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Review Article

Use of Silver Diamine Fluoride: Past to Present

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Abstract

Bacteria in the oral cavity have a great impact on caries formation by demineralizing tooth enamel. Bacterial infection should be prevented before restorative treatments. Rather than invasive treatment of existing caries, arresting bacterial activity in carious lesion and remineralizing dental tissue have become the goal of contemporary caries management philosophy. Silver compounds with antimicrobial effects have been developed over time and have taken their place in dentistry. 'Silver Diamine Fluoride' was created by combining the remineralizing effect of fluoride with the cariostatic effect of silver. Its popularity has increased because it appeals to the general population. It's application is painless, simple, and affordable. Our aim in this review is to provide a general perspective on the usage areas of Silver Diamine Fluoride from past to present and to create a guide for its use in pediatric patients.

Keywords: Silver diamine fluoride, preventive dentistry, conservative treatment

INTRODUCTION

The most common chronic disease, affecting people in all countries and age groups, is tooth decay. It imposes a heavy economic burden on families and the health care system. Many factors, such as microbial, behavioral, genetic and environmental determinants, affect the formation of caries (1). Regular use of medications, high sugar consumption, poor oral hygiene, low socioeconomic conditions, income rate, and parental education are high risk factors for tooth decay. It is often very difficult to obtain children's cooperation during dental treatment, and high-risk treatments such as general anesthesia or sedation for behavior management are common. In addition to its cost, it requires advanced skills of clinicians. Therefore, minimally invasive techniques have been recommended for caries treatment (2).

The philosophy of contemporary caries treatment has altered from the traditional to a minimally invasive approach that containes using of fluoride and antimicrobial agents (3). Traditionally, the treatment of dental caries has consisted of less conservative treatments that require removing of extra healthy dental tissue to increase surface areas for the mechanical retention of the restorative material. It has been proposed that minimally invasive treatments are alternative treatment options to traditional treatments with the emergence of new biomaterials (4,5). Beyond just focusing on restorative treatment, strategies should be developed to eliminate the bacterial factors that cause caries and prevent further bacterial infections. The aim should be to remineralize the decay rather than merely eliminate it. By using professionally applied fluoride-based materials, caries lesions can be both arrested and prevented (3-6).

The Historical Journey of Silver Compounds

Silver has been used for a long time due to its material properties and effects (5,7). It was started to use in dentistry and medicine due to its anti-cavity, antimicrobial and antirheumatic traits in 1800s. Silver compounds gotten popularity in the treatment of tetanus and rheumatism in the 1900s. Before antibiotics were discovered, silver compounds began to be used by some physicians in the treatment of colds and gonorrhea (8,9). The use of silver nitrate (SN) solution, a silver compound, as eye drops in newborns has become widespread in the treatment of venereal diseases such as umbilical granuloma and warts, and to prevent the transmission of Gonorrhea from the mother to the baby's eyes during birth (5,10).

Silver compounds have been started to use in dentistry at nearly 659 AD. SN was used to arrest dental caries as the first silver compound because it was used in the early

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1840s to reduce the incidence rate of caries in children with primary dentition (6). It was reported that SN could arrest dental caries in both dentition (11). In the 1960s, a combined beneficial the idea of combining silver with fluoride as an anti-caries agent was put forward to create the effect (7,11).

Today, a new silver compound named 'Silver Diamine Fluoride (SDF)' has been improved, which has the remineralizing feature of fluoride along with the cariostatic effect of the silver (5). SDF, which is its commonly used form at 38% concentration, contains of 25% silver and 5% fluoride ions dissolved in 8% amine, which is structurally like to SN, and sodium fluoride (NaF), which is a fluoride varnish. The cariostatic and biochemical effects of SDF on tooth structure and bacteria are like to SN. Both reinforce the structure of the tooth by creating fluorapatite crystals and reduce bacterial DNA and proteins with the effect of silver ion (12).

It is not necessary to remove the bruise before applying silver compounds. Their application is simple and painless. They do not require advanced instruments or techniques, so they are cost-effective agents in caries management. Its use is suitable for the general population (2).

Silver Diamine Fluoride

It is a colorless solution with antimicrobial properties and remineralizing ability. A 38% solution of SDF containing 253,900 ppm silver and 44,800 ppm fluoride ions is widely used (13). Because of an alkaline solution, silver and fluoride in SDF act synergetically to arrest caries lesions (14). Due to silver is an antimicrobial agent,it inhibits the development of cariogenic biofilm by denatured enzymes that destroys collagenous dentin. Fluoride stimulates remineralization and prevents demineralization of teeth under acid attack (15,16). The fluoride in SDF supports the accumulation of fluorapatite crystals, that are more resilient to acidic attack on the tooth structure (17). Silver fluoride inhibits Streptococcus mutans, a primer pathogen in caries. It has been shown that a thinner biofilm layer is formed on teeth treated with SDF (18). Systematic reviews have reported that SDF is an efficacious cariostatic agent in arresting caries (2,19). SDF promotes calcium absorption and increases the mineral content of dental hard tissues. Therefore, it is known that the surface microhardness of carious lesions treated with SDF increases significantly (20-22).

SDF was confirmed for using as a therapeutic agent in Japan in the 1960s (23). In 2014, the United States Food and Drug Administration (FDA) approved the first SDF product for use in the USA (24). SDF has so far been used to arrest caries lesions of primary teeth in children (20), to inhibit pit and fissure caries of erupting permanent molars (25), and root caries in older people. It has taken its place in the literature with its various usage areas (26).

There are solutions containing SDF in different concentrations in the market, such as 3.8% (Saforide RC, Japan), 10% (Cariostatic, Brazil), 12% (Cariestop and Ancarie, Brazil), 30% (Cariestop and Ancarie, Brazil) and 38% (Advantage Arrest (USA), Bioride (Brazil), Fagamin, Fluoroplat (Argentina), Saforide (Japan), e-SDF, Dengen Caries Arrest (India), Topamine (Thailand), Riva Star (Australia)) (27). Studies have shown that the amount of fluoride and silver in SDF solutions can vary from brand to brand and even from bottle to bottle within the same brand. For example, it is thought that the difference between studies is due to the fact that the content of a 38% SDF solution consists of silver, fluoride and ammonia ions, which will be 38% in total, and that it is within certain average ranges (28).

Atraumatic restorative treatment (ART) is a minimally invasive approach that was initiated by Jo Frencken in Tanzania in the 1980s, where the restoration is completed after cleaning the carious tissue using hand instruments. Literature studies show that it is not necessary to completely remove the infected dentin in deep carious lesions if a sealed restoration is made. This procedure, which uses SDF and glass ionomer cement (GIC) with the ART method, is called silver modified atraumatic restorative technique (SMART). This technique provides children with the opportunity to restore the tooth by stopping the carious lesion without creating aerosols as an alternative to traditional restorative treatment methods and reduces dentist anxiety in children (29).

Uses of Silver Diamine Fluoride

Treatment of SDF is basic, non-invasive, painless, unexpensive and does not generate aerosols. The unit can also be used for treatment of children who are non-cooperative or too young to accept traditional restorative treatment (30). The SDF application using technique can be individually arranged according to needs of the patients in the clinic. A recommended SDF application technique for patients with cooperation problems is drying, applying and protecting. It is recommended that physicians check one to three weeks after application to see whether the carious lesion has been stopped. If the caries lesion has not arrested, SDF should be applied all over. If it has arrested, the agent should be renewed every three to six months (24).

- The manufacturer's recommendation is that the bottle in which SDF is stored should not transmit light, and since it can dissolve metal and glass, it should be placed in a plastic container during application and used as soon as possible after removal. Because if SDF is exposed to light, it can become unstable and break down into silver ions.
- SDF is an agent that is applied topically to the involved tooth surface only. Avoid using more than one drop of SDF solution per patient in a single visit (28).
- Vaseline should be applied around the mouth. Gingival barrier and rubber dam should be applied to inhibit accidental contact and staining with the skin, gums, mucosa and lips. The areas to be treated should be isolated with cotton rolls (8,31).

- Superficial debris can be removed to increase the contaction area between the solution and carious lesion. It is not necessary to remove carious dentin; however, the rate of arrested caries lesions that turn black when removed can be reduced and can be taken into account for aesthetic purposes.
- The lesion should be dried with compressed air; because it is thought to increase the effectiveness of the process.
- It should be applied by dipping the brush into the solution and scrubbing it directly into the lesion for 1 minute.
- It should be waiting for 1-3 minutes for reaction between the solution and carious lesion.
- It should be applied a light compressed airflow until the solution dries (31).
- To minimize systemic absorption, it is recommended to remove excess SDF with a cotton roll or sterile sponge after application and continue isolation for at least 3 more minutes.
- According to the manufacturer's recommendations; it can then be air dried for 30-60 seconds. Washing is not required after the application.
- Finally, a thin layer of 5% NaF varnish is applied to the SDF applied surface.
- It is recommended that the patient does not eat or drink anything for an average of one hour after the procedure.

It has been reported that application times can vary between 10 seconds and 3 minutes in clinical studies. Although no correlation has been found between application time and the effectiveness of SDF in clinical studies, it is recommended to pay attention to the time, especially when applied for the first time. It has been stated that a longer application time may reduce the possibility of removing SDF from the lesion in case of washing after treatment (28).

Advantages

SDF is widely used worldwide to treat dentin hypersensitivity and carious lesions (2,32). It supposed that SDF has a multiple effect of preventing caries and cariogenic biofilm, protecting collagen from degradation, and increasing dentin microhardness (33). SDF It is a practical and low-cost remedy to stop the growth of decayed layers in both dentition (34). It is a simple treatment option that is cost-effective, minimally invasive, and easily clinically applicable for most patients. Due to its advantages, it has become a promising strategy for caries treatment in children who are very young or have behavioral or medical treatment difficulties due to their special needs, have a high caries risk, have multiple cavitations, and have difficulty accessing dental treatment. In a meta-analysis review, it was stated that active caries decreased by 71% after 30 months in patients receiving SDF treatment in the primary dentition (2). Another clinical study reported that using of 38% SDF every six months succeed a 74% caries arresting ratio in primary teeth (35). However, there are also studies that say approximately 11-32% of caries lesions remain active after SDF treatment4. A study on 976 school-age Nepali children reported that a one practition of SDF was efficacious in preventing caries at 6, 12, and 24-month follow-ups (36). Another research found that using of 38% SDF every 6 months was efficient in arresting carious dentin lesions. It has been shown to be more effective than 5% NaF application (37). In another study, similarly, annual 38% SDF application was more efficient than 5% NaF application every three months. A research with 375 preschool children showed that the practition of SDF once in a year was better than application of 5% NaF every three months. However, many researches have shown that the use of SDF is more efficient than glass ionomer cement or fluoride varnish in inhibiting the growth of primary tooth decay (22).

Disadvantages and Limitations

The most evident disadvantage of using silver compounds in dentistry is that silver-containing solutions permanently dye carious lesions black (5). SDF solution is colorless and odorless; but it can blot skin, clothing, countertops, flooring, and appliances (2). The reason of this discoloration is oxidation of ionized silver to metallic silver; This restricts the clinical utilizzation of silver compounds in patients with aesthetic demands (8). Some researchers have recommended applying a tooth-colored material, like glass ionomer cement, on the black colored and stalled caries lesion to solve this aesthetic problem (5).

It is very significant to explain the disadvantages to the patient before application to prevent displeasure and complaints. A study conducted in New York found that coloring on their children's premolar and molar teeth treated with silver compounds was more admissible to parents than becoming stain on the anterior teeth, that parental acceptance of children with more difficulty in receiving treatment increased with socioeconomic status, and that parents with lower levels of education reported that the acceptability rate was higher (38).

When solutions containing silver come into contact with the skin, a temporary henna stain appears. If silver does not pass through into the dermis, skin pigmentation disappears within 7 to 14 days (8). When exposed to a small amount of the solution, there are no immediate or side effects other than coloring of the skin. If a stain occurs on the skin, it is recommended to wash it immediately with water or wipe it with a salty slurry. If exposure is repeated, undesirable effects may become more evident. Long time exposure to large amounts of silver on parts of the body exposed to light can cause irreversible pigmentation of the skin or eyes (32). Another disadvantage is that desquamative processes such as ulcerative gingivitis may occur if adequate soft tissue isolation is not performed. However, these symptoms are

temporary and disappear within 48 hours (39). In order to prevent and reduce the discoloration effect of SDF, compounds such as glutathione (GSH) or potassium iodide (KI) have been introduced to the market. GSH is an antioxidant and reducing agent commonly found in the human body. It forms a layer around silver ions and restricts their release. It is mixed with SDF and applied to the relevant tooth surface (28).

A new approach proposed in 2005 to prevent unwanted staining is the application of saturated KI immediately after the application of SDF. The most important reason for the reversal of the black stain is suggested to be the formation of a white powder from tripotassium phosphate. Another product formed by the reaction of silver with iodide ions is silver iodide. It is a light-sensitive yellowish-white powder that darkens when exposed to light (39).

The recommended usage protocol for KI is as follows:

- A sufficient amount of KI should be put into a disposable medicine container.
- It should be applied to the relevant tooth surface with the help of a micro brush saturated with KI, like SDF application. Reaction products are formed immediately.
- The restoration should then be completed with resin-modified glass ionomer or composite (39).

The SDF/KI combination has been shown to not prevent fluoride uptake into demineralized tooth tissue and to significantly increase the microtensile and shear bond strength of GIC and dentin. Recently, a commercial SDF/KI agent (Riva Star; SDI, Bayswater, Australia) consisting of a KI solution saturated with 30–35% SDF has been introduced for the treatment of dentin hypersensitivity. The SDF/KI protocol has been found to be less anticariogenic and more effective in reducing staining compared with SDF alone. Insignificant color change has been reported when used under GIC compared with irrigation with deionized water. The use of KI should be restricted in pregnant and lactating women because it has been reported to cause fetal harm, thyroid abnormalities, and goiter (39).

The toxicity of solutions containing silver compounds is about the dose used; however, the dosage for use in the treatment of dental caries is excessively low (32). It is reported that accumualtion of excess silver is in the skin, liver, kidneys, spleen, corneas, gums, mucous membranes and nails. There is little data reporting possible toxic effects of the use of silver compounds. In general, it has been reported about low cell toxicity of silver ions. Few reports about silver allergy have been reported (8).

A bibliometric analysis revealed that global attention in SDF has shown an increase exponentially (40). However, SDF is not available in every country. When using the 25% SN + 5% NaF varnish, that is currently convenient throughout the world, it is possible to achieve similar results, although the silver and fluoride concentrations are lower than 38% SDF (22). The same applies to the treatment cost. So, first 25% SN then 5% NaF varnish using may be more suitable for using in young children, considering availability and cost throughout the world (34).

CONCLUSION

Using of silver compounds have became widespread in many areas from past to present with their healing properties. Silver diamine fluoride has become popular with silver's antimicrobial and fluoride's remineralizing feature. Since caries removal is not required and its cost is low, it has taken an important place in caries management in dentistry.

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REFERENCES

1. Global Burden of Disease Cancer Collaboration. Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-Adjusted life-years for 29 cancer groups, 1990 to 2017: a systematic analysis for the global burden of disease study. JAMA Oncol, 2019;5:1749-68. Erratum in: JAMA Oncol. 2021;7:466.
2. Gao SS, Zhao IS, Hiraishi N, et al. Clinical trials of silver diamine fluoride in arresting caries among children: a systematic review. JDR Clin Trans Res. 2016;1:201-10.
3. Chu CH, Mei ML, Lo ECM. Use of fluorides in dental caries management. Gen Dent. 2010;58:37-43.
4. Crystal YO, Marghalani AA, Ureles SD, et al. Use of silver diamine fluoride for dental caries management in children and adolescents, including those with special health care needs. Pediatr Dent. 2017;39:135E-45.
5. Arrow P, Klobas E. Minimum intervention dentistry approach to managing early childhood caries: a randomized control trial. Commun Dent Oral Epidemiol. 2015;43:511-20.
6. Gao SS, Zhao IS, Duffin S, et al. Revitalising silver nitrate for caries management. Int J Environ Res Public Health. 2018;15:80.
7. Silvestry-Rodriguez N, Sicairos-Ruelas EE, Gerba CP, Bright KR. Silver as a disinfectant. Rev Environ Contam Toxicol. 2007;191:23-45.
8. Peng JJY, Botelho MG, Matinlinna JP. Silver compounds used in dentistry for caries management: a review. J Dent. 2012;40:531-41.
9. Wahlberg V. Reconsideration of Credé prophylaxis. A study of maternity and neonatal care. Acta Paediatr Scand Suppl. 1982;295:1-73.
10. Moir J, Serra MP. The use of silver nitrate in wound management. Ann Ital Chir. 2012;83:45-8.
11. Klein U, Kanellis MJ, Drake D. Effects of four anticaries agents on lesion depth progression in an in vitro caries model. Pediatr Dent. 1999;21:176-80.
12. Brooke MO, Fukuoka DMD. Features L. Clinical use of silver diamine fluoride. Decisions Dent. 2018;4:35-6.

13. Yan IG, Zheng FM, Gao SS, et al. Ion concentration of silver diamine fluoride solutions. Int Dent J. 2022;72:779-84.

14. Zhao IS, Gao SS, Hiraishi N, et al. Mechanisms of silver diamine fluoride on arresting caries: a literature review. Int Dent J. 2018;68:67-76.

15. Yan IG, Zheng FM, Gao SS, et al. Fluoride delivered via a topical application of 38% SDF and 5% NaF. Int Dent J. 2022;72:773-8.

16. Youravong N, Carlen A, Teanpaisan R, Dahlen G. Metal-ion susceptibility of oral bacterial species. Lett Appl Microbiol. 2011;53:324-8.

17. Gold J. Limited evidence links silver diamine fluoride and caries arrest in children. J Evid Based Dent Pract. 2017;17:265-7.

18. Knight GM, McIntyre JM, Craig GG, et al. Inability to form a biofilm of Streptococcus mutans on silver fluoride- and potassium iodide-treated demineralized dentin. Quintessence Int. 2009;40:155-61.

19. Gao SS, Zhang S, Mei ML, et al. Caries remineralisation and arresting effect in children by professionally applied fluoride treatment- a systematic review. BMC Oral Health. 2016;16:12.

20. Mei ML, Chu CH, Low KH, et al. Caries arresting effect of silver diamine fluoride on dentine carious lesion with S. mutans and L. acidophilus dual-species cariogenic biofilm. Med Oral Patol Oral Y Cirugia Bucal. 2013;18:e824-31.

21. Mei ML, Ito L, Cao Y, et al. An ex vivo study of arrested primary teeth caries with silver diamine fluoride therapy. J Dent. 2014;42:395-402.

22. Chu CH, Man Lo EC, Lin HC. Effectiveness of silver diamine fluoride and sodium fluoride varnish in arresting dentin caries in Chinese pre-school children. J Dent Res. 2002;81:767-70.

23. Shah SG, Bhaskar V, Chawla S, et al. Efficacy of silver diamine fluoride as a topical fluoride agent compared to fluoride varnish and acidulated phosphate fluoride gel: an in vivo study. J Pediatr Dent. 2014;2:5-12.

24. Horst JA, Ellenikiotis H, Milgrom PM. UCSF protocol for caries arrest using silver diamine fluoride: rationale, indications, and consent. J Calif Dent Assoc. 2016;44:16-28.

25. Buzalaf MAR, Pessan JP, Honório HM, Cate JMT. Mechanisms of action of fluoride for caries control. Monogr Oral Sci. 2011;22: 97-114.

26. Tan HP, Lo ECM, Dyson JE, et al. A randomized trial on root caries prevention in elders. J Dent Res. 2010;89:1086-90.

27. Zheng FM, Yan IG, Duangthip D, et al. Silver diamine fluoride therapy for dental care. Japanese Dental Science Review. 2022;58:249-57.

28. Karaduran B, Koruyucu M. Diş hekimliğinde kullanılan gümüş içerikli materyallere güncel yaklaşım: geleneksel derleme. Turkiye Klinikleri J Dent Sci. 2024;30:150-63.

29. Natarajan, D. Silver modified atraumatic restorative technique: a way towards "SMART" pediatric dentistry during the COVID-19 pandemic. Frontiers in Dentistry. 2022;19:12.

30. Muntean A, Mzoughi SM, Pacurar M, et al. Silver diamine fluoride in pediatric dentistry: effectiveness in preventing and arresting dental caries-a systematic review. Children (Basel). 2024;11:499.

31. Mei ML, Li Q, Chu CH, et al. Antibacterial effects of silver diamine fluoride on multi-species cariogenic biofilm on caries. Ann Clin Microbiol Antimicrob. 2013;12:4.

32. Chan AKY, Tsang YC, Yu OY, et al. Clinical evidence for silver diamine fluoride to reduce dentine hypersensitivity: a systematic review. J Dent. 2024;142:104868.

33. Duangthip D, Wong MCM, Chu CH, Lo ECM. Caries arrest by topical fluorides in preschool children: 30-month results. J Dent. 2018;70:74-9.

34. Devji T. Silver diamine fluoride is probably more effective than atraumatic restorative treatment, fluoride varnish, or no treatment for controlling caries progression in children. J Am Dent Assoc. 2018;149:e65.

35. Fung MHT, Duangthip D, Wong MCM, et al. Arresting dentine caries with different concentration and periodicity of silver diamine fluoride. JDR Clin Trans Res. 2016;1:143-52.

36. Yee R, Holmgren C, Mulder J, et al. Efficacy of silver diamine fluoride for arresting caries treatment. J Dent Res. 2009;88:644-7.

37. Mabangkhru S, Duangthip D, Chu CH, et al. A randomized clinical trial to arrest dentin caries in young children using silver diamine fluoride. J Dent. 2020;99:103375.

38. Crystal YO, Janal MN, Hamilton DS, Niederman N. Parental perceptions and acceptance of silver diamine fluoride staining. J Am Dent Assoc. 2017;148:510-8.

39. Khurshid Z, Shabbir J, Al-Otaibi AK, et al. Role of silver diamine fluoride in dentistry. Eur Dent Res Biomater J. 2020;1:27-31.

40. Jiang CM, Duangthip D, Chan AKY. Global research interest regarding silver diamine fluoride in dentistry: A bibliometric analysis. J Dent. 2021;113:103778.