Silver Diamine Fluoride - The unsung hero

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Abstract— Silver diamine fluoride (SDF) is used in dentistry to prevent and arrest caries. It is a safe and effective treatment modality which is highly effective compared traditional fillings in preventing the progression of cavities. A non-aerosol generating material, makes it a good option for dentists who are looking to reduce the risk of disease transmission. SDF works by killing the bacteria that cause cavities and by strengthening the teeth. It is also relatively inexpensive and easy to use.This review talks about the History, composition, mechanism of action, clinical indications and contraindications and the chairside procedure for its application.
. (Abstract)

Index Terms— sdf, Silver Diammine fluoride. (key words)

I. INTRODUCTION

Dental caries is a biofilm-controlled, sugar-driven, multifactorial, disease which results in the phasic demineralization and remineralization of dental hard tissues. Over the past 25 years, caries has become more common in children, affecting 50% of Indian children. A greater risk of caries being severe is frequently linked to socioeconomic disadvantage. Another difficult aspect of caries for the dentist is getting a child to cooperate with the treatment. Therefore, a different approach that is affordable, effective in treating patients with high-risk dental caries, and accessible to dental caries is needed in order to lessen the burden of caries and prevent potential sequelae associated with it. Silver compounds are used in treating dental caries from a long time. This approach provides relatively easy, fast and economic application.[1]

II. HISTORY

Silver compounds have been used for centuries to prevent dental caries and treat various infections. In Japan, it was customary for women to blacken their teeth with silver compounds, a practice known as "ohaguro," to signify their marital status. The first medicinal use of silver compounds was around 1000 B.C., when they were used to treat infections. Silver-based materials such as silver foil, silver nitrate, and silver sutures have been used in medical science for many years.

In dentistry, silver compounds have been used to prevent dental caries since the 19th century. In 1891, Stebbins used silver amalgam and nitric acid to prevent dental caries. In 1917, Howe et al. used a solution of silver nitrate directly on caries lesions to prevent their progression. This solution, known as "Howe's solution," has been used ever since as a caries arresting solution.

Silver compounds work by killing bacteria, which are the primary cause of dental caries. They also help to strengthen the tooth enamel, making it more resistant to decay. Silver compounds are generally safe and effective, but they can cause some side effects, such as tooth discoloration.[2]

III. COMPOSITION [3]

Silver	24-27%
Ammoia	7.5- 11%
Fluoride	5-6%
Blue Colouring	<1%
Deionized water	<62.5%

IV. MECHANISM OF ACTION

Silver has been used as an antibacterial agent for centuries, even before the introduction of antibiotics. It has played a significant role in wound healing and radiology. Silver ions kill microorganisms by blocking their respiratory enzymes, without harming human cells. They can also cause condensation of DNA in microorganisms, which leads to the loss of their ability to replicate. Silver ions can also interact with thiol groups, which are essential for the function of many bacterial enzymes.

Kill micro-organisms by

- Blocking respiratory enzymes: Silver ions can bind to the respiratory enzymes of microorganisms, which prevents them from getting the oxygen they need to survive. This is a very effective way to kill microorganisms, as it does not require the silver ions to enter the cell.
- Condensing DNA: Silver ions can also cause the DNA of microorganisms to condense, which makes it difficult for the cells to replicate. This is a less effective way to kill microorganisms, but it can be useful in combination with other methods.
- Interacting with thiol groups: Thiol groups are sulfur-containing groups that are essential for the function of many bacterial enzymes. Silver ions can bind to thiol groups, which inhibits the activity of these enzymes and eventually leads to the death of the cell.

Overall, silver is a very effective antibacterial agent that has been used for centuries. It is safe for humans and can be used in a variety of applications, including wound healing, water purification, and food preservation. It is important to note that the exact mechanism of action of SDF is still not fully understood. However, the evidence suggests that it can be an effective way to prevent and treat dental caries.

The possible mechanisms of action of silver diamine fluoride (SDF) on dental caries are:

- Obturation of dentinal tubules: Dentinal tubules are microscopic channels that run through the dentin, the layer of tissue beneath the enamel. Bacteria and acids can enter the tooth through these channels, which can lead to the formation of a cavity. SDF can block the dentinal tubules, which can prevent the bacteria and acids from reaching the tooth.
- Reaction products of SDF and mineral content of the tooth: SDF reacts with the minerals in the tooth, such as calcium and phosphate, to form calcium fluoride and silver phosphate. These compounds are more decay-resistant than the minerals in the tooth, which can help to strengthen the tooth and make it more resistant to decay.
- Antienzymatic actions of the reaction products: SDF can inhibit the activity of enzymes that are involved in the breakdown of tooth enamel. These enzymes include acid phosphatase, dextranase, and glucan phosphorylase. By inhibiting these enzymes, SDF can help to prevent the formation of cavities.
- Inhibition of matrix metalloproteinases (MMPs): MMPs are enzymes that break down the collagen in dentin. Collagen is the main component of dentin. By inhibiting the activity of MMPs, SDF can help to protect the dentin from decay.
- Formation of fluorhydroxyapatite: SDF can react with calcium and phosphate ions in the saliva to form fluorhydroxyapatite. Fluorhydroxyapatite is a more decay-resistant form of tooth enamel than the enamel that is naturally produced by the body. [1,4]

V. Clinical Indications

- Immediate relief of dentine hypersensitivity: SDF can block the dentinal tubules, which are the tiny canals that run through the dentin, the layer of tissue beneath the enamel. This can help to relieve the pain and sensitivity that is caused by exposed dentin.
- Relief of symptoms from carious cavities: SDF can kill the bacteria that cause cavities and can also help to strengthen the tooth enamel, making it more resistant to decay. This can help to relieve the pain and discomfort that is caused by a cavity.
- Promotes minimally invasive cavity preparation: SDF can help to prevent the need for extensive cavity preparation, which is the process of removing decayed tooth tissue. This can help to save tooth structure and reduce the need for dental fillings.
- Minimises the need for aerosol generating procedures: SDF is a liquid solution that does not produce aerosols, which are tiny droplets of water and saliva that can spread bacteria and viruses. This makes it a safe and effective treatment for patients who are at risk of infection, such as those with weakened immune systems.
- Inexpensive and obviates the need for local anaesthesia: SDF is a relatively inexpensive treatment that does not require the use of local anesthesia. This makes it a good option for patients who are afraid of needles or who have difficulty sitting still for dental treatment.
- Quick and easy application makes it useful for patients who are: vulnerable, uncooperative, have behavioural problems and those with limited access to conventional dental treatment: SDF can be applied quickly and easily, making it a good option for patients who are difficult to treat, such as young children, people with special needs, and those who live in remote areas.
- Stabilisation/arrest of caries into dentine in deciduous teeth: SDF can be used to stabilize cavities in baby teeth, which can help to prevent the need for extractions.
- Stabilisation of deciduous teeth soon to be exfoliated: SDF can be used to stabilize baby teeth that are about to fall out. This can help to prevent pain and infection and can also make it easier for the permanent teeth to come in.
- Stabilisation/arrest of caries in elderly patients: SDF can be used to stabilize cavities in older adults, who may be more susceptible to dental decay.

- Acclimatisation to dental treatment and stabilisation of multiple lesions: SDF can be used to help patients get used to dental treatment and to stabilize multiple cavities.
- Remineralisation of incipient carious lesions: SDF can help to remineralize incipient, or early, carious lesions. This can help to prevent the lesions from progressing into cavities.
- Endodontic irrigation and inter-appointment medicament: SDF can be used to irrigate the root canals of teeth during endodontic treatment. It can also be used as an inter-appointment medicament, which is a medication that is placed in the root canals between appointments. [5]

VI. CONTRAINDICATIONS

- Silver/heavy metal allergy: SDF is a liquid solution that contains silver ions. If you are allergic to silver or other heavy metals, you should not have SDF treatment.
- Pregnancy and breastfeeding: SDF contains iodide, which is a type of iodine. Iodine is important for the development of the fetus and the baby, but too much iodine can be harmful. If you are pregnant or breastfeeding, you should talk to your dentist about the risks and benefits of SDF treatment.
- Lesions close to the pulp/possible pulpal involvement: The pulp is the soft tissue inside the tooth that contains nerves and blood vessels. SDF can cause staining of the pulp, so it is not recommended for lesions that are close to the pulp or that may involve the pulp.
- Signs and symptoms of periapical pathology (clinical and/or radiographic): Periapical pathology is a condition that affects the tissues around the root of the tooth. If you have signs or symptoms of periapical pathology, such as pain, swelling, or a sinus tract, you should not have SDF treatment.
- Ulceration, mucositis or stomatitis: SDF can cause irritation to the gums and other soft tissues in the mouth. If you have ulceration, mucositis, or stomatitis, you should not have SDF treatment.
- Restoration of permanent anterior teeth: SDF can cause staining of the teeth, so it is not recommended for the restoration of permanent anterior teeth. *Anterior teeth are the teeth that are visible when you smile.* [5]

VII. CASE SELECTION FOR APPLICATION OF SILVER DIAMINE FLUORIDE (SDF)

SDF can be a safe and effective treatment for dental caries in certain patients. Patients who may benefit from SDF include those who:

- Have a high risk of developing cavities
- Have active, cavitated (decayed) cavities in their front or back teeth
- Are difficult to treat due to behavioral or medical challenges
- Have multiple cavities that cannot all be treated in one visit
- Have cavities that are difficult to treat with traditional methods
- Do not have regular access to dental care

When considering SDF treatment, the clinician should look for the following criteria:

- There are no signs of pulpal inflammation or pain.
- The cavities are not close to the pulp. If possible, x-rays will be taken to assess the depth of the cavities.
- The cavities are accessible for SDF application. (Orthodontic separators may be used to help gain access to proximal lesions.)[6]

VIII. CLINICAL PROCEDURE

The following steps are involved in the application of silver diamine fluoride (SDF):

- Remove any gross debris from the cavity to allow better contact between the SDF and the denatured dentin.
- Carious dentin excavation is not necessary before SDF application. However, it may be considered for aesthetic purposes, as it may reduce the proportion of arrested caries lesions that become black.
- Apply a protective coating to the lips and skin to prevent a temporary henna-like tattoo that can occur if SDF comes into contact with soft tissues.
- Isolate the area to be treated with cotton rolls or other isolation methods. If applying cocoa butter or any other product to protect the surrounding gingival tissues, be careful not to inadvertently coat the surfaces of the caries lesions.
- Take caution when applying SDF to primary teeth adjacent to permanent anterior teeth that may have noncavitated (white-spot) lesions, to avoid inadvertent staining.
- Careful application with a microbrush should be sufficient to prevent exposure of soft tissues inside and outside the mouth. No more than one drop of SDF should be used for the entire appointment.
- Dry the lesion with a gentle stream of compressed air.

- Bend the microsponge brush. Dip the brush into the SDF and dab it on the side of the plastic dappen dish to remove excess liquid before application. Apply the SDF directly to the affected tooth surface only. Remove excess SDF with gauze, cotton roll, or cotton pellet to minimize systemic absorption.
- The application time should be at least one minute, if possible. (The application time may be shorter in very young and difficult-to-manage patients. When using shorter application periods, monitor carefully at postoperative and recall visits to evaluate arrest and consider reapplication.)
- Apply a gentle stream of compressed air until the medicament is dry. Try to keep the area isolated for as long as three minutes.
- The entire dentition may be treated with 5% sodium fluoride varnish after SDF treatment to help prevent caries on the teeth and sites not treated with SDF. [6]

IX. Follow-up after SDF treatment

The effectiveness of SDF in arresting dental caries lesions ranges from 47 to 90% with a single application, depending on the size of the cavity and the location of the tooth. Anterior teeth have higher rates of arrest than posterior teeth. Therefore, follow-up is advisable to evaluate the arrest of the lesions.

The following are the recommended follow-up procedures:

- Two to four weeks after initial treatment: The dentist will check the lesions to see if they have been arrested. If the lesions do not appear arrested, the dentist may recommend reapplication of SDF.
- Reapplication of SDF: Additional SDF can be applied at recall appointments as needed, based on the color and hardness of the lesion or evidence of lesion progression.
- Restoration of caries lesions: Caries lesions can be restored after treatment with SDF.
- Biannual reapplication: When lesions are not restored after SDF therapy, biannual reapplication shows an increased caries arrest rate compared to a single application.

X. Adverse effects of silver diamine fluoride (SDF)

SDF is generally a safe and effective treatment for dental caries. However, it can cause some adverse effects, including:

- Staining: SDF can cause staining of the teeth, gums, and other tissues that it comes into contact with. The staining is usually permanent and can be more noticeable in dark-coloured teeth.
- Metallic taste: SDF can leave a metallic taste in the mouth for a few hours after treatment.
- Irritation: SDF can cause irritation to the gums and other soft tissues in the mouth. This is usually mild and goes away on its own within a few days.
- Gum bleaching: SDF can cause the gums to bleach temporarily. This is usually not a cause for concern and the gums will return to their normal color within a few weeks.
- Transient gum swelling: SDF can cause the gums to swell temporarily. This is usually not a cause for concern and the swelling will go away on its own within a few days.

The risk of these adverse effects is low and they are usually mild. However, it is important to be aware of them before undergoing SDF treatment.

Black staining: Black staining is the most common adverse effect of SDF. It is caused by the formation of silver phosphate and silver sulfide, which are the reactionary products of SDF. The staining is usually permanent and can be more noticeable in areas with surface irregularities.

The staining usually occurs within 2 minutes of application and becomes more noticeable within 5 minutes. The amount of staining is directly proportional to the concentration of SDF and the frequency of application. [1,7]

XI. Silver Modified Atraumatic Restorative Technique

The COVID-19 pandemic has highlighted the importance of providing oral health care with minimal risk of disease transmission. Traditional dental procedures can generate aerosols, which can spread viruses and bacteria. To meet the recommendations of the Center for Disease Control and Prevention (CDC), dentists are seeking alternative non-aerosol generating techniques.

- One promising alternative is silver diamine fluoride (SDF). SDF is a liquid solution that can be applied to teeth to prevent and arrest caries. It is a non-aerosol generating material and has been shown to be effective in both children and adults.
- SDF works by killing the bacteria that cause cavities and by strengthening the teeth. It is also relatively inexpensive and easy to use.
- Another advantage of SDF is that it can be used in conjunction with atraumatic restorative treatment (ART). ART is a minimally invasive way to restore teeth that does not require drilling or anesthesia. This makes it a good option for children and other patients who are afraid of dental treatment.
- In ART, SDF is applied to the carious tooth and then the lesion is restored with a glass ionomer cement (GIC). GIC is a tooth-colored material that is also non-adhesive and can help to prevent the spread of bacteria.

- The combination of SDF and ART is a promising new approach to caries management that can help to reduce the risk of disease transmission while also providing effective treatment for cavities.

XII. RATIONALE FOR THE SMART TECHNIQUE

The SMART technique is based on the principle that by biologically sealing a tooth with caries, the viable bacteria present in the remaining carious dentin will lose their viability by being deprived of their sucrose substrate.
This means that if the bacteria in the carious dentin are killed using silver diamine fluoride (SDF) and the staining is eliminated using potassium iodide (KI), then a restorative material like glass ionomer cement (GIC) can be placed to significantly improve the prognosis of the tooth.
The placement of a restoration following SDF would also eliminate the risk of imminent fracture of the remaining tooth structure, prevent space loss, provide easy access for biofilm removal, and eliminate the need for advanced behavior guidance while satisfying the parents' demands or needs.
The rationale for the SMART technique:

- SDF kills bacteria: SDF is a liquid solution that contains silver ions and fluoride ions. The silver ions kill the bacteria that cause cavities, while the fluoride ions help to strengthen the teeth.
- KI eliminates staining: KI is a topical antiseptic that can be used to eliminate the black staining that can occur after SDF treatment.
- GIC is a restorative material: GIC is a tooth-colored material that is used to restore teeth. It is a good choice for use with SDF because it is also non-adhesive and can help to prevent the spread of bacteria.

XIII. CONCLUSION

Silver diamine fluoride (SDF) is a liquid solution used to prevent and arrest caries. It has been shown to provide a safe and effective treatment compared to traditional fillings in preventing the progression of cavities. This non-aerosol generating material, makes it a good option for clinicians who are looking to reduce the risk of disease transmission.

Here are some of the advantages of using SDF in dentistry:

- Safe and effective treatment for caries
- Non-aerosol generating material
- Can be used in conjunction with ART
- Relatively inexpensive and easy to use
- Can be used in both children and adults

Here are some of the disadvantages of using SDF in dentistry:

- Can cause staining of the teeth
- May not be suitable for all types of caries lesions
- Requires reapplication every few years

Overall, SDF is a promising new treatment for caries that can help to reduce the risk of disease transmission while also providing effective treatment. It is a safe and effective option for both children and adults.

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