Journal of Operative and Esthetic Dentistry

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Quock RL et al., J Oper Esthet Dent. 2016, 1(2):6-9
http://dx.doi.org/10.14312/2398-029X.2016-2

Review

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Silver diamine fluoride: An operative dentistry perspective

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Abstract

The rationale for much of operative dental therapy is to address local tooth destruction due to the dental caries process. While mechanical tooth preparation and restorative biomaterial concepts continue to evolve, attention should also be paid to the biological challenges of the caries disease. Silver diamine fluoride is a therapeutic agent that shows great promise for the operative dentist due to its ability to stimulate arrest of active caries and prevent new lesions. Clinical and laboratory studies continue to demonstrate silver diamine fluoride's efficacy in treating dental caries. This practical review summarizes the current evidence for its use in operative dentistry.

Keywords: caries; caries arrest; fluoride; silver; silver diamine fluoride

Introduction

The operative preparation and restoration of teeth has long been an integral part of acute dental caries treatment. Cavitated lesions are traditionally targeted for operative treatment because vital enamel substructure has been lost, rendering complete remineralization impossible. Indeed, a well-sealed restoration can be a strong contributor to the arrest of the caries lesion, seemingly regardless of the level of excavation [1, 2].

Although the science seems to suggest that not all caries affected dentin needs to be removed prior to restoration [3], there is hesitation in the practicing community to adopt this perspective [4, 5]. The reluctance to "leave caries" before restoration relates to skepticism of caries arrest under the restoration. Not being able to clinically observe dentin hardness may be uncomfortable for clinicians [4, 5].

If the growing scientific evidence supporting minimal tooth preparation has not been enough to convince clinicians to be less invasive, perhaps an emerging therapy will help to bridge the gap. Silver diamine fluoride (SDF) is a solution that has demonstrated through clinical research the ability to arrest active caries lesions, and also prevent the occurrence of new ones. Clinical manifestation of arrest is typically hardening of the dentin surface to the point of resistance to penetration with a sharp probe, usually accompanied by color change. This practical review aims to summarize the current understanding of silver diamine fluoride and direct the reader toward applications in daily operative dental practice.

Composition and action

Silver diamine fluoride [$Ag(NH_3)_2F$] is a clear, ammonia solution with two active ingredients – silver and fluoride [7, 8]. It has been commercially available in Asia and South America for at least three decades, but only recently was introduced to the USA market. In 2014, the United States Food and Drug Administration approved SDF as a dentin sensitivity agent, similarly to fluoride varnishes. The use for anticaries purposes will be off-label.

Although variances exist in application protocols, simply scrubbing SDF onto the surface of a cavitated lesion with a brush or small cotton pellet appears to be an acceptable approach. A three-part mechanism of action has been proposed for SDF. First, silver salts formed on the dentin surface stimulate sclerosis/calcification [8]. Laboratory studies indicate some penetration of silver ions into dentin [9] as well as detectable increase in hardness of arrested lesions [10]. Also, the intermediate product silver nitrate has an antibacterial effect [8]. A number of in vitro studies have demonstrated an antimicrobial action of SDF [11-14]. And not surprisingly, fluoride is active in remineralization and prevention [8]. The most commonly studied and marketed form of this product, 38% SDF, presents approximately

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Received 3 March 2016 *Revised* 25 May 2016 *Accepted* 7 June 2016 *Published* 14 June 2016

Citation: Quock RL, Silver diamine fluoride: An operative dentistry perspective. J Oper Esthet Dent. 2016; 1(2):6-9. DOI: 10.14312/2398-029X.2016-2

44,800 ppm of fluoride. As a comparison, five percent sodium fluoride varnish presents 22,600 ppm of fluoride. Arrested lesions treated with SDF show superficial bands of increased calcium and phosphate [15]. It appears that SDF slows down the progression of lesions [16].

Silver diamine fluoride is not known to elicit any consistent adverse pulpal effects [17]. It may actually contribute to tertiary dentin deposition when incorporated into indirect pulp treatment [18]. Systemic concerns secondary to ingestion after SDF application are also minimal, with regard to both fluoride and silver levels in the blood [19]. The primary adverse effect resulting from caries management with SDF is esthetic in nature. Lesions arrested by SDF tend to exhibit darkened color. Restorative management of this possible inconvenience will be addressed later in this review.

Clinical efficacy

Concomitant to the FDA approval, it appears that the application of SDF in caries management is gaining momentum. Dental schools are incorporating SDF into theoretical and practical curriculum [20]. Much of the rationale for SDF use is based upon its effectiveness in arresting caries, especially in dentin (65.9%) [21]. For the purpose of this review, and based on available clinical studies of SDF [22-26], arrest will be described as hardening or resistance of previously carious dentin to penetration with a sharp probe – this is often accompanied by darkening in color and, in theory, lack of progression of the lesion. Since 38% SDF is the most studied formulation, and widely available commercially, summaries of clinical studies that tested this product are presented below (Table 1).

Table 1 Summary of clinical studies in caries arrest efficacy of silver diamine fluoride.

Author, Year [Reference]	*Method (Sample size)*	*Comparative percentage arrest of caries*
Chu et al, 2002 [22]	Primary teeth, 30 months (n=375) Exp1 = 38% SDF annually Exp2 = 5% NaF 4x/year Control = no treatment	Exp1>Exp2, Control (p<0.001)
Llodra et al, 2005 [23]	Primary and permanent teeth, 36 months (n=373) Exp = 38% SDF 2x/year Control = no treatment	Exp>Control (p<0.001)
Yee et al, 2009 [24]	Primary and permanent teeth, 24 months (n=976) Exp1 = 38% SDF at baseline Exp2 = 12% SDF at baseline Control = no treatment	Exp1>Exp2, Control (p<0.001)
Zhi et al, 2012 [25]	Primary teeth, 24 months (n=181) Exp1 = 38% SDF annually Exp2 = 38% SDF 2x/year Exp3 = Glass ionomer annually	Exp2>Exp1, Exp3 (p=0.007)

In 2002, Chu and colleagues published results of a 30 months study of cavitated anterior primary tooth caries in Chinese pre-school children [22]. Three hundred seventy five participants (aged 3-5) were divided into a control group and four experimental groups as follows: yearly applications of 38% SDF or quarterly applications of 5% NaF varnish (half of each modality experienced excavation of soft dentin prior to fluoride treatment, while half received no mechanical preparation). Cavities were not restored. Silver diamine fluoride groups, regardless of whether caries excavation took place or not, presented with nearly twice as many arrested lesions as varnish and control groups [22].

Llodra et al., published the results of their 36 months study of cavitated primary teeth and permanent molars in 2005 [23]. Three hundred seventy three schoolchildren (average age 6) participated, with experimental groups receiving 38% SDF every six months for the duration of the study. Soft carious dentin was removed from permanent molars, while no excavation was performed on primary teeth. A significantly greater percentage of SDF treated lesions experienced arrest compared to the control group [23]. SDF treated teeth also experienced less than half the number of new decayed surfaces, demonstrating its preventive potential [23].

A study of 976 Nepalese children (aged 3-9) published in 2009 involved cavitated primary teeth [24]. The teeth were not excavated prior to application of either 12% or 38% SDF, which were applied only once at baseline. Follow up occurred every six months for two years, with no restorations placed. 38% SDF groups experience significantly more caries lesion arrest (more than two surfaces on average at the two year mark) than 12% SDF or control groups [24].

Zhi and colleagues studied one hundred eight one Chinese schoolchildren with cavitated caries lesions [25]. Superficial soft dentin was removed with prior to one of the following three treatments: annual application of 38% SDF, biannual application of 38% SDF, and annual application of low-viscosity glass ionomer. The caries arrest rate at 24 months was significantly better for the biannual applications of SDF (91% arrest rate) [25].

Pediatric populations have drawn the most attention for clinical studies regarding SDF, but adult populations are being targeted as well. A 2013 study of root surfaces in an elderly Chinese population showed significantly better arrest and prevention of root lesions when treated with SDF [26]. Prevention of caries in pits-and-fissures has also been explored, although one study reported that SDF lacked the ability to prevent pit-and-fissure caries [27], another study suggests that annual applications of SDF to occlusal surfaces does prevent caries [28]. Overall, the reported data is favorable: the most recent systematic review, with meta-analysis, of SDF reports an overall dentin caries arrest rate of 65.9% [21], slightly tempering results from an earlier review [8].

Considerations for use in operative dentistry

The general procedure for application of SDF to caries lesions is fairly simple. Contraindications include patients with silver allergy and/or ulcerative gingivitis or stomatitis. Following standard infection control protocols, one drop of SDF is placed into a dappen dish (enough for approximately five teeth). Excess bulk saliva is removed, preferably with a saliva ejector, and soft tissue isolation is achieved with a dental dam or cotton rolls/gauze. If a dental dam cannot be placed, gingiva in the application area can be coated with a thin layer of petroleum jelly. Tooth surfaces are then gently air dried, and a small brush is used to scrub the SDF onto the target lesion surface for approximately one minute. Rinsing with water is not mandatory, but if desired, should be done so in the presence of a high volume evacuator.

If part of the goal in restoring a cavitated lesion is caries control, then SDF clearly presents an opportunity to ensure arrest of the lesion. Following this rationale, the arrest and hardening of existing dentinal caries by SDF dovetails with the concept of minimally invasive preparation and tooth conservation [29]. It has been demonstrated that SDF does not adversely affect the bond strength of resin composite to dentin, regardless of whether an etch-and-rinse or self-etch adhesive is used [30]. In bovine dentin, SDF seems to enhance the bond strength of glass ionomer cement [31]. These factors appear to justify the addition of SDF to the clinician's armamentarium.

As mentioned earlier, the primary adverse effect of SDF on dentin is the staining of the arrested lesion. There are at least two options to address this possible esthetic challenge. Potassium iodide applied to the SDF treated surface in a two-step process has been investigated previously. The result is a white precipitate, which may be more esthetically pleasing for some patients [32]. Additionally, a glass ionomer or resin-modified glass ionomer liner can be placed over stained axial or pulpal walls to cover over stained areas. This is an interesting option due to the glass ionomer's possible affinity for SDF treated dentin [31].

Once esthetic concerns are addressed by either of the above options, the clinician needs to decide when to restore the cavity. One line of thought is that the longer the SDF treated cavity is able to be exposed to the oral environment, the greater the arrest [7], this may be due to the available minerals in the saliva. If patient and practitioner are willing to delay restoration until clinically detectible arrest is achieved, then the operative dentist may elect to reapply SDF at determined intervals until acceptable arrest occurs. Recent investigation suggests that accelerated arrest can be achieved with three early applications of SDF, each one week apart [33].

Once dentin arrest is observed, the clinician can proceed with typical conservative operative dentistry, removing unsupported enamel and caries at the DEJ with retention of arrested axial or pulpal walls. Full-mouth rehabilitation of teeth subjected to extreme caries insult has been reported, with SDF providing the opportunity to save many otherwise hopeless teeth [34]. Follow up on SDF treated lesions that have been restored should be approached in the same way as any restoration is monitored; the absence of clinical and radiographic evidence of caries activity or progression will relate to success. If recurrent caries or progression is determined, the operator may decide to commence with repair or replacement of the restoration.

Conclusion

Silver diamine fluoride appears to be effective in arresting active caries lesions, and preventing new ones from occurring. These advantages should be of interest to dental professionals. The use of silver diamine fluoride in dentistry is further supported by its apparent compatibility with existing restorative materials.

Conflicts of interest

Author declares no conflicts of interest.

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