Intraoral Slow-Release Fluoride Devices: A Review

Abstract

Dental caries still continues to be a problem for majority of individuals and it can be a serious problem for medically compromised, developmentally disabled and elderly individuals. Water fluoridation, systemic and topical fluorides have been used for many years to supply supplemental fluoride to combat dental caries. The latest fluoride research is investigating the use of slow release devices for long term provision of fluoride. Slow-release fluoride devices were developed based on the inverse relationship existing between intra-oral fluoride levels and dental caries experience. A substantial number of studies have demonstrated that these devices are effective in raising intra-oral F concentrations at levels able to reduce enamel solubility, resulting in a caries-protective effect. However, retention rates have been shown to be the main problem related to these devices and still require further improvements. Although the results of these studies are very promising, further randomized clinical trials are needed in order to validate the use of these devices in clinical practice. The concept of continuously providing low levels of intra-oral fluoride has great potential for caries prevention in high caries-risk groups.

Key Words

Fluorides; slow fluoride-releasing device; dental caries; prevention

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INTRODUCTION

Dental caries is caused by acids produced by bacteria in dental biofilm, which slowly but progressively demineralizes the enamel. Among various caries-preventive strategies, which include education in oral health, chemical and mechanical control of dental biofilms the use of fluorides has proved to be most effective clinically. A large number of clinical trials, literature reviews and more recently meta-analyses demonstrate the ability of F in controlling dental caries involving the use of rinses, gels, varnishes and dentifrices.[1-4] The current belief is that the cariostatic effect of F is predominantly exerted by its topical rather than systemic effect.[5] The efficacy of topical F in preventing dental caries has been documented as this trace element exerts its maximum cariostatic effect through its constant presence at the plaque-saliva-enamel interface.[6,7] The activity of the F ion at the liquid phase surrounding the enamel has also been found to be crucial in preventing enamel demineralization[8] rather than having a high F concentration intra-orally or a high surface enamel F concentration.[9] Generally, baseline F levels in saliva are known to be around 0.02 ppm or less, dependent on the F level in drinking water and the use of F products,[10] and are adequate for low or medium caries risk individuals, but not for high caries risk.[11] Considering that intra-oral levels of F play a key role in the dynamics of dental caries, it has been suggested that the use of controlled and sustained delivery systems - similar to the ones used for birth control, treatment of glaucoma and prevention of motion sickness - can be considered as a means of controlling dental caries incidence in high-risk individuals.[12] The most important point for preferring control release systems to conventional fluoride applications is their ability to increase the salivary fluoride levels without substantially increasing serum and urinary fluoride

concentrations during the treatment period. Intra-oral F-releasing devices have been introduced in dentistry in an attempt to overcome the issues of patient compliance for high caries-risk groups. These devices are showing promising results both in vitro and in vivo with no associated side effects and are aimed to target high-risk groups.[13]

Development of Fluoride-Releasing Devices

One of the basic principles of delivering a drug is to ensure provision of an adequate but non-toxic level of drug at the intended site of action for a sufficient duration to permit it to exert its maximum therapeutic effect.[14] In addition to F-containing restorative dental materials, the concept of controlled releasing delivery systems have been researched using three different approaches:

1. A sustained F-release from tablets/capsules,
2. An aerosol system for delivering microcapsulated F,
3. F-releasing intra-oral devices.

The reported F release from the tablets/capsules and aerosols was relatively short lived, while the F devices were shown to provide significant sustained elevation of salivary F levels for prolonged periods.[15-17]

Different Types of Fluoride-Releasing Devices

The various types of fluoride releasing devices described under are:

1. Copolymer membrane devices developed in USA,
2. Glass devices that were developed in UK.
3. Hydroxyapatite-Eudragit RS100 diffusion controlled fluoride system
4. Slow fluoride release tablets for intrabuccal use

Copolymer membrane device: This was developed by Cowsar *et al*. [1976] in the form of a membrane-controlled reservoir. It consists of an acrylic polymer matrix impregnated with granulated sodium fluoride (NaF) that is encased in an acrylic polymer (membrane). The inner core consists of hydroxyethyl methacrylate (HEMA)/methyl methacrylate (MMA) copolymer (50/50 mixture) and a precise amount of sodium fluoride (NaF). The core is surrounded by a 30/70 HEMA/MMA copolymer membrane, which controls the F release rate. When the matrix becomes hydrated, small quantities of granulated NaF are diluted until the matrix itself becomes saturated. The matrix contains 20.3% water and the membrane contains 8.7% water. The precise water absorption enables the device to act accurately and reliably as a release

controlling mechanism.[13] Once placed in the mouth, the device becomes hydrated with saliva and its characteristics lead it to release a constant rate of sodium fluoride of 0.02-1.0mg/day for upto 4-6 months, depending on the size of the device.[18] The device is approximately 8 mm in length, 3mm in width, and 2 mm in thickness (Fig. 1). It is usually attached to the buccal surface of first permanent molar by means of stainless steel retainers spot welded to plain, standard orthodontic bands[19] or is bonded to the tooth surface by adhesive resin.[15] A new holder known as CIPI made of biocompatible elastic alloy is specifically designed for orthodontic patients and consists of a retentive four wire cage provided with a cannula and a clasp. The cage contains the device and is secured by the cannula and clasp to a molar tube.[18]

Glass device: The glass device was developed by Curzon in 1984. The fluoride glass device dissolves slowly when it is moist, thus releasing F without affecting the device integrity significantly. The original device was dome shape (4 mm in diameter) attached to the buccal surface of first permanent molar using adhesive resins.[21] Due to low retention rates of the original device, it was further substantially changed to a kidney shaped device being 6mm long, 2.5mm wide and 2.3mm deep, and it proved effective in both fluoride release as well as retention rates.[21] More recently, the device has been shaped in the form of a disk that is placed within plastic bracket to facilitate device handling, attachment and replacement. (Fig. 2).[18] The device can be easily installed without the need for debonding, removing remnants of composite resins and performing a new acid etch to bond the device (Fig. 3).

Hydroxyapatite - Eudragit RS100 diffusion controlled F-system: This is the newest type of slow release F device, which consists of a mixture of hydroxyapatite, NaF and Eudragit RS100. It contains 18 mg of NaF and is intended to release 0.15 mg F/day. It was demonstrated that the use of this device is able to significantly increase salivary and urinary F concentrations for at least 1 month.[22] Not much information is available in the literature about this device.

Slow fluoride release tablets for intrabuccal use: Controlled release fluoride delivering system for intrabuccal use was developed, permitting to reach high enough local concentrations for desirable therapeutic effect with minimal side effects. Tablets of 160-200mg were formulated which were
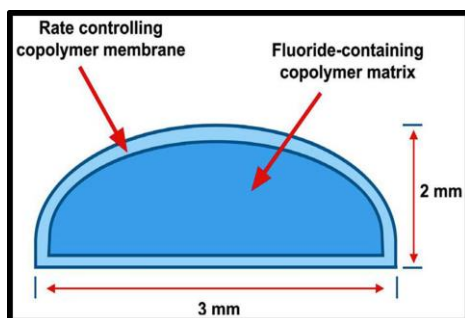
Fig. 1: Schematic cross-sectional view of the copolymer device, which originally had 8 mm in length, 3 mm in width, and 2 mm in thickness
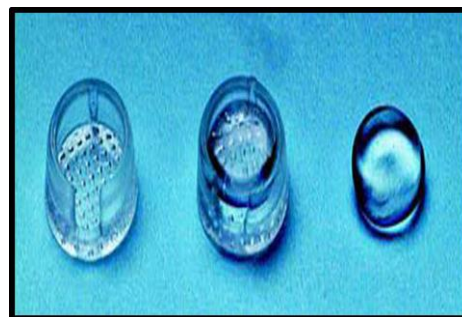

Fig. 2: The latest version of the fluoride glass slow release device and plastic retention bracket

Fig. 3: Latest glass device and bracket attached to upper first permanent molar tooth

intended to be fixed on a tooth. These tablets have a granular matrix composed of pure hydroxyapatite, Eudragit and/or ethylcellulose. NaF is added by mechanical mixing or an impregnation method.[23] Such a mode of fluoride administration can be extended to all chronic pathologies of the buccal cavity.

Applications of Intraoral Fluoride Releasing Devices

Effect on intra-oral fluoride Concentrations: Several in vitro and in vivo studies were conducted in order to evaluate the resulting F levels in saliva and dental plaque, which are the sites where the F ion can exert its cariostatic effect during the cariogenic challenge. Significant increases were found in plaque F concentrations, both for the copolymer membrane and glass devices. In a double-blind crossover study, it was demonstrated that the glass device significantly elevated F levels in plaque (~ tenfold) after 1 month of placement of the bead.[24]

Effect on Caries Prevalence Reduction: Reduction in caries occurs due to significantly increased salivary F levels for prolonged periods of time. The results of a study on 174 children in UK showed 67% fewer new carious teeth and 76% fewer new carious surfaces.[17] Mirth *et al.*,[25] demonstrated 55% fewer new occlusal fissures carious cavities, showing that the constant supply of low doses of F

is able to protect not only approximal and free surfaces, but also those not normally protected by traditional fluoride regimens. Corpron, *et al.*,[26] (1986) demonstrated that enamel can be remineralised within 7 days after the use of a copolymer membrane device, due to the constant release of F ions into the oral environment. The same authors suggested that the low F levels in saliva allow the slow mineral uptake in the base of the carious lesion, and not only on enamel surface, as frequently occurs when high F vehicles are applied.[27]

Prevention of root caries: In vivo studies showed significantly higher fluoride uptake throughout the entire carious lesion depth. Fluoride peaks were present at deeper levels in the lesions treated by fluoride devices rather than those treated with a mouth rinses (100ppm) or a MFP dentifrice (1,000 ppm)[28] or from chewing gums.[29] This may be attributed to the formation of calcium fluoride at the outer surface of the lesions following the use of the topical agents with fluoride being blocked from penetration into the lesions body.

Medically compromised individuals: Dental caries is a major problem in individuals with special needs that are unable to maintain their oral health because of disability or any debilitating condition. Intraoral fluoride releasing devices have a substantial

potential to inhibit caries development in these individuals.[19]

Patients undergoing radiation therapy and xerostomia: Patients experiencing xerostomia from radiation therapy or cancer chemotherapy are at a particular risk for major and minor oral infections.[30] These devices can be of help to patients who are more at a risk of developing dental caries.[18]

Reduction of orthodontic white spot lesions: A copolymer device, intended to release F for 6 months, is able to avoid the development of white spot lesions after 1 year of using the devices by patients under orthodontic treatment.[18]

Dentin sensitivity: In a study on subjects presenting with dentine sensitivity, the subjects reported that the symptoms decreased significantly, remaining absent through the duration of the treatment after 4 weeks of using the device.[31]

Cost-Effectiveness

The F-release glass devices have a favorable benefit-cost and cost-effectiveness ratios showing that they are capable of providing maximum benefits of the resources expended.[18]

Toxicity and Side-Effects of Fluoride Devices

Fluoride devices and toxicity: One of the primary concerns about the use of the slow release fluoride device was the possibility of de-bonding and its subsequent ingestion, which could lead to acute toxic effects. Thus studies have been conducted in order to verify the degree of safety when using these devices in humans, especially in children. No signs of toxicity were verified in dogs after ingestion of devices containing 6 months' supply of fluoride (equivalent of 458 mg F).[14] A similar finding reported by the same authors showed no changes in serum or urine fluoride levels in eleven subjects who were fitted copolymer devices.[15]

Fluoride devices and side-effects: Mucosal irritation was reported in few patients who were fitted with copolymer devices. Erythema and/or small ulcers were seen on the buccal mucosa opposites to the site of the devices in some.[15] Marini[18] reported no adverse effects of the oral tissues. Andreadis[21] dealt with the glass-type devices in both children and adolescents, did not report any local or systemic effects.

CONCLUSION

The use of slow-release fluoride devices is effective in many aspects. Its application for use in high risk groups is considered an ideal adjunctive measure to ensure optimum oral health. With the additional benefit of the devices being cost-effective, these devices can be considered as ideal solution for high-risk groups who have demonstrated poor oral hygiene and lack of motivation. High-risk groups include patients with low socio-economic status, ethnic minorities, special needs patients or orthodontic patients who cannot maintain good oral hygiene. These high caries risk groups who have poor compliance would benefit from use of slow-release devices.

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