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Fluoride dentifrices in oral health: A review

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Abstract
The dental caries process and its prevention has greatly advanced over the past fifty years, it is fair to state that the management of this disease at the level of the individual patient remains largely empirical. There is a general understanding that the fluoride compound, concentration, frequency of use, duration of exposure, and method of delivery can influence fluoride efficacy. Two important factors are (1) the initial interaction of relatively high concentrations of fluoride with the tooth surface and plaque during application and (2) the retention of fluoride in oral fluids after application. Fluoride dentifrices remain the most widely used method of delivering topical fluoride. The efficacy of this approach in preventing dental caries is beyond dispute. However, the vast majority of currently marketed dentifrice products have not been clinically tested and have met only the minimal requirements of the FDA monograph using mainly laboratory testing and animal caries testing. Daily use of fluoride dental rinses as an adjunct to fluoride dentifrice has been shown to be clinically effective as has biweekly use of higher concentration fluoride rinses. The use of remineralizing agents (Other than fluoride), directed at reversing or arresting non-cavitated lesions, remains a promising yet largely unproven strategy. High fluoride concentration compounds, e.g., AgF, Ag $(NH_3)_2$ F, to arrest more advanced carious lesions with and without prior removal of carious tissue are being used in several countries as part of the Atraumatic Restorative Treatment (ART) approach. Most of the recent innovations in oral care products have been directed toward making cosmetic marketing claims. There continues to be a need for innovation and collaboration with other scientific disciplines to fully understand and prevent dental caries.

Keywords: Fluoride dentifrices, oral health

Introduction
The term "Fluorine" is derived from a Latin word "Fluore" which means to flow, since it was used as a flux. Fluorine is the most electro negative of all chemical elements and therefore never encountered in nature in the free elemental form. It is the 13th most abundant element and 17th in order of frequency of occurrence of the elements and represents about 0.06-0.09% of the earth's crust [1].

Dental caries being a global health problem can be brought under control with fluoride dentifrices. It was hypothesized that fluoride inhibits tooth decay by rendering the outer layer of the tooth less soluble to acid [1].

Fluoride used for dental applications is available from two major sources: products containing fluoride in their formulations (Topical) and fluorides that are ingested into the body from treated water and other sources (Systemic) [2] [as shown in figure 1].

Topical fluorides strengthen teeth already present in the mouth making them more decay resistant. It includes toothpastes, mouth rinses and professionally applied fluoride therapies [2].

Systemic fluorides are those that are ingested into the body and become incorporated into tooth structure as they form. Sources of systemic fluorides includes water, dietary fluoride supplements in the forms of tablets, drops, or lozenges, and fluoride present in food and beverages [3].

Dentifrices (Toothpastes) have been used since antiquity but recently, formulations which deliver active compounds aimed at preventing and/or treating oral diseases have been developed [3]. A tooth paste may be classed as either a cosmetic or a medicine depending on the claims that are made and the level of certain constituent. The primary function of a tooth paste is to clean the teeth which are considered to be a cosmetic benefit. The use of words such as protects, cleans, freshens, breath, fights bacteria, which may cause gum problem's, whitens

or fights tartar are considered to be cosmetic claims [3]. In 1955, in U.S.A the first active principle added to toothpaste was fluoride- introduced as an anti-caries agent (in the U.K in the mid- 1960s) [4].

The optimal use of fluoride is an essential and basic public health strategy in the prevention and control of dental caries, the most common non-communicable disease on the planet. Although a whole range of fluoride vehicles are available for fluoride use (drinking water, salt, milk, varnish, etc.), the most widely used method for maintaining a constant low level of fluoride in the oral environment is fluoride toothpaste. As one of the key components of the WHO endorsed Basic Package of Oral Care, the promotion of affordable and effective fluoride toothpaste is important.

History

The toothpaste history timeline goes back to 3000-5000 BC when Egyptians made a toothpaste like dental cream by mixing powdered ashes of oxen hooves with myrrh, burned egg shells, pumice, and water. Toothpaste use was recorded in India and China in 500 BC. An 18th century American and British toothpaste recipe called for burnt bread. Another formula around this time called for dragon's blood (A resin), cinnamon and burnt alum [5].

First 'modern' toothpastes in the 1800s were homemade, with chalk, soap and salt as common ingredients and were sold in jars either as a powder or paste. In 1824, Dr. Peabody, a dentist added soap to toothpaste. John Harris in 1850 added chalk to toothpaste.

It was not until 1914 that Cecil Ludolph Lidgey introduced a mixture of tri phosphate of calcium and calcium fluoride to dentifrice and received British patent GB 3,034 which was the most important breakthrough in the history of toothpaste. In 1919, Viggo Valdemar Julius Andresen, of Kopenhagen, Denmark received, German patent DE 386,339 for remineralizing dentifrices by adding calcium fluoride with calcium carbonate and sodium carbonate which can be used on a toothbrush for cleaning teeth. Roy Cross of Kansas City suggested that hardening properties of dentifrices can be provided by sodium fluoride which also prevents tooth decay. He filed for U.S patent in 1929. However, the use of fluorides was considered irrational and unscientific and was not permitted by American Dental Association. Another interesting dentifrice patent, which included fluoride with asbestos as abrasive was given to Jean Ripert [6].

Fluoride toothpaste received the ADA's approval in 1950's. To develop the first ADA-approved fluoride toothpaste. Procter & Gamble developed a joint research project team headed by Dr. Joseph Muhler at Indiana University. In 1955, Procter & Gamble's Crest launched its first clinically proven fluoride-containing toothpaste.

In 1969, Colgate with mono-fluoro-phosphate received seal in US. In the year 1980, Crest converted to sodium fluoride due to formulation challenges with stannous fluoride.

Recommended dietary allowance

The adequate daily intake of fluoride for males is 4mg and females is 3mg. Various studies have indicated that children less than 6 years of age swallow 24% to 60% of dentifrices, which is almost completely absorbed. All dentifrices contain 1000 or 15000 ppm fluoride as sodium fluoride or mono fluoro phosphate. If an 18kg 5-year old child applies 0.5g of dentifrices to the toothbrush and ingests 44%, fluoride ingestion will be 12 micrograms/kg. If the child brushes his teeth twice daily; ingestion will be 24 microgram/kg /day [7].

Composition of fluoride dentifrices

Table 1: Excipients used in dentifrices

Binding Agents	Flavours	Sweetners	Colouring Agents	Film Agents	Preservatives
Carbopols carboxy methyl cellulose carrageenan xanthan gum silica thickeners plant extracts	Aniseed clove oil fennel seeds menthol	Acusulfame aspartame sorbitol saccharine xylitol	Titanium Di Oxide	Cyclomethicone Dimethicone Siliglycol	Alcohols Benzoic Acid Ethyl Parabens Methyl Parabens Formaldehyde

Mechanism of action of fluoride dentifrices

The interaction of fluoride with the mineral component of teeth produces a fluorohydroxyapatite (FHAP or FAP) mineral, by substitution of OH- with F-. This results in increased hydrogen bonding, a denser crystal lattice, and an overall decrease in solubility. The incorporation of fluoride into the hydroxyapatite (HAP) lattice may occur while the tooth is forming or by ion exchange after it has erupted. A decrease in solubility increases with greater amounts of fluoride incorporation, but rarely do we exceed several thousand parts per millions of fluoride in the outer enamel Thus, only limited protection from fluoride substitution would be expected as compared to pure FAP that has 40,000 ppm fluoride.

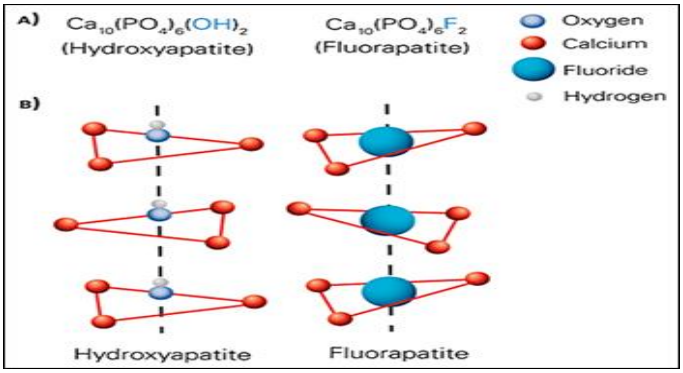

Fig 1: (A) Fluoride ions (F–) replace hydroxyl ions (OH–) in hydroxyapatite to form fluorapatite in the tooth enamel. (B) A portion of the apatite crystal lattice is depicted showing the replacement of hydroxide for fluoride.

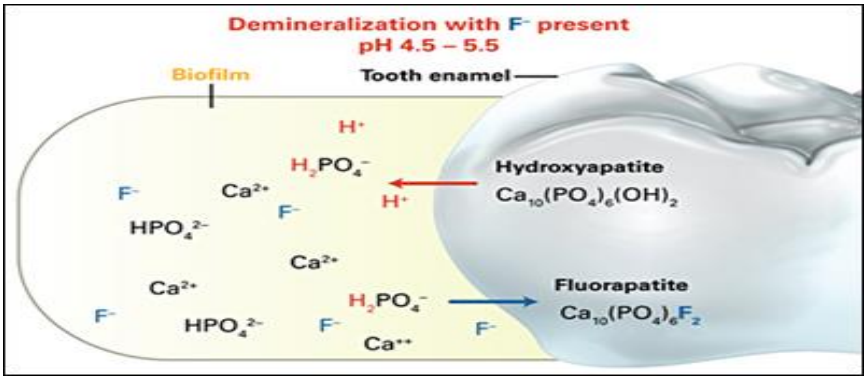

Fig 2: Fluoride reactivity

The use of low concentration fluoride products, such as dentifrices on a daily basis, will help maintain this favorable saturation. Thus, remineralization of the lesion may result in the repair of the existing lesion with less soluble mineral and render this portion of the tooth less susceptible to future episodes of demineralization (Figure 2). This is probably one of the most important modes of action of fluoride [8].

Effect of fluoride dentifrices on enamel

Dental enamel has the highest mineral content of all the mineralized dental tissue in the body. It comprises of 96% of a crystalline calcium phosphate mineral close in composition to hydroxyapatite [9].

On developing enamel

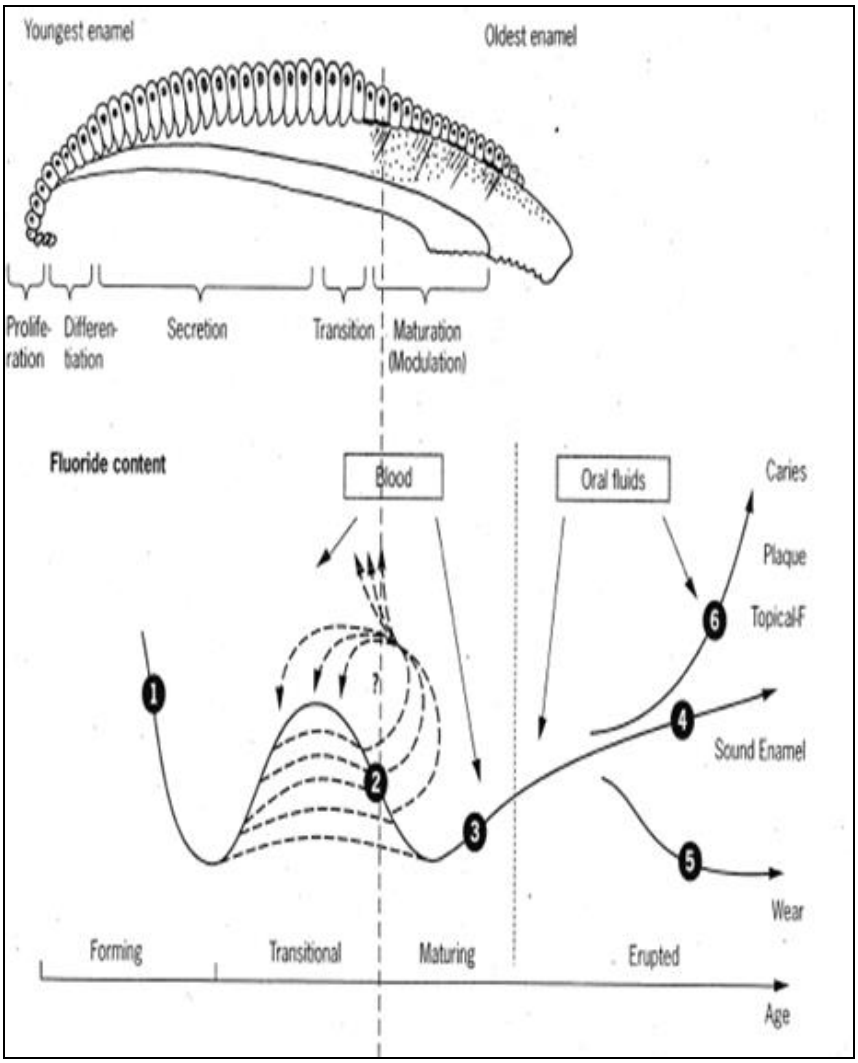

Fig 3: 1. Preferential accumulation then seems to occur at the transition/ maturation interface. 2. Fluoride concentrations rise in the surface regions during late maturation when ameloblast between ruffled and smooth ended morphologies. 3. This continues until after eruption, little fluoride being taken up by fully mineralized sound enamel. 4. Some fluoride is lost by wear. 5.Fluoride can be acquired by sound fully mineralized enamel only at high concentrations of topical applications or if the enamel becomes porous due to carious attack.

On erupted enamel

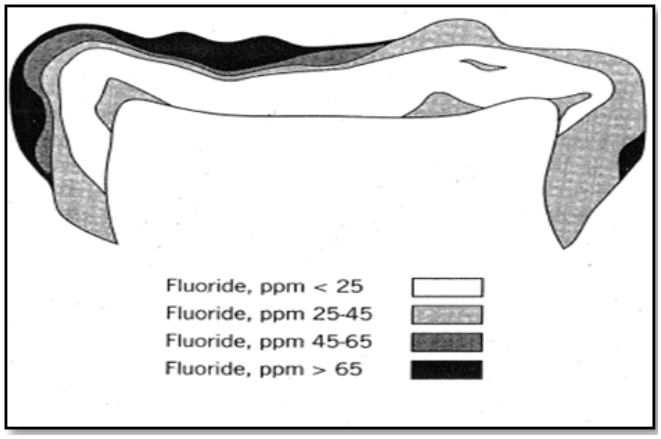

Fig 4: Distribution of fluoride in single section of molar enamel. Fluoride concentrations can be seen to be highest at the enamel surface falling to plateau in the interior and rising slightly again at the junction with dentin

Efficacy of fluoride dentifrices on dentin

Dentin, like cementum and bone, is a mesenchymal tissue. Unlike enamel, which is ectodermal, mesenchymal tissues have a collagenous matrices and these are retained during the process of mineralization [9]. The apatite crystallites are considerably smaller than those of enamel and much less crystallized. The capacity for fluoride uptake in dentine is therefore much greater because of the increased surface area of the crystallites, the tubular structure and higher degree of tissue hydration. It is also metabolically active and continues to grow throughout the life of the tooth [10].

Efficacy of fluoride dentifrices on cementum

Cementum forms a thin layer (50-100 micrometre) on the surfaces of tooth roots. Like bone and dentin, it is a collagenous mesenchymal tissue. It is much closer to bone and dentin, however in terms of histologic structure. The small crystal size and poor crystallinity characteristic of mesenchymal tissues. It is much closer to bone and dentin however in terms of its histologic structure [11].

As with all of other mineralized tissues, the highest fluoride concentration of cementum tends to be found near the outer surfaces, falling towards the interior of the tissue. (Graph) This would appear to be function of accessibility of tissue fluid to the outer cemental surface would also explain the tendency for higher fluoride concentrations at the interface with the dentin [12]. A relationship between cementum thickness and fluoride concentration also suggests that the rate of cementum deposition could affect fluoride concentrations such that rapidly forming tissues would not have sufficient time to accumulate fluoride [13].

Effect of fluoride dentifrices on caries

The term dental caries and lesion are used synonymously and are generally defined as the local destruction of hard tissues. However, what we record clinically are the symptoms and not the disease itself [14].

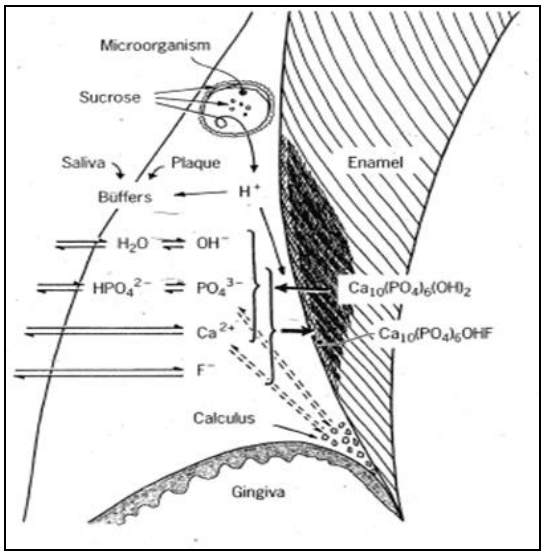

Fig 5: Effect of fluoride dentifrices on dental caries

Major chemical changes in enamel and plaque during bacterial fermentation and carbohydrates. Initially hydrogen will be taken up by buffers in plaque and saliva.

Eventually when the pH declines the fluid medium will be depleted of hydroxyl and phosphate ions which react with hydrogen to form water and HPO_4. Below the critical pH of about 5.5 the aqueous phase becomes unsaturated with respect to hydroxyapatite. Most often it remains supersaturated with respect to fluoroapatite. The chemical condition lead to a dissolution of hydroxyapatite, preferentially from enamel surface. Dissolution of mineral in plaque.

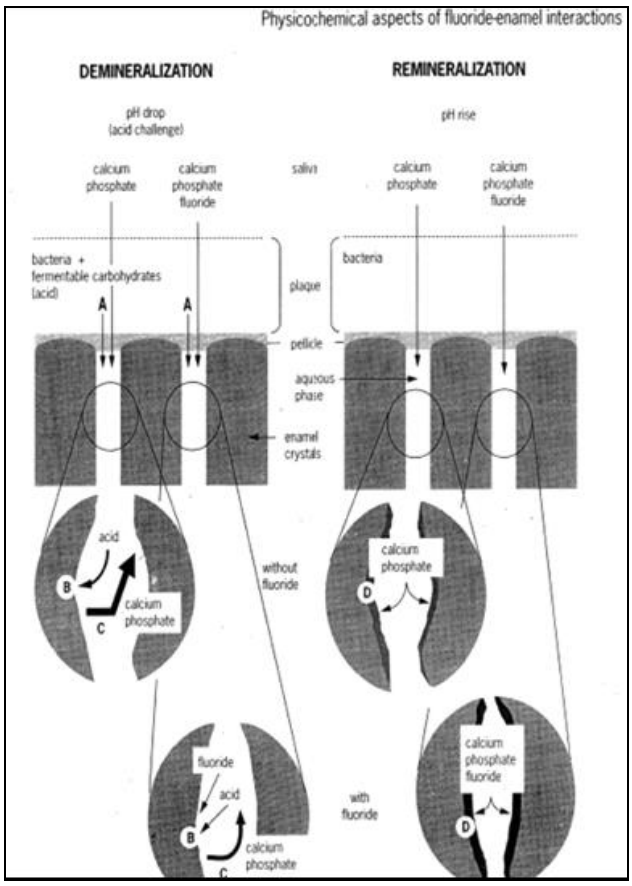

Fig 6: Physico-chemical aspects of fluoride enamel interactions

Steps in the caries process are designated by
A: Diffusion into the tooth;
B: Demineralization at the crystal surface;
C: Diffusion of mineral components outwards;
D: Remineralization at the crystal surface.
Saliva as a source for calcium and phosphates.
The two sets of inserts represent events with and without fluoride.

Effect of fluoride dentifrices on saliva

The concentration of salivary fluoride from the parotid and submandibular/sublingual glands is about 2/3rds of plasma fluoride concentration and seems to be independent of flow rate in contrast to most electrolytes. The low concentration of fluoride and the small volume of resting saliva present in the oral cavity about 1ml indicate the fluoride from the ductal saliva is not normally an important source of fluoride in plaque or plaque fluid [15]. However, following the topical application of fluoride in the form of mouth rinses, tooth pastes or any other fluoride vehicles there is a 100-1000-fold increase in salivary fluoride concentration, depending on the fluoride concentration of the fluoride agent. This high concentration of fluoride in saliva falls rapidly. 2 and sometimes 3 exponential phase in the decline of saliva fluoride concentration curve are seen [16, 17].

Effect of fluoride dentifrices on dentinal hypersensitivity

Dentinal hypersensitivity is a highly prevalent condition reported to affect from 4% to 57% of the population. The causes of sensitivity are well characterized as exposed dentinal tubules most commonly resulting from gingival recession followed by loss of cementum [18].

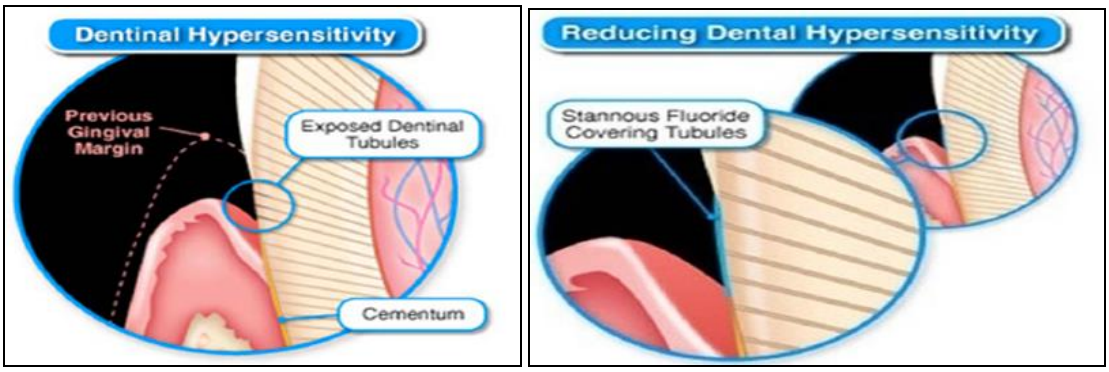

Fig 7: Stannous fluoride containing dentifrice provides an effective treatment for patients with dentinal hypersensitivity, significantly reducing sensitivity

Table 2: Dosage of fluorine in dental products and its probable lethal dose

Dosage of fluorine used in dental products and probable lethal dose			Concentration of fluoride		Amount of product and F usually used		Amount containing the ptd	
Vehicle	**Compound**	**Amount**	**%**	**PPM**	**Product**	**Fluoride**	**10 Kg Child**	**20 Kg Child**
Rinse	NaF	0.05	0.023	230	10ml	2.3mg	215ml	430ml
	NaF	0.20	0.091	910	10ml	9.1mg	55ml	110ml
	SnF_2	0.40	0.097	970	10ml	9.7mg	50ml	100ml
Dentifrice	NaF	0.22	0.10	1000	1g	1.0mg	50g	100g
	MFP	0.76	0.10	1000	1g	1.0mg	50g	100g
	MFP	1.14	0.15	1500	1g	1.0mg	33g	66g
Topical Gel Or Solution	NaF (APF)	2.72	1.23	12300	5ml	61.5mg	4ml	8ml
	SnF_2	0.40	0.097	970	1ml	0.97mg	50ml	100ml
	SnF_2	8.0	1.94	19400	1ml	19.4mg	2.5ml	5ml
Tablet	0.25mg F	_	_	_	1/day	0.25mg	200 mg	400 Mg
	0.50mgF	_	_	_	1/day	0.50mg	100 Mg	200 Mg

Conclusion

Dental caries has been shown to have a negative impact on the quality of life, psychological and social aspects of children's lives and community. Fluoride plays an important role in improving overall health amongst the population by reducing the occurrence of dental caries (Decay). Fluoride in different ways it is used today, is universally agreed to have been the principal influence in this major public health phenomenon. It has profoundly affected the way dentistry is practiced today, and it has led to extension changes in the curricula of dental schools. Caries prevention from a fluoridated regimen were found to be influenced by various factors such as pH, preferable uptake of fluoride by carious tooth and solubility of calcium fluoride and fluoroapatite simultaneously as said by D. J. White and G. H. Nancollas *et al.* 1990.

In developed countries worldwide, fluoride dentifrices most likely have made the greatest single contribution to the decline in the prevalence of dental caries. The evidence from countless clinical trials conducted to test a variety of fluoride preparations applied in a toothpaste vehicle on a wide spectrum of populations of diverse age from all parts of the world falls clearly on the side of fluoride toothpastes being universally accepted as the primary preventive strategy for coronal caries because of their ease of use, ability to produce significant reductions in dental decay and low cost.

In the past half century, dental care has benefited enormously from the parallel development of fluoride-based dental care as a public health practice. Whether needed fluoride is obtained through drinking water, supplements, tooth paste, mouth rinses, or fluoride treatments at the dentist office, modern dental health relies on this important and silently effective element.

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