

# Recent advancements in fluoride: A systematic review

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## Abstract

To review advancements of fluoride in dentistry, a search of 21 electronic databases and World Wide Web was conducted. Relevant journals were hand searched and further information was requested from authors. Inclusion criteria were a predefined hierarchy of evidence and objectives. Study validity was assessed with checklists. Two reviewers independently screened sources, extracted data, and assessed validity. Fluoride has become an important tool in preventive dentistry. Current research is focused on the development of strategies to improve fluoride efficacy. Fluoride therapy in the form of varnish, gel, mouth rinse, or toothpaste has been used extensively as a caries-preventive intervention for over three decades. The purpose of this review is to inform the reader about new research related to the use of fluoride for the prevention of dental caries.

**Key words:** *Fluoridation, fluoride, varnishes*

## INTRODUCTION

Main benefit of fluoride is in reducing the risk of dental caries. In recent years, rapid changes have occurred in the prevalence of dental caries across countries. Today countries show a decline in the prevalence in dental caries and more children are becoming caries free. Decline in dental caries may be attributed to the cariostatic efficacy of fluoride.<sup>[1]</sup> Research into the mechanisms of anticaries efficacy of fluoride is ongoing, which may lead to better prevention strategies. New and/or improved fluoride products are entering the marketplace at an increased rate; these products include toothpastes, fluoride varnishes, fluoride-containing whitening agents, and other fluoride-containing cleaning products.

In early 2011, after years of review and evaluation, the Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), and the American Dental Association (ADA) CDC, EPA, and the ADA proposed a modification to their recommendations for the amount of fluoride in drinking water to be 0.7 µg/ml (ppm) at all places in the United States. Thus, until 2011, the CDC and the ADA had recommended that the amount of fluoride in drinking water should range from 0.7 ppm in warmer climates to 1.2 ppm in cooler climates.

Studies have shown that some brands contain sufficient amounts of fluoride; therefore, when mixed with optimally fluoridated water, they result in greater than

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optimal amounts of fluoride in the formula. The CDC and ADA have varied their recommendations regarding this in recent years. In 2006, the CDC and ADA had recommended that low-fluoride water be used to reconstitute infant formula to guard against exposing the infant to excess amounts of fluoride. Recent evidence reviewed by the CDC suggests that “mixing powdered or liquid infant formula concentrate with fluoridated water on a regular basis may increase the chance of a child developing the faint, white markings of very mild or mild enamel fluorosis.”

There are some recent studies in which the amount of fluoride made available in the oral cavity during tooth brushing (for approximately 2 min) was measured. It seems that in developing regions of the world, there are toothpastes marketed that contain the total fluoride as indicated on the label, but they do not release sufficient fluoride during use to prevent caries. This is due to the composition of the toothpaste which can render a significant amount of the fluoride unavailable.<sup>[2]</sup>

A clinical study in 2006 by Weintraub also confirmed that fluoride varnish is efficacious in reducing early childhood caries incidence. Clinical studies have demonstrated that varnishes can supply fluoride more efficiently than other topical agents.<sup>[3]</sup>

A recent comprehensive systematic review by Twetman *et al.* summarized literatures on “fluoride toothpaste” from 2002 to 2008 and concluded, “There was strong evidence that daily use of fluoride toothpaste has a significant caries-preventive effect in children, compared with placebo (prevented fraction 24%). The effect was boosted by supervised tooth brushing, increased brushing frequency to twice daily, and use of a toothpaste concentration of 1500 ppm fluoride.”<sup>[4]</sup>

The aim of this study is to describe the knowledge currently available on this topic and to suggest how this information could be used by clinicians to advise their patients on the ideal use of the currently available products.

## RESULTS

A total of 334 potentially relevant records were found in the seven databases, 75 of which were duplicated. A total of 157 references were excluded based on the abstracts and 65 were selected for full-text analysis, 25 which were selected for inclusion in the study.

Worldwide, extensive fluoridation programs have been introduced in Australia, Brazil, Chile, Colombia,

Canada, Hong Kong Special Administrative Region of China, Ireland, Israel, Malaysia, New Zealand, Singapore, the UK, and elsewhere. More recently, new programs have been introduced in large conurbations in the south and west of the USA, including Los Angeles (in 1999), Las Vegas (in 2000), Sacramento (in 2000), and San Antonio (in 2002).

In 2000, a report from California’s Children’s Dental Health Initiative Advisory Committee stressed the benefits of water fluoridation and recommended that access should be expanded.<sup>[5]</sup>

Two evidence-based reviews (Yeung *et al.*, 2005; National Health and Medical Research Council, 2007) indicate that there is limited support that fluoridated milk has a caries-preventive effect.<sup>[6]</sup>

Currently milk fluoridation programs exist in several countries including Bulgaria, Chile, China, Peru, the Russian Federation, Thailand, and the UK.<sup>[7]</sup>

In 1994–2004, salt fluoridation was introduced as a caries-preventive measure.<sup>[8]</sup> Fluoridated salt is widely used in Germany, France, and Switzerland, with 30–80% of the marketed salt for domestic use being fluoridated (Marthaler and Petersen, 2005). More than 30 other countries worldwide use fluoridated salt and this type of fluoride delivery is highly recommended by the World Health Organization (WHO). There is no randomized clinical trial (RCT) conducted on this topic, according to recent reviews (Swedish Council on Technology Assessment in Health Care, 2002; National Health and Medical Research Council, 2007; Espelid, 2008). Some cross-sectional studies and controlled clinical trials do indicate the caries-preventive effect of salt, but fluoridated salt is probably less effective among small children due to the low-salt diet now recommended for this age group.<sup>[6]</sup>

Fluoridated dentifrices undoubtedly have been the cornerstone of caries prevention worldwide and account for the caries decline observed in the past few decades in industrialized countries. It is found to cause 15–30% decrease in caries experience (CDC, 2001), while a recent systematic review concluded that the caries reduction was 24% (Marinho *et al.*, 2003).<sup>[9]</sup>

In 2005, a stannous fluoride sodium hexametaphosphate (SFSH) formula was introduced offering protection against a broad range of health and cosmetic conditions commonly experienced by patients. Sodium hexametaphosphate was first introduced in a dentifrice in 2000. It provides better coverage and retention on the

tooth surface, thus increasing its ability to inhibit both calculus and stain formation on the enamel surface.<sup>[10]</sup>

A clear evidence of caries-inhibiting effect of fluoride gel in permanent dentition with 28% reduction in decayed, missing, and filled tooth surfaces (DMFS) has been found (Marinho *et al.*, 2002).<sup>[9]</sup>

Some studies have compared fluoride varnishes with other topical fluoride delivery vehicles. Tewari and associates compared Duraphat with a 2% NaF solution, a 1.23% acidulated phosphate fluoride (APF), gel, and a negative control. They reported that after 2.5 years, the varnish resulted in a higher percentage of caries reduction (74%) than did the NaF solution (28%) and the APF gel (37%).<sup>[11]</sup>

Fluoride-releasing dental restorative materials may provide an additional benefit in preventive dentistry. Comparison of fluoride ion release was made from four different dental restorations (Fuji VII, Fuji II LC, Dyract, and Z350) in de-ionized water from day 1 until day 5. The result showed significantly different fluoride ion release from all of them. The fluoride release was highest in Fuji VII, followed by Fuji II LC, Dyract, and Z350. The result also revealed a significant association of fluoride ion release from dental restorations in de-ionized water and artificial saliva, except for Z350 ( $P = 0.787$ ). There was greater amount of fluoride release by all the tested materials in de-ionized water compared with artificial saliva.<sup>[12]</sup>

Various studies found that silver diamine fluoride is used as a caries-arresting agent. Hiraishi *et al.* and Mathew *et al.* (2012) found that silver diamine fluoride is used as an endodontic irrigant.<sup>[13]</sup>

A new system has been introduced in dentistry for achieving a constant rate of continuous fluoride release for a longer period in the oral cavity which is the intraoral fluoride releasing device to be used in high-risk groups (Mirth *et al.*, 1982; Kula *et al.*, 1987; Toumba and Curzon, 2005).<sup>[14]</sup>

Moberg Sköld *et al.* studied the effect of additional fluoride rinses and varnishes given and supervised in a school environment and observed that even in groups of adolescents with moderate caries experience, caries initiation and progression were significantly reduced.

All published RCT data when combined, give the conclusion that fluoride toothpastes, mouth rinses, gels, and varnishes have similar effectiveness in preventing caries.

A summary of RCTs on fluoride concentration in toothpastes showed a positive dose response: Pastes with 1000–1500 ppm F showed 23% caries reduction compared to fluoride-free placebo; this value increased to 36% for pastes with around 2500 ppm F. For pastes having below 1000 ppm F, no significant difference was found with placebo, probably due to the small number of studies.<sup>[15]</sup>

Theobromine is used as a caries-preventing agent and it is present in cocoa. Sadeghpour (2007) stated that the cocoa extract is more effective than fluoride in reducing dental caries. Similar to fluoride, theobromine can prevent demineralization and improve resilience of tooth by acid.<sup>[16]</sup>

Recently, new fluoridated products have been introduced in the market, which are presented in Tables 1 and 2.

## DISCUSSION

The most serious defect of the studies was the lack of appropriate design and analysis. Many studies did not present an analysis at all. There are a limited number of studies on advancements in fluoride, so it was difficult to correlate different studies.

Fluoride is still the cornerstone of modern noninvasive dental caries management. The prevalence of dental caries has steadily declined over the last 20 years due to dental hygiene practices and the increased use of fluoride-containing products. Health surveys still estimate the percentage of adults with DMFS to be 98.3% (Brown).

In 2008, extensive water fluoridation programs were introduced in Australia, Denmark, Ireland, England, New York, Brazil, and Lithuania.

Zorec Karlovsek *et al.* conducted a study as a project to introduce salt fluoridation. In the study, the authors analyzed urine of children residing in different parts of Slovenia. They concluded that fluoride exposure was low, as the mean daily urinary F excretion was found to be 0.19 mg F/24 h.

Recently, milk fluoridation program was launched in Thailand in 2000 and in Macedonia in 2009.

In 2002, Nakamoto proved that theobromine can increase the size of apatite crystals and increase resistance of tooth to acid dissolution. The conclusion is fluoride and theobromine increase resistance of enamel

**Table 1: Recently, new fluoridated foams, gels, varnishes, rinses have been introduced in the market, which are presented in table**

Fluoride products	Product name	Active ingredients	Features
Fluoride foams	Topex neutral fluoride foam	Neutral fluoride	It claims deeper fluoride infiltration and lengthier fluoride retention in saliva after treatment
	KOLORZ neutral fluoride foam	Neutral fluoride	It claims deeper fluoride infiltration and lengthier fluoride retention in saliva after treatment
	DentiFoam topical fluoride foam	Acidulated fluoride	It claims deeper fluoride infiltration and lengthier fluoride retention in saliva after treatment
Fluoride gels <sup>[17]</sup>	NeutraGard Home Care Gel	5000 ppm fluoride	Used for topical fluoride application for those with recurrent decay around restorations and for those at risk for root caries
	NeutraGard Advanced Gel	1.1% neutral sodium fluoride	Used for prevention of root cavities, tooth hypersensitivity, and orthodontic decalcification
	Zap Fluoride Gel	1.23% acidulated phosphate fluoride ion with xylitol	Provides fast fluoride protection with 1 min long-lasting unique formula
Fluoride varnishes <sup>[18]</sup>	EnamelPro® Varnish	5% NaF + ACP	It provides more fluoride uptake into the sound enamel
	Fluoro Dose®	5% NaF	It is used for treating dentinal sensitivity
	Flor-Opal Varnish White	5% NaF	Provides a quick and easy application in unit doses
	Fluor Protector	0.1% difluorosilane	Shows excellent adhesion to the teeth
	Fluoridex Lasting Defense™ 5	5% NaF	Used to alleviate sensitivity associated with gingival recession and cervical abrasion
	Profluorid Varnish	5% NaF + xylitol	It helps in more fluoride uptake into the sound enamel
	Waterpik® Ultrathin Varnish	5% NaF	Used for the treatment of dental hypersensitivity and for use as a cavity liner
	Varnish America™	5% NaF	It gives a natural tooth color and sets rapidly in the presence of saliva
	Zooby® Fluoride Varnish	5% NaF	Indicated for dentinal hypersensitivity and for the reduction of postoperative sensitivity
Fluoridated rinses <sup>[19]</sup>	Stan-Gard Perio Rinse	0.63% stannous fluoride	Used in the treatment of periodontal disease; reduces gingival inflammation and bleeding
	ACT Total Care	0.05% and 0.02% sodium fluoride	Aids in the prevention of dental caries
	ACT Anticavity Fluoride Rinse	0.05% sodium fluoride	Aids in the prevention of dental caries
	CariFree Maintenance Rinse	0.05% sodium fluoride	Aids in the prevention of dental caries
	Orthowash™ Daily Rinse	0.044% sodium fluoride in an acidulated rinse	Decalcification, caries
	Listerine Total Care	0.0221% sodium fluoride	Helps prevent cavities, restores enamel, strengthens teeth, kills bad breath germs
	PreviDent Rinse	0.2% neutral sodium fluoride	Used as dental caries prevention agent
	Gel-Kam Oral Care Rinse	0.63% stannous fluoride	For daily self-applied topical use as a dental caries prevention agent
	Crest Pro-Health Rinse	0.07% Cetylpyridinium chloride	Helps prevent and reduce plaque and gingivitis

ACP=Amorphous calcium phosphate

to acid dissolution as well as influence the hardness of enamel surface.

Many reports have been published throughout the world about the pros and cons of fluoride. After many years, the scientific conclusion has been reached that fluoride toothpaste and fluoridated water, salt, and milk are of great benefit to dental health, help to reduce decay, and cause no harmful side effects to general health.

Thus, fluoride in various forms, i.e., varnishes, rinses, foams, gels, dentifrices, slow releasing devices, prophylaxis paste, remineralizing agents, and in restorative materials, is now available to dental professionals for use in clinical practice and to be used by patients at home.

Their different formulas and concentrations make them suitable for therapeutic management of a

**Table 2: Recently, new fluoridated prophylaxis paste and restorative materials have been introduced in the market, which are presented in table**

Fluoride products	Product name	Active ingredients	Features
Prophylaxis pastes <sup>[20]</sup>	Clinpro™ Propy Paste	Sodium fluoride	Helps in stain removal; a coarse paste with less abrasion to dentin and enamel
	Next Propy Paste	1.23% fluoride	Clean and fine; offers low abrasivity; has low splatter, good taste; available in kids, adult, and mint variety packs; gluten free
	Oral-B Propy Paste	1.23% sodium fluoride	Removes stains efficiently because it clings to tooth surfaces
	Waterpik® Propy Paste	Fluoride	Tough on stains and plaque
	Glitter™	Fluoride	Gluten free and splatter free
	BreathRx Propy Paste	Sodium fluoride	Low-splatter formula with sodium fluoride for efficient stain removal
	Glitz Premium Propy Paste	Fluoride	Enhanced stain remover
Fluoridated rinses <sup>[21]</sup>	Enamel Pro®	Amorphous calcium phosphate (ACP), fluoride	ACP stimulates remineralization of tooth enamel; delivers fluoride and increases luster
	Ziroxide™	Fluoride	Gluten free, creamier texture
	GC Fuji Triage White and Pink	Fluoride releasing	Surface protection with antimicrobial properties
	Riva Protect	Fluoride releasing	Self-adheres to the tooth
	UltraSeal XT plus Pit and Fissure Sealant	Fluoride releasing	Ideal viscosity for placement and shear thinning
	Helioseal F	Fluoride releasing	Self-adheres to the tooth
	AdheSE One F	Fluoride releasing	Self-etching
	Delton FS Plus Pit and Fissure Sealant	Fluoride releasing	Self-adheres to the tooth
	EcuSeal Pit and Fissure Sealant	Fluoride releasing	It adapts to the smallest fissures; fluoride and zinc release for maximum caries protection
	VersaFlo Light-activated Flowable Composite Resin	Fluoride releasing	Wear resistant with fluoride release
	Seal and Protect	Fluoride releasing	Reduces dentinal hypersensitivity for up to 12 months
Seal-Rite	Fluoride releasing	Self-adheres to the tooth	

number of dental problems including prophylactic prevention of dental caries, dentinal hypersensitivity, control of all caries from incipient to rampant, and reduction in the rate of dental erosion. For the dental professional to be able to choose the formula and concentration of the topical agent that is most effective in managing a specific dental problem for a particular patient, it is necessary to be aware of a number of properties of the agent selected. Despite its long-standing history and use, clinicians should have basic knowledge of the products and safe use of these products. Communication to the patient is an important adjunct to maximize the benefits and minimize the risks.

Many studies have been published throughout the world about the defluoridation methods.<sup>[22]</sup> Few investigators have studied reverse for arsenic and fluoride removal. However, recent work by Fox and Huxstep has shown reverse osmosis to be effective in reducing the concentration of fluoride.

The improvements in design and materials of the membranes have made the water treatment process economically competitive and highly reliable. Thus with improved management; this new technology for drinking water production might be the best option. On the basis of results and extensive investigations, different researchers had developed a simple and economical domestic defluoridation processes.

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### Conflicts of interest

There are no conflicts of interest.

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