



The Role of Silver Diamine Fluoride in Reducing Caries Activity in Children and the Elderly: A review

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Abstract

Silver Diamine Fluoride (SDF) has created immense interest among the dental community in recent times because of its potential to generate remineralization and its non-invasive nature of application in managing dental caries. Therefore, the authors have taken the initiative to review existing literature on SDF critically. The critical overview of the global evidence to date has been put together to provide insights into SDF. A literature search was performed in Medline database without date restrictions using relevant keywords for the synthesis of data. The bibliographic information was gathered, and relevant full-length articles were obtained for the critical overview. This overview critically summarizes the existing, published evidence for the efficacy and safety of SDF, discusses its mechanisms of action, and lays down the recommendations for its use. It also presents its indications, contraindications, risks and benefits. The overview describes caries prevention in children and elderly patients. SDF can be effectively used for caries prevention among groups such as pediatric, geriatric, special health care needs, and those that are limited in access to oral health care

Keywords: Minimally Invasive Dentistry; Primary Teeth; Silver Compounds; Dental Caries

Introduction

Dental caries is one of the most common diseases, affecting the world's population at large regardless of gender, age, and ethnicity [1]. Early Childhood Caries (ECC) affects a great majority of preschool children throughout the world. About 80% of the ECC is found in children from low income families, and it is a serious global health problem [2]. Around 35% of people have untreated caries in their permanent dentition with the numbers increasing in children, proving to be a challenging dental disease for clinicians [2]. Various approaches for caries prevention have emerged based on the evidence reported. These strategies of prevention in children and the elderly require significant financial investment and infrastructure and depend heavily on the availability of the oral health care workforce [2]. However, improved preventive efforts and treatment strategies for children and the elderly population

remain sparse as both age groups need special attention. SDF is being used to arrest dental caries in various parts of the world [3-5]. In 2015, Elevate oral care introduced "Advantage Arrest™ Silver diamine fluoride 38%" to the dental market in North America [6]. The chemistry and nomenclature for SDF (AgFH₆N₂) describes it as Silver diamine fluoride, a metal ammine complex of silver fluoride [6]. Silver material with a nanoparticle size has been recently developed, which retains the antimicrobial properties of the larger sized silver ion material without its undesired discoloring effects [7]. In the United States, the Food and Drug Administration approved SDF as fluoride to manage hypersensitive teeth [5]. Off-label use of SDF for prevention of caries is now permissible and appropriate under U.S. law [7]. In 2016 a CDT code was also approved for medicaments used in arresting caries to help with

documentation and billing [8,9]. A recent survey on the use of SDF showed that it is being adopted in training programs of graduate pediatric dentistry, and the majority are ready to incorporate it into their clinics and teaching curricula [10]. A longitudinal, pragmatic, cluster-randomized, single-blind, non-inferiority trial is going on in the state of New Hampshire in low-income rural children of public elementary schools from 2018 to 2023. This study is aimed to compare SDF's effectiveness in prevention and arrest of dental caries with a secondary objective to compare cost-effectiveness [11,12].

SDF's history and mechanism of action

The use of silver nitrate can be traced back to around 1000 AD in Japan, when it was used to blacken teeth for cosmetic purposes. Silver compounds like silver nitrate, silver sutures and silver foil have been used in the prevention and treatment of surgical, ocular, and dental infections [13]. SDF is a clear, odorless liquid used for the desensitization of non-cariou lesions [14]. 38% topical SDF was shown to be safe and was well tolerated in healthy adult volunteers [15]. A 38% SDF equivalent to 44,800 ppm fluoride ions solution is used to arrest caries of primary teeth in young non-compliant children [2,3,16,17]. In vitro studies of SDF indicate bactericidal action against *S. mutans* [18,19]. SDF slows down the demineralization of dentine [20-23]. Its clinical success could be credited to this dual action [20]. SDF is also effective in reducing the numbers of *S. mutans* in dentinal tubules [24]. Antifungal potency of SDF against *C. albicans*, *C. krusei* and *C. glabrata* was demonstrated [25]. Many in vitro studies proved the effectiveness of SDF in inhibiting dentine demineralization and collagenases such as matrix metalloproteinases and cysteine cathepsins thus preventing dentine collagen degradation [26-28]. Silver inhibits bacterial growth by interacting with the bacterial cell membrane and bacterial enzymes. Doping of silver onto hydroxyapatite has an antibacterial effect on silver doped hydroxyapatite [28]. Fluoride forms fluor hydroxyapatite and enhances mineral formation with reduced solubility [28]. The elevated levels of calcium and phosphorus significantly increase microhardness [28]. In an alkaline solution silver and fluoride combine synergistically and arrest dentinal caries [28]. Post intervention using 38% SDF showed reduced relative abundance of microbial profiles of plaque biofilms of cervical caries in some acid producing species [29,30].

The histologic examination of the primary human tooth with deep caries and six months after being treated with SDF showed the formation of tertiary dentin, a flattened odontoblastic layer, dentinal tubules with silver deposits up to a depth of 1mm without any bacteria, a pulp without marked inflammation, and no carious pulp exposure [31]. In vitro study on primary dentition showed that SDF is efficient in preventing the demineralization of teeth [32]. Studies indicate the formation of silver-enriched barriers surrounding the carious lesions [33]. Spectrum analysis of the lesions treated

with SDF identified the following elements silver, calcium, carbon, oxygen, phosphorus, and chlorine [33]. Additionally, zinc, sodium, aluminum, magnesium, sulfur, fluorine, and silicon were detected as the minor elements. Such observations provide sources of new evidence for defining the mode of action of SDF in arresting caries [33]. SDF at a concentration of 38%, 30%, and 12% inhibits the activity of cathepsin B and K that causes caries progression through collagen degradation [34]. Ex-vivo study after SDF application showed highly remineralized zone rich in calcium and phosphate on the arrested cavitated lesion which protects the collagen [23,35]. Fluor hydroxyapatite was produced when SDF reacted with calcium and phosphate ions. This is one of the key mechanisms that brought about the arrest of caries by reducing the solubility of the region [36]. SDF was suggested as a potential indirect pulp capping material due to its remineralizing efficacy [36]. SDF's use as a drill less dental filling has been mentioned [37-40].

SDF in caries prevention and reduction

Atraumatic management of carious lesions by way of using minimally invasive techniques have been proposed [9,27,41-44]. A prospective, controlled clinical trial was conducted in Chinese pre-school kids to study the effectiveness of topical fluoride applications in arresting dentinal caries by using a solution containing 44,800 ppm of SDF and 22,600 ppm of NaF annually [45]. SDF was found to be effective in arresting dentinal caries in primary anterior teeth in pre-school children [46] and secondary caries prevention in primary teeth [40]. Two double blind randomized placebo-controlled superiority trials with two parallel groups showed the application of topical 38% SDF to be effective and safe in arresting cavities in preschool children [47,48]. A prospective controlled clinical trial on the deciduous teeth among six-year-old school children found that SDF reduced caries in primary teeth and first permanent molars [49]. In cases where restorative treatment for primary teeth was not available 38% SDF proved effective [50]. Randomized clinical trials in preschool children showed the arrest of active dentine caries and suggested an application frequency of six to twelve months among children with poor oral hygiene [48,51-58]. Many systematic reviews were performed to understand the effectiveness of SDF in comparison to fluoride varnish for prevention of caries and concluded that SDF is more effective than fluoride varnish and proved to be a valuable caries preventive intervention [13,59-63].

SDF is a safe, efficient, and effective caries preventive agent and can fulfill the criteria of the WHO millennium goals as well as US institute of medicine's standards for 21st-century medical care [5,13,52,62]. Many meta-analyses were performed to understand the efficacy of SDF in the prevention of caries progression [64-72]. Chu CH. et al. [4] found that 38% SDF arrested dentine caries, and the overall proportion of arrested caries was 65.9 % among five studies. Other systematic reviews showed 38%, 30% and 10% of

SDF to arrest caries in primary teeth and showed 81% of arrested caries [65-67]. Chibinski et al. [68] found that the use of SDF is 89% more effective in arresting caries than other treatments or placebos [68]. Gugnani N et al. [69] found that 38% SDF is effective in arresting active dentine caries [69-72]. The study of [13] has shown limited quality patient-oriented evidence [73]. SDF treatment is a promising strategy in managing dental caries in young children and those with special needs [65,74-77]. SDF should form an essential addition to every dentist's armamentarium [61]. SDF is more effective in controlling caries in children than atraumatic restorative treatment or fluoride varnish [78,79]. Chu CH et al. reported a successfully treated case of severe rampant dental decay in a young teenager using SDF [80]. A study on the stability of silver and fluoride cautioned clinicians to replace the cap immediately and use it as soon as it is dispensed [81]. Because the drops are larger than expected, and each drop delivers higher quantities of silver and fluoride than expected [81].

Caries prevention in the elderly with SDF

This part of the review also considered caries prevention in the elderly as root caries is prevalent in institutionalized elders, emphasizing the need for effective prevention methods. A randomized trial performed in elders on root caries has shown that SDF solution, sodium fluoride varnish, and chlorhexidine varnish were more effective than Oral Hygiene Education (OHE) [82]. A controlled clinical trial investigating the aspects of preventing and arresting root caries among community dwelling elders showed that once a year application of SDF along with OHE every six months was effective in arresting root caries [83]. Gugnani N et al. [84] literature review showed that 38% Silver diamine fluoride is effective in the prevention of root caries and recommended it as a "best choice" solution if professionally applied annually [84]. A randomized, double-blind, placebo-controlled clinical trial showed that SDF is simple, low-cost, and a promising intervention for arresting proximal surface caries [85]. A survey on the perceptions of SDF as a therapeutic agent for the treatment of dental caries [86] in underserved populations by registered dental hygienists showed that 85% of them felt it advantageous [87]. SDF is used to arrest and prevent new caries so that it maintains fixed and removable prostheses and supporting teeth cost-effectively in medically compromised, xerostomic, elderly patients. It is a medical management approach used successfully in those patients [88]. Homebound populations in the state of New Hampshire reported a positive experience and satisfaction with care received from certified public health dental hygienists using SDF [89]. Many systematic reviews evaluated the use of SDF for both root caries prevention and arrest in older adults showed the effective prevention and arrest in root caries, remineralization of deep occlusal lesions and treatment of hypersensitive dentin [90-95]. An in vitro study showed conditioning of teeth with 38% SDF can

increase the resistance of glass ionomer cement and composite restorations to secondary caries [96,97]. The use of SDF is rapid, inexpensive and non-threatening. It is suitable for treating frail elders, dementia patients exhibiting challenging behaviors and patients with multiple rapidly progressing decay [86,98-100]. A detailed guide for its application has been provided [101-103]. SDF application positively influences enamel and dentine remineralization [23,104]. It showed improvement in the retention of a fissure sealant along with decreased microleakage and increased micro tensile bond strength of adhesives [105,106].

Disadvantages and contraindications associated with the application of SDF

The use of SDF in anterior teeth remineralization makes it unsuitable due to staining [107]. Use of Potassium Iodide (KI) with SDF showed a lower intensity of discoloration than that occurred solely with SDF treatment [108,109]. The onset of black staining occurred within two minutes and increased up to six hours post-application of SDF irrespective of SDF concentrations [110]. Less staining of the carious dentine or surrounding enamel was noted when KI was used immediately after SDF [110,111]. Therefore, clinicians need to understand the staining effect of SDF and parental sensitivities for the use of SDF in pediatric patient's caries management [42,112-115]. A study on parental perceptions and acceptance of SDF use in Saudi Arabia showed the use of SDF was rejected due of staining. Clinicians are cautioned to provide proper informed consent along with clear photographs showing discolorations prior to treatment [116]. SDF use is contraindicated when immediate invasive action is required for the intended tooth like pain, infection, or sepsis, and where there is no readiness to change behaviors that lead to the development of the disease in the first place [117].

Consensus on the use of SDF

A national survey to assess U.S. pediatric dentists' education, knowledge, attitudes, and professional behavior for the use of SDF showed positive attitudes towards the use of SDF [118]. 31% of the respondents used SDF often to arrest carious lesions in primary teeth, and 87% expected increased future use of SDF [118]. For restorations on children with behavioral issues, the medically frail or with severe dental anxiety SDF was regarded as an excellent treatment alternative [118]. A survey on the use of SDF in U.S. dental schools showed that SDF use is increasing rapidly in the U.S. and its adoption in most dental schools [119]. When esthetics is not a primary concern, SDF can prove to be a valuable tool in caries management [120]. Depth of visibility of the staining and the location of the cavities seem to play a major role in its acceptance [114]. In a scoping review on the esthetic perception, acceptability and satisfaction using SDF it was concluded that parents were satisfied with and found SDF acceptable [115,121,122]. Caregiver

acceptance of SDF treatment was found to be high in a survey of caregiver acculturation and acceptance. The child's age and comfort of the caregiver play a prominent role in its approval [123,124]. U.S born caregivers had more approval than the non-U. S born caregivers [123]. Projection of economic impact study in the US showed that SDF is much more economical than the restorative treatment options in children among 1-5 years of age [125,126]. A novel intervention utilizing physician applied SDF in a primary care "Cavity Clinic" strategy in the US showed that it is feasible to prevent early childhood caries and suggested for partnership with an on-site hygienist but physician only sessions were still beneficial [127]. Determinants for implementation of SDF protocol include characteristics like the dental clinic's environment, the dental clinics themselves combined with the personality and training of dental staff [128].

Conclusion

SDF can be safely and effectively used to manage caries in primary dentition in children and the root caries in the elderly. In spite of the short comings in terms of esthetics, SDF has proven to be beneficial in caries management especially in populations having limited access to dental treatments such as in children who are difficult to manage or the elderly populations at the nursing homes. The recent pandemic has challenged the dental community in a multitude of ways and minimally invasive treatments were the only caries management options available for several months across the world. SDF was used as a major caries management technique during that period due to its efficacy and ease of use. Now more than ever a need has arisen to stabilize the carious lesions from progressing until comprehensive treatment can be performed. The authors encourage the members of the dental community to consider SDF as part of their caries management program due to its inherent advantages and its unique applicability to certain clinical situations.

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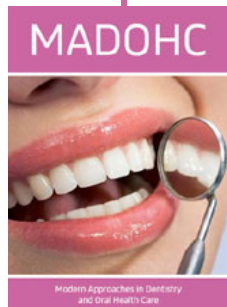
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