CHAPTER II

LITERATURE REVIEW

There were six parts of the literature review described as follows :

- Structure of enamel and effect of fluoride on its surface
- Clinical feature of dental fluorosis
- Histopathology of dental fluorosis
- Acid etching
- Etching pattern
- Clinical implication

Structure of enamel and effect of fluoride on its surface

The enamel structure has been described by Gwinnett (1992) and Ten cate (1994) as follows. Enamel was the most highly mineralized. It consisted of 96 % mineral and 4 % organic material and water. The inorganic content of enamel consisted of crystalline calcium phosphate known as hydroxyapatite, which was also found in bone, calcified cartilage, dentine, and cementum. During enamel formation, various ions, such as strontium, magnesium, and fluoride, might be incorporated into or adsorbed by the hydroxyapatite. The organic material that included in composition appeared between the highly packed hydroxyapatite crystal. The bulk of this organic material consisted of the TRAP peptide (tyrosine-rich amelogenin protein) sequence tightly bound to the hydroxyapatite crystal as well as non-amelogenin protein. For the physical properties, enamel was extremely hard because of its high mineral contents. It had a high elastic modulus and relatively low tensile strength, indicating a brittle characteristic but offset by the high compressive strength of the dentine. This property enables it to withstand the mechanical force applied during its functions. Enamel colour was translucent and varied from light yellow to grayish white. It was also varied in thickness, from maximum of 2.5 millimeters over working surface to a featheredge at the cervical line. This variation influenced to the colour of enamel. The enamel structure studied under the light microscope by means of transmitted light showed the basic structure called enamel rod with average width of 5 micrometers. Each rod contained tighly packed mass of hydroxyapatite crystals existed in a highly organized pattern of crystal orientation that was parallel to the rod axis. Rod shape like a cylinder and was made up of crystals whose long axis run, for the most part, parallel to the longitudinal axis of the rod particularly in the central. The interrod region was an area surrounding each rod in which crystals were oriented in a different direction (Figure 1).

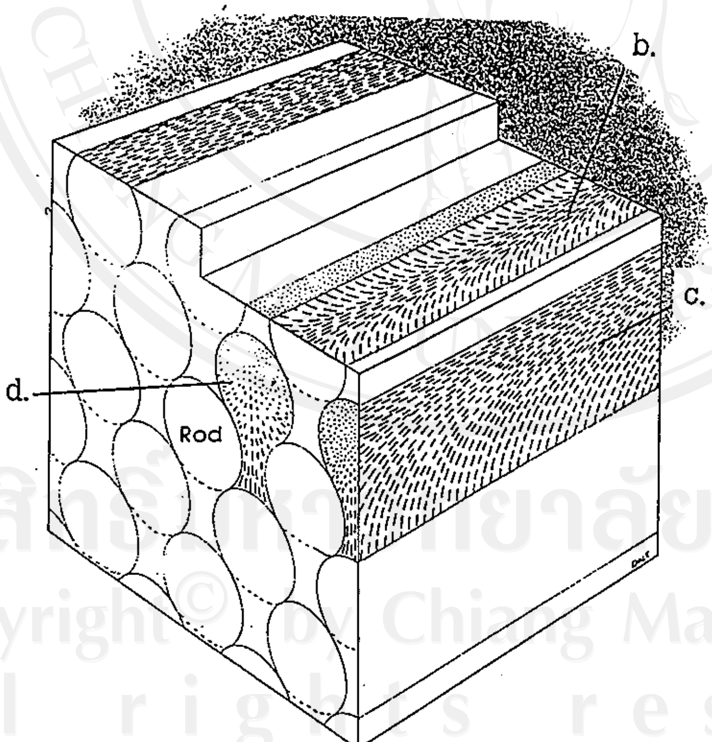


Figure 1 Fine structure of enamel. a. Crystal orientation of three faces of a block of enamel, showing the rod structure. b. to d. Electron micrographs of three faces. (Ten Cate AR., 1994)

The boundary where the crystals of rod met those of the interrod region at sharp angles called "rod sheath". In some areas of surface enamel that the enamel prisms did not reach the surfaces, called "prismless enamel". These prismless enamel was found in more than 70 % of permanent teeth and almost covered on the gingival third of tooth. Recent report from Johnston et al. (1996) concluded that the prismless enamel often was found on the cervical two-third of molar which extending to a depth of 13 to 20 micrometers. On the surface of enamel it had many selectively permeable porous, allowing the passage of water and ion excluding large molecules. Fluoride was the one kind of ion that could pass through the pore and effected to enamel structure. They found that fluoride metabolism pass through blood plasma after absorption via the gastrointestinal tract. It was bound and released from several tissues and had major route for elimination from the body by kidney (Fejerskov et al., 1996). When the body received fluoride, most of it spreaded to bone and teeth. On tooth surface, fluoride would incorporate within the interior of mineral crystallites. Phosphate and Hydroxyl ions from the tooth mineral would enter the plasma or tissue fluid fluoride and fluoride would be deposited as CaF_2 or other fluoride-rich phases on or in the outer enamel. For example, hydroxyapatite structure of the tooth would be changed to fluoroapatite by changing the hydroxyl group by fluoride ion as following chemical equation.

$$\underset{\text{Enamel hydroxyapatite}}{Ca_{10}(PO_4)_6(OH)_2} + \underset{\text{fluoride}}{2F} \text{ --------> } \underset{\text{fluoroapatite}}{Ca_{10}(PO_4)_6F_2} + \underset{\text{Hydroxyl}}{2\,OH^-}$$

It was reported that the fluoride concentration in the teeth were varied due to :

1) level of fluoride intake

2) duration of exposure and

3) interrelated factors, eg. the stage of tissue development, its rate of growth, vascularity, surface area and reactivity of mineral crystallites, porosity and degree of mineralization (Fejerskov et al., 1996).

This incorporation of fluoride could significantly alter the properties of teeth. It could greatly increase lattice stability by attracting the proton of adjacent apatite hydroxyl ions. The lattice would be greater and more completely formed. Furthermore, an enamel structure would have low carbonate composition causing the lower of solubility of the tooth surface. The result was that the fluoridated apatite lattices would be more crystalline, more stable and therefore less soluble in acid. This reactivity explained the role of fluoride in caries prevention. It has been found that if the fluoride was present as enamel was being formed, all enamel structure would be more resistance to acid dissolution.

Concentration of fluoride on tooth surface was depended on the stage of tooth formation and amount of fluoride uptake. Fluoride concentration was relatively high in the earliest formed enamel and rose in the surface region during late maturation. This continued until of the eruptions. Little fluoride was being uptaken by fully mineralized sound enamel. Some fluoride was lost by wear and could be acquired by sound fully mineralized enamel only at high concentration of topical fluoride application or if the enamel became porous due to carious attack. It has been found that the fluoride concentration was not homogeneously distributed across the thickness of enamel. Fluoride concentration was the highest at the enamel surface (2,000-3,000 ppm) and falling to a plateu in the interior and rose slightly again at the junction with the dentine (1,500 ppm) (Figure 2).

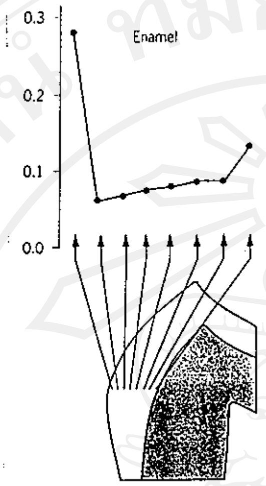


Figure 2 Fluoride distribution across section of human molar enamel. The fluoride concentration is high in the surface region and falls to a plateau in the enamel interior. (Fejerskov et al., 1996)

Weatherell et al. (1977) reported that the fluoride concentration in the outer 2 micrometers of permanent enamel averaged about 1,700 ppm in nonfluoridated area (0.1 ppm) and 2,200 to 3,200 ppm in optimally fluoridated area (1.0 ppm) and over 4,800 ppm in areas with fluoride level of 5 to 7 ppm in the water supply. At the depth of 5 micrometers, fluoride concentration would be decreased to about 1,100 and 2,200 ppm in area of nonfluoridated and fluoridated areas corresponding.

Moreover after the tooth eruption, the fluoride concentration also varied topographically in the tooth surface and the pattern changed with age and dental experience. In young anterior teeth, surface fluoride concentration was found to be the highest near the occlusal surface and decreased steeply toward the cervical region that was more recently formed. The older teeth had an inverted effect that fluoride concentration in the cervical region of enamel surface increased, while the high surface concentration near the occlusal surface was gradually reduced by weariness (Figure 3).

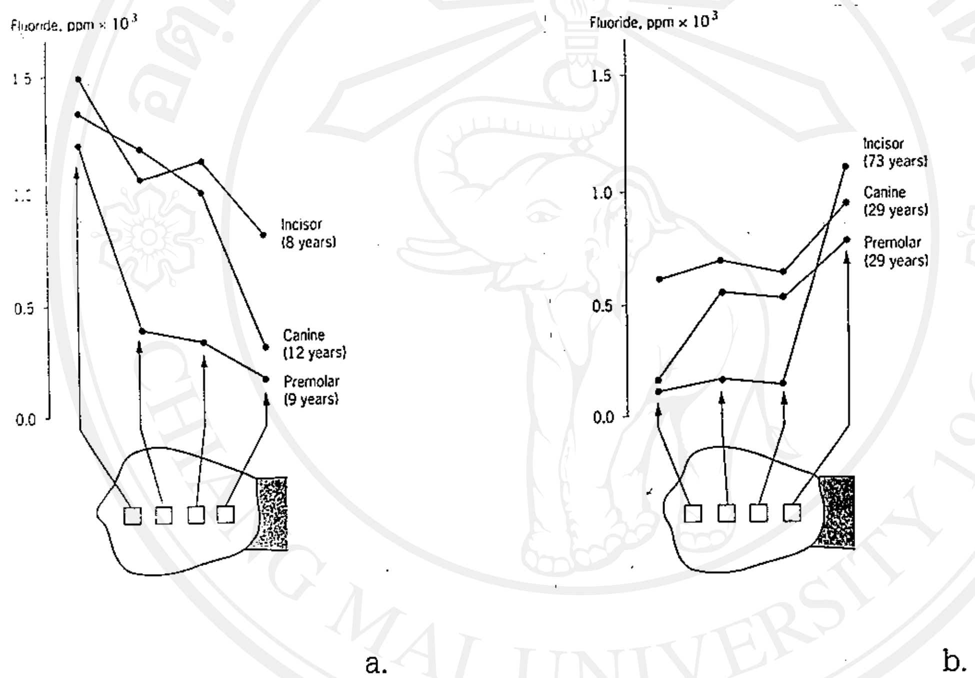


Figure 3 a. Fluoride distribution in the labial or buccal surface of three young anterior teeth. The fluoride concentration falls from the biting edge to the cervical margin. b. Fluoride distribution in the labial or buccal surfaces of older anterior teeth. The fluoride concentration rises from the biting edge to the cervical margin. (Fejerskov et al., 1996)

Gedalia and Kalderon (1964) reported that surface enamel had a much higher fluoride content than the whole enamel. In their study of one hundred and thirty five sound and carious teeth, they summerized that there was no significant difference of mean fluoride values of the buccal (527.7 ppm) and lingual surface enamel (534.8 ppm). Difference between the mean fluoride values of the upper (625.2 ppm) and the lower (621.4 ppm) teeth was not significant, as well as that of the mesial and the distal surface enamel. However, the mean fluoride of surface enamel found significant difference in according to the age of person or to their eruption age. They found that there was more fluoride concentration in older tooth surface.

Weatherell et al. (1973) studied the effect of tooth wear on the distribution of fluoride. They found that fluoride concentration was lower in the area of tooth wear.

In the high fluoride area, such as Northern Thailand, is well known that the fluoride ion is incorporated into or adsorbed by the hydroxyapatite crystal. This makes enamel become more resist to acid dissolution. If there was too much fluoride in the period of tooth formation, an unsightly mottling or fluorosis could be developed. Enamel mottling was first described in resident of Naples, Italy, and in Colorado and Arizona (Fejerskov et al., 1996). They demonstrated that these enamel changes were related to the high concentration of fluoride in water supply.

Dennis (1986) studied the prevalence of dental fluorosis. He stated that in the fluoridated community had more dental fluorosis than in nonfluoridated community.

Woltgens et al. (1989) studied the prevalence of mottled enamel in Netherlands. They reported that more teeth were affected and the degree of mottling was higher when children started to use fluoride at an earlier age. They suggested that an unintentional ingestion of tooth-paste contained 0.15% fluoride during frequent tooth brushing in combination with the daily intake of fluoride tablet before the age of four might have explained the high prevalence of mottled enamel.

Fejerskov et al. (1996) had cited 0.25-0.5 mg fluoride per kilogram of body weight as the optimum daily dosage of fluoride. The amount of fluoride in drinking water less than or equal 1 ppm was effected in carious prevention and was nontoxicity to body and tooth. However, in a longitudinal study of fluoride supplementation of 0.5 mg/day before 3 years of age in a nonfluoridated area, they found that 14 % of children were observed to have moderate fluorosis. Excessive fluoride ingestion, 0.1 mg/kg of body weight per day, during calcification of teeth could cause mild or very mild fluorosis (Chalerm-pong et al., 1995).

The severity of dental fluorosis was directly related to the excessive fluoride concentration in the drinking water. Excessive amout of fluoride intake, such as 2 to 10 ppm in drinking water could cause an increasing degrees of enamel fluorosis. Enamel fluorosis was developed due to excessive fluoride ingestion during tooth formation (Amelogenesis). Once the crowns of the teeth were formed, no further fluorosis could be induced by additional intake of fluoride or by posteruptive topical application of fluoride. However, the patients with dental fluorosis might still have dental caries, and if the caries activity was high, these patients should receive additional professional topical fluoride or home fluoride such as fluoride tablets, rinse, gel and dentifrices.

Clinical feature of dental fluorosis

Fejerskov et al. (1996) stated that there were several degrees of dental fluorosis. The first sign of dental fluorosis was thin white striae across the enamel surface and could distinguish after air drying the tooth surface. On the cusp tip, incisal edge or marginal ridge might have appeared opaque white or "Snow cap phenomenon". In more affected teeth, the fine white lines were broader and more pronounced. Occasional merging of several lines, irregular, cloudy or paper-white areas scattered over the surface with increasing severity, the entire tooth surface exhibited distinct, irregular, opaque or cloudy white area. The next degree of severity manifested as irregular opaque area which merge so that the entire tooth surface appear chalky white. These opaque enamel was relatively hard on probing and part of the surface enamel might flake off after probed vigorously. In even more severe stages, the tooth surface was entirely opaque with focal loss of the outer most enamel usually designated as "Pits". The pits were varied in diameter and occur scattered over the surface. With increasing severity these pits would merge to form horizontal band.

In more severely affected teeth, confluence of pits area produced larger "corroded" area. Surface enamel of incisal edge and cusp may have been flaked off and discolored.

In most severely affected teeth exhibited an almost total loss of surface enamel and affected to entire normal tooth morphology. Extensive loss of surface enamel occurred and only a cervical rim intact. The remaining part of surface enamel often exhibited a dark brownish discoloration.

Distribution of dental fluorosis within individual had the similarly pattern. It was found that in severely affected population, the posterior teeth were more affected than the anterior teeth in both maxilla and mandible but it was slightly differented in low fluoride areas. It was apparent that the incisors and the first molars were least affected, but that the most affected teeth were in the second molars and premolars. This means that the later teeth undergoes mineralization, the greater would be the prevalence and severity of dental fluorosis.

Dean (1942) established the useful classical criterias for diagnosis of enamel fluorosis (Fluorosis Index) in Table 1.

Table 1 Fluorosis Index (Dean HT., 1982)

Dean's score	Type	Description
0	Normal	The surface is smooth, glossy, and usually of a pale creamy white colour.
0.5	Questionable	The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few flecks to occasional white spots.
1	Very mild	Small, opaque, paper white areas scattered irregularly over the tooth but not involving as much as approximately 25 % of tooth surface. Frequently included in this classification are teeth showing no more than about 1 - 2 mm of white opacity at the tip of the summit of the cusps of the bicuspids or second molars.
2	Mild	The white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50 % of the tooth.
3	Moderate	All enamel surfaces of the teeth are affected, and surfaces subject to attrition show marked wear. Brown stain is frequently a distinguring feature.
4.	Severe	All enamel surfaces are affected, and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is the discrete or confluent pitting. Brown stains are widespread, and teeth often present a corroded-like appearance.

Dean's Fluorosis index was easily and more practicable for used in clinical diagnosis of fluorosis teeth. Following pictures illustrated the feature of each degree of fluorosis condition.

a. Normal (0)

b. Questionable (0.5)

c. Very mild (1)

d. Mild (2)

e. Moderate (3)

f. Severe (4)

Figure 4 a-f showed degrees of dental fluorosis features according to Dean's classification system.

Histopathology of dental fluorosis

Histopathology of dental fluorosis described by using the light and electron microscopy was described as follows. In initial of tooth formation, an increasing ingestion of fluoride led to an increase in outer enamel porosity. The pore volumn was about 5 % and exceeded in more severely formed dental fluorosis. It was found that, in severely formed dental fluorosis, the subsurface pore volumn exceeded 25 % at time of eruption and the lesion extended almost to the enamel-dentine junction in the cervical region (Fejerskov et al., 1996). These porous areas were highly hypomineralized. When examined by transmission electronmicroscope, it was apparented that these hypomineralization or increased porosity area was a result of an increase in intercrystalline spaces both in rod and interrod enamel, and was particularly pronounced along the arcade-shaped rod boundaries. These wide intercrystalline spaces were occupied by water and insoluble protein which might be visualized in the scanning electron microscope as a fine network after demineralization of the enamel. The hypomineralized enamel was easily destroyed after eruption resulting an irregular surface enamel. In more severely formed dental fluorosis it was possible affected in the dentine layer.

For physical feature of fluorosis teeth, it appeared that the fluorosis teeth should have had more brittle enamel surface because of it porosed surface. Many studies have shown the alteration of physical properties from normal enamel surface.

Newbrun and Brudevold (1960) studied the physical properties of 13 fluorosis teeth, in area of 2.2-5.0 ppm fluoride in water, by microradiographic method showed area of radiolucency. They found that at lower fluoride level these area were all found in the outer third of the enamel but at the higher level (5.0 ppm), the depth of the radiolucent zone was increased so that half and even three-quarters of the enamel thickness was involved.

Thylstrup et al. (1978) studied in human primary teeth enamel from a high fluoride area and concluded that the subsurface porosity zone became more pronounced corresponding to an increasing degree of fluorosis.

Acid etching

Bunocore (1955) and Newman (1969) reported the usefulness of acid etching. The use of acid etching and incorporation with direct bonding bracket on tooth surface have become an important technique in orthodontic treatment. It achieved the desired effect in two aspects 1) to remove plaque and other debris, along with a thin layer of enamel, 2) to increase the porosity of exposed surfaces through selective dissolution of crystals, which improved the retention of bonding adhesive (Ng'ang'a et al., 1992). Now the use of several types and concentrations of acid on tooth surface almost provided the depth of etch only about 10 micrometers. For example, when 30-40 % phosphoric acid in concentration was applied to enamel surface for 60 seconds, it provided an adequate etch for retention of sealants or orthodontic bracket.

There were three factors related to the effect of etching procedure.

1) Type of etchant
2) Concentration of etchant
3) Duration of etching procedure

1) Type of etchant

Phosphoric acid (H_3PO_4) was the most favorited etchant used in orthodontic practices. It could create beautiful and suitable etching pattern and could give reliable bond strength.

2) Concentration of etchant

Pertaining to the concentration of the etchant, numerous studies showed that optimal concentration of phosphoric acid ranged from 8 to 65 %.

Silverstone (1974) found that phosphoric acid in concentration between 20 to 50 % which applied on tooth surface for 60 seconds, could create the most retentive condition.

Moin and Dogon (1972) studied the effect of different concentration of phosphoric acid gel and solution. They found that phosphoric acid with 30-40 % solution produced superior etched surfaces and the most suitable uniform etching pattern when compared with the gel.

Retief and Sadowsky (1975) reported that 50 % of phosphoric acid was the most suitable concentration for epoxy resin formulation.

Denys and Retief (1982) reported that overall etching effect of different concentration of phosphoric acid was similar.

Sadowsky et al. (1990) reported that the reduction of etching concentration from 37 % to 15 % phosphoric acid applied for 60 seconds had no significantly different effect on the retention of bonded orthodontic attachment.

3) Duration of etching procedure

Duration of acid etching procedure was also important. Many investigators have reported the effect of various etching times as follows.

Brannstrom and Nordenvall (1982) found no significant difference between 15 and 60 seconds etching times with 37 % phosphoric acid.

Barkmeier et al. (1985, 1986) studied the effect of 15 and 60 seconds etching time with 50 % phosphoric acid. They showed no morphological differences in the pattern of etched enamel rod, whether treated for 15 or 60 seconds.

Carstensen (1986) studied the clinical failure rate between 15-20 seconds and 30-35 seconds etching times and summarized that 15 seconds etching was sufficient for producing bond strength in anterior teeth.

Alan et al. (1988) reported no significant difference between the 15 seconds and 60 seconds etching time.

Sadowsky et al. (1990) reported that there was no significant difference by reducing the etching time of 37 % phosphoric acid from 60 seconds to 15 seconds.

Wang and Lu (1991) studied the results of various etching time of 37 % phosphoric acid. They found no statistically different of tensile bond strength for 15, 30, 60 or 90 seconds etching time, and stated that the 120 seconds etching time would significantly decrease the bond strength.

Russell et al. (1991) reported that the minimal enamel etching time of 5 seconds allowed adequate bond strength to composite resin on enamel surface.

Johnston et al. (1996) studied the influence of varying etching time by scanning electron microscope in molar teeth. They summarized that 15 seconds etching time failed to produce any optimal etch pattern, and the best etching pattern were found in molars etched for 60 seconds.

In this study, we have to recognize the effect of acid etching procedure on the two major types of teeth, non-fluorosis and fluorosis teeth.

Etching pattern

Etching pattern was the micro features of enamel surface after contact with acid solution or gel. Enamel rods reach to the tooth surface with different orientation. These regional variation might play a role of etching pattern. The etching pattern was described in the two types of teeth, normal or fluorosis teeth.

1. Normal teeth

In normal teeth, the effect of acid etching on enamel surface can be beautifully demonstrated by the scanning electron microscope to five types of etching pattern according to Silverstone et al. (1975). The most common was type I, characterized by preferential removal of the rod core (Figure 5a). The reverse, type II, also occurred in which the rod periphery in preferentially removed and the core remains intact (Figure 5b). Type III was less frequently occurred, which was a mixture of type I and II that irregular and in discriminate (Figure 5c). Type IV was classified when enamel surface appeared to be pitted as well as structure which like unfinished puzzle, maps or network (Figure 5d). The last pattern was type V which appeared to be flat as smooth surface (Figure 5e).

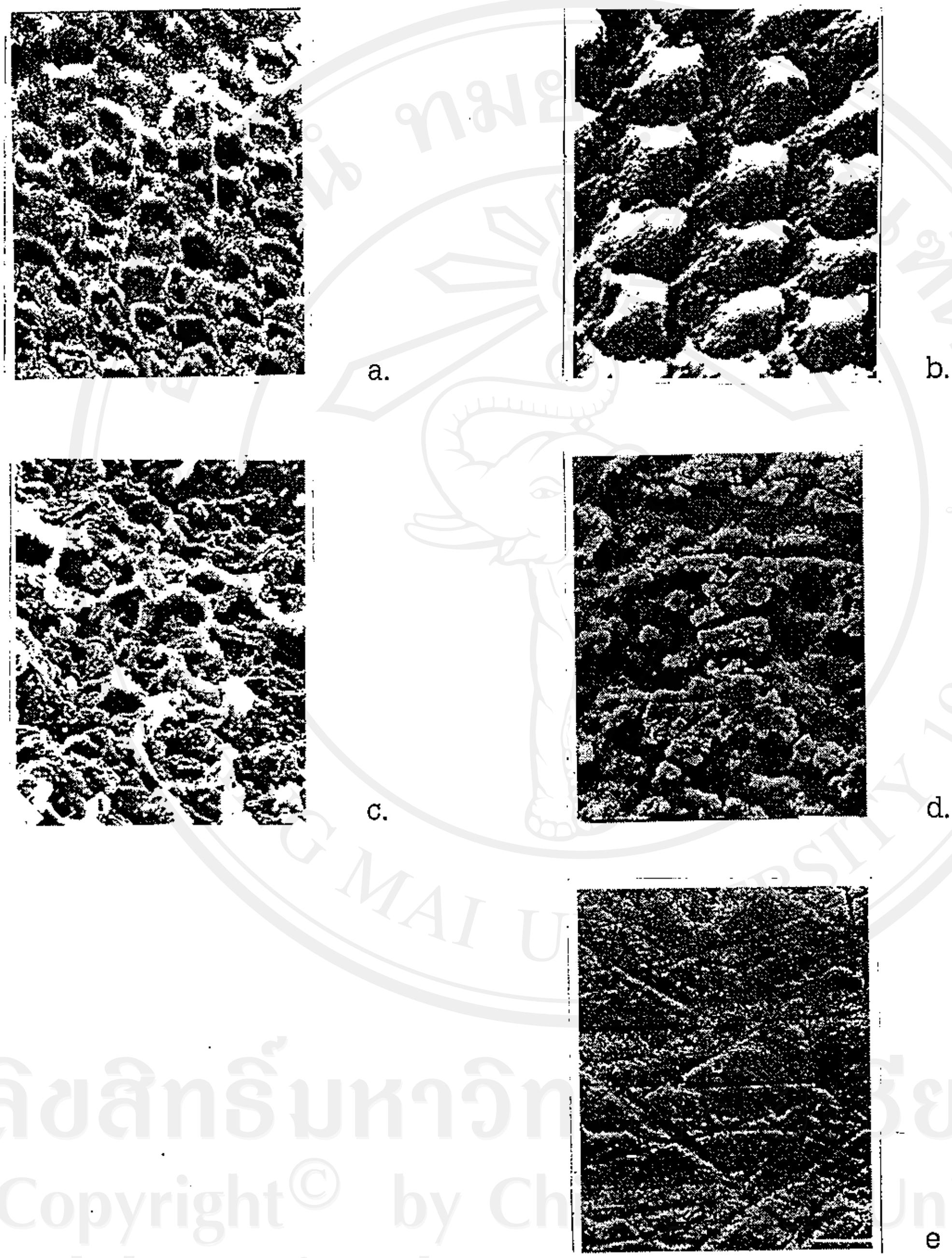


Figure 5 a-e Scanning electron micrographs of etching pattern in enamel. a. Type I pattern, rod core preferentially eroded; b. Type II pattern, rod boundary preferentially eroded; c. Type III pattern, indiscriminate erosion; d. Type IV pattern, unfinished puzzle or map like; e. Type V pattern, flat surface with scratch. (Ten Cate AR., 1992)

These five types of etching pattern occurred because of crystals would dissolve more readily at their ends than on their sides. Thus, crystals lying perpendicular to the enamel surface were the most vulnerable and etching pattern often to be type I. On contralateral teeth, the regional variation might also play a role that the same areas on contralateral teeth seem to have almost identical etching patterns. However, the type of etching pattern might result from differences in the type, concentration and duration of etching procedure.

Bozalis et al. (1979) reported the effect of prolonged etching time on primary teeth and summarized that well-developed etching pattern was produced by the etching time up to about 1.5 to 3 minutes. Prolonged etching periods produced a progressive flattening of the enamel topography.

Carstensen (1992) reported the effect of different phosphoric acid concentration on enamel surface by electron microscope. He summarized that in higher acid concentration the type II etching pattern occurred predominantly and that in softer acid concentration etching pattern was mainly the type I.

Other factors that related the etching pattern were the area of etched tooth surface and type of tooth, deciduous or permanent teeth. In the central and incisal part of tooth that the crystal orientation with the same direction would give more likely etching pattern. But in cervical area, because of its different crystal orientation, the different etching pattern would occur.

Galil and Wright (1979) reported that type I, II, III etching pattern were mainly found in the coronal and middle thirds of the buccal surface and type IV and V etching pattern were mainly located in the cervical third of the buccal surface.

Arakawa et al. (1979) reported the significant difference in morphology of etched enamel surface and tag formation between the cervical region and other region of buccal enamel surface.

Carstensen (1992) summarized that etching pattern were similar in the incisal and central area of buccal surface, but differed from that in the cervical area.

Many studied have suggested the effect of prismless enamel surface on bonding and recommended the way to enhance the bond strength. Prismless enamel surface, mostly on cervical third, was differed from that of the prismatic variety. These prismless enamel influenced to acid etching that failed to generate adequate porosity in enamel surface. Therefore, bond strength of orthodontic's adhesive was reduced. Etching pattern of these prismless enamel alway represented the type III etching pattern.

Gwinnett (1973) reported that the prismless enamel, common in deciduous teeth, significantly influenced resin retention due to its limited porosity and penetrability during acid-conditioning. He stated that crystal orientation exclusively perpendicular to enamel surface with relatively dense and less in interprismatic space. These crystals were dissoluted and limited to create porosity. He suggested that grinding of outer layer of prismless enamel was appropriated for better resin retention, but prolonged etching times were contraindicated.

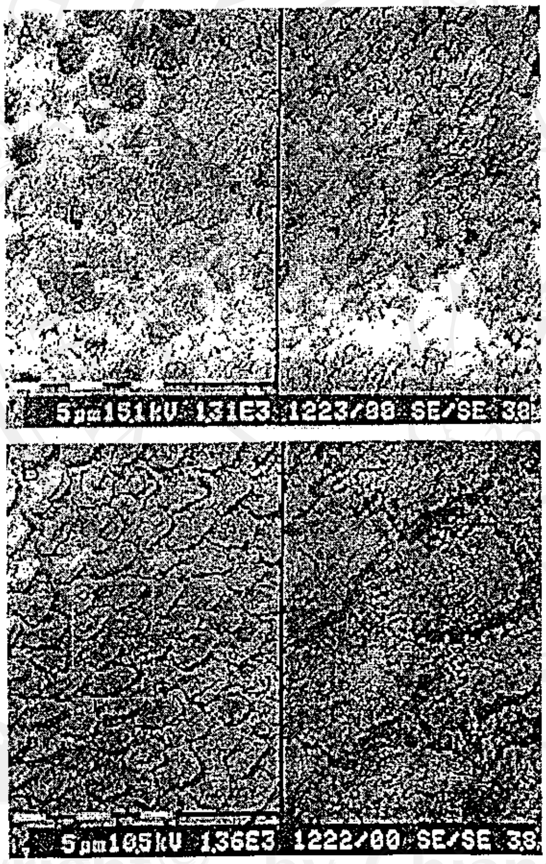
Fuks et al. (1977) studied the effect of mechanical and acid treatment in primary teeth and suggested the use of prolonged etching time to produce the favorable bonding surface.

2. Fluorosis teeth

The data related to fluorosis etching pattern was scantly. Many previous studies claimed that enamel with high fluoride content would resist to acid etching procedure resulting in fewer irregularity of enamel surface.

Opinya and Cornelis (1986) studied in normal and fluorosis Kenyan teeth. They observed that the etching pattern of fluorosis teeth for 120 seconds and 180 seconds appeared to generate a similar etching pattern to normal teeth etched for 60 seconds.

Ng'ang'a et al. (1992) studied in normal and fluorosis teeth and summarized that the fluorosis teeth had the same etching pattern but had some distinct to normal tooth. In type I etching pattern of fluorosis teeth, it was distincted pattern that showed hollowing of prismcenter with relatively intact peripheral regions (Figure 6a) that not conform to prism structure. When evaluated the type II pattern, there were some variations where prism peripheries appeared to be removed or heavily damaged (Figure 6b).



a.

b.

Figure 6 Scanning electron micrographs of two fluorosis enamel surfaces from different teeth after etching with 40 % phosphoric acid gel for 60 seconds. a. The surface shows a pattern where the prism cores have been removed and adjacent regions that do not conform to prism structure., b. The surface shows preferential removal of prism peripheries leaving the prism cores projecting toward the original enamel surface (Ng'ang'a et al., 1992)

Clinical Implication

In orthodontic practices, bonding the appliance seem to be difficult with fluorosis teeth. These fluorosis teeth resisted to acid etching procedure and gave poor surface preparation during bonding. Therefore, the failure of appliance was easily occurred. The factors related to bond failure during bonding procedure were :

1) Moisture contamination

2) Bracket adaptation to tooth surface

3) Force exceeding the bond strength

4) Individual variations (such as different enamel composition and responsibility to etching procedure, effect of rebonded bracket, surface prebonding condition)

Previous studies reported the effect of fluorosis on bond strength of orthodontic's adhesive.

Opinya and Cornelis (1986) studied in 40 Kenyan fluorosis and 40 normal American and 40 normal Kenyan teeth. They reported the significant differences between mean bond strength of fluorosis and non-fluorosis teeth. They suggested that grinding and then acid etching resulted in an increase in the tensile bond strength of fluorosis teeth.

Ng'ang'a et al. (1992) studied in 40 normal and 40 fluorosis teeth and reported no significant differences between mean bond strength of both groups. They suggested that mean tensile bond strength of orthodontic adhesive on fluorosis and non-fluorosis teeth in their studied were within the wide range of values regarded as adequate for orthodontic brackets and appliances.

It is interesting to find whether the fluorosis teeth will effect to bond failure of orthodontic appliance when the other factors are controlled.