriately. Despite its effectiveness in caries management and biocompatible nature, silver diamine fluoride can cause some adverse effects, particularly when applied inappropriately or in high concentrations. These may include dark staining of tooth surface or soft tissue such as gingiva, lips, or mucous membrane; mild irritation or discomfort if contact with soft tissues and allergic reactions to SDF that may present as itching, rash, or other signs of hypersensitivity.^[18]

In addition to potential adverse effects, there are several safety considerations associated with the use of SDF that is, it is toxic if ingested in large quantities. Therefore, dentists should take precautions to minimize the risk of ingestion by instructing patients to avoid swallowing saliva during SDF application. Moreover, dental professionals should use appropriate personal protective equipment (PPE) when handling and applying SDF.^[18]

Discussion

Various invasive and non-invasive techniques for the prevention and treatment of dental caries in children are available. Using fluoridated toothpaste is the most abundant and widespread of all and is available Over-the-counter (OTC). Other methods

include pit and fissure sealants, fluoride varnishes, hall crown technique, and conventional management of carious lesions that include elimination of caries surgically followed by replacement of tooth structure with a suitable restorative material. The interest of researchers and clinicians has emerged recently and has centered around SDF due to some of its unique features that include: ease and simplicity of use, affordability of material, minimal requirement of specialized training, less chair-side time and most importantly its minimally invasive approach.^[19]

The impact of Silver Diamine Fluoride (SDF) has been well known for many years, but it is only now that its hypothesized role as a “Caries Bullet” due to its caries detecting, arresting, and preventing capability is investigated in detail for its effectiveness in managing dental caries in children majorly in primary dentition. This hypothesized role is said to be derived from the combined effect of silver salt that stimulates the sclerotic or calcified dentin formation, silver nitrate’s germicidal potential and the ability of fluoride to reduce the decay.^[20,21,22,23,24]

Many in-vivo and in-vitro studies that have demonstrated the successful use of SDF in preventive and curative aspects of clinical dentistry. Initial clinical reports of in-vitro studies and in-vivo studies suggested that SDF may be effective in controlling dental caries.^[7,25,26,27] Results of clinical trials on suggested that SDF was substantially more effective than fluoride varnish or water in both arresting and preventing caries.^[28] Another clinical trial indicated that for both primary teeth and permanent molars, SDF was beneficial.^[29,30]

According to the available literature, SDF can be of great help in treatments such as arresting and preventing active carious lesions that can be implemented regularly at the community level to halt the progression of the carious lesion and reduce the public health burden of dental caries. Such promising results with SDF have made it to be a safe, effective, efficient, and equitable caries-preventive agent that can be used to fulfill the oral health goals in terms of the WHO Millennium Development Goals for Health.^[8]

Conclusion

Silver Diamine Fluoride (SDF) represents a transformative approach in modern dentistry for arresting, preventing, and managing dental caries, especially in apprehensive or anxiety-prone pediatric patients, offering a valuable alternative to the traditional drill and fill technique. Through its minimally invasive nature, SDF has the potential to revolutionize pediatric dentistry by shrinking the need for traumatic and invasive procedures, reducing patient discomfort, and improving treatment outcomes. SDF addresses the underlying causes of dental decay while preserving tooth structure and function by effectively arresting carious lesions due to its antibacterial and remineralizing properties. Moreover, SDF’s simplicity of application, cost-effectiveness, and wide availability make it a practical solution for addressing childhood caries in diverse clinical settings.^[17] As dental professionals increasingly recognize the benefits of SDF, its integration into clinical practice can enhance patient experiences, increase access to care, and promote preventive dentistry strategies. While SDF offers significant benefits, dental professionals should carefully weigh the potential risks and benefits and adhere to recommended protocols which includes careful patient selection, proper application techniques, and thorough follow-up to ensure its safe use and effective treatment outcomes.^[16] Additionally, research into SDF continues, focusing on optimizing its application techniques, exploring its long-term effects, and developing alternative formulations to minimize its staining effects on teeth. Also, efforts are underway to expand its availability and accessibility in regions with high rates of dental caries and limited access to dental care. With the ongoing research and advancements in SDF, it continues to hold promise as a key component of preventive and restorative dentistry strategies aimed at improving oral health and reducing the burden of dental caries worldwide.^[18]

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