Review Article

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Dentistry Section

Approaches to Arresting Dental Caries: An Update

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ABSTRACT

Background: Dental caries is one of the most prevalent chronic oral diseases across the globe that can be both treated and prevented. Preventive management strategies can effectively arrest and even completely reverse the caries process. This article aimed to review the literature on different approaches explored towards arresting caries progression.

Materials and Methods: Literature search of publications in Pubmed/Medline was carried out. Total 73 articles including clinical trials, invitro studies, case reports and review articles were reviewed.

Results: Twenty-two clinical trials and invitro studies were selected for review. Most studies suggested use of Silver Diamine Fluoride (SDF) as simple and effective caries arresting approach. Fluoride varnish treatment effectively arrests caries by inhibiting demineralization, resulting in highly significant caries reductions. Arginine with an insoluble calcium compound enhances arresting and reversing buccal, coronal and root caries. A few clinical studies have shown that sealants placed in caries fissures can arrest the caries process.

Conclusion: Various fluoride containing agents are clinically effective in arresting progression of carious lesion. However, these materials should be used appropriately understanding their scope and limitations to arrest dental caries.

Keywords: Arrest, Fluorides, Prevention, Silver diamine fluoride, Varnish

INTRODUCTION

The prevalence of oral diseases has a considerable economical impact on health care provision across the world; with dental caries affecting over 80% of the population in many countries, has a significant influence on quality of life, as well as implications for systemic health [1].

A decline in caries has been observed in most industrialized countries over the past 20 years or so. The changing pattern can be attributed to effective use of fluorides, together with changing lifestyles and improved self-care practices. In developing countries, little, if any, importance is given to preventive or restorative dental care and teeth are often left untreated or are extracted to relieve pain or discomfort [2].

Dental caries is a multifactorial disease in which the disease process is initiated within the bacterial biofilm that covers the tooth surface [3]. The major factors involved in dental caries are fermentable carbohydrates, salivary parameters and acidogenic bacteria. Antibacterial agents, fluoride from extrinsic sources and diet have been employed in arresting dental caries [4].

Once the first clinically visible signs have been discovered, the detection should be followed by diagnosis of severity and extent of the lesion and whether it is an active process or not. In general, there is ample time—between lesion initiation in enamel and subsequent progression into dentin involvement—to interrupt this process using preventive and repair strategies [5].

Untreated dental caries with associated discomfort or toothache contributes to altered growth as well as the cognitive development of children and growing adults [6]. Caries may be managed by a combination of natural and/or therapeutic procedures [4]. By providing proper repair options that encourage remineralisation, the damage of the tooth by caries process may be healed. Dental treatment makes a very significant difference to the psychological and social aspects of the patient's life [6].

Traditional management of a caries lesion is primarily focused on operative treatment. This often demands restorations which require several replacements over time with increasing restoration size and restorative cycle [5].

Contemporary caries management is focused on the various options to cope with the locally out-of-balance oral biofilm and stop progression of the disease. After the caries process has been halted or arrested, causative factors need to be evaluated and individual treatment regimens installed that will prevent occurrence of the new caries disease. For successful non-invasive management, the lesions have to be detected early on, so they can be managed in a non-operative way [5].

Approaches to arresting dental caries have been a matter of interest for more than couple of decades. Previous reviews have highlighted use of Silver Diamine Fluoride (SDF) and other silver compounds for caries management. To date, there has been no systematic investigation evaluating the overall effectiveness of various techniques and/or approaches towards arresting caries progression. Hence this work is undertaken to review the literature on different approaches explored towards arresting caries with the objective to have clearer understanding of the scope and limitations in arresting caries progression.

MATERIALS AND METHODS

To explore the various approaches for arresting dental caries the following strategy was adopted:

- **Research question:** "What are the techniques and/or approaches for arresting the progression of carious lesions?"
- **Search strategy:** The PubMed/Medline were searched to identify relevant studies published from 1981 to November 2014. The search strategy employed the following keywords related to the caries outcome: "Arresting" or "Arrest" or "Progression" or "Arrested" or "Arrestment".
- **Inclusion and exclusion criteria:** The selection was limited to clinical trials and *in vitro* studies published in English that evaluated the arresting of carious lesions were included. Review articles and case reports were excluded. Studies which only suggested effectiveness of material in arresting without evidence were also excluded.
- **Data Extraction:** Two independent reviewers searched studies using a two stage screening process. In the first stage, titles

and abstracts were screened to select relevant articles that met the inclusion/exclusion criteria. In the second stage, the reviewers independently verified study eligibility after reading full texts. Various criteria for assessing arresting of caries among the studies were: clinical assessment, radiographic examination, Diagnodent measurements, reduction of biofilm count, change in micro hardness of surface, reduction in colony forming units (CFUs) of bacteria and surface changes in F^- and Ca/P levels. Data extraction and quality assessment were performed for included studies. Disagreements about the inclusion or exclusion of a study were resolved by consensus.

- **Analysis of these studies addressed:** (1) Materials used for arresting dental caries including concentration and frequency of use (2) Efficacy and clinical safety issues associated with the arresting technique (3) Study designs.

RESULTS

The initial search identified 73 articles in PubMed/Medline. Case reports and review articles were excluded, leaving 21eligible articles for analysis [Table/Fig-1].

Silver Diamine Fluoride (SDF): The preventive fraction in deciduous teeth was 79.7% whereas in permanent molars it was 65%.The SDF group had significantly more surfaces with inactive caries than controls (p< 0.05) [7]. The single application of 38% SDF with or without tannic acid was effective in arresting caries after six months (4.5 and 4.2 mean number of arrested surfaces; *p*< 0.001), after one year (4.1 and 3.4; *p*<0.001), and after two years (2.2 and 2.1; *p*< 0.01) [8]. Biofilm counts were reduced in SDF group than control (*p*< 0.01). Surfaces of carious lesions were harder after SDF application than after water application (*p*< 0.05) [9].The relative micro hardness at 25 to 50 µm below the surface was higher in the SDF group than in the control group (p < 0.05) [10].CFU of *S. mutans* and *L. acidophilus* in the SDF group was significantly lower than control group [11].The mean numbers of arrested root caries surfaces in oral hygiene instructions(OHI) group, OHI/SDF and OHI/SDF/OHE(Oral Health Education) were 0.04, 0.28 and 0.33, respectively (*p*< 0.01) [12].

SDF and other compounds: An annual application of SDF showed more arrested caries lesions in their upper anterior teeth than in other groups (p< 0.001). The control group developed more new caries lesions in their upper anterior teeth (*p*<0.001) than those receiving SDF and NaF varnish [13]. After 3 and 6 months, SDF showed a significantly greater capacity for arresting caries lesions than CTT and GIC (*p*<.001). At 18- and 30-month evaluations, no differences were observed among the 3 groups (*p*>0.05) [14]. Higher caries arrest rates were found in lesions treated in semi-annual SDF (OR = 2.98, *p* = 0.007), those in anterior teeth (OR = 5.55, *p*< 0.001), and those in buccal/lingual smooth surfaces (OR = 15.6, *p* = 0.004) [15].F% and Ca/P ratio were significantly higher on dentin surfaces after AHF application [16].

Fluorides: Seventy four percent of the approximal surface lesions and 90% of the occlusal surface lesions that were in enamel at baseline remained unchanged. The greatest change occurred in the approximal surface lesions that were within 1 mm of the pulp at baseline [17]. At the third annual examination, 45% of the caries lesions on the proximal surfaces of primary anterior teeth had become arrested [18]. Arrestment proportions were 84.4% (NaF) and 85.3% (NaF+CHX) (*p* = 0.71) [19]. Caries prevalence was significantly lower in the varnish group after seven months (*p*<0.001 for DeMFT, DeMFS) [20]. A significant difference in lesion progression was only found between the Infiltration+Fluoride varnish and the Sealing+Fluoride varnish group of teeth (p = 0.021) [21].

Sealants: Fissure sealing and tooth restoration were equally effective in the management of non-cavitated dentin occlusal caries in primary teeth [22]. Sealed teeth presented lower caries progression when analysed by radiographic examination (*p*=0.004) [23].

Sl. No.	Author	Study design	Year	Material used
1	Llodra JC et al., [7]	Clinical trial	2005	SDF
2	Yee R et al., [8]	Clinical trial	2009	SDF
3	Chu CH et al., [9]	*In vitro*	2012	SDF
4	Mie ML et al., [10]	*In vitro*	2013	SDF
5	Mei ML et al., [11]	*In vitro*	2013	SDF
6	Zhang W et al., [12]	Clinical trial	2013	SDF
7	Chu CH et al., [13]	Clinical trial	2002	SDF NaF
8	Braga MM et al., [14]	Clinical trial	2009	SDF CTT GIC
9	Zhi QH et al., [15]	Clinical trial	2009	SDF GIC
10	Hosoya Y et al., [16]	*In vitro*	2012	SDF AHF
11	Craig GG et al., [17]	Clinical trial	1981	AgF followed by SnF_2
12	Lo ECM et al., [18]	Clinical trial	1998	Fluoride toothpaste
13	Duarte AR et al., [19]	Clinical trial	2008	NaF CHX
14	Xhemnica L et al [20]	Clinical trial	2008	Fluoride varnish
15	Bakhshandeh A et al., [21]	Clinical trial	2015	Fluoride varnish
16	Borges BCD et al., [22]	Clinical trial	2012	Resin Based sealants
17	Silviera ADS et al., [23]	Clinical trial	2012	GIC sealants
18	Souza MLR et al., [24]	Clinical trial	2013	1.5% Arginine and SMFP
19	Srisilapanan P et al [25]	Clinical trial	2013	1.5% Arginine and SMFP
20	Yin W et al., [26]	Clinical trial	2013	1.5% Arginine and SMFP, NaF
21	dos Santos VE et al., [27]	Clinical trial	2014	Nano Silver Fluoride

[Table/Fig-1]: Summary of studies included in the study
SDF- Silver diamine fluoride; NaF- Sodium Fluoride; CTT- Cross tooth-brushing technique; GIC- Glass ionomer cements; AHF- Ammonium hexafluorosilicate; AgF- Silver fluoride; SMFP- Sodium monofluoro phosphate; CHX- Chlorhexidine digluconate

Arginine: Difference in the number of root caries lesions becoming hard in the two groups was statistically significant (p = 0.038) after six months. The unadjusted odds ratio for lesions becoming in the experimental group compared to the control was 1.73 (95% CI 1.03–2.91) [24]. The difference between the two groups was statistically significant (*p*< 0.001). The difference in lesion area between the two groups also attained statistical significance (*p* = 0.003) [25]. Arginine demonstrated an improvement after only three months that was almost identical to that achieved by the conventional 1450 ppm fluoride dentifrice after 6 months [26]. At 12 months, 66.7% of the lesions treated with NSF were still arrested, while the control group had 34.7% remaining arrested (*p* = 0.003) (PF = 50%). The number need to treat (NNT) at five months and 12 months were two and three respectively [27].

DISCUSSION

Dental caries is a multifactorial, bacteriologically mediated, chronic disease that can damage the dentition of both children and adults. The emphasis in treatment planning has shifted from the restoration of carious teeth to the prevention of decay with minimal intervention [20].

The literature describes various approaches which halt a continuous caries process. Cariostatic properties are attributed to some materials, supposedly ensuring reduction of remaining microorganisms attributing to lesion arrest [28]. Studies have been conducted

regarding arresting active caries in Japan and other Asian countries, Australia and South America for a considerable period of time [23].

Silver Diamine Fluoride (SDF): Since 1960s Silver diamine fluoride (SDF) has been used for arresting caries. The silver ion has bactericidal properties, and it is not caustic because it lacks the nitrate group.

Concentration: Although attempted in different concentrations, 38% SDF is the most widely studied concentration in clinical trials.

A single application of 38% SDF, with or without the use of tea as a reducing agent, was significantly more effective in arresting dental caries in both the anterior and posterior primary dentitions of young children than 12% SDF and no application (control) [8].

In another study 10% SDF solution showed a faster ability to inactivate lesions compared to the other non-invasive techniques tested (GIC and CTT) [14].

Clinical trials have analysed the caries arresting efficacy of SDF over varying period of time ranging from three months to three years. In a prospective randomized trial a single application of 38% SDF was sufficient to prevent only 50% of the arrested surfaces at 6 months from reverting to active lesions again over 24 months. Arresting caries effect of 38% SDF decreases slowly over time [8].

An 18 months prospective controlled clinical trial showed that annual applications of SDF solution are effective in arresting dentin caries in primary anterior teeth [29]. The 30-month results of a study reported that the annual application of SDF solution was effective in arresting dentin caries in primary anterior teeth [13].

In a split-mouth study, 10% SDF showed a greater capacity for arresting the carious lesions than CTT and GIC at three and six months. At the 12-month follow-up examination, SDF and GIC were equivalent at arresting the lesions, but both were more efficient than CTT. At 18- and 30-month evaluations, no differences were observed among the 3 groups. After 30 months of follow up, SDF exhibited a faster ability to inactivate lesions compared to the other non-invasive techniques tested [14]. Another 36-month controlled clinical trial using 38% SDF solution proved that the six-monthly application of SDF is efficacious to arrest caries showing high preventive fraction of SDF in deciduous dentition [30].

A controlled clinical trial showed greater number of active root caries surfaces which became arrested in group with OHI and SDF application annually, plus an oral health education (OHE) programme every six months as compared to other groups with OHI annually and group with OHI and SDF application annually [9].

In vitro studies showed that SDF possess an antimicrobial activity against cariogenic biofilms of *Streptococcus mutans* [8,15]. *Lactobacillus acidophilus* [8] and *A. Naeslundii* [15] formed on dentine surfaces. The surface of the dentine carious lesions was significantly harder in the subgroup treated with SDF than in the controls. In addition, SDF slowed down demineralisation of dentine [8,15].

A computer-controlled artificial mouth study showed that 38% SDF inhibits multi-species cariogenic biofilm formation on dentin carious lesions and reduces the demineralization process [10].

Type of dentition: Most of the studies suggested higher efficacy of SDF in primary dentition. Whereas one study demonstrated that SDF promotes a faster arrestment of caries lesions in permanent first molars [14].

Frequency of application: The optimal frequency of application of SDF is unknown, but in resource-limited situations, repeated applications of SDF are unlikely to be either practical or affordable to local communities, even when applied by trained primary-health-care workers [8]. There is no documented evidence that starting treatment with multiple applications in a short period is preferable to starting with a single initial application [30].

A 24-month SDF study showed that a single spot application of SDF is effective in arresting caries lesions, but the effectiveness decreases over time [31]. In another 30-month study, SDF showed a faster ability to inactivate lesions compared to the other noninvasive techniques tested when applied twice over a period of one week [14].

A 36 months study showed that the six-monthly application of a 38% SDF solution is efficacious to control caries in deciduous teeth [30]. A 30-months study showed that the annual application of SDF solution is effective in arresting dentin caries in primary anterior teeth [32]. A study reported that efficacy of SDF solution can be enhanced by increasing the frequency of application from annually to every six months [33]. Six monthly application of SDF coincides with the commonly recommended frequency of recall visits for high risk patients. Better results can be expected if SDF solution is applied onto the carious lesions every time a child visits a dentist at this recall frequency [15].

Adverse effects of SDF: The formation of metallic silver from silver compounds results in staining carious tissue black. To counter this effect, researchers have investigated an alternative agent, ammonium hexafluorosilicate, $(NH_4)_2SiF_6$ as an antibacterial agent, which does not contain silver. This was not however found to be effective in reducing lesion progression in vitro compared to SDF [34].

Excavation of carious tissue: In several studies, caries excavation or no caries removal have been performed prior to silver compound application [34]. This finding is important if SDF is to be considered as a therapeutic agent in controlling the caries situation of children in community based programs. First, the treatment procedures will be much simpler when caries excavation is not carried out. Second, non-dental personnel can carry out the treatment after receiving simple training. Third, the non-invasive nature of the therapy makes subject compliance possible, even for young children [15]. Further clinical trials are necessary to determine if excavation is required so that unnecessary clinical procedure may be omitted [34].

Cost effectiveness: SDF is more economical than NaF varnishes and they are significantly less expensive than standard treatments. Hence SDF may be recommended as an alternative in developing countries with limited access to dental care [35].

Other Silver Compounds: Full mouth 'spot' application of silver fluoride, the silver component of aqueous silver fluoride solution may play the principal role in arresting caries [36]. A 2-stage topical treatment regimen (AgF followed by SnF_2) showed that arrest of caries was there in 65% of all primary molars used [16].

Fluorides: Fluoride is a key component of oral health promotion and caries prevention. Fluoride treatment aims to prolong the contact time between fluoride and the tooth surface, thereby improving fluoride incorporation into the surface layers of the enamel.

A study found that 45% of the caries lesions on the proximal surfaces of primary anterior teeth in KG1 children had become arrested during daily tooth brushing exercise using fluoridated toothpaste (1000 ppm F) [18]. The addition of CHX to NaF mouth rinse to arrest active caries resulted in similar arrestment proportions in group with combination of 0.05% NaF + 0.12% CHX and group with 0.05% NaF alone but did not improve the arrestment capacity of the NaF mouth rinse [19]. A study showed repeated applications of fluoride varnish in the clinic every three months along with two daily two-minute rinses with sodium fluoride at home arrests interproximal decay [33].

Sealants: Sealed caries fissures showed significantly more micro leakage and insufficient sealant penetration depth than sound fissures suggesting limited usage of sealants in arresting caries [32].

Sealed teeth presented arrest and lower caries progression when analysed by radiographic examination [23]. Another study showed that fissure sealing and tooth restoration were equally effective in the management of non-cavitated dentin occlusal caries in primary teeth [22].

Arginine: Dentifrice with 1.5% arginine, 1450 ppm fluoride, as sodium monofluorophosphate, in an insoluble calcium base has the

potential to significantly enhance the caries preventive benefits of traditional fluoride dentifrices [37].

Arginine dentifrice proved superior efficacy in arresting and reversing active coronal caries lesions in children than brushing with a matched positive control dentifrice containing fluoride alone [25].

Statistically significant superior efficacy of arginine containing toothpaste in arresting and reversing buccal caries [26] and root caries [24] lesions were demonstrated when compared to a conventional dentifrice containing fluoride alone.

CONCLUSION

SDF is simple, inexpensive and has caries arresting properties, effective at semi-annual application at 38% concentration, with most studies performed on primary teeth. SDF has a potential to be included in dental armamentarium addressing caries burden in developing countries. Fluoride varnish treatment effectively inhibits demineralization, resulting in highly significant caries reductions. Arginine with an insoluble calcium compound in dentifrices has the potential to significantly enhance arresting and reversing dental caries lesions.

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