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Silver Diamine Fluoride (SDF): The Miracle Fluid

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Abstract

Although there has been a decrease in the prevalence and the severity of dental caries in children over the past few decades, still, various studies in literature worldwide report high prevalence of dental caries. Traditional restorative methods for treating dental caries are not always affordable or possible, as it requires patient cooperation for desirable outcome. To overcome this problem, Silver diamine fluoride (SDF) was first promoted in Japan in late 1960's. The antimicrobial effect of silver compounds has been proven by the 100-year-old application of silver compounds for the prevention and treatment of various infections. Now in many countries a 38% (44,800 ppm fluoride) SDF solution is commonly used to arrest caries and to reduce hypersensitivity. Application of SDF to arrest dental caries is a non-invasive procedure that is quick and simple to use. When SDF is applied on carious lesions, the fluoride enhances remineralization and the silver ions act as an antibacterial agent and inhibit the growth of cariogenic biofilms. However, it has certain drawbacks like black discoloration of the carious teeth and an unpleasant metallic taste. But, the low cost of SDF and its simplicity in application suggest this as a novel preventive agent in public dental health projects.

Keywords: Silver diamine fluoride; Silver; Dental caries; Preventive dentistry.

Introduction

Dental caries is the quotidian pandemic, inflicting all ages of the world's population.[1] Dental caries is a bacterial driven, generally chronic, site-specific, multifactorial, dynamic disease process that results from the imbalance in the physiologic equilibrium between the tooth mineral and the plaque fluid; that is, when the pH drop results in net mineral loss over time.[2]

However, research has shown that caries can be prevented or arrested by timely approach and action. Multitude of evidence-based approaches for caries prevention have been reported; however, these strategies demand significant financial investment and depend on the availability of oral health workforces and facilities.[3]

Preventive measures include the use of fluoride varnish—such as 5% sodium fluoride (NaF)—and the use of fluoridated toothpaste[4–7]and atraumatic

restorative treatment (ART). ART is painless, low cost, and can be applied outside the clinical setting or when conventional treatment is not available. High rate of failure is one of the major drawbacks of Silver topical products, such as silver nitrate.[8]

SDF have been used in Japan for over 40 years to arrest caries and reduce tooth hypersensitivity in primary and permanent teeth. During the past decade, many other countries such as Australia and China have started using this compound with similar success.[9,10]

The exact mechanism of SDF is not well demarcated. It is predicted that fluoride ions act mainly on the tooth structure, while silver ions, like other heavy metals, exert antimicrobial action. Further, SDF reacts with hydroxyapatite in an alkaline environment to form calcium fluoride (CaF_2) and silver phosphate as major reaction products. CaF_2 provides a fluoride reservoir to form fluorapatite which is less soluble than hydroxyapatite in an acidic environment.[11,12]

Nevertheless, the black staining of the lesions associated with the application of SDF is inevitable. In the United States, SDF is marketed as 38 percent silver diamine fluoride which is equivalent to five percent fluoride in a colorless liquid, with a pH of 10. SDF reportedly also has approximately 2–3 times more fluoride retained than delivered by sodium fluoride, stannous fluoride, or acidulated phosphate fluoride (APF) commonly found in foams, gels, and varnishes.[13] Also, SDF has not been shown any deterrent effect on adhesion of resinor glass ionomer restorative material[11,14,15]

SDF has shown promising results in a horde of studies. Thus, this systematic review is an attempt to provide an insight to mechanism and effectiveness of SDF in preventive and therapeutic dentistry.

Method of literature search

A literature search of PubMed®/MEDLINE and Google Scholar databases were conducted using the terms: diamine silver fluoride and caries, and silver diamine fluoride. A total of around 83 articles were found. Inclusion criteria were all *in vivo* and *in vitro* studies in which SDF was used as a study group as well as review articles on SDF. Exclusion criteria were: early reports of longer studies, editorials, (with exceptions of few articles in Chinese and Japanese journals that included early study and history of SDF).

Milestones of SDF

Silver (Ag) has been documented to be used for medicinal purposes dating back to 1000 bc for storage of water.[16] Before silver diamine fluoride (SDF), silver nitrate followed by fluoride varnish was the only noninvasive option available for caries treatment.[17] Case series of carious lesions arrested by silver nitrate date to the 19th century, where 87 of 142 treated lesions were arrested.[18]
Around AD 1000, in Japan, there was a custom among the ladies to dye their teeth black called "Ohaguro," for expressing married. Although, it was tooth cosmetics, ought to prevent dental caries.[19]
SDF has been accepted as a therapeutic agent by the Central Pharmaceutical Council of the Ministry of Health and Welfare in Japan for dental treatment since the 1960s.[20]
Craig *et al*. reported that AgF solution was used in dentistry as early as the 1970s.[21]
In 1891, silver amalgam and nitric acid was used on carious teeth and had caries arresting properties[18] Silver nitrate was directly applied to carious cavities with analogous outcomes, and it was termed as Howe's solution, which was used for caries inhibition.[22]
A solution of 38% SDF was also used in China to arrest caries.[23]
Also, a few dentists in Southern California who used SDF to arrest caries of young children with earlychildhood caries.[24]
SDF has been widely used in Australia and Brazil since 1980 with *in vivo* studies done in the respective countries.[25,26] Interest in SDF has resurfaced in recent times with several studies proving its effectiveness in preventing and arresting caries in the primary dentition and first permanent molar in children.[27–32]
The need for anticaries agents such as SDF is perhaps best understood in terms of the World Health Organization (WHO) Millennium Development Goals for Health and particularly oral health.[33]
In Western Australia, 40% silver fluoride (AgF) was applied as the treatment for deep dental caries in primary teeth at school dental care services.[19]
For past few decades, SDF has also been in used in Australia and China to prevent dental decay.[34,35]
SDF has been used in many community dental health programs in various concentrations has been used in Argentina, Brazil and Spain; and additionally community health programs were designed for sub-Saharan Africa and for other countries of Africa.[36]
In 2005, SDF was approved by the US Food and Drug Administration for management of tooth hypersensitivity.[37]
Its extensive use started in China in start of 21st century as a caries arresting agent in school going children.[13,29]
From 2005 to 2009 in Australia, a series of in vitro studies were conducted and proved effect of SDF on *Streptococcus mutans* and dental bio-film as acaries arresting and antimicrobial agent respectively.[38–41]
In 2013, SDF was used to prevent root caries in elderly.[42]
Studies were conducted in India providing literature of successful use of SDF as a caries arresting agent.[43,44]
A study in 2018 found that SDF was successful in arresting active caries in primary teeth of young children in USA and was also well received by their parents.[45]

Mechanism of action of silver

Multiple modes of action have been proposed for silver. Studies have indicated that silver interacts with sulfhydryl groups of proteins and with deoxyribonucleic acid (DNA), altering hydrogen bonding and inhibiting respiratory processes, DNA unwinding, cell-wall synthesis, and cell division.[23,46] At the macro level these interactions effect bacterial killing and inhibit biofilm formation.[47]

Three possible mechanisms of action of SDF on caries as described by Shimizu and Kawagoe are:[49]

1. Obturation of dentinal tubules.

   It has been proven that invasion of dentinal tubules by microorganisms is the hallway for caries, thus obturation of these organic roads can lead to prevention of dental caries[50] Shimizu evinced that dentin treated with SDF showed increased electric resistance and decreased dye permeability[52] because silver and its compounds blocked the peritubular and intertubular dentin, oligodynanamic action of silver lead to inhibition of microgroorganisms[52,53] demonstrated that the use of 38% SDF inhibited demineralization and preserved collagen from degradation in demineralized dentin.

2. Cariostatic action of the reaction products between SDF and mineral component of the tooth.

   F^- ion of SDF applied to dentin under *in vivo* conditions penetrated to a depth of 50–100 μ.[54,55] It has been reported that SDF ($Ag(NH_3)_2F$) reacts with the tooth mineral hydroxyapatite (HA)($Ca_{10}(PO_4)_6(OH)_2$) to release calcium fluoride (CaF_2) and silver phosphate (Ag_3PO_4), which are responsible for the prevention and hardening of dental caries. A simplified chemical reaction was suggested as shown below[12,13]

   $Ca_{10}(PO_4)_6(OH)_2 + Ag(NH_3)_2F \rightarrow CaF_2 + Ag_3PO_4 + NH_4OH$

   $CaF_2 \rightarrow Ca^{++} + 2F^-$

   $Ca_{10}(PO_4)_6(OH)_2 + 2F^- \rightarrow Ca_{10}(PO_4)_6F_2 + 2OH^-$

3. Antienzymatic actions of the reaction products between $Ag(NH_3)_2F$ and organic component of the tooth.

   Its antibacterial properties arise from inhibition of the enzyme activities and dextran-induced agglutination of cariogenic strains of *Streptococcus mutans*.[56] Sunada *et al*.[57] found that dentin, which had been treated with $Ag(NH_3)_2OH$ by ionophoresis increased in resistance to trypsin and stated that it-might beowing to reaction of Ag and organic component of dentin. Yanagida *et al*.[58] showed that dentin protein treated with $Ag(NH_3)_2F$ had increased in resistance to collagenase and trypsin. These actions of Ag and$Ag(NH_3)_2F$ to organic component of the tooth may also be contribute to inhibit caries.

   Suzuki *et al*.[56] studied the mechanism of antiplaque action of diamine silver fluoride [$Ag(NH_3)_2F$] and indicated that silver ion may inhibit the colonization of *S. mutans* on enamel surface and offer apossible explanation for the antiplaque action of the agent. It was also shown that the binding of glucan to HA was inhibited by the treatment of HA with fluoride solution, but was slightly promoted by that with silver solution. The adsorption of salivary proteins by HA was inhibited by the treatment of HA with $Ag(NH_3)_2F$. This was due to both fluoride and silver ions. Thus, the potential to inhibit the *S. mutans* is more for SDF than any other fluoridated solution.

   Also, Mei *et al*. (2013) mentioned that 38% SDF inhibits multi-species cariogenic biofilm formation on dentin carious lesions and reduces the demineralization process.[54] Suzuki *et al*. showed that after SDF application, fluoride ions penetrated the enamel diffusely to about 25 μ, whereas silver ions were mainly deposited on the surface and some penetrated as far as 20 μ into the enamel.[59]

Clinical applications of Silver Diamine Fluoride

Prevention and arrest of early childhood caries

Conventional treatment of early childhood caries in young children is an arduous task due to behavioral issue and lack of cooperative ability.

Hence, majority of patients are left untreated, causing premature loss of teeth paving them to cause psychological trauma, and hamper the timely eruption and normal occlusion in permanent teeth. From such point of view, the application of silver diamine fluoride, caries can be arrested, and above-described problems can be vanquished.[60]

Once the carious process is halted, caries removal can be postponed to later stage when the child has the cooperative ability. SDF can be easily applied without any complicated tools and equipment, this allows treatment for children by allied staff under supervision in non-clinical environments, like outreach services in kindergartens, thus prevention at mass level.[11]

Various studies mentioned below supports this implication. Hihara *et al*.[61] in Japan, McDonald and Sheiham[62] in London, Llodra *et al*. in Cuba,[29] Braga *et al*. in Brazil[41] in Nepal found that SDF is significantly effective in arresting the cavitated as well as incipient carious lesions.

SDF is a colorless solution that can be applied on a tooth surface with a tiny applicator or brush. The concentration of SDF in commercial preparations varied from 3.8% to 38%. Preparation of 3.8% is specifically formulated for root canal treatment while 38% SDF is recommended for arrest of caries.[60]

To prevent pit and fissure caries

Owing to the morphology and inaccessibility to clean, pits and fissures have higher susceptibility to dental caries. For the same reason, the topical fluoride application is revealed to be less effective for the prevention of the pit and fissure caries than that of the smooth surface. Due to its antibacterial and caries preventive property SDF has shown to be effective in the prevention of pits and fissures caries of the first molar teeth.[63]

In an another study by Nishino and Massler, caries score of $Ag(NH_3)_2F$ treated teeth was significantly lower than the fissures treated with 8% SnF_2 or $Ag(NO)_3$.[64]

Since SDF application also produces grayish black stain similar to incipient caries, recording of SDF application is mandatory.[65]

To prevent secondary caries

For many decades, true adhesion has been the conundrum of dental restorative materials. No matter how much the restorative material adhere to the tooth structure completely; bacteria and food debris can always escape between the cavity walls and the restorative materials, making them more prone to recurrent caries. Thus, the resistance of cavity wall must be enhanced to prevent secondary caries.[66]

SDF application on the cavity walls prior to amalgam restoration in primary teeth leads to complete eradication of recurrent caries for 26 months.[49] While SDF has shown no adverse effect on bonding of composite resin,[67] showed 50% decrease in dentin bond strength of GIC.[68]

SDF reduced dentin bonding strength of resin based crown cement by ~1/3.[69] As a result, rinsing is advised for direct restorations, while removal of the SDF treated superficial dentin is recommended for cementing crowns.

To arrest root caries

Myriad of studies have mentioned increased incidence and prevalence of root caries with declining years.[70–73] SDF, due its ability to arrest dental caries, annual application has been found to be quite effective in arresting root surface caries.[42,74]

To desensitize sensitive teeth

Gottlieb,[50] suggested that the mechanism of arresting the dental caries is similar to that of desensitizing the hypersensitive dentin. Hence, SDF, owing to its ability to occlude dentinal tubules can be used to eliminate hypersensitivity.

A study by Kimura *et al*.[75] revealed that SDF was successful in eradicating sensitivity caused by erosion and abrasion. It was found that no more than four times application is needed for desensitizing effect.

To treat infected root canals

Tanaka conveyed that an aqueous solution of AgF has powerful disinfectant, protein-coagulation action; and occludes the dentinal tubules of root canal wall in terms of the electric resistance.[76] It has been mentioned that 3.8% SDF can be used as an eloquent root canal irrigant effectively exterminates the microbes present in the canal and circumpulpal dentin.[77,78]

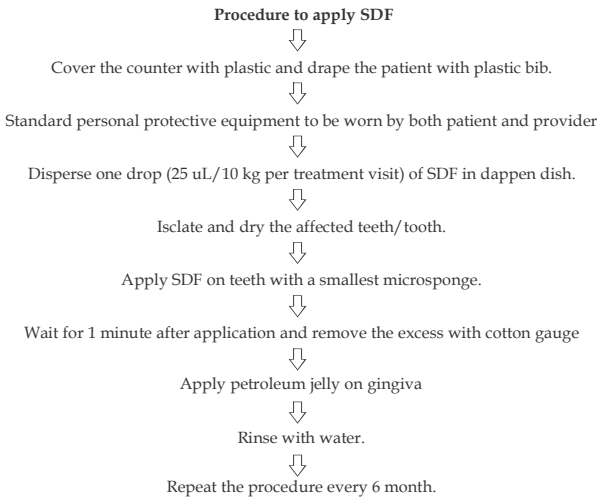
As an indirect pulp capping agent

As described by Yamaga *et al*., if SDF is applied in the presence of softened dentin, it will arrest the subsequent progress of dental caries.[12]

SDF application in the presence of softened dentin has shown to arrest the progress of carious lesion. An *in vitro* study by Gupta *et al.*, manifested highest zone of bacterial inhibition around SDF.[79]

Besides, an *in vivo* study quoted that SDF has remineralizing, re-hardening and antimicrobial virtue; thus, it can prove to be a prudent material for Indirect Pulp Capping.[80]

Procedure[81]



Safety margin[81]

- Average LD_{50} by oral administration is 520 mg/kg, and by subcutaneous administration is 380 mg/kg. One drop (25 μL), adequate to treat 5 teeth contains 9.5 mg SDF.
- Presume that the child patient is of 10 kg, the dose would be 0.95 mg/kg child.
- Hence, the relative safety margin of utilizing a full drop on a 10-kg child is: 380 mg/kg
- LD_{50}/0.95 mg/kg dose = 400-fold safety margin.

Unfavourable consequences[81]

- Among various interventional studies only a small, mildly painful white lesion in the mucosa which disappeared after 2 days without treatment, has been revealed.[13,29,30,42]
- SDF causes darkening of the carious lesions.
- Patients may combat a short-term metallic or bitter taste.
- Little amount of SDF can result in "temporary tattoo" on skin with no harm. Stain on the skin fade away with the natural skin depilation, in 2–14 days.
- SDF stains the clinic surfaces and clothes. Spills should be cleaned up immediately with copious water, ethanol, or bleach.

Conclusion

Biannual application of 38% SDF has shown promising results over other minimal invasive techniques. Also, it is easy to use with minimal side effects and wide array of safety margin. Nevertheless, it is obscure to predict the long-term outcome of such lesions. Further clinical trials are recommended to establish the same.

References

1. Subbiah GK, Nithin Gopinathan NM. Is Silver Diamine Fluoride Effective in Preventing and Arresting Caries in Elderly Adults? A Systematic Review. J Int Soc Prev Community Dent. 2018;8(3):191–199.
2. Shah S, Bhaskar V, Venkatraghavan K, *et al*. A Review and Current Applications. Journal of Advanced Oral Research. 2014;5(1):25–35.
3. US Department of Health and Human Services, National Institute of Dental and Craniofacial Research, National Institutes of Health; 2000. Chapter 9: provision of oral health care. Last updated March 7, 2014.
4. Weintraub JA, Ramos-Gomez F, Jue B, *et al*. Fluoride varnish efficacy in preventing early childhood caries. J Dent Res. 2006;85(2):172–76.
5. American Dental Association Council on Scientific Affairs. Professionally applied topical fluoride: evidence-based clinical recommendations. J Am Dent Assoc. 2006;137(8):1151–59.
6. American Academy of Pediatric Dentistry. Policy on Early Childhood Caries (ECC): classification, consequences, and preventive strategies. Pediatr Dent. 2014;37(6):50–52.
7. Walsh T, Worthington HV, Glenny AM, *et al*. Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. 2010;(1):CD007868.
8. Contreras V, Toro MJ, Boneta AR, *et al*. Effectiveness of silver diamine fluoride in caries prevention and arrest: a systematic literature review. Gen Dent. 2017;65(3):22–29.
9. Mei ML, Zhao IS, Ito L, *et al*. Prevention of secondary caries by silver diamine fluoride. Int Dent J 2016;66(2):71–77.
10. Zhao IS, Gao SS, Hiraishi N, *et al*. Mechanisms of silver diamine fluoride on arresting caries: a literature review. Int Dent J. 2018;68(2):67–76.
11. Fung MHT, Wong MCM, Lo ECM, *et al*. Arresting early childhood caries with silver diamine fluoride: A literature review. J Oral Hyg Health. 2013;1:117.
12. Yamaga R, Nishino M, Yoshida S, *et al*. Diammine silver fluoride and its clinical application. J Osaka Univ Dent Sch. 1972; 12:1–20.

13. Chu CH, Lo EC, Lin HC. Efectiveness of silver diamine fluoride and sodium fluoride varnish in arresting dentin caries in Chinese pre-school children. J Dent Res. 2002;81(11):767–70.
14. American Academy of Pediatric Dentistry. Policy on use of fluoride. Pediatr Dent. 2018;40(6):49–50.
15. Han L, Okiji T. Dentin tubule occluding ability of dentin desensitizers. Am J Dent. 2015;28(2):90–94.
16. Russell AD, Hugo WB. Antimicrobiological activity and action of silver. Prog Med Chem. 1994;31:351–70.
17. Duffin S. Back to the future: The medical management of caries introduction. J Calif Dent Assoc. 2012;40:852–8.
18. Stebbins EA. What value has argentinitras as a therapeutic agent in dentistry? Int Dent J. 1891;12:661–70.
19. Yamaga R, Yokomizo I. Arrestment of caries of deciduous teeth with diamine silver fluoride. Dental Outlook. 1969 33:1007–1013.
20. Zhi QH, Lo EC, Lin HC. Randomized clinical trial on effectiveness of silver diamine fluoride and glass ionomer in arresting dentine caries in preschool children. J Dent. 2012;40:962–7.
21. Craig GG, Powell KR, Cooper MH. Caries progression in primary molars: 24-month results from a minimal treatment programme. Community Dent Oral Epidemiol. 1998;19:260–65.
22. Howe PR. A method of sterilizing and at the same time impregnating with a metal affected dentinal tissue. Dent Cosmos. 1917;59:891–904.
23. Lansdown AB. Silver in health care: antimicrobial effects and safety in use. CurrProbl Dermatol. 2006;33:17–34.
24. Duperon DF. Early childhood caries: a continuing dilemma. J Calif Dent Assoc. 1995;23:15–25.
25. Gotjamanos T. Silver fluoride use. Aust Dent J. 1997;42:138.
26. Almeida IC. Evaluation of the Cariostatic, Anticariogenic and Anti-Microbial Effect of 12 Percent Silver Diaminefluoride Solution (BIORIDE) in Children from 5 1/2 to 6 Years Old. Dissertation, Univ. of Sao Paulo, Bauru, Brazil. 1994.
27. Fung MH, Duangthip D, Wong MC, *et al*. Randomized clinical trial of 12% and 38% silver diamine fluoride treatment. J Dent Res. 2018;97:171–8.
28. Lo EC, Chu CH, Lin HC. A community-based caries control program for pre-school children using topical fluorides: 18-month results. J Dent Res. 2001;80:2071–4.
29. Llodra JC, Rodriguez A, Ferrer B, *et al*. Efficacy of silver diamine fluoride for caries reduction in primary teeth and first permanent molars of schoolchildren: 36-month clinical trial. J Dent Res. 2005;4(84):721.
30. Yee R, Holmgren C, Mulder J, *et al*. Efficacy of silver diamine fluoride for arresting caries treatment. J Dent Res. 2009;88:644–7.
31. Zhi QH, Lo EC, Lin HC. Randomized clinical trial on effectiveness of silver diamine fluoride and glass ionomer in arresting dentine caries in preschool children. J Dent. 2012;40:962–7.
32. Hobdell M, Petersen PE, Clarkson J, *et al*. Global goals for oral health 2020. Int Dent J. 2003;53:285–8.
33. Gotjamanos T. Pulp response in primary teeth with deepresidual caries treated with silver fluoride and glass ionomer cement ('atraumatic' technique). Aust Dent J. 1996;41:328–34.
34. Li YJ. Effect of a silver ammonia fluoride solution on the prevention and inhibition of caries. Zhonghua Kou Qiang Ke Za Zhi. 1984;19:97–100 [in Chinese]
35. Bedi R, Infirri JS. Oral Health Care in Disadvantaged Communities. London: FDI World Dental Press, 1999.
36. Rosenblatt A, Stamford TCM, Niederman R. Silver Diamine Fluoride: A Caries "Silver Fluoride Bullet". J Dent Res. 2009; 88:116–25.
37. Knight GM, McIntyre JM, Craig GG *et al*. An in vitro model to measure the effect of a silver fluoride and potassium iodide treatment on the permeability of emineralized dentine to *Streptococcus mutans*. Aust Dent J. 2005;50: 242–5.
38. Knight GM, Mclntyre JM, Craig GG *et al*. Ion uptake into demineralized dentine from glass-ionomer cement following pretreatment with silver fluoride and potassium iodide. Aust Dent J. 2006;51:237–41.
39. Knight GM, Mclntyre JM, Craig GG *et al*. Differences between normal and demineralized dentine pretreated with silver fluoride and potassium iodide after an in vitro challenge by *Streptococcus mutans*. Aust Dent J. 2007;52:16–21.
40. Knight GM, Mclntyre JM, Craig GG *et al*. Inability to form a biofiim of *Streptococcus mutans* on silver fluoride- and potassium iodide treated demineralized dentin. Quintessence Int. 2009;40:155-61.
41. Braga MM, Mendes FM, Benedetto MS. Effect of silver diammine fluoride on incipient caries lesions in erupting permanent first molars: a pilot study. J Dent Child. 2009;76:28–33.
42. Zhang W, McGrath C, Lo EC, *et al*. Silver diaminefluoride and education to prevent and

arrest root caries among community-dwelling elders. Caries Res. 2013;47(4):284–90.

43. Shah S, Bhaskar V, Venkataraghavan K, *et al*. Efficacy of silver diamine fluoridеas an antibacterial as well as antiplaque agent compared to fluoride varnish and acidulated phosphate fluoride gel: An in vivo study. Indian Journal of Dent Res. 2013;24(5):575.
44. Gugnani N, Gugnani S. Remineralisation and arresting caries in children with topical fluorides. Evidence-based Dent. 2017;18(2):41.
45. Clemens J, Gold J, Chaffin J. Effect and acceptance of silver diamine fluoride treatment on dental caries in primary teeth. J Pub Health Dent. 2018;78(1):6–8.
46. Lansdown AB. Silver I: Its antibacterial properties and mechanism of action. J Wound Care. 2002;11:125–30
47. Wu MY, Suryanarayanan K, van Ooij WJ, *et al*. Using microbial genomics to evaluate the effectiveness of silver to prevent biofilm formation. Water Sci Technol. 2007;55: 413–19.
48. Russell AD, Hugo WB. Antimicrobiological activity and action of silver. Prog Med Chem. 1994;31:351–70.
49. Shimizu A, Kawagoe M. A clinical study of diamine silver fluoride on recurrent caries. J Osaka Univ Dent Sch. 1976;16:103–09.
50. Gottlieb B. Dental Caries. Philadelphia: Lea & Febiger, 1947:222–36.
51. Shimizu A. Effect of diammine silver fluoride on recurrent caries. Jap. J. Conserv. Dent. 1974;17:183–201.
52. Yamaga R. Mechanisms of action of diammine silver fluoride and its use. Nippon Dent. Rev. 1970;328:180–87.
53. Mei ML, Ito L, Cao Y, *et al*. The inhibitory effects of silver diamine fluorides on cysteine cathepsins. J Dent. 2013 Dec 3. doi:pii: S0300-5712(13)00318–7
54. Selvig K. A. Ultrastructural changes in human dentine exposed to a weak acid. Archs oral Biol. 1968;13:719–34.
55. Shimooka S. On the penetration of silver nitrate and ammoniacal silver fluoride into microstructure of the sound dentin. J. Nippon Dent. Coll. 1972;59:534–66.
56. Suzuki T, Sobue S, Suginaka H. Mechanism of antiplaque action of diamine silver fluoride. J Osaka Univ Dent Sch. 1976;16:87–95.
57. Sunada I, Kuriyama S, Komamura T *et al*. Resistance to acid and enzyme of dentin treated by metal ion ionophoresis. J Conserv Dent. 1962;5:6–10.
58. Yanagida I, Nishino M, Hano T. Effects of diammine silver fluoride on organic components of dentin of deciduous teeth. Jap. J. Pedo. 1971;9:39–46.
59. Suzuki T, Nishida M, Sobue S. Effects of diamine silver fluoride on tooth enamel. J Osaka Univ Dent Sch. 1974;14:61–72.
60. Galui S, Pal S, Pabale SL, *et al*. Stretching new boundaries of caries prevention with silver diamine fluoride: A review of literature. Int J Pedod Rehabil. 2018;3:1–4.
61. Hihara T, Nishino M, Yasutomi Y *et al*. Effects of diamine silver fluoride on arrestment and prevention of caries in primary tooth. Dentistry in Japan.1994;31:93–95.
62. McDonald SP, Sheiham A. A clinical comparison of non-traumatic methods of treating dental caries. Int Dent J. 1994;44:465–70.
63. Sato R, Sailo Y. Clinical Application of Silver Ammonia Fluoride (Saforide) to Children. The Nippon Dental Review. 1970;332,66–67.
64. Nishino M, Massler M. Immunization of Caries-susceptible Pits and Fissures with a Diammine Silver Fluoride Solution. The Japanese Journal of Pedodontics. 1972;10:6–11
65. Shah S, Bhaskar V, Venkatraghavan K, *et al*. Silver Diamine Fluoride: A Review and Current Applications Journal of Advanced Oral Research. 2014;5:25–35.
66. Anusavice K J. Science of Dental Materials, 11th ed. Sounders Co., Philadelphia 2003.
67. Quock RL, Barros JA, Yang SW, *et al*. Effect of Silver Diamine Fluoride on Microtensile Bond Strength to Dentin. Oper Dent. 2012;37(6):610–6.
68. Yamaga M, Koide T, Hieda T. Adhesiveness of glass ionomer cement containing tannin-fluoride preparation (HY agent) to dentin--an evaluation of adding various ratios of HY agent and combination with application diammine silver fluoride. Dent Mater J. 1993;12(1):36–44.
69. Soeno K, Taira Y, Matsumura H, *et al*. Effect of desensitizers on bond strength of adhesive luting agents to dentin. J Oral Rehabil. 2001;28(12):1122–8.
70. Griffin SO, Griffin PM, Swann JL. Estimating rates of new root caries in older adults. J Dent Res. 2004;83:634–38.
71. Chalmers JM, Hodge C, Fuss JM *et al*. The prevalence and experience of oral diseases in Adelaide nursing home residents. Aust Dent J. 2002;47:123–30.
72. Lo EC, Luo Y, Dyson JE. Oral health status of institutionalised elderly in Hong Kong. Community Dent Health. 2004;21:224–26.
73. Simunkovic SK, Boras VV, Panduric J *et al.* Oral health among institutionalised elderly in

Zagreb, Croatia. Gerodontology. 2005;22:238–41.

74. Tan HP, Lo EC, Dyson JE *et al*. A randomized trial on root caries prevention in elders. J Dent Res. 2010;89:1086–90.
75. Kimura K, Iso Y, Ohno M. Clinical Test of Diammine Silver Fluoride (Saforide) Applied to Hypersensitive Dentin. Shikagakuho. 1971;71:708–13.
76. Tanaka M. The effect of Silver Fluoride Applied in Pulp-removed Root Canal, J. Osaka Univ. Dent. Soc. 1970;15:34–47.
77. Hiraishi N, Yiu CK, King NM. Antimicrobial efficacy of 3.8% silver diamine fluoride and its effect on root dentin. J Endod. 2010;36:1026–9.
78. Mathew VB, Madhusudhana K, Sivakumar N, *et al*. Anti-microbial efficiency of silver diamine fluoride as an endodontic medicament: An ex vivo study. Contemp Clin Dent. 2012;3(3):262–4.
79. Gupta A, Sinha N, Logani A, *et al*. An ex vivo study to evaluate the remineralizing and antimicrobial efficacy of silver diamine fluoride and glass ionomer cement type VII for their proposed use as indirect pulp capping materials - Part I. J Conserv Dent. 2011;14:113–16.
80. Sinha N, Gupta A, Logani A, *et al*. Remineralizing efficacy of silver diamine fluoride and glass ionomer type VII for their proposed use as indirect pulp capping materials - Part II (A clinical study). J Conserv Dent. 2011;14:233–36.
81. Horst JA, Ellenikiotis H, Milgrom PM, UCSF Silver Caries Arrest Committee. UCSF protocol for caries arrest using silver diamine fluoride: rationale, indications, and consent. J California Dent Asso. 2016;44(1):16.