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Are fluoride releasing dental materials clinically effective on caries control?☆

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ABSTRACT

Objectives. (1) To describe caries lesions development and the role of fluoride in controlling disease progression; (2) to evaluate whether the use of fluoride-releasing pit and fissure sealants, bonding orthodontic agents and restorative materials, in comparison to a non-fluoride releasing material, reduces caries incidence in children or adults, and (3) to discuss how the anti-caries properties of these materials have been evaluated *in vitro* and *in situ*.
Methods. The search was performed on the Cochrane Database of Systematic Reviews and on Medline *via* Pubmed.
Results. Caries is a biofilm-sugar dependent disease and as such it provokes progressive destruction of mineral structure of any dental surface – intact, sealed or restored – where biofilm remains accumulated and is regularly exposed to sugar. The mechanism of action of fluoride released from dental materials on caries is similar to that of fluoride found in dentifrices or other vehicles of fluoride delivery. Fluoride-releasing materials are unable to interfere with the formation of biofilm on dental surfaces adjacent to them or to inhibit acid production by dental biofilms. However, the fluoride released slows down the progression of caries lesions in tooth surfaces adjacent to dental materials. This effect has been clearly shown by *in vitro* and *in situ* studies but not in randomized clinical trials.
Significance. The anti-caries effect of fluoride releasing materials is still not based on clinical evidence, and, in addition, it can be overwhelmed by fluoride delivered from dentifrices.

1. Introduction

Dental materials are used in Dentistry for many clinical purposes. If the material is used to rebuild the tooth and does not have properties that may help to control caries adjacent to the filling, the role of this material is only to make the tooth functional again and esthetically appealing to the patient. However, when dental materials have the ability to release fluoride, it is expected that, besides restoring function and esthetics, they may control the recurrence of caries on dental structure adjacent to the filling and/or even contribute to reduce caries incidence in the entire dentition.

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In addition, fluoride-releasing materials are also used as sealants to prevent caries in pits and fissures and as materials for bonding and/or cementing orthodontic brackets and bands. In this case, it is also expected that the fluoride released by these materials will work reducing the progression of enamel caries around them.

The development of caries on dental surfaces adjacent to dental materials should not be considered different from that occurring on intact (natural) dental surfaces. Also, the mechanism of action of fluoride on caries control adjacent to these materials may be considered the same as that reported for other ways or vehicles of fluoride delivery, such as fluoride dentifrices (toothpastes). These concepts are discussed in Sections 2 and 3 of this paper.

2. Dental caries

Caries lesions develop on dental surfaces in which biofilms are formed, allowed to accumulate and retained for long periods of time (*e.g.*, occlusal surfaces, interproximal areas, along gingival margins and on enamel-cementum junction) [1]. Although necessary for caries lesion progression, biofilm accumulation alone is not enough. Sugars are the pivotal, negative factor, responsible for caries lesion progression [2]. The acid pH produced from the fermentation of dietary sugars not only provokes dissolution of the underlying dental minerals, but also selects in the biofilm formed the most cariogenic bacteria [3].

Therefore, caries is a biofilm-sugar dependent disease [1] and, among the dietary sugars, sucrose is the most cariogenic because besides being easily fermented into acids, it is the only carbohydrate that change the matrix of the biofilm formed, making the biofilm more cariogenic [4].

Thus, biofilm accumulation is the necessary factor and sugar exposure the negative determinant factor for caries progression in any dental surface, intact or restored (Fig. 1). The only difference between caries progression on enamel or dentin adjacent to a filling, in comparison with a natural intact surface, is the possibility of biofilm accumulation in the gap between the wall of the cavity and the filling material [5,6]. Every time sugar is ingested, biofilm bacteria produce acids and, consequently, the pH drops in the biofilm fluid. Thus, pH is the driving force governing the loss or gain of Ca and Pi from the mineral structure of the teeth. While pH remains below around 6.5 for dentin and 5.5 for enamel, the minerals of these tissues are dissolved (demineralization) (Fig. 1a). After around 20–30 min, the pH rises again and, above 5.5 for enamel and 6.5 for dentin, saliva tries to repair Ca and Pi loss (remineralization) (Fig. 1b). However, saliva alone is not 100% effective to repair all Ca and Pi minerals lost during the demineralizing process. The balance toward demineralization or remineralization will be dependent on the daily frequency of dietary sugars ingestion.

Thus, caries lesions progression on dental surfaces, restored or not, is provoked by the same factors, biofilm accumulation and sugar exposure. Also, the process (chemical events) of caries lesions development is the same in any dental surface (Fig. 1a and b).

Table 1 – Approaches for fluoride use and vehicles for its delivery in the oral environment.

Approaches for fluoride use	Vehicles (examples)
Community level	Water fluoridation
Individual level	Fluoride dentifrice, mouthrinse
Professionally applied	Fluoride-releasing dental materials, topical fluoride application (gel, varnish)
Combinations	Fluoride dentifrice + fluoride-releasing dental materials

Therefore, dental caries as a disease is, by nature, primary, and its control, either in intact dental surfaces or adjacent to dental materials ("secondary caries"), is achieved by biofilm mechanical disruption and sugar restriction.

Also, caries is not the result of fluoride deficiency [7] but this ion is the only therapeutic agent known to effectively control caries progression, and fluoride-releasing materials may be considered a way or vehicle of fluoride delivery (Table 1).

3. Fluoride effect

The old concept that fluoride strengthens the teeth, making them more resistant to caries, is still prevalent. However, fluoride is not able to prevent caries lesion development because it does not avoid the formation of biofilm in any dental surface, either intact or adjacent to fluoride-releasing materials. Furthermore, the *in vivo* effect of fluoride inhibiting acid production from sugars in the biofim is negligible [7].

In fact, fluoride interferes with the caries process, reducing demineralization and enhancing remineralization of enamel and dentin [8]. This physico-chemical mechanism occurs every time sugar is ingested and the pH falls in biofilm fluid; if fluoride is present, the amount of mineral dissolved is reduced because part of Ca and Pi lost as hydroxyapatite returns to the tooth as fluorapatite (reduction of demineralization) (Fig. 2a). When the ingestion of sugar ceases and the pH rises again, fluoride present in the oral fluids enhances the natural phenomenon of remineralization (Fig. 2b). As a consequence, the progression of caries lesions is slowed down [7]. Also, following the exchange of minerals between the biofilm fluid and enamel or dentin in the presence of fluoride, an enrichment of fluoride concentration in enamel or dentin surfaces occurs – a consequence of the effect of fluoride on the caries process, and not the cause of caries lesions reduction [9].

The anti-caries effect of fluoride can be obtained by the same mode of action irrespective of the ways or vehicles of fluoride use. Among them, toothbrushing with fluoride dentifrices is the only one whose results on caries reduction are strongly based on scientific evidence [10]. Besides their effectiveness to control the incidence of caries in originally intact dental surfaces, fluoride dentifrices can also interfere with caries lesion progression adjacent to dental materials because during toothbrushing fluoride is spread throughout the mouth, and enriches remainings of biofilm not perfectly removed [11].