# CHAPTER 7

# DISCUSSIONS

In this thesis, the critical objective was to emphasize on the hardness changes as a function of distance on the surface and subsurface of human teeth. All the experiments from chapter 3 to chapter 6 were established in order to compete those questions. In chapter III was the preliminary test to evaluate the amount of fluoride released from the experimented tooth-colored restorative materials. The dimensions of the sample (3x3x1 mm) simulated the size of the cavity prepared. This would represent the fluoride released in relation to the quality of material prepared for the restoration.

In chapter 4, non carious human premolars were used in order to investigate the surface hardness changes after acid challenges. This was to give as close as possible the actual information of human enamel and dentin hardness change. The tooth specimens were selected before they were soaked in demineralization solution (pH 5.0) and the surface hardness measurements were attempted. Since tooth hardness of the two positions next to each other were proved to have no significant difference, hardness changes after soaking in the demineralization solution could be determined. The surface hardness of tooth structure reduces due to loss of mineral content under acidic condition and the microhardness which is an easy index could be detected (Waters,1980; Boyer,1987). As many investigators proposed that the fluoride releasing materials had caries inhibition effect (Forsten, 1995; Tam, Chan and Yim, 1997), however, the hardness of tooth surface which can also represent the index of mechanical strength after using fluoride releasing materials has not been clarified in terms of the distance from the restoration. The results was exhibited that there were some mechanical property changes in enamel group with resin modified glass ionomer cement restoration within the distance of 100 μm to 300 μm from the edge of the materials. At the same time there were no enamel hardness changes among the three distances in negative and positive control groups. Due to this result the inhibition zone affected by resin modified glass ionomer cement and polyacid modified resin composite was in a limiting area not more than 100 μm. Then the sample was sectionally cut through the restoration in order to obtain the subsurface tooth structure underneath and continued to investigate the harness changes. The subsurface of tooth structure was expected to see less change due to the difficulty in transportation of fluoride ion through tooth structure. Nanohardness indentation test was applied to investigate the small area next to the interface since this test can perform smaller size of indentation while the microhardness cannot. With this technology, the effect of fluoride releasing materials on three dimensions of the adjacent tooth structure can be investigated. Nanohardness test can provide the maximum depth of penetration with precise measurement and less bias. The maximum depth of penetration represents the degree of hardness. The more depth created on the surface, the less resistance belongs to the material.

In chapter 5, there was an attempt to investigate the affected subsurface area. The first investigation was created with distance of less than 100 μm from the tooth-material interface, but vertically into the subsurface for 160 μm, the second investigation was expanded to 300 μm from the tooth-material interface and vertically 100 μm from the surface. The results from the second attempt exhibited that resin modified glass ionomer cement group showed some effect on the penetration depth at the column of 50 μm from the interface compared to these of 150, 200, 250 and 300 μm. However, there were no statistically differences in the groups of 50 and 100 μm next to the interface which confirmed the result of the first investigation. As many investigators reported of caries resistance in vitro of fluoride releasing material by polarized light microscope (Hicks,1986a; Marinelli et.al,1997; Millar, Abiden and Nicholson,1998; Pereira et.al., 1998; Tam, Chan and Yim,1997). Their results concluded that the fluoride releasing materials imparted resistance against the development of carious lesion in vitro. Previous reports have suggested that glass ionomer cement may promote remineralization by possibly depositing minerals and fluoride, therefore increasing the acid resistance (Tencate 1995, Modesto et al, 1997). Diaz-arnold (1995) observed that a conventional glass ionomer cement released greater amount of fluoride than resin modified glass ionomer cement. However, Forsten (1995) found that the fluoride levels released by resin modified glass ionomer cement were higher or the same as the conventional glass ionomer cement. Therefore, the explanation of their result in fluoride release may be the difference fluoride content of the materials and the different methods used to determine fluoride release.

In this study, the surface hardness was used to determine the effect of fluoride releasing materials instead of direct method of fluoride release and uptake. The results also showed that the subsurface hardness of enamel and dentin next to the fluoride releasing materials were harder as well as their surface hardness. The affected area was also found in the limited area. The surface enamel and dentin hardness next to restoration is expected to be harder due to fluoride ion. Fluoride bound to minerals could promote less soluble enamel and dentin. Fluoroapatite as a result of remineralization process is also harder and more acid resistance (Fejerskov and Clarkson,1996). The effect of fluoride on hardness is therefore needed further investigation. The surface microhardness of human enamel and dentin in this study can be implied that the fluoride had effects on the surface hardness changes and also agreed that type of materials had effects in prevention of secondary caries since there were statistically significant difference among groups of materials.

Featherstone et al. (1990) suggested that 1 ppm of fluoride in acid solution reduced the dissolution rate of carbonate apatite in vitro. This report was confirmed by the present study because the positive group which contained fluoride 10 ppm showed slightly surface hardness change compared to other groups after soaking in the demineralization solution. Fluoride was thought to be the major caries inhibitor by inhibiting demineralization, enhancing remineralization and inhibiting bacteria activity. The caries process begins when acid diffuses through the porous enamel or exposed dentin, dissociating to produce hydrogen ions. The hydrogen ions readily dissolve the mineral, freeing calcium and phosphate from the tooth structure surface into solution. The major effects of fluoride through out the body occurs in mineralization tissues. Biological hydroxyapatite may dissolve in acidic environment and free $OH^-$. If $OH^-$ in hydroxyapatite is replaced by fluoride ion, it turns to be fluorapatite which is more acid resistance. Both resin modified glass ionomer cement and polyacid modified resin composite released fluoride and showed some differences of hardness change among distances studied while the negative and positive control groups showed none. This also supported that surface hardness change adjacent to the fluoride releasing materials within 100 μm was less than the other two distances studied. It can be implied that enamel at 100 μm from the edge of the restoration tended to be harder. The causes can be explained in terms of two factors. One was some buffer components such as bicarbonate and phosphate that neutralize acid and raised pH back towards neutral. This phenomena slowed down and stopped the sub-surface dissolution. The other was fluoride which can speed up the remineralization process by adsorbing to the surface and attracting calcium ion. The new fluorapatite was formed so that the newly formed crystal would behave like low solubility when soaked in acid solution.

In chapter 6, the relationship of the affected area and the amount of fluoride was demonstrated using EDS. This X-ray method measured the amount of specific element at different areas of specimen and the outcome was relative concentration of the measured element to the total constituents. The result of the study showed that the areas within 100 μm from the interface and tooth surface had the highest value of fluoride content compared to other areas in resin modified glass ionomer cement and polyacid modified resin composite groups. The high fluoride content was found at the locations where the tooth hardness was high (in chapter 4) and penetration depth was less (in chapter 5). This showed that fluoride content would give higher hardness value or less penetration ability when subjected to the same force. This phenomena could be explained by the penetration of fluoride ions through pores and gaps within enamel structure and through the tubule walls (ten Cate, Damen and Buiji 1998). If fluoride had an effect on the microhardness change, the difference amount of fluoride could be detected. The big difference in the results was found in the groups of negative and positive control where the same material was used. Though the two groups were subjected to the same method but the positive group where the higher concentration of fluoride was applied showed much higher hardness value. This confirmed that the fluoride could penetrate into tooth structure and at the same time reduce the hardness drop due to the demineralization solution. Therefore, fluoride could be transferred to tooth structure in which more fluoride content was found using EDS in accordance to the high value of hardness measured by both indentation methods. Overall, the present study has shown the relationship of fluoride and the reduction of hardness changes. Also the inhibition zone resulted from the fluoride releasing materials had accomplished in terms of hardness index. With the new technology, the limited affected area could be investigate in terms of hardness and it can be related to other mechanical properties. The future research will be the attempt to explore the appropriate amount of fluoride to reduce caries using hardness assessment.

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