Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 12, Issue, 06, pp.12006-12016, June, 2020

DOI: https://doi.org/10.24941/ijcr.38788.06.2020

ISSN: 0975-833X

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

IMPACT OF FLUOROSIS ON DENTAL TREATMENT - A CRITICAL REVIEW OF LITERATURE

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ARTICLE INFO

Article History:
Received 20th March, 2020
Received in revised form
09h April, 2020
Accepted 17th May, 2020
Published online 29th June, 2020

Key Words:
Bleaching, Bonding,
Fluorosis, Management, Microabrasion.

ABSTRACT

Dental fluorosis is one of the most common colour disorders which results in discoloured teeth, with white or brown spots. The aspect may be different depending on the severity of the fluorosis and the degree of the damage of the enamel and dentine. This article describes different approaches to treat a dental fluorosis. It is suggested that mild-to-moderate fluorosis be treated by microabrasion and bleaching, while severe fluorosis, with loss of some surface enamel, is managed by veneering and crowning. This option allows us to totally remake the patient'sunpleasant smile.

Citation: ***Dr. Ashvini A. Meshram, Dr. Seema pattanaik and Dr. Bikash Pattanaik.*** **2020.** "Impact of fluorosis on dental treatment - a critical review of literature", *International Journal of Current Research*, 12, (06), 12006-12016.

INTRODUCTION

Dental fluorosis is a tooth malformation characterized by outer hypermineralization and subsurface hypomineralization (1). It is caused by the chronic ingestion of fluoride during tooth development. Numerous studies have reported that water fluoridation is a safe and effective public health measure for reducing the occurrence of dental caries (2,3). However, excessive fluoride in drinking water, exceeding a concentration of 0.5–1.5mg/l, can lead to metabolic alteration in ameloblasts; this results in a defective matrix and improper calcification of teeth, known as dental fluorosis (4). Dental fluorosis becomes a cosmetic concern particularly if it affects the anterior teeth. Dental fluorosis is a specific disturbance due to chronic ingestion of excessive fluoride during the formative period of the dentition (5). As far back as 1888, it was described as a condition that appeared to be endemic dental fluorosis in certain areas of Mexico (6). It was not until 1931 that Churchill discovered the correlation between fluoride from drinking water and dental fluorosis, a condition that is still endemic in many parts of the world, including certain areas of Africa, China, India, Middle East and South America (7). Epidemiological indices Several indices have been used to describe the clinical appearance of dental fluorosis.

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There are three most widely used Indices (8,9,10,11) More recently, the Fluorosis Risk Index (FRI) (12) has been in use. In addition, there are the descriptive indices that attempt to differentiate dental fluorosis from other causes of enamel opacities.

Dean's index The Dean's index is of historical interest because most of the older studies have used this index (10)

normal (0),
questionable (0.5),
very mild (1),
mild (2),
moderate (3) and
severe (4).

The index presupposes the diagnosis of the condition and the diagnostic criteria are unclear, imprecise and not sensitive enough to measure dental fluorosis in persons exposed to very high or very low fluoride levels. (13) Consequently, the index may not be suitable for the determination of appropriate treatment option for a fluorosed tooth.

Thylstrup and Fejerskov indexof the epidemiological indices, the Thylstrup and Fejerskov (T-F) index is, perhaps, the most suitable for use in the clinical management of dental fluorosis (8) This classification was modified in 1988 and is based on the observed clinical and pathological changes in fluorosed teeth (14).

Score of 0 through 9 are assigned, depending on the severity of the condition . Tooth surfaces are dried before diagnosis.. Classification of dental fluorosis according to Thylstrup and Fejerskov Index*, TFI (7)

TFI Features on enamel surface

0 Normal creamy surface after drying
1 Faint white lines
2 Distinct white lines, with some merged
3 Cloudy opacities with white lines in between
4 Paper white opacities on entire surface
5 Pitted and opaque surface
6 Merged pits form rows <2 mm high
7 Irregular pattern of enamel loss (<½)
8 ½ surface enamel lost, remaining enamel being opaque
9 Cervical rim of opaque enamel.

Management Options: Although the causes and characteristics of dental fluorosis have been widely reported, fewer studies have discussed the proper treatment of fluorosed teeth. The selection of an appropriate treatment plan depends on the severity of fluorosis(15).Bleaching and microabrasion have been recommended for treating mild cases of fluorosis; however, in moderate to severe cases, bleaching and microabrasion are either ineffective or may lead to only transient improvement,(16) while composite restorations are prone to discoloration, chipping, and debonding. Ceramic veneers are the restoration of choice for moderate to severe cases of fluorosis given their color maintainability, wear resistance, and biocompatibility (17). Discoloration of teeth is the most common reason why patients seek treatment of fluorosed teeth. The discoloration may be due to white opacity resulting from enamel hypomineralization. Uptake of extrinsic stains into the porous subsurface enamel may give rise to discoloration which may be yellowish, light brown, dark brown or black (Figures 1 and 2). To restore the natural white creamy enamel appearance, the tooth may be bleached or the subsurface porosities abraded together with the entrapped extrinsic stains, by microabrasion or macroabrasion.

If the subsurface porosities (Figure 3) are so deep-seated that they cannot be easily removed by microabrasion without causing hypersensitivity or resulting in unaesthetic tooth morphology, the enamel surface is veneered with porcelain or resin composite. Where more than 50% of surface enamel has been lost as a result of fluorosis, the remaining enamel may be insufficient for adhesive bonding; in which case, the fluorosed tooth may have to be crowned (16). It has been reported that the more severe the enamel fluorosis, the more deep-seated the subsurface porosities.(17) Thus, Akpata(15) suggested that mild fluorosis with T-F score of 1-2 should be managed by bleaching, as the subsurface porosities may be sufficiently superficial for the entrapped extrinsic stains to be removed by the bleaching agent. To make it easier for the bleaching agent to penetrate to the area of enamel subsurface porosities, the hypermineralized surface enamel may be etched with phosphoric acid. At T-F scores of 3-4, Akpata(15)in 2001 suggested microabrasion because the subsurface porosities may be so deep-seated that entrapped extrinsic stains may not be accessible to the bleaching alone. Rather, it is felt that microabrasion may remove the subsurface porosities together with the entrapped extrinsic stains. As loss of surface enamel of a fluorosed tooth is due to post-eruptive occlusal trauma, a tooth with TFI = 4 may have the potential to transform to T-F score of 5 when it has been subjected to sufficiently high occlusal trauma.(17) Therefore, in order to be as conservative as possible in the management of dental fluorosis, it has been suggested that microabrasion should first be tried on teeth with TFI = 4, and if ineffective, the tooth should then be treated by laminate veneer.(16) For teeth with TFI = 5-7 veneering is suggested, but if more than 50% of enamel surface has been lost, as in teeth with TFI = 8-9, the fluorosed tooth should be crowned. The management options suggested for discolored fluorosed teeth are, therefore, bleaching, microabrasion (or macroabrasion), veneering and crowning. The literature shows variations in the application of these management options.

Bleaching: Discolored, mildly fluorosed teeth have been treated by in-office or at-home bleaching or a combination of both. Hydrogen peroxide (35%) and carbamide peroxide (10%) are the commonly used bleaching agents. High concentrations (e.g. 35% hydrogen peroxide) of the bleaching gel are used for in-office bleaching. The teeth are isolated and cleaned before applying the gel directly to the teeth. Action of the gel may be accelerated by halogen or light-emitting diode (LED) curing light. It may require several sessions of in-office bleaching to achieve the desired result. To facilitate penetration of the bleaching agent to the subsurface porosities of the fluorosed tooth, the hypermineralized surface layer may be conditioned with 37% phosphoric acid. (18) The inoffice bleaching may be followed by at-home bleaching until the desired shade is attained. Sometimes, white enamel opacities of fluorosed teeth may be the cause of the patient's concern. In cases with focal areas of opacities, as may be found in teeth with TFI = 3, the unaffected portion of the enamel surface may be bleached until it matches the opaque part of the tooth surface. This was the approach followed by Bussadoriet al.(18) 2004, in the esthetic management of fluorosis blemishes on the maxillary incisors of an 8-year-old boy. Furthermore, it has been suggested that application of calcium sucrose phosphate gel could improve the appearance of areas of the fluorosed tooth affected by white opacities (19).

The tooth is cleaned and etched with 37% phosphoric acid for 2 minutes, followed by application of 2% sodium fluoride for 4 minutes. Finally, 40% calcium sucrose phosphate is applied. The best results were obtained in children than adults, while results were poor in teeth with very dark stains and those with chalky fluorosis. Enamel blemishes due to dental fluorosis may also be removed by making use of the Wright's protocol. (20) The fluorosed tooth is cleaned, using prophylaxis paste. The enamel surface is then etched with 35% phosphoric acid to facilitate penetration of sodium hypochlorite that acts as the bleaching agent. The bleaching session may be repeated until the desired shade is attained. After bleaching, the enamel pores are sealed with low viscosity resin composite to prevent further uptake of stains into the subsurface porosities. The Wright's protocol was applied to fluorosis stains on the teeth of 33 young children, and found significant improvement in color of the teeth, assessed by Minolta Chroma Meter CR300 (Chromameter, Minolta, Osaka, Japan) (21) The fluorosed teeth selected for the bleaching technique were within grades 1-4 of the TSIF. (22) The technique suggested by Belkiret al. (23) in 1991 is not much different from the Wright's protocol. In this technique, enamel is etched with 12% hydrochloric acid to remove the post-eruptive calcified surface enamel and denude microcavities containing the stains. This is followed by the application of pure sodium hypochlorite to remove the stain.

Finally, the chemically opened micro-cavities are filled with resin composite. The effectiveness of night guard vital bleaching technique (NGVBT) in the removal of dental fluorosis stain was studied in 2003. Different concentrations of carbamide peroxide and hydrogen peroxide were used: 20% carbamide peroxide (Opalescence/Ultradent, USA), 10% carbamide peroxide (NuProgold/Dentsply, USA) and 7.5% hydrogen peroxide (Day White/Discus Dental, USA).(24) The teeth of the subjects in the double blind clinical trial, had TSIF of 1-3, while patients with TSIF of 4-5 were excluded. The three bleaching products were effective in bleaching the discolored teeth, the 20% carbamide peroxide being most effective after 1 week of bleaching.

Microabrasion: Microabrasion is the controlled removal of superficial stain from enamel. The technique is used for removing stains due to mild-to-moderate fluorosis. (25) Microabrasion is often combined with bleaching to effectively remove fluorosis stains. It was suggested that this is a treatment of choice when fluorosis is mild (TFI = 1-3) (Figure 4), but it may also be tried in cases with moderate fluorosis (TFI = 4).(15) The technique is conservative and if unsuccessful, more invasive treatment options can still be followed. The discolored tooth may be etched with phosphoric acid, after which a thick mix of pumice and 18% hydrochloric acid is used to abrade the tooth surface. Micro abrasion removes the enamel porosities together with the entrapped extrinsic stains. Lower concentrations of hydrochloric acid have been used in commercially produced pastes. For example, Premamicroabrasion kit (Premier Dental) contains 15% hydrochloric acid with silicon carbide in water soluble slurry, while Opalustre (Ultradent) is made up of 6.6% hydrochloric acid combined with silicon carbide abrasive, and silica gel as a binding agent. The slurry may be applied with a rubber cup at slow speed (about 100 revolutions per minute)(25) or with gentle pressure from a wooden tongue spatula.(26) Generally, microabrasion is recommended when the enamel discoloration is not more than 0.2-0.3 mm deep.(27) To reduce tooth hypersensitivity after microabrasion, amorphous calcium phosphate (ACP) was applied.(25) It should also be noted that a complex comprising casein phosphopeptide (CPP) and ACP has the potential to reduce the opaque white discoloration of enamel fluorosis by encouraging remineralization.(22)

A combination of microabrasion and at-home bleaching: As recommended, followed by chair-side recreation of superficial enamel microstructure. (28) In this technique, microabrasion is aimed at removing the hypermineralized, white-colored superficial enamel layer, while at-home bleaching is to remove the extrinsic stains entrapped in the subsurface porosities. The clinicians reported only one case. They made use of Opalustre (Ultradent) for microabrasion, then sodium fluoride to minimize hypersensitivity, followed by at-home bleaching with 10% carbamide peroxide for 2 weeks. Finally, the enamel surface was reshaped with fine-grit diamond to recreate natural enamel appearance. The effectiveness of two commercial microabrasion products was compared, and it was found that Opalustre (Ultradent, USA) more effective than Prema (Premier Dental, USA) although both products were effective in removing dental fluorosis stains. (29) It should, nevertheless, be realized that the effectiveness of an abrasion product is influenced by the type of acid content, grit and hardness of the abrasive as well as the pressure of application of the abrasive to the tooth surface. The enamel surface was roughened with fine grit diamond at low speed, and used rubber cup and brush to apply 1 mm thick 6.6% hydrochloric acid microabrasion slurry to fluorosed enamel surface for 60 seconds. No bleaching agent was used. Scanning electron microscopic study showed that enamel etching patterns were not different from those of non-fluorosed control teeth. Abrasion of enamel prisms combined with enamel erosion by acid from the abrasion slurry results in compacted prism-free enamel surface, with altered optical properties. This is sometimes referred to as the ‘abrasion effect’ or ‘enamel glaze’.(30,31) The amount of surface enamel removed by microabrasion is negligible, being less than 100 µm in most cases.Esthetic improvement and surface alterations have been evaluated when fluorosis stain was removed, using the commercial microabrasion product, Prema; the paste was applied with 10:1 gear reduction hand piece.(32) It was found that 10, 30 second (total 5 minutes), applications were sufficient to remove stains from most cases of mild fluorosis, classified according to Dean’s index.(10) The results were not as good when cases of moderate-to-severe fluorosis were treated by this technique. Surface irregularities (due to exposure of extensive deep-seated porosities) were apparent after treatment of severe fluorosis. It was concluded that microabrasion could only be recommended for treatment of mild fluorosis. Faster methods for removing fluorosis stains, sometimes referred to as macroabrasion, have been advocated, and these include the use of fine-grit diamond points at high speed, or sandpaper discs at slow speed. These methods may be used to remove deep-seated fluorosis stains, but they may also result in excessive tooth tissue removal (34)

Composite/Ceramic crown/Laminate veneers: Laminate veneers are used to manage severe dental fluorosis, especially where there has been surface enamel loss. It has been suggested that teeth with TFI = 5-7 should be restored with laminate veneers. (10) Likewise cases with TFI = 4 in which microabrasion or macroabrasion have not been successful. The veneer may be made of porcelain or resin composite. As adhesive bonding to enamel produces more predictable outcome than bonding to dentin, laminate veneer is not recommended when more than 30% of the labial enamel has been lost. (18) Moreover, considerable enamel loss makes it difficult to avoid placing margins of the veneer preparation in dentin and thus reduce the possibility of postoperative sensitivity. Hence, it has been suggested that teeth with TFI = 8-9 be crowned, as more than 50% of enamel has been lost in such fluorosedteeth. (10) Porcelain laminate veneers have very good track records. Not only do they have excellent appearance and predictability, they are biocompatible. In a prospective longitudinal study of 323 porcelain laminate veneers, (19) survival rate, after 3-11 years, was very good, there being de-bonding in 9% of the restorations. Marginal integrity was excellent in 98% of the cases, and about the same percentage of the patients rated the treatment outcome to be excellent. There were very few fractures (4%), but gingival recession occurred in 7.7% of cases, while gingival bleeding was observed in 21.6% of cases. Hypersensitivity and change in sensibility of the restored teeth were uncommon (about 3%), and recurrent caries in 3% of the patients. In contrast, resin composite laminate veneers suffer from a number of disadvantages: Marginal staining, material loss, and gingival irritation. In a 2-year clinical evaluation of resin composite laminate veneers, marginal staining occurred in 75% of the treated teeth, while chipping was recorded in 52% of lateral incisors, and 79% of central incisors and canines. Gingival irritation was highly prevalent.

Thus, prognosis of resin composite appears not to be good. However, the introduction of the modern bonding systems and fiber-reinforced resin composites may result in resin composite veneers with better prognosis. (20)

Tooth preparation: Preparation of severely fluorosed teeth for laminate veneers follows the usual general principles. Nevertheless, certain special considerations need to be borne in mind. Display of incisal enamel would be unaesthetic. Therefore, the window type (39,40) of labial enamel preparation, should be avoided. Rather, the incisal bevel preparation is preferable (41). After removing 0.3-0.5 mm of labial enamel during preparation of a severely fluorosed tooth for a laminate veneer, there may be residual enamel discoloration. The enamel stain should be removed by in-office bleaching, using 25-38% hydrogen peroxide or 35-40% carbamideperoxide. (10) Teeth that mineralize later in life are more severely affected by fluorosis. (42) Therefore, fluorosis blemishes tend to be darker on premolars. If only the anterior teeth are being prepared for veneer, and the premolars are very dark, the posterior teeth should be bleached before shade selection for the veneers. Alternatively, the shade should be made progressively lighter from the posterior to the anterior teeth.

Etching of fluorosed enamel: Management of severely fluorosed teeth by means of veneers or crowns requires adhesive cementation of the restorations to enamel and dentin. To achieve this, the hard dental tissues need to be etched. As part of the hydroxyapatite in the hypermineralized surface layer of enamel has been replaced by the acid-resistant fluoroapatite, fluorosis will be expected to make etching of enamel more difficult. Hence, it has been suggested that etching time for fluorosed teeth should be doubled.(41).Moreover, the fluoride content of fluorosed enamel depends on the severity of fluorosis.(31,41) Consequently, the effect of varying severity of fluorosis on the pattern and depth of etch (depth of demineralization) of human enamel was investigated, using 37% phosphoric acid, an etchant commonly used in restorative dentistry.(43) It was observed that the depth of etching teeth with mild fluorosis (TFI = 1-3) was similar to that in non-fluorosed teeth (TFI = 0), suggesting that etching of teeth with mild or no fluorosis should be similar. A similar observation was seen in East Africa. (44) This is not surprising because fluoride concentration of surface enamel of mildly fluorosed (TFI = 1-3) teeth is not significantly different from that in non-fluorosed teeth (TFI = 0). (41,45) In contrast, etching time had to be doubled in teeth with moderate fluorosis (TFI = 4) to obtain the depth of etch as with non-fluorosed teeth. This indicates that etching time of teeth with TFI = 4 should be, at least, twice that for non-fluorosed teeth. In teeth with surface enamel loss (TFI = 5+), depth of etch depended on whether the surface enamel was intact or detached (45)

Bonding to Fluorosed teeth

Enamel: Resin cements are used for bonding laminate veneers and crowns in the esthetic management of severe fluorosis. Several laboratory studies have, therefore, been carried out to investigate the effect of fluorosis on bond strength of resin composite to enamel. Some of the studies were done with the hypermineralized surface enamel intact, while in other investigations, the outer 2-3 mm of enamel was removed to flatten the tooth surface for shear bond strength testing.

In studies in which the hypermineralized surface enamel was left intact, bond strength was adversely affected by fluorosis.(46) On the other hand, bond strength was unaffected by severity of fluorosis when surface enamel was removed prior to bond strength testing.(47,48) Furthermore, microtensile bond strength of porcelain laminate veneer, bonded to enamel after removal of the hypermineralized surface layer, was unaffected by severity of fluorosis.(48) Also, it was reported that shear bond strength was significantly lower with self-etching and etch-and-rinse bonding systems when enamel was ground.(49) It should be remembered that high fluoride concentration is usually in the outer 200 µm.(41) This hypermineralized surface layer is more resistant to acid dissolution. Removal of the outer 2-3 mm exposes the subsurface enamel with lower fluoride concentration. This possibly explains why bond strength may be unaffected by severity of fluorosis when the hypermineralized surface enamel is removed.

It has been reported that the mode of bond failure is influenced by age and severity of fluorosis. For example, it was reported that shear bond strength of resin composite to fluorosed enamel was significantly higher in teeth extracted from patients aged below 40 years than those aged 40 years and above(47) At T-F score of 1-3, bond failure was predominantly mixed at all ages and etching times, but at TFI = 4-6, bond failure was mostly cohesive in enamel, especially in teeth of patients aged 40 years and above.(47) This may be due to extensive subsurface porosity and protracted posteruptive occlusal trauma in teeth with moderate-to severe fluorosis. Bond strength of different types of bonding systems on fluorosed enamel has been studied by a number of investigators. Just as in non-fluorosed teeth, bond strength was significantly higher with etch-and-rinse bonding systems than self-etch adhesives.(46,49,53) Preetching with 37% phosphoric acid improved bonding to moderately and severely fluorosed enamel when self-etching primer was used.(50) The bond strength of 2 mm × 3 mm ceramic discs was investigated (IPS Empress 2) to fluorosed and non-fluorosed tooth surfaces, using etch-and-rinse or self-etch luting resin cements.(51) Shear bond strength was significantly higher with the etch-and-rinse resin cement. The micro-shear bond strength (MSBS) of two all-in-one dentin bonding systems to unground enamel surfaces of fluorosed and non-fluorosed teeth was studied. (52) It was observed that fluorosis had no significant effect on MSBS. This may be due to the shallow hybrid layer produced by both adhesives. Moreover, bond failure was mostly adhesive. The purported advantage of using all-in-one adhesive for cementation of an esthetic restoration on unprepared fluorosed teeth is that the treatment would be noninvasive: If the restoration fails, enamel surface would not have been damaged. By measuring MSBS, there was no need to flatten the enamel surface for shear bond strength testing (50).

Dentin: As dentin may sometimes be exposed in teeth prepared for laminate veneers or crowns, cementation of the restorations with resin cement may involve dentin. Thus, information on bond strength of resin composite to fluorosed dentin is of interest. No statistically significant difference was observed when Scotchbond Multipurpose (3M) (an etch-and-rinse bonding system) was used for bonding resin composite to dentin of teeth with mild, moderate and severe fluorosis.(55) Similarly, it was also observed that fluorosis had no significant effect on shear bond strength when Clearfil SE Bond(Kuraray ESPE) was used as an adhesive (56).

Table 1. Study design, interventions, and outcome of clinical trials

Author	Study design	Total patient; age	Patient info	Fluorosis index	Intervention	Outcome
Loguercio 2007[28]	Randomized Controlled Trial	36; 10-12 years	Moderate-Good Oral hygiene	DFI; questionable, mild	Group 1: enamel microabrasion PREMA Group 2: enamel very mild, microabrasionOpalustre	Esthetic improvement in VAS Participant satisfaction Tooth surface
Bharath 2014[33]	Randomized Controlled Trial	30; 9-14 years	Objectionable esthetics	DFI; mild moderate	Group 1: McInnes bleaching (36% HCl, 30% H_2O_2, Diethyl ether) Group 2: enamel microabrasion (18% HCl, pumice powder)	Esthetic improvement in VAS Tooth sensitivity
Castro 2014[25]	Randomized Controlled Trial	70; 15-39 years	Good oral hygiene, vital anterior teeth without loss or fracture previously no orthodontic treatment.	TFI; mild moderate	Group 1: enamel microabrasion (37% phosphoric acid, pumice) Group 2: enamel microabrasion (37% phosphoric acid, pumice), at-home bleaching (10% carbamide peroxide)	Reduction in opacity Esthetic improvement in VAS Participant satisfaction in VAS Tooth sensitivity/gingival irritation in VAS
Gugnani 2017[27]	Randomized Controlled Trial	80; 6-12 years old	School children, no history of allergy to dental materials, systemic or local conditions and treatment of dental fluorosis.	TFI; mild moderate	Group 1: in-office bleaching (35% H_2O_2) Group 2: resin infiltration (15% HClgel ethanol drying agent, resin infiltration) Group 3: resin infiltration with double application of infiltrant Group 4: in-office bleaching (35% H_2O_2) resin infiltration	Esthetic changes in VAS Improvement in opacity or stain in VAS
SôniaSaeger 2018[26]	Randomized Controlled Trial	70; 15-39 years	Good oral hygiene, vital anterior teeth without loss or fracture previously no orthodontic treatment, non-pregnant	TFI; mild moderate	Group 1: enamel microabrasion (37% phosphoric acid), fine-grained pumice Group 2: microabrasion and at-home tooth bleaching (10% carbamide peroxide)	Reduction in stained area Tooth sensitivity/gingival irritation in OIDP Esthetic improvement in OIDP

2. Adhesion to dental substrates affected by fluorosis

Authors and Years	Type of study	Objectives	Sample	Results
Ateyah and Akpata [15].	Prospective study	*To study the impact of the fluorosis severity and the etchnig time on the composite adhesion to enamel.	*170 teeth (TF Index = 0, 1-3, 4-6)	*The fluorosis severity does not affect the composite adhesion to enamel (TF Index =0, 1-3, 4-6) *Prolonged etching, from 60 seconds to 120 seconds, improves the adhesion.
Jayasooriya and co-workers [24].	Prospective study	*To assess the effectiveness of 2 components self-etching system: -regarding the non-etched fluorotic enamel with prolonged priming -regarding etched fluorotic enamel, roughened by enamel preparation.	*30 teeth	*The mechanical pretreatment of fluoritic enamel improve the adhesiveness values of self-etching system. *Prolonged priming does not have a significant effect on the adhesion to fluorotic enamel. *Type 2 structure predominates within etched fluorotic enamel, while more superficial etched surface is obtained on the nonetched enamel, even with a prolonged priming.
Ermis and Gokay [20].	Prospective study	*To study the effect of fluorosis on the dentin adhesion, using a self-etching system.	*40 teeth (TF Index = 3, 4 and 5)	*No significant difference on the adhesiveness value of the fluorotic dentin.
Weerasinghe and co-workers [19].	Prospective study	*To assess the adhesion of 2 components self-etching system on fluorotic enamel. *To study the influence of phosphoric acid etching before self-etching application on fluorotic enamel.	*80 fluorotic teeth categorized according to TF Index to 4 groups (TFI 0, 1, 3, 4-6, 7-8)	*No significant difference regarding the adhesion to enamel within different fluorosis degrees. *The application of 37% phosphoric acid before self-etching gives higher adhesiveness values, compared to self-etching. This difference is significant within moderate to severe fluorotic teeth.
Ermis and coworkers [20].	Prospective study	*To compare the effectiveness of etch-and-rinse and self-etching on fluorotic enamel. *To evaluate the effect on adhesion of the enamel prepared with diamond bur.	*10 fluorotic teeth (TFI = 5) and 11 teeth (TFI=0)	*The etch-and-rinse system gives better adhesion than the 2 components self-etching, whether on flurotoic or healthy enamel. *Regarding the 2 adhesive systems, the fluorotic enamel has better adhesiveness values when roughened and prepared with diamond bur.
Waidysekera and co-workers [22].	Prospective study	*To evaluate the effectiveness of 3 adhesive systems on the fluorotic dentin: 1 component self-etching, 2 components self-etching and etch-and-rinse.	*48 fluorotic teeth with different degrees of severity (TFI= 1-3, TFI= 4-6)	*The adhesiveness values to the healthy dentin are higher compared to slightly fluorotic dentin, followed by moderate fluorotic, which has the lower values. *The 2 components self-etching provides the best adhesiveness values, followed by etch-and-rinse, then 1 component selfetching, for the different degrees of fluorosis.
Ertugrul and co-workers [17].	Prospective study	*To evaluate the effectiveness on fluorotic enamel of the three adhesive systems: etch-and-rinse, 2 components self-etching and 1 component selfetching.	*136 fluorotic teeth (TFI= 4-6)	*The adhesiveness values to fluorotic enamel are significantly lower compared to healthy enamel. *The etch-and-rinse system provides the best adhesiveness values, whether the teeth are fluorotic or healthy.
Shida and coworkers [18].	Propsective study	*To evaluate the adhesion tofluorotic enamel of 2 components self-etching system. *To measure the surface pH level in order to assess the acid resistance.	*20 fluorotic teeth (TFI =1-3)	*The adhesiveness values to fluorotic enamel are significantly lower compared to healthy teeth. *Statistical discrepancies have been found regarding the surface pH levels, within fluorotic and non-fluorotic enamel, before and after 2 components self-etching application.
Isci and coworkers [21].	Prospective study	*To compare the braces adhesiveness values to fluorotic enamel, using two systems: self-etching and etch-andrinse.	*40 slightly fluorotic teeth (TFI = 1-3)	*There is no significant difference with the adhesiveness values, between fluorotic and non-fluorotic enamel, using etch-and-rinse system. *The self-etching system schows lower adhesiveness values to fluorotic enamel.
Silva Benitez and co-workers [16].	Prospective study	*To study the effect of fluorosis on the adhesion of orthodontic tubes and identify the optimal surface treatment to improve it.	*140 moderate to severe fluorotic molars.	*Fluorotic teeth have lower adhesiveness values compared to healthy ones. *Prolonged etching, to 150 seconds of moderate fluorotic teeth, provides better adhesiveness values. *Micro abrasion procedure followed by 15 seconds normal etching improves significantly the adhesion to severe fluorotic teeth.

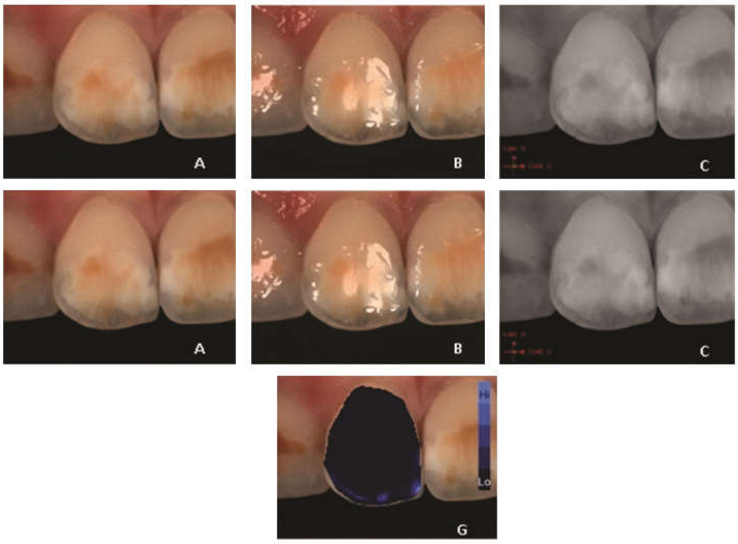

Figure 3. Example-measurementsofdemarcatedopacityonuppercentralrightincisor:(a)polarizedimage;(b)glossmodeallowing the identification of "pure enamel zones"; (c) contrast image; (d) evaluation of the three equal zones along the median axis: gingival, central, and incisal; (e) colour distribution and detailed mapping of the defect surface; (f) overall detailed mapping; (g) translucency.[67]

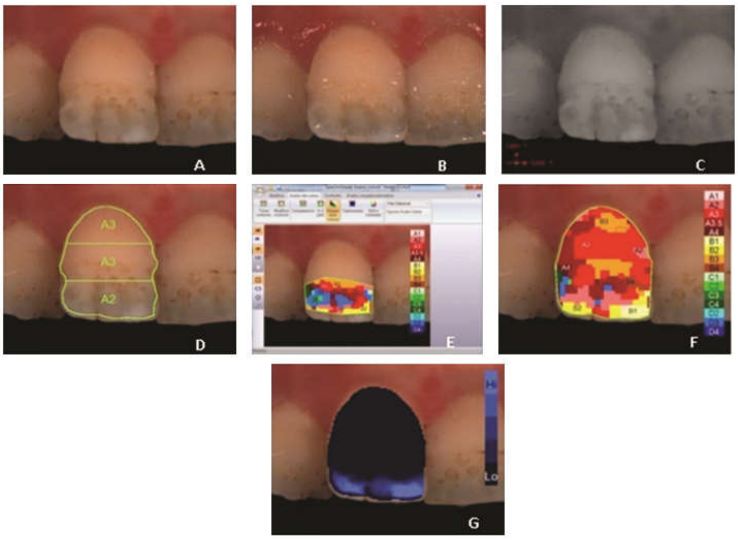

Figure 4. Examplemeasurements of hypoplastic defects on upper central incisor: (a) polarized image; (b) gloss mode allowing the identification of "pure enamel zones"; (c) contrast image; (d) evaluation of the three equal zones along the median axis: gingival, central, and incisal; (e) colour distribution and detailed mapping of the defect surface; (f) overall detailed mapping; (g) translucency.[67]

Material	Manufacturer	Batch # luting systems	Material composition
Varolink-2/Excite DSC	Ivoclar Vivadent Schaan, Liechtenstein	Etchant: J11093	37% phosphoric acid
		Excite DSC (Dual-curing single-bottle bonding agent): J12791	Phosphoric acid acrylate, dimethacrylates, HEMA, highly dispersed silicondioxide, ethanol, catalysts, stabilizers Microbrush: coated with initiators
		Cement base: J13724	Bis-GMA, UEDMA, TEGDMA, filler
		Cement high viscosity catalyst: J13735	Bis-GMA, UEDMA, TEGDMA, filler
		Silane (Monobond S): J14325	3-Methacryloxy propyltrimethoxysilane, water, ethanol, acetic acid (pH 4)
		Ceramic etchant: J07372	5% hydrofluoric acid
		Oxygen inhibiting gel: J08775	Glycerine, silica
Clearfil Esthetic Cement/ED Primer II	Kuraray, Tokyo, Japan	ED Primer A: 00232A	HEMA, MDP, water, accelerator
		ED Primer B: 00110A	Methacrylate monomers, water, initiator, accelerator
		Cement base: 0001AA	Bis-GMA, TEGDMA, other methacrylate monomers, silanated glass filler, colloidal silica
		Cement catalyst: 0001AA	Bis-GMA, TEGDMA, other methacrylate monomers, silanated glass filler, silanated silica, colloidal silica, benzoyl peroxide, di-camphorquinone, pigments
		Silane (Clearfil Ceramic Primer): 00001A	3-Methacryloxypropyl trimethoxysilane, 10-methacryloyloxydecyl dihydrogen phosphate, ethanol
		Ceramic etchant (K-etchant Gel): 00389B	Water, phosphoric acid, colloidal silica, pigments

Table 3. Mean failure loads (MPa) for each group

	n	Mean (MPa)	S.D.	95% Confidence interval for mean	
				Lower bound	Upper bound
Group VF	12	18.30	3.08	16.34	20.26
Group V	12	18.79	2.65	17.11	20.48
Group CF	12	8.43	2.45	6.87	9.99
Group C	12	13.53	1.68	12.46	14.60
Total	48	14.76	2.46	13.34	16.18

Characteristic	Alpha	Bravo	Charlie	Delta
Color match	Matches shade	Matches shade	Mismatches	Not applicable
	tab in	tab in	shade tab in	
	color/shade	color/shade	color/shade by one shade tab gradation or more	
Marginal	No visible	Visible evidence	Explorer	Restoration
adaptation	evidence of	of a crevice	penetrates	is mobile,
	crevice along the	along the margin	crevice,	fractured or
	margin that the	that the explorer	reaching dentin,	missing
	explorer will	will	or	
	penetrate	penetrate	base is exposed	
Cavosurface	No discoloration	Discoloration	Discoloration has	Not applicable
marginal	anywhere on the	present, but has	penetrated along	
discoloration	margin between	not penetrated	the margin in a	
	the restoration	along the	pulpal direction	
	and	margin in a		
	the tooth	pulpal		
	structure	direction		
Secondary	No caries as	Evidence of	Not applicable	Not applicable
Caries	evidenced by	caries at		
	softness, opacity	margin of the		
	or etch at the margin of the restoration	restoration		
Postoperative	No postoperative	Postoperative	Not applicable	Not applicable
sensitivity	Sensitivity	sensitivity		

These two studies suggest that fluorosis may not adversely affect adhesive cementation of veneers and crowns to dentin of fluorosedteeth. The micro-tensile bond strength of resin composite to teeth with either mild, moderate or severe fluorosis was compared.(59)It was observed that the twostep self-etching adhesive (Clearfiil SE Bond/Kuraray Medical) generally had higher bond strength than the all-in-one bonding system (Clearfil Tri S Bond/Kuraray Medical) and the etch-and-rinse bonding system (Single Bond/3M-ESPE). Although the bond strength of Clearfil SE Bond was higher than that of Single Bond for moderately fluorosed dentin, the difference was not statistically significant. The high bond strength with Clear filSE Bond may be due to the fact that its primer is only mildly acidic, enabling its adhesive monomer (10-methacryloyloxydecyl dihydrogen phosphate, 10-MDP) to chemically bond with residual hydroxyapatite crystals in the hybrid layer. This may be a result of altered mineralization of interglobular dentin of fluorosed teeth. It is possibly analogous to decrease in bond strength of glass-ionomer-based materials to dentin with increasing severity of fluorosis; calcium ions for bonding to carboxyl group of glass-ionomers are depleted in interglobular dentin of severely fluorosedteeth.(58)Further research, particularly clinical trials, are needed to clarify the effect of fluorosis on dentin bond strengths of different types of adhesive systems.

Shade selection: Little is known about the optical properties of developmental defects of enamel in a young population. Clinical detecting of DDE is more frequent everyday but there is a lack of information about the optical properties of the defect surface and the surrounding sound enamel surface. The tooth optical properties describe a complex phenomenon, which can be even more complex if a developmental defect of enamel is present on labial tooth surface.

Value, hue, and chroma describe tooth colour, but there are more subtle secondary optical properties that affect the overall tooth appearance translucency, opalescence, opacityiridescence, surface gloss, andfluorescence (60,61). Translucency, opacity, and opalescence have been viewed as the most important indicator soft the quality and quantity of light reflection (62). In this study the tooth labial surface was divided into three equal zones (incisal, central, and gingival) along the median axis and the aspects we consider most important for tooth perception, that is, $L*$, $a*$, and$b*$ (resp., the amount of luminosity, green/red, and blue/yellow), were analyzed. Sound enamel surface and affected surface were analyzed using the same spectrophotometric method. The developmental defect of enamel can be localized at the cervical, middle, or incisal area of the tooth. In a sound tooth the seareas have different optical properties, because of the structure complexity and avariability of enamel thickness and the below dentine. Some considerations can be illustrated about the optical properties of a sound tooth. Hasewaga has measured $L*a*b*$ in 5 locations along the median axis and found significant variation. $L*$ is highest in the center zone ($L*$ = 73) and becomes lower in the gingival zone ($L*$ = 69) and lower towards the incisal edge ($L*$ = 64); the highest$a*$ value is in the gingival area ($a*$ = 8,5) and it gradually becomes lower towards the incisal edge ($a*$ = 2,0); $b*$ is highest in gingival region ($b*$ = 20) and gradually decreases towards the incisal edge ($b*$ = 13) (63). The existing differences between these zones are statistically and clinically significant also for detecting and describing enamel color alteration when developmental defects are present. Translucency indicates the quality and quantity of light reflection and it decreases from incisal towards central tooth area. In our opinion, the less the defect is integrated within the surrounding sound enamel surface, the more the DDE is clinically evident, this condition increasing from gingival to incisal tooth area. Loss of surface gloss affects the tooth vitality appearance. When a demarcated opacity is present on the incisal zone with white, yellow, and/or brown characterization, the surface gloss is completely altered. Developmental defects of enamel interest also tertiary anatomy. The tertiary anatomy is defined by vertical, horizontal, and Enamel hypoplasia such as pitted enamel hypoplasia often can affect also vertical tertiary anatomy, determining in the meanwhile a complete aberration of tertiary characterizations. Spectrophotometric analysis presents a lot of advantages: it excludes bias due to subjective evaluation and analyses every 1–10nm of the visible spectrum and the collected data are accurate. Incisal, central, and gingival zones have really different CIE $L*$, $a*$, and$b*$, because of changing thickness in enamel and dentine layers. Moving from the incisal zone to the gingival, the tooth thickness increases and opacity and $a*$ values increase too, while luminosity ($L*$ values) decreases. The gingival zone has been shown to have the lowest translucency (63) and significantly higher$a*$values; $b*$ values slightly increase with thickness, in a constant and linear way (66). According to Modified DDE Index, a defect can be considered greater if the covered surface is more than 1mm of diameter. In our opinion the defect localization on the three previously described zones (incisal, central, and gingival) is an important factor for the defect characterization. Optical properties of the defect have to be confronted with the optical properties of the corresponding sound enamel zone and the more they diverge in$a*$ and $b*$values, the more is the perception of the existing contrast .For example ,as gingival zone has the lowest translucency, higher$a*$values, and increased $b*$ values but decreased luminosity ($L*$ values), a defect with similar optical properties will be more accepted in this zone, while the same defect in the incisal zone will appear more evident due to higher differences in optical properties with the interested zone. A recent study presented a correlation between the colour of enamel and the severity of hypo mineralization, where yellow and brown colour of the hypo mineralized enamel was at a higher risk for PEB (post eruptive breakdown) compared with white defects (65).

Cementation: In this study, for shear bond strength evaluation, higher shear bond strength was recorded for etch-and-rinse dentin bonding agent (Varolink-2/Excite DSC) than self-etch dentin bonding agent (Clearfil Esthetic Cement/ED Primer II) with both fluorosed and non-fluorosed enamel surfaces. Enamel–resin bonds, when produced by etch-and-rinse adhesives, are more stable over time.(70)Several studies reported that phosphoric acid application for obtaining the micromechanical retention to the prepared non-fluorosed enamel surface before the application of dentin bonding agent increased the bond strength to the enamel surface.(68,71)This result is compatible with the result obtained from the present study. In an in vitro study it was found that the longer the acid-etching time with phosphoric acid to moderate and severe fluorosed enamel surface the higher the bond strength (72). There are few studies on the bonding performance of dentin bonding systems to fluorosed enamel surfaces (71,72). In an in vitro study; micro-shear bond strength of composite filling material to fluorosed enamel surface was evaluated and it was found that the self-etch dentin bonding system investigated is as effective as phosphoric acid etching when bonding is performed on non-fluorosed and mild fluorosed enamel (71). On the other hand, the self-etch dentin bonding system is inferior to phosphoric acid etching when bonding is performed on moderate and severe fluorosed enamel (71). It is probably due to the fact that moderate fluorosed enamel surface may be more resistant to acid in the primer of self-etch system than non-fluorosed enamel. The same result was found in Weerasinghe et al.'s study as well (71). In Ermis et al.'s study it was reported that bond strength of etch-and-rinse dentin bonding system was higher than self-etch dentin bonding system on unground fluorosed enamel surfaces.

Post-operative/ follow up: The baseline evaluation was completed at two weeks after the restorations were placed. One-year evaluations followed. Modified Ryge criteria to evaluate the clinical outcome, results were found Alfa-rated and no difference between baseline and after 1-year follow-up.(74) Patients did not report tooth sensitivity or adverse reactions. All restorations showed that the combination of a glazed etched-porcelain to preparedtooth interface, together with maintenance of good oral hygiene, gave satisfactory esthetic results as well as good gingival response. There was no breakage or discoloration of veneers during the evaluation. The pre- and post-treatment photographs show a significant improvement in esthetics (74). The durability and clinical success of PLV has been extensively studied. The reported success rate is more than 95%, and the average durability is more than 5 years (75). Veneers have been shown to provide excellent service over 3 years of function (76). Satisfactory results with PLV restorations were reported at 18 months regarding surface, color, marginal integrity, fracture rate, and gingival tissue response (77). Satisfactory esthetic results were observed in a six-year recall of fluorosed teeth restored with PLV.(80)Other studies have shown that moderate PLV has been extensively studied. The reported success rate is more than 95%, and the average durability is more than 5 years.(75)Veneers have been shown to provide excellent service over 3 years of function.(76)Satisfactory results with PLV restorations were reported at 18 months regarding surface, color, marginal integrity, fracture rate, and gingival tissue response.(77)Satisfactory esthetic results were observed in a six-year recall of fluorosed teeth restored with PLV.(80)Other studies have shown that moderate fluorosis or fluorosis-like discolored teeth restored with PLV demonstrated satisfactory results.(78,79)Following the recommended treatment plan, in this case 16 PLV restorations were placed on the upper and lower anterior and premolar teeth.

Conclusion

- As a result of the use of fluoride in preventive dentistry, the prevalence of mild to moderate dental fluorosis is on the increase in most countries. Because mild fluorosis may not necessarily be of esthetic concern in many communities, therapeutic intervention may not be required in many of such cases.
- The Thylstrup and Fejerskov classification provides an index that is most useful in the selection of the appropriate treatment option for esthetically objectionable fluorosed teeth.
- Teeth with TFI = 3+ are of esthetic concern in most communities and as the effects on the hard dental tissues are irreversible, therapeutic intervention is needed to improve appearance.
- Esthetically objectionable fluorosed teeth with no loss of surface enamel (TFI = 1-4) may be treated by a combination of microabrasion and bleaching. 5. Where there has been loss of surface enamel, esthetically

objectionable fluorosed teeth may be managed by porcelain laminate veneers, provided not more than 30-50% of labial enamel has been lost, and the margins of the restoration can be placed on intact enamel.

- Cases of fluorosed teeth in which more than 50% of surface enamel has been lost (TFI = 8-9) should be treated by crowning.
- If porcelain laminate veneer is bonded to a fluorosed tooth after removal of the hypermineralized enamel surface layer, bond strength may not be adversely affected by severity of fluorosis. However, if the ceramic veneer is bonded to unprepared tooth surface, fluorosis may compromise bond strength; and, in such a circumstance, etch-and rinse bonding system should be preferred.
- Long-term clinical studies are required to evaluate the various management options for teeth with varying severity of fluorosis, measured by TFI.

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