



IN GOD WE  
**TRUST**



# Silver Diamine Fluoride (SDF)

Dr. Leila Simaei

Pediatric department of GUMS







- The current crisis of **COVID-19** has brought a significant impact on the dental profession as a whole.
- Apart from the current pandemic, dental care setups have always been at a risk for **spread of diseases**, that can be transmitted through **droplets**.
- Recently, recommendations have been published, which emphasizes the usage of **minimally invasive procedures** eliminating aerosol generation largely in children.
- In this regard, we would like to highlight the use of silver diamine fluoride (SDF), the use of which as a **safe** and **effective therapy** to **treat** and **prevent** caries is already well established.
- Thus, SDF is an integral tool for providing minimally invasive pediatric dentistry (MIPD) coupled with aerosol free dentistry (AFD)



- A plethora of fluoride based prevention systems are available in the management of dental decay. However, recently, the use of **silver diamine fluoride (SDF)** has appeared as one of the more popular and effective methods for the prevention and management of the dental disease
- with a systematic review by Rosenblatt *et al.* finding that SDF is **more** effective than **fluoride varnish** and may be a valuable **caries-preventative intervention**.



- SDF,  $\text{Ag}(\text{NH}_3)_2\text{F}$  (also referred to as **diamine silver fluoride** and **silver ammonium fluoride**) is a **colorless** alkaline solution containing **silver** and **fluoride**, which forms a complex with ammonia.
- The **ammonia ions** combine with **silver ions** to produce a complex called the **diamine-silver ion**, and this complex is **more stable than silver fluoride**.
- SDF is not merely a simple salt of silver, ammonium and fluoride ions, but rather a mixed heavy-metal halide coordination complex.
- SDF reportedly releases **two to three times** more fluoride than sodium fluoride, stannous fluoride or acidulated phosphate fluoride, substances commonly found in foams gels and varnishes.



### **SDF in preoperative child**

A: Pre-operative

B: Immediate post op followed by FV

C: 3 months follow up, D: 6 months follow-up and second application

E: 12 months follow up





# History

- Probably the **earliest** medical use of silver was for **water disinfection** and **storage**.
- Use of silver in **dentistry** was reported as early as the 1840s, where silver nitrate was reported for its use in **arresting caries**.
- In 1917, Howe reported the use of an ammoniacal silver nitrate solution, referred to as 'Howe's solution', applied **directly** to caries lesions.
- Howe's solution was believed to **penetrate** into **affected** dentine, having an **antibacterial effect**,
- At the end of the twentieth century and the beginning of the twenty-first century, a range of both *in vivo* and *in vitro* studies documented the effectiveness of silver fluoride compounds at arresting caries lesions.
- Ammonium has since been included with the compound, resulting in the formation of SDF





## **SDF mechanism of action**

- The anti-cariogenic mechanism of SDF is two-fold:
  - I. with direct actions on bacteria
  - II. teeth





# Antibacterial action

- Both **fluoride** and **silver** ions contained in SDF appear to have the ability to **inhibit the formation of cariogenic biofilms**.
- An *in vitro* study demonstrated that **dentine** surfaces treated with **SDF** had significantly **reduced *Streptococcus mutans*** quantities, which is one of the most important pathogens associated with the **initiation** and **progression** of the caries lesion.
- The **antimicrobial action of the SDF** has also been demonstrated on **multi-species cariogenic biofilms** and ***Lactobacillus* species**.
- **High-concentration fluorides** inhibit biofilm formation by **binding** to **bacterial cellular components** and influencing **enzymes** related to both **carbohydrate metabolism** and **sugar uptake**.
- Silver ions' antibacterial action is three fold:
  - ✓ **penetrating** and **destroying** bacteria **cell wall** structures,
  - ✓ **Inhibiting enzymatic activity** thus influencing **metabolic processes**,
  - ✓ and **inhibiting** the **replication of bacterial DNA**.



# Teeth

- SDF has been shown to have a **remineralization effect** on dentine caries.
- One proposed chemical reaction between **SDF** and **hydroxyapatite** of teeth involves the formation of **silver phosphate** and **calcium fluoride**, which aid in **elevation** of **pH** and **formation of fluoride reservoirs**.
- The subsequent **dissolution of fluoride** and **calcium facilitates** the formation of **insoluble fluorapatite**.
- It has been demonstrated that the **reaction** between **SDF** and **hydroxyapatite** also leads to the formation of **nanoscopic metallic silver particles** attached to hydroxyapatite crystals.
- The **incorporation of silver particles into the hydroxyapatite** is significant due to the antibacterial and anti-cariogenic nature of the silver ,thus inhibiting the development of **future caries** on the arrested lesion.



- SDF has also been shown to have an **inhibitory effect** on **matrix metalloproteinases (MMPs)** and **cysteine cathepsins** (or cathepsins).
- MMPs and cathepsins are **proteolytic enzymes** that contribute to **dentine collagen degradation** and **caries progression**.
- MMPs and cathepsins are also responsible for the **hydrolytic degradation of collagen matrix in the dentine-adhesive interface**;



# Indications and evidence for SDF



## Caries arrest and caries prevention

- The most common application for SDF is its use as a **caries-preventative** and **caries arresting agent**.
- In 2002 a prospective controlled clinical trial comparing the use of **annual** application of **38% SDF (48,000 ppm F)** to the use of **5% sodium fluoride (NaF) varnish (22,600 pp F)**.
- Both products were applied every three months to on carious primary anterior teeth.
- The study found that **SDF's** prevented fractions for caries arrest and prevention in primary teeth **were >96% and >70%**, respectively.
- The study also found **no** significant benefit of caries **excavation** before application of SDF



- In 2005, Llodra *et al.* undertook a three-year prospective controlled clinical trial examining the efficacy of **applying 38% SDF solution twice a year** for caries reduction in carious **primary** and **permanent** teeth.
- The study found that, for **primary** teeth, the **prevented fractions for SDF** were **55.6%** and **78.6%** for **caries arrest and prevention**, respectively.
- In **permanent** teeth, the **prevented fractions for SDF** were **100%** and **63.6%** for caries **arrest and prevention**, respectively.



- Braga *et al.* compared the effectiveness of **SDF** to other **non-invasive** approaches (cross-tooth brushing technique [CTT] and glass-ionomer cement [GIC] fissure sealants) in arresting occlusal caries in erupting permanent first molars.
- The study found that, after three and six months, 10% SDF showed a significantly higher capacity for arresting caries.





## Sensitivity

- The use of SDF for management of dentine **hypersensitivity** has also been examined.
- The mechanism behind SDF and sensitivity control is that the **aqueous silver** and **fluoride solution** can produce a **squamous layer** over the exposed dentine, partially **plugging** the **dentinal tubules** of the exposed dentine, thus **reducing fluid shifts** in the dentinal tubules.
- One of the issues with the use of SDF as a sensitivity agent is the **possible discoloration**. However, the Castillo *et al.* study found that, unless **existing caries** was present on the surface of the exposed dentine, no staining occurred.

## Endodontic irrigant and inter appointment medication

- The **elimination of microorganisms** of the root canal in endodontic treatment is fundamental for successful treatment.
- The antimicrobial **effectiveness** of the SDF irrigant was measured by examining **quantitative reductions** in *Enterococcus faecalis* biofilms.
- In 2010:
  - ✓ the effectiveness of a 3.8% SDF solution (a 1:10 dilution of the original 38% SDF for root canal infection) with the Controls of 5.25% NaOCl (sodium hypochlorite) and saline (0.9% NaCl)
  - ✓ study showed that *Enterococcus faecalis* was **completely killed** by **SDF** and NaOCl after exposure to these agents for 60 minutes.





- The presence of **silver deposits** in **dentinal tubules** suggests that it is possible for the SDF to **penetrate** and **reduce/eliminate biofilms** formed in dentinal tubules. Thus, this demonstrates that **SDF** may be **effective** as both an **irrigant** and **inter-appointment medication**.
- **use** is likely to be **limited** to areas whereby **staining** resulting from the SDF is **unlikely to be of significant concern**.
- However, incorporation of **silver particles** into the **dentine tubules** is likely to provide a potential means of **substantively** that **permits the gradual release** of silver and a **longer-lasting antimicrobial effect** than other respective irrigant



# Contraindications for SDF

- Silver allergy(a complete contraindication to SDF).
  - Significant **desquamative gingivitis** or **mucositis**
  - Pregnancy
  - Breastfeeding
  - **Restorations** and **Caries** in the **aesthetic zone**
  - Signs or symptoms of **periapical pathology**
  - **Radiographic** signs or symptoms of periapical pathology.
- ✓ Use of **potassium iodide (KI)** for discoloration, is contraindicated in **pregnant women** and during the **first six months of breastfeeding** due to concern of **overloading the developing thyroid with iodide.**





- ❖ Discoloration
- ❖ Bond strength
- ❖ Effect on dentino-pulp complex
- ❖ effect on the gingiva

## **SIDE EFFECTS OF SDF**

# Discoloration

- One of the most frequently reported side effects
- Discoloration tends to be **black/dark brown** and is thought to result from **silver phosphate** ( $\text{Ag}_3\text{PO}_4$ ), which is formed when dental caries is treated with SDF.
- **Silver phosphate** readily turns **black** under **sunlight**







- One method for overcoming the issue of discoloration is the **application of a salt afar SDF placement**.
- The salt **reacts** with the **remaining free silver ions**, preventing the formation of silver phosphate and the resulting discoloration.
- One of the salts to prevent staining is **KI**, which **produces silver iodide**, a **creamy white reaction product** that after adequate application turns **colorless**.
- However, **there is no clinical data** to prove the effectiveness of KI in reducing staining in the long term and, in the authors' experience, staining still **occurs** (however noticeably less) when KI is applied.



- It has been reported that the staining/ discoloration was **not** a **concern** to patients/ parents.
- Parents are more likely to **accept staining** on **primary** teeth and teeth in the **posterior** quadrant.
- Discoloration **can be polished off** or **removed** through more **invasive** measures. (even with polishing, discoloration remains, particularly at restoration **margins**).
- Due to the **metallic nature of the discoloration**, dental **bleaching** **does not** remove the discoloration.



## Bond strength

- It has been postulated that SDF **reduces** the bond strength to **adhesive** materials due to the introduction of **a new interface** at the **tooth-restoration complex** and the **occlusion of dentinal tubules**, thus reducing the penetration of the adhesive agents into the tubules.
- Interestingly, contradictory to this, some products even claim an improvement in bond strengths.



- If SDF and KI are to be used, it is essential that the precipitate is **washed** and **air-dried** thoroughly before application of the adhesive system or material.
- Use of a **conditioning agent** or **acid etch** post-application of SDF/KI may further improve bond strength.
- Additionally, **surface abrasion** may improve bond strength, although there is **no clinical research** to demonstrate this.
- Finally, if an adhesive resin cement is required, **more invasive measures** may be required, such as partial **removal** of SDF-affected dentine.





## Effect on dentino-pulp complex

- It has been suggested that SDF **should not** be used in carious lesions with close **proximity to the pulp**, due to the potential for **silver ion** penetration into the pulp complex, but studies show that SDF induces minimal adverse effects to the pulp.
- SDF, therefore, shows promising properties as an **indirect pulp-capping material** and for use in deep carious lesions.
- Its ability to arrest dentine caries could also **reduce the amount of iatrogenic pulpal exposures** by reducing the amount of tissue requiring removal.
- **No** literature currently examines the effect of SDF with regards to pulp exposures and **direct pulp capping** treatments. Until further evidence is produced, use of SDF in this application would **not be recommended**

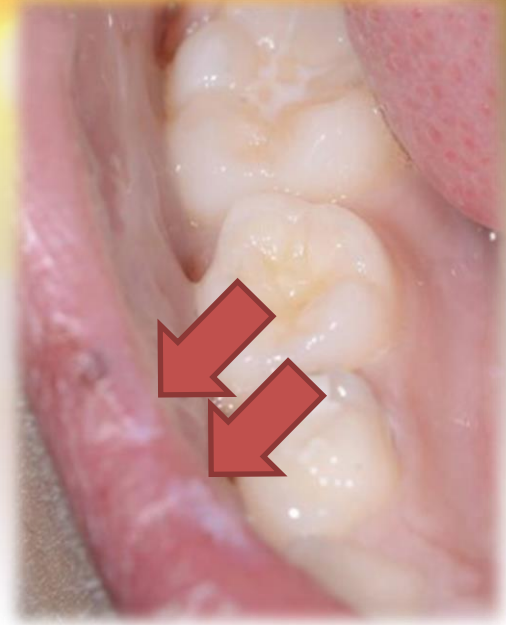


## SDF effect on the gingiva

- SDF has been reported to potentially result in:
- gingival **erythema**,
- gingival inflammation,
- gingival bleaching
- gingival pain
- This was noted as being **transient** (less than seven days) and was **not severe**.
- Additionally, this erythema was **not accompanied** by any **long-term staining** of the gingiva.

# SDF effect on mucosa and skin

- Due to the **high pH of SDF**, mucosal or skin burns may occur post-application .
- The burns tend to be **small**, mildly painful **white** lesions in the mucosa, which **disappear** after **48 hours** without treatment.
- Moreover, SDF can **stain clothes and skin of the body**. Tough it does not cause pain or damage, SDF skin staining cannot be easily washed away and takes around seven days to disappear.
- SDF **clothes** staining however is **permanent!!!!!!**





## PATIENT SELECTION AND MANAGEMENT

- Patients who **do not have immediate access** to traditional restorative care can benefit from SDF therapy to **arrest** existing dentin caries lesions.
- Patients should be **monitored** closely to verify arrest of all lesions on a periodic basis **based on risk factors**; this is especially important when applied to **permanent** teeth.
- **Follow-up** should ideally include **radiographic examination** and the caries management plan should include **plaque control, dietary counseling**, combination of other **fluoride modalities for caries prevention** (like F varnish, fluoride gels, fluoride rinses and fluoride toothpaste) and **sealants**, depending on patient's age and individual situation.
- Follow-up on **large lesions** or **lesions in hard-to-clean areas** can be combined with the use of **glass ionomer** restorations or traditional restorative treatment, as patient circumstances allows.



# Clinical technique


- **Preparation**

SDF has the potential to stain clinical worktops and clothing. Therefore, use of a **plastic lined work surface** should be implemented. Additionally, plastic bibs for patients are required.

- **Isolation**

- ✓ **Ideally**, use of complete isolation with a **rubber dam** should be undertaken;



- 
- ✓ Some products include a **light-cured liquid dam** to apply onto the mucosa of the teeth and adjacent teeth receiving treatment.
  - ✓ If rubber dam or liquid dam is not available, it is essential that **petroleum jelly is placed onto the gingiva** and **cotton wool** used to isolate the tooth





- **Caries removal**

As described previously, **no** significant benefit of caries excavation before application of SDF, however, the **authors'** recommendation to **remove soft, necrotic, infected dentine** before application of SDF, in order to sufficiently **reduce the bacterial load**. However, this is **case dependent**, and risk of iatrogenic exposure must be weighed up before caries removal.





- **Application**

- ✓ A **micro brush** should be fully immersed in SDF solution and applied **directly** to the tooth surface in question.
- ✓ SDF should ideally be left for **one to three minutes**
- ✓ Patients will often describe a '**metallic taste**' when SDF is applied.
- ✓ **Excess** should then be appropriately removed with **cotton wool** or a **gauze**.







- ✓ If **KI** is to be applied, then a micro brush, fully immersed in the KI, should be applied to the SDF
- ✓ Initially, a **white precipitate** will form.
- ✓ KI should be **repeatedly** applied until the precipitate turns **colorless**.





- ✓ As mentioned previously, **leaving** precipitate on the tooth may result in a **reduction in bond strength**; therefore, precipitate should be **rinsed away** and the tooth **air-dried** before undertaking further restorative intervention.
- ✓ If contact with the mucosa occurs, it is essential that the area be thoroughly rinsed.
- ✓ The burn/staining usually appears as a **mixed white/black lesion**, which usually resolves **within one to two weeks**



## Further restorative treatment

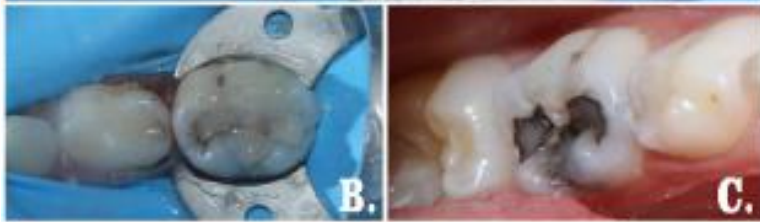
- **acid etchant** or **acid conditioning** agent should be applied only **after** application of the SDF (with or without KI).
- SDF (with or without KI) should be thoroughly **washed** and **air-dried** after application.
- SDF application should be **restricted** to **dentine** wherever possible to **minimize SDF contamination of enamel**;



## **SMART (Silver Modified Atraumatic Restorative Treatment/therapy)**

- is a most recent, **non-invasive** and **inexpensive ART** of this millennium.
- The **amalgamation** of glass ionomers **hydrophilicity**, **bio-chemical property**, **fluoride release**, **quick set**, **ease of handling** along with **carriostatic property of SDF** makes it literally the smart way of doing restorations in a **pre cooperative** or a child with **limited coping ability**.
- **clinical** and **radiographic** success can be achieved when using SDF under **SMART** restoration and under **Hall's crown**.
- **SDF** coupled with **Hall's crown** has an added advantage of a **better coronal seal** as compared to the conventional SMART glass ionomer restoration in high caries risk children.





## **SDF as SMART with MIPD (Minimally Invasive Pediatric Dentistry) approach**

A: Pre-operative

B: Immediate post op followed

C: 6 months follow-up

D: 12 months follow up



## **SDF with SMART HALLS crown**

A: Preoperative with elastics placed

B: Intraoperative

C: Immediately after application of SDF

D: Post stainless steel crown cementation

E: Radiographs at Preop, follow up at 12 months and 24 months





## SDF concentrations

- ✓ Two prospective randomized control trials have examined the effect of concentration on caries arrest.
- Both studies compared **38% and 12%** SDF in its ability to arrest caries.
- Both studies found that **38% SDF** was **more effective** in arresting caries than 12% SDF.

## Frequency of application

- ✓ **six monthly SDF application** is **more effective** at arresting caries than yearly application.

## Post-application

- ✓ If **fluoride varnish** is to be used post-application of the SDF, the varnish must not be applied to the surfaces where SDF has been placed, as it may **reduce the antibacterial action of the SDF**



## **SDF in mandibular anterior**

A: Preoperative

B: 6 months follow-up

C: 12 months clinical follow-up







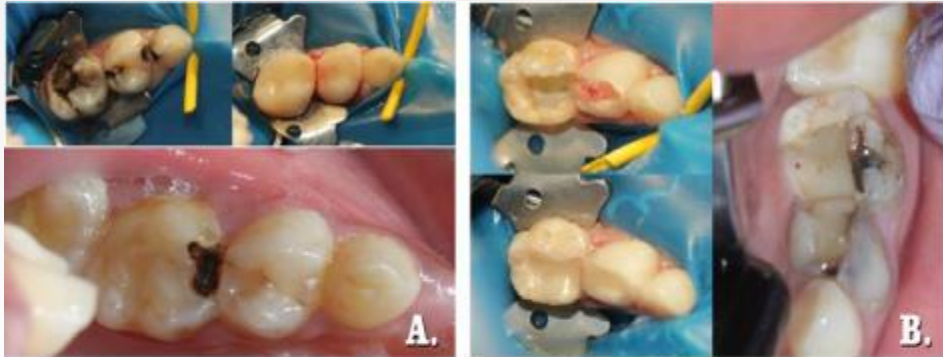
## **SDF to arrest secondary caries**

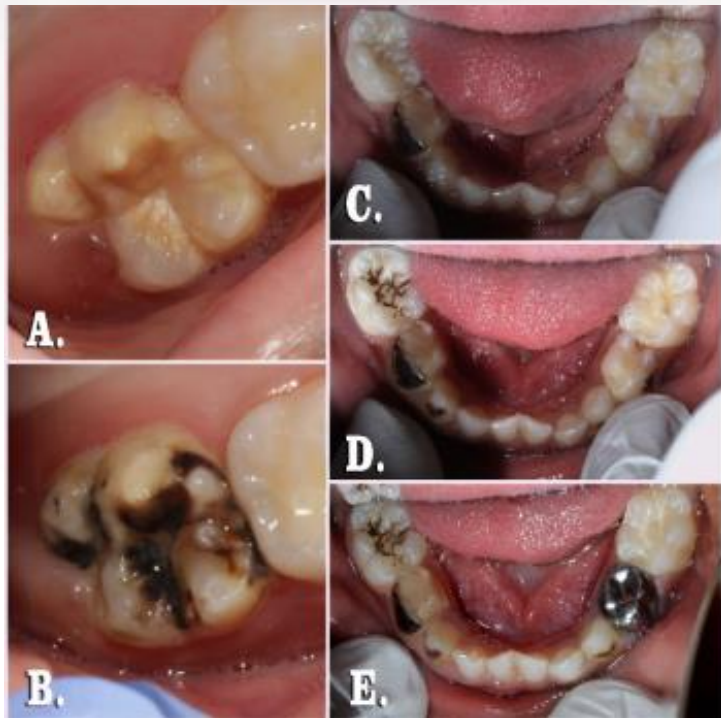
A: proximal

B: Occlusal

C: SDF in children with special needs:  
Preoperative

D: SDF in children with special needs:  
6 months follow-up





## **SDF as sealant in MIH affected permanent first molar**

A: Preoperative

B: Postoperative

C: SDF as sealant in primary molar

D: SDF as sealant in primary molar 12 months follow-up

E: SDF as sealant in primary molar 24 months follow-up

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*The end...*