บทความปริทัศน์
Review Article

ผลของฟันตกกระต่อความแข็งแรงการยึดติดทางทันตกรรมจัดฟัน: บทความปริทัศน์

Effect of Dental Fluorosis on Orthodontic Bond Strength: A Review of the Literature

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บทคัดย่อ

ฟันตกกระคือสภาวะที่มีการสะสมแร่ธาตุน้อยเกินไปของผิวเคลือบฟันเกิดจากการบริโภคฟลูออไรด์อย่างต่อเนื่องมากเกินไประหว่างการสร้างผิวเคลือบฟัน ผิวเคลือบฟันตกกระที่บริเวณผิวนอกมีลักษณะการสะสมแร่ธาตุฟลูออไรด์ปริมาณมาก เป็นชั้นที่ต้านต่อการกัดของกรด ส่วนชั้นภายใต้ผิวนอกประกอบด้วยรูพรุนและมีการสะสมแร่ธาตุฟลูออไรด์ปริมาณน้อย ลักษณะผิวเคลือบฟันตกกระที่ถูกปรับสภาพด้วยกรดมีลักษณะความขรุขระน้อยกว่าฟันปกติ ทันตแพทย์จัดฟันประสบปัญหาในการยึดติดแบร็กเก็ตกับฟันตกกระ ระบบสารยึดติดสำหรับการยึดแบร็กเกตกับฟันตกกระแบ่งเป็นสองระบบคือระบบโททอล-เอทช์ชิง และ ระบบเซลฟ์-เอทช์ชิง ประสิทธิภาพในการยึดติดกับฟันตกกระยัง

Abstract

Dental fluorosis is the hypomineralization of the enamel caused by continuous ingestion of excessive fluoride during enamel formation. Fluorosed enamel is characterized by an outer hypermineralized, acid resistant layer, and by the formation of more porous enamel in the area of the subsurface hypomineralization. The etching pattern of fluorsoed enamel has less irregularity than that of normal enamel. Orthodontists face difficulties in bonding brackets to fluorotic teeth. There are two bonding systems for bonding brackets to fluorotic teeth: total-etching and self-etching bonding systems. The effectiveness of

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เป็นที่โต้แย้งกัน วัตถุประสงค์ของบทความปริทัศน์นี้เพื่อบรรยายเกี่ยวกับฟันตกกระในแง่ ลักษณะทางคลินิก อุบัติการณ์ การจัดแบ่งประเภท ลักษณะผิวเคลือบฟันตกกระที่ถูกปรับสภาพด้วยกรด และเพื่อบรรยายและเปรียบเทียบความแข็งแรงยึดของระบบระบบโททอล-เอทช์ชิง และ ระบบเซลฟ์-เอทช์ชิงเมื่อใช้ยึดแบร็กเกตจัดฟันกับฟันตกกระ

bonding to fluorotic teeth is controversial. The purposes of this review article are to describe dental fluorosis in terms of clinical appearance, incidence, classification and etching pattern of fluorosed enamel, and to describe and compare the bond strength of total-etching and self-etching bonding systems when used to bond brackets to fluorotic teeth.

คำสำคัญ: ผิวเคลือบฟันตกกระ ความแข็งแรงยึด

Keywords: Fluorosed enamel, Bond strength

Introduction

Excessive fluoride ingestion during tooth formation leads to dental fluorosis.[1] The features of fluorosis vary from white lines in the enamel to chalky, pitted and discolored enamel.[1-2] The main factor causing dental fluorosis is taking high doses of fluoride from drinking water.[3] There are many endemic fluorosis regions such as Colorado, USA; Sri Lanka; Isparta, Turkey; the Hail Region, Saudi Arabia;[4] and Northern Thailand.[5] Orthodontists working in those areas encounter difficulties in bonding brackets to fluorosed enamel.[3] There are reports that it is difficult to bond brackets to fluorotic teeth and there is a notable clinical failure rate for bonding to such teeth.[6] Several investigators have tested bond strength between composite material and fluorosed enamel.[4,7-11] Some have reported that strength of the bond with fluorosed enamel is not different from that with normal enamel.[8-9] In contrast, some have reported that it is less than that with normal enamel.[4,10-11]

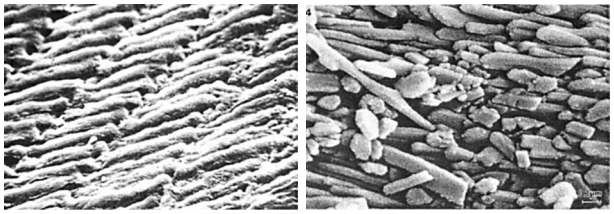
Dental fluorosis

Dental fluorosis is a specific disturbance of tooth formation caused by excess fluoride intake.[12] It can occur either as an acute or chronic exposure during tooth formation. Its characteristics include retention of amelogenins in the early maturation stage and formation of porous enamel in the subsurface layer.[1] Severity of dental fluorosis depends on many factors, such as the amount of fluoride ingested, the duration of exposure, individual susceptibility and the stage of amelogenesis at the time of exposure.[1-2]

The histology of fluorosed enamel shows that the general arrangement of prisms of enamel rods is irregular[13] (Figure 1) and subsurface hypomineralization is accompanied by a higher proportion of protein than normal.[12,14] If pore volume in the subsurface layer is more than 10-15%, fracture of enamel can result.[15] The main feature of fluorosed enamel is an outer hypermineralized and acid-resistant layer, which is difficult to bond because a reliably etched enamel surface cannot be produced.[4]

The clinical appearance of dental fluorosis has various characteristics, such as fine white lines across the entire tooth surface, small, white, opaque areas, brownish discolorations or pitted enamel.[2] Teeth exhibiting severe forms of dental fluorosis are prone to fracture and wear (Figure 2).[1,36]

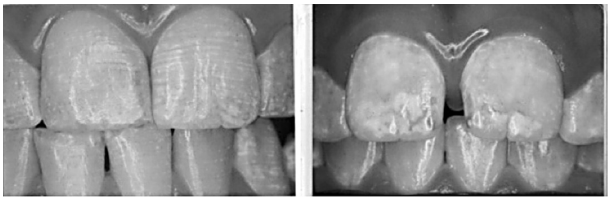
The risk of dental fluorosis depends on the dose of fluoride relative to body weight. If children between the ages of 15 and 30 months ingest



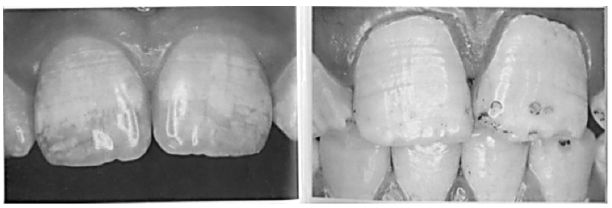
(A) (B)

Figure 1 *(A) Scanning electron micrograph of normal enamel. (B) Scanning electron micrograph of fluorosed enamel.*[13,32]

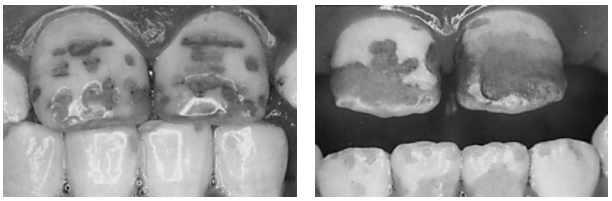
รูปที่ 1 *(A) ภาพถ่ายจากกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราดของผิวเคลือบฟันปกติ (B) ภาพถ่ายจากกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราดผิวเคลือบฟันตกกระ*



(A) Mild form



(B) Moderate form



(C) Severe form

Figure 2 *Types of severity of dental fluorosis: (A) Mild form (B) Moderate form (C) Severe form.*

รูปที่ 2 *ชนิดความรุนแรงของฟันตกกระ (A) ระดับเล็กน้อย (B) ระดับปานกลาง (C) ระดับรุนแรง*

excessive fluoride, their upper central incisors are at most risk of develolping dental fluorosis. When the first permanent molars erupt at about 6 years, the coronal parts of the anterior teeth are nearly complete, and ingestion of fluoride at this age will have little effect on the development of the anterior teeth. In older children, the risk of dental fluorosis moves to the posterior teeth.[2] Dental fluorosis is more severe in posterior teeth than in anterior teeth, in both maxilla and mandible.[16] Whereas the maxillary molars and premolars are more affected on the palatal surface, the mandibular teeth appear more severely affected on the buccal surface.[15]

The first report of dental fluorosis was by Kuhn in 1888, in Mexico.[17] Data in the United States of America, suggests that in areas with fluoride addition in the water supply 8-51% of children develop dental fluorosis, whereas in areas with no fluoride addition only 3-26% of children develop dental fluorosis.[18] In the north of Thailand the water has a high natural level of fluoride.[19] The provinces of northern Thailand with high fluoride levels are: Chiang Rai, Chiang Mai, Phayao, Mae Hong Sorn, Lampang, Lampoon, Tak, Sukothai, Chainat, Phichit and Phetchburi. National dental health surveys in 1994 found that dental fluorosis in 12-year-old children in Northern Thailand was 17%.[5] The percentages of distribution of dental fluorosis in the northern part of Thailand were: Chiang Rai 45.6 %, Chiang Mai 50%, Phayao 32.6%, Mae Hong Sorn 53.7%, Lampang 59.8%, Lampoon 30.3%, Tak 41.1% , Sukhothai 4.4%, Chai Nat 14.2%, Phichit 28.4% and Phetchburi 47.4%.

The intensity of fluorosis ranges from noticeable, whitish striations that may affect small portions of the enamel to confluent pitting of almost the entire enamel surface and unsightly dark brown to black staining. In order to assess the presence and severity of dental fluorosis, Dean(20) developed a classification system in 1934 and modified the classification system in 1942

But Dean's index has many limitations, such as difficulty of classification into various categories in the milder forms, lack of clarity, imprecision and lack of sensitivity.[20-21] In 1987, Thylstrup and Fejerskov established a new classification systems for dental fluorosis, called the TF index (after the initials of the authors' names).[15] The TF index is more precise, sensitive and easier to use than Dean's index.[21]

Since Buonocore[22] introduced the acid etch bonding technique in 1955, others have developed applications of the concept of bonding various resins to enamel in all fields of dentistry, including the bonding of orthodontic brackets.[23-24] The process involves etching the enamel surface with phosphoric acid to increase porosity and enhance retention.[25] The degree of dental fluorosis affects etched enamel. Fluorosed enamel demonstrates an outer hypermineralized and acid-resistant layer, where it is difficult to attach bonds because a reliable etched enamel surface cannot be produced.[1] Most studies of bond strength with fluorosed enamel use the TF index for the classification of dental fluorosis because it is based on the clinical changes in fluorotic teeth and is highy reproducible.[4,9,11,26-30]

Direct bonding of orthodontic attachments can be used successfully as a routine clinical procedure. Bonding orthodontic brackets to fluorosed teeth remains a notable clinical challenge

Table 1 *Thylstrup and Fejerskov's fluorosis index.*[36]
ตารางที่ 1 *แสดงดัชนีระดับฟันตกกระของไทซทรัฟและฟีเจอซคอฟ*

Classification	Criteria
TF score 0	The normal translucency of the glossy, creamy-white enamel remains after wiping and drying of the surface
TF score 1	Thin, white, opaque lines are seen running across the tooth surface. Such lines are found on all parts of the surface. The lines correspond to the position of the perikymata. In some cases, a slight "snow-capping" of cusps/incisal edges may also be seen.
TF score 2	The opaque, white lines are more pronounced and frequently merge to form small cloudy areas scattered over the whole surface. "Snow-capping" of incisal edges and cusp tips is common.
TF score 3	Merging of white lines occurs, and cloudy areas of opacity occur spread over many parts of the surface. In between the cloudy areas white lines can also be seen.
TF score 4	The entire surface exhibits a marked opacity, or appears chalky white. Parts of the surface exposed to attrition or wear may appear to be less affected.
TF score 5	The entire surface is opaque, and there are round pits (focal loss of the outermost enamel) that are less than 2 mm in diameter.
TF score 6	The small pits may frequently be seen merging in the opaque enamel to form bands that are less than 2 mm in vertical height. In this class are included surfaces where the cuspal rim of facial enamel has been chipped off , and the vertical dimension of the resulting damage is less than 2 mm.
TF score 7	There is a loss of the outermost enamel in irregular areas, and less than half the surface is so involved. The remaining intact enamel is opaque.
TF score 8	The loss of the outermost enamel involves more than half the enamel. The remaining intact enamel is opaque.
TF score 9	The loss of the major part of the outer enamel results in a change of the anatomical shape of the surface/tooth. A cervical rim of opaque enamel is often noted.

because of frequent bracket failure at the compromised enamel interface.[6] The mechanical locking of adhesive to irregularities in the enamel surface of the tooth is a factor affecting direct bonding. So, the etching pattern of enamel is an important factor in bonding in orthodontics.[31]

Etching pattern of fluorosed enamel

Generally, enamel etching produces three different micromorphologic types of surface, which can be seen with scanning electron microscopy (SEM).[32] The most common is Type I, characterized by preferential removal of the rod core. In the reverse, Type II, the rod periphery is removed and the core remains intact. Occurring less frequently is Type III, in which the pattern of the enamel surface is irregular.

Fluorotic teeth have the highest concentration of fluoride in the outer 200 µm of enamel. The concentration of fluoride in this region increases with TF score.[33] The hypermineralized surface layer of fluorotic enamel is difficult to etch, resulting in less irregularity of the enamel surface than in normal enamel.[7,34-35] Those findings are consistent with those of Shida et al.,[30] who reported that the fluorosed enamel surface has an etching pattern different from that of normal enamel. The fluorosed enamel surface also has a lower efficacy than the non-fluorosed enamel surface when self-etching primer is used (Figure 3).

The depth of etch for the fluorosed enamel tends to increase with etching time at TF scores of 0-3. On the other hand, depth of etch fluctuates at TF scores of 4 and 6. Although there was positive correlation between the depth of etch and etching time at the score of 5, the depths were generally shallower than at scores of 0-3. However, the etching patterns become more accentuated with increased etching time. So, Al-Sugair and Akpata[35] recommended that an etching time of at least 30 seconds for fluorotic teeth with a TF score of 4 and at least 90 seconds for more severely fluorotic teeth.

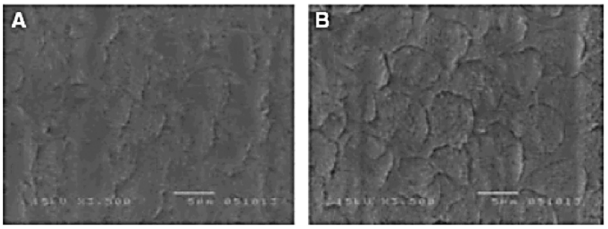


Figure 3 *Scanning electron microscopy images of enamel surfaces treated with Clearfil SE bond primer for 20 seconds (A) Fluorosed enamel surfaces. (B) Non-fluorosed enamel surfaces. The etching effect on the fluorosed enamel surface appeared to be less than that on the nonfluorosed enamel surface.[30]*

รูปที่ 3 *ภาพถ่ายจากกล้องอิเล็คตรอนแบบส่องกราดของผิวเคลือบฟันถูกปรับสภาพโดย เคลียร์ฟิลเอสอีบอนด์ไพร์มเมอร์ เป็นเวลา 20 วินาที (A) ผิวฟันเคลือบฟันตกกระ (B) ผิวเคลือบฟันปกติ ผลของการกัดของกรดบนผิวเคลือบฟันตกกระกรดกัดได้น้อยกว่าฟันปกติ*

Bond strength

Most studies of bond strength with fluorosed enamel have used the TF index for classification of dental flurosis.[4,8-9,11,14,26-30] The majority of these studies[4,8-9,11,14,27,29] selected fluorotic teeth with TF scores of 4 to 6 (moderate fluorosis). This selection may be because the bond strength between brackets and teeth with mild fluorosis is not significantly different from that between brackets and normal teeth.[9] Moreover, in severe fluorosis, the outer enamel is lost and not available for bonding.[36] Adhesive systems that are used to bond with fluorosed enamel are divided in to two groups: total-etching bonding and self-etching bonding systems.

Total-etching bonding systems

Successful orthodontic treatment depends on adequate bond strength between the adhesive and the orthodontic bracket and between the adhesive and the enamel. It has been suggested that sufficient bond strength for clinical orthodontic bonding is 6 to 8 MPa.[37] Adanir et al.[4,11] reported that fluorotic teeth significantly decreased the shear bond strength of adhesives used with orthodontic brackets. They bonded brackets to moderately fluorotic teeth (TF score of 4). Gungor et al.[29] studied shear bond strength using orthodontic brackets on moderately fluorotic teeth (TF score of 4). They found that enamel fluorosis significantly decreased bond strength. Ertugrul et al.[27] studied shear bond strength on moderately fluorotic teeth (TF score of 4 to 6). They found that the etch and rinse technique significantly decreased bonding effectiveness to fluorotic teeth. These findings are consistent with those of Opinya and Pameijer,[7] who reported that fluorotic teeth demonstrated significantly lower tensile bond strength than did normal teeth. Although fluorotic teeth significantly decrease bond strength, it is sufficient for clinical orthodontic bonding.

In contrast, Ng'ang'a et al.[8] found no statistically significant difference between the mean values for tensile bond strength with fluorotic (TF scores of 3 to 4) and non-fluorotic teeth. They bonded brackets with a composite resin after over-etching the enamel surface with 40% phosphoric acid for 60 seconds. Their study revealed that fluorotic teeth did not decrease bond strength compared with non-fluorotic teeth. These findings are consistent with those of Ateyah and Akapata,[9] who reported that the degree of fluorosis had no significant effect on shear bond strength of composite resin bonded to enamel and with those of Weerasinghe et al.,[10] who reported that the severity of fluorosis does not affected the micro-shear bond strength of a total-etching bonding system used with fluorosed enamel.

Many studies have reported significantly decreased bond strength with fluorotic teeth.[4,7,11,27,29] There are many techniques to increase bond strength with fluorotic teeth. Miller[6] suggested that microabrasion of fluorosed enamel used concomitantly with acid etching improves bond strength. However, drawbacks to microabrasion include damage to enamel, increased chair time and cost, and potential allergy to the aluminum oxide or silicone carbide powder. Some investigators have suggested extended enamel conditioning with phosphoric acid when bonding composite resin to fluorosed enamel to remove the acid resistant hypermineralized surface layer and increase bond strength.[7,9] Opinya and Pameijer[7] suggested extended enamel conditioning for 150 seconds. Ateyah and Akapata[9] suggested extended enamel conditioning for 120 seconds.

Adanir et al.[4] suggested that adhesion promoters increase bond strength with fluorotic teeth. This finding is consistent with that of Noble et al.,[38] who reported that an adhesion promoter provides a clinically successful adhesive bonding protocol for bonding orthodontic brackets to fluorotic teeth. Adanir et al.[4] used Enhance LC (Reliance, Itasca, Illinois, USA), whose manufacturers claim that it significantly increases adhesion of resins to fluorosed enamel. It is composed of hydroxyethyl methacrylate (HEMA), tetrahydrofurfuryl cyclohexane dimethacrylate, and ethanol. The HEMA molecule contains two functional groups, one hydrophobic and the other hydrophilic.[39] Hydrophobic monomers adhere to resin. Hydrophilic monomers in these adhesive systems facilitate the infiltration of resin into the etched enamel by wetting the etched surface, and reduce interfacial porosity and, therefore, increase adhesion, achieving greater bond strength through

polymerization.[38,40]

In severely flurotic teeth, Duan et al.[41] suggested placing a light-cured veneer on the teeth before bonding orthodontic attachments. This method indicates that such an esthetic treatment can also enhance the bond strength between the fluorotic tooth and the bracket.

Self-etching bonding systems

Ertugrul et al.[27] studied shear bond strength on moderately fluorotic teeth (TF scores of 4 to 6). They found that self-etching systems (one and two step self-etching systems) significantly decreased the bonding effectiveness to fluorotic teeth. This finding is consistent with those of Ermis et al. and Shida et al.[26,30] They reported that fluorotic teeth demonstrated significantly lower bond strength than normal teeth.

In contrast, Gungor et al.[29] studied the shear bond strength of orthodontic brackets on moderately fluorotic teeth (TF score of 4). They found that enamel fluorosis did not significantly decrease bond strength with orthdontic brackets when self-etching adhesive systems were used. This finding is consistent with those of Weerasinghe et al.[10] and Ratnaweera et al.[28] They reported that self-etching systems when used with fluorosed enamel were not influenced by the severity of fluorosis.

When comparing total-etching and self-etching bonding systems, Ertugrul et al.[27] found that self-etching systems (one and two step self-etching systems) significantly decreased the bonding effectiveness to fluorotic teeth compared to total-etching systems. They suggested that moderately fluorotic teeth may be more resistant than non-fluorotic teeth to acid contained in the primer of self-etching bonding systems. These findings are consistent with those of Weerasinghe et al.[10] and Ermis et al.[26] They reported that the bonding effectiveness to enamel in fluorotic teeth was lower in self-etching systems than in total-etching systems.

Discussion

Orthodontists working in regions with endemic fluorosis face difficulties in bonding brackets to fluorotic teeth. Repeated bonding is time-consuming and has a negative effect on successful orthodontic treatment. Some findings demonstrated that fluorotic teeth significantly reduced shear bond strength when bonding brackets to enamel.[4,7,11,27,29] Those decreases may be due to the acid-resistant outer layer of the fluorosed enamel.[4] Some findings demonstrated that bond strength with fluorotic teeth was not significantly different from that with normal teeth.[8-9] That lack of difference may be because the authors of one study[8] used mildly fluorotic teeth and those of another[9] ground the outer, hypermineralized, acid-resistant outer layer before testing. When comparing total- and self-etching bonding systems on fluorotic teeth, those differences may be because the etching pattern of self-etching primers was not deep enough to obtain adequate penetration of bonding resin when applied to intact enamel.[28] The difference may be because the severity of fluorosis and the materials used in each study were different.

Conclusions

Dental fluorosis is found in many areas of the world. We can classify dental fluorosis by its severity. It was found clinically that orthodontic bonding in fluorotic teeth was very difficult. Bond strength with fluorosed enamel is controversial. Some investigators have reported that bond strengt was not significantly different from that of normal teeth. In contrast, some investigators have reported that bond strength is lower with fluorotic teeth than with normal teeth. However, many techniques,

such as extending etching time, adding a light-cured veneer before bonding, or adding an adhesion promoter to the bonding agent, can increase bond strength when bonding brackets to fluorosed enamel.

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References

1. DenBesten PK, Thariani H. Biological mechanisms of fluorosis and level and timing of systemic exposure to fluoride with respect to fluorosis. *J Dent Res* 1992; 71: 1238-1243.
2. Kidd EA. Fluoride supplement. *Essentials of dental caries the disease and its mangement*. 1st ed. Narayana:Blackwell Munkgaard 2005: 109-125.
3. Vuttipitayamongkol C. Decentralization and community participation in dealing with fluorosis in Lampang province, Thailand. *Proceeding of the 3rd international workshop on fluorosis prevention and defluoridation water* 2002: 120-124.
4. Adanir N, Türkkahraman H, Yalcin Güngör A. Effects of adhesion promoters on the shear bond strengths orthodontic brackets to fluorosed enamel. *Eur J Orthod* 2009;31: 276-280.
5. Juntharavijit S. Report of study. Report of The risk builds the health from receiving fluoride 2003: 7-12.
6. Miller RA. Bonding fluorosed teeth: new materials for old problems. *J Clin Orthod* 1995; 29: 424-427.
7. Opinya GN, Pameijer CH. Tensile bond strength of fluorosed Kenyan teeth using the acid etch technique. *Int Dent J* 1986;36: 225-229.
8. Ng'ang'a PM, Ogaard B, Cruz R, Chindia ML, Aasrum E. Tensile strength of orthodontic brackets bonded directly to fluorotic and nonfluorotic teeth: an in vitro comparative study. *Am J Orthod Dentofacial Orthop* 1992; 102: 244-250.
9. Ateyah N, Akpata E. Factors affecting shear bond strength of composite resin to fluorosed human enamel. *Oper Dent* 2000; 25: 216-222.
10. Weerasinghe DS, Nikaido T, Wettasinghe KA, Abayakoon JB, Tagami J. Micro-shear bond strength and morphological analysis of a self-etching primer adhesive system to fluorosed enamel. *J Dent* 2005; 33: 419-426.
11. Adanir N, Türkkahraman H, Güngör AY. Effects of Fluorosis and Bleaching on Shear Bond Strengths of Orthodontic Brackets. *Eur J Dent* 2007; 1: 230-235.
12. Murray JJ, Rugg-Gunn AJ, Jenkins GN. *Fluorides in caries prevention*. 3rd ed. Cambridge: Butterworth-Heinemann; 1991: 324-336.
13. Yanagisawa T, Takuma S, Fejerskov O. Ultrastructure and composition of enamel in human dental fluorosis. *Adv Dent Res* 1989; 3: 203-210.
14. Ng F, Manton DJ. Aesthetic management of severely fluorosed incisors in an adolescent female. *Aust Dent J* 2007; 52: 243-248.
15. Thylstrup A, Fejerskov O. Clinical appearance of dental fluorosis in permanent teeth in relation to histologic changes. *Community Dent Oral Epidemiol* 1978; 6: 315-328.

16. Wenzel A, Thystrup A, Melsen B, Fejerskov O. The relationship between water-born fluoride, dental fluorosis and skeletal development in 11-15 year old Tanzanian girls. *Arch Oral Biol* 1982; 27: 1007-1011.
17. Murray JJ, Rugg-Gunn AJ, Jenkins GN. *Fluorides in caries prevention*. 3rd ed. Cambridge: Butterworth-Heinemann; 1991: 222-261.
18. National Research Council (NRC). *Health effects of ingested fluoride*. Washington, D.C.: National academy press 1993.
19. Noppakun W, Ratanasthein B, Prapamontol T, Asanchinda P, Obsuwan K, Na Suwna J,Promputha. *Occurence of fluorosis due to Geothermal Sources in a Northern Thailand Subdistrict*. 3rd international workshop on fluorosis prevention and defluoridation of water 2002: 22-29.
20. Horowitz HS. Indexes for measuring dental fluorosis. *J Public Health Dent* 1986; 46: 179-183.
21. Fejerskov O, Manji F, Baelum V. The nature and mechanisms of dental fluorosis in man. *J Dent Res* 1990; 69: 692-701
22. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. *J Dent Res* 1955; 34: 849-853.
23. Newman GV, Snyder WH, Wilson CE, Jr. Acrylic adhesives for bonding attachments to tooth surfaces. *Angle Orthod* 1968; 38: 12-18.
24. Retief DH, Dreyer CJ, Gavron G. The direct bonding of orthodontic attachments to teeth by means of an epoxy resin adhesive. *Am J Orthod* 1970; 58: 21-40.
25. Newman GV. Epoxy adhesives for orthodontic attachments: progress report. *Am J Orthod* 1965; 51: 901-912.
26. Ermis RB, De Munck J, Cardoso MV, Coutinho E, Van Landuyt KL, Poitevin A et al. Bonding to ground versus unground enamel in fluorosed teeth. *Dent Mater* 2007; 23: 1250-1255.
27. Ertugrul F, Turkun M, Turkun LS, Toman M, Cal E. Bond strength of different dentin bonding systems to fluorotic enamel. *J Adhes Dent* 2009; 11: 299-303.
28. Ratnaweera PM, Nikaido T, Weerasinghe D, Wettasinghe KA, Miura H, Tagami J. Micro-shear bond strength of two all-in-one adhesive systems to unground fluorosed enamel. *Dent Mater J* 2007; 26: 355-360.
29. Güngör AY, Türkkahraman H, Adanir N, Alkis H. Effects of fluorosis and self etching primers on shear bond strengths of orthodontic brackets. *Eur J Dent* 2009; 3: 173-177.
30. Shida K, Kitasako Y, Burrow MF, Tagami J. Micro-shear bond strengths and etching efficacy of a two-step self-etching adhesive system to fluorosed and non-fluorosed enamel. *Eur J Oral Sci* 2009;117:182-186.
31. Proffit WR. *Contemporary orthodontic*. 3rd ed. St. Louis: Mosby ; 2000: 397.
32. Ten Cate AR. *Oral histology : development, structure, and function* 5th ed. St. Louis: Mosby; 1998: 218-235.
33. Richards A, Fejerskov O, Baelum V. Enamel fluoride in relation to severity of human dental fluorosis. *Adv Dent Res* 1989; 3: 147-153.
34. Kochavi D, Gedalia I, Anaise J. Effect of conditioning with fluoride and phosphoric acid on enamel surfaces as evaluated by scanning electron microscopy and fluoride incorporation. *J Dent Res* 1975; 54: 304-309.
35. Al-Sugair MH, Akpata ES. Effect of fluorosis on etching of human enamel. *J Oral Rehabil* 1999; 26: 521-528.

36. Fejerskov O, Manji F, Baelum V. *Dental fluorosis-a handbook for health workers*. 1st. ed. Copenhagen; Munksgarrd 1988: 11-50.
37. Reynold JR. A review of direct orthodontic bonding. *Br J Orthod* 1975; 2: 171-178.
38. Noble J, Karaiskos NE, Wiltshire WA. In vivo bonding of orthodontic brackets to fluorosed enamel using an adhesion promotor. *Angle Orthod* 2008; 78: 357-360.
39. Nakabayashi N, Kojima K, Masuhara E. The promotion of adhesion by the infiltration of monomers into tooth substrates. *J Biomed Mater Res* 1982; 16: 265-273.
40. Hotta K, Mogi M, Miura F, Nakabayashi N. Effect of 4-MET on bond strength and penetration of monomers into enamel. *Dent Mater* 1992; 8: 173-175.
41. Duan Y, Chen X, WU j. Clinical composition of bond failures using different enamel preparations of severely fluorotic teeth. *J Clin Orthod* 2006: 152-154.