EFFECT OF CARBONATED BEVERAGE AND FLUORIDE MOUTH RINSES ON ENAMEL SURFACE AND SHEAR BOND STRENGTH OF CONVENTIONAL RESIN BASED ORTHODONTIC ADHESIVE COMPOSITE

By

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Dedication

To my wife for her love, support and patience

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In the name of ALLAH the most gracious the most merciful

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ABSTRAK

Minuman berkarbonat mengandungi jumlah gula dan asid yang tinggi yang boleh memberi kesan negatif ke atas kesihatan mulut. Terdapat beberapa penemuan bahawa kumuran mulut memberi kesan hakisan asid di permukaan enamel. Kajian ini telah dijalankan untuk mengenal pasti kesan jangka panjang minuman berkarbonat dan kumuran mulut berflourida pada permukaan enamel dan kekuatan ikatan ricihan resin konvensional yang berasaskan komposit pelekat ortodontik.

Kajian in vitro telah dilakukan ke atas 180 gigi manusia yang telah dicabut. Pendakap gigi diikat dengan pelekat ortodontik Transbond XT pada gigi. Gigi-gigi telah dibahagikan sama rata secara rawak kepada 6 kumpulan. Semua kumpulan tersebut telah didedahkan selama 25 hari kitaran seperti berikut; kumpulan 1 (air suling), kumpulan 2 (Coca Cola), kumpulan 3 (kumuran mulut Colgate), kumpulan 4 (kumuran mulut Oral-B), kumpulan 5 (Coca Cola campur kumuran mulut Colgate), kumpulan 6 (Coca Cola campur kumuran mulut Oral-B). Penganalisis imej telah digunakan dan peratusan dekalsifikasi kawasan permukaan enamel telah dikira untuk menilai dekalsifikasi enamel. Mesin ujian universal telah digunakan untuk menentukan kekuatan ikatan ricihan. Penganalisis imej juga digunakan selepas nyahikatan untuk mengira sisa index pelekat ke atas permukaan enamel.

Data dimasukkan dalam PASW versi 18. Ujian Kruskal-Wallis dan ujian Mann Whitney digunakan untuk membandingkan peratusan dekalsifikasi kawasan permukaan enamel di antara kumpulan-kumpulan tersebut. Didapati bahawa semua kumpulan mempunyai dekalsifikasi enamel yang tinggi daripada kumpulan kawalan pada keterukan yang berbeza. Ujian ANOVA sehala dan ujian perbandingan pelbagai Scheffe digunakan untuk membandingkan perbezaan yang signifikan ke atas kekuatan ikatan ricih dengan kumpulan kajian. Terdapat perbezaan yang signifikan antara kumpulan kawalan 1/ kumpulan 2 (p=0.001) dan 5 (p=0.047). Terdapat tiada perbezaan yang signifikan antara kumpulan kawalan 1/ kumpulan 3 (p=0.983), 4 (p=0.480) dan 6 (p=0.670). Ujian Kruskal-Wallis dan ujian Mann Whitney pula telah digunakan untuk menunjukkan perbezaan signifikan sisa index pelekat di antara semua kumpulan kajian. Tiada perbezaan yang signifikan antara semua kumpulan kajian.

Kajian ini boleh dirumuskan bahawa dalam tempoh yang panjang penggunaan minuman berkarbonat menyebabkan dekalsifikasi enamel; mengurangkan kekuatan ikatan ricihan pelekat ortodontik dan menyebabkan kegagalan kawasan nyahikatan pada antara muka pelekat enamel. Penggunaan kumuran mulut flourida berasid yang berpanjangan boleh menyebabkan dekalsifikasi enamel, tidak memberi kesan ke atas kekuatan ikatan ricihan dan menyebabkan kegagalan kawasan nyahikatan pada antara muka pelekat enamel. Pengunaan kumuran mulut berfluorida diikuti dengan minuman berkarbonat tidak mempunyai kesan ke atas kekuatan ikatan ricihan kecuali pada kumuran mulut Oral-B; dekalsifikasi enamel dan kawasan yang mengalami kegagalan.

EFFECT OF CARBONATED BEVERAGE AND FLUORIDE MOUTH RINSES ON ENAMEL SURFACE AND SHEAR BOND STRENGTH OF CONVENTIONAL RESIN BASED ORTHODONTIC ADHESIVE COMPOSITE

ABSTRACT

Carbonated beverages contains high amount of sugar and acids that can affect the oral health negatively. There were some indications about the erosive effect of acidic mouth rinses on enamel surface. This study was conducted to determine the long term consumption of carbonated beverage and use of fluoride mouth rinses on enamel surface and shear bond strength of conventional resin based orthodontic adhesive composite.

An in vitro study was done on 180 extracted human teeth. The brackets were bonded on the teeth with Transbond XT orthodontic adhesive. The teeth were divided randomly and equally into six groups. 25 days exposure cycles were done for all groups as following: group 1 control (distilled water), group 2 (Coca Cola), group 3 (Colgate mouth rinse), group 4 (Oral-B mouth rinse), group 5 (Coca Cola plus Colgate mouth rinse) and group 6 (Coca Cola plus Oral-B mouth rinse). Image analyzer was used and the percentage of enamel decalcification surface area was calculated to evaluate enamel decalcification. Universal test machine was used to determine shear bond strength. Image analyzer was also used for calculating adhesive remnant index on enamel surface after debonding.

Data were entered in PASW version 18. Kruskal-Wallis test and Mann Whitney test were used to compare the percentage of enamel decalcification surface area between groups. It was found that all groups have enamel decalcification greater than control group with different degrees. One-way ANOVA test and Scheffe multiple comparisons test were used to compare significant differences of shear bond strength between study groups. There was a significant difference between control group 1 / group 2 (p = 0.001) and 5 (p = 0.047). There was no significant difference between group 1 / group 3 (p = 0.983), 4 (p = 0.480) and 6 (p = 0.670). Moreover, Kruskal-Wallis test and Mann Whitney test were used to compare significant differences of adhesive remnant index among study groups. There was no significant difference among study groups.

This study concluded that the long period consumption of carbonated beverage cause enamel decalcification; reduce shear bond strength of the orthodontic adhesive and cause debonding failure site at enamel-adhesive interface. The long use of acidic fluoride mouth rinses can cause enamel decalcification, could not affect shear bond strength and cause debonding failure site at enamel-adhesive interface. The use of fluoride mouth rinses after carbonated beverage consumption has limited effect on shear bond strength except for Oral-B mouth rinse; enamel decalcification and failure site.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The management of orthodontic cases is normally carried out by using the fixed or removable appliance. Orthodontic treatment using fixed appliance involve the bonding of resins to the enamel surface. This technique of bonding resins to enamel has developed and it is now widely used in all fields of dentistry, including orthodontics (Eminkahyagil *et al.*, 2006). The bonding of resin to enamel surface is dependent on the mechanical locking of an adhesive material to irregularities in the enamel surface of the tooth and the orthodontic attachment (Proffit *et al.*, 2007). The mechanical locks are also present at the base of the orthodontic attachment.

The fixed orthodontic appliance therapy can restrict tooth brushing access to certain areas around the teeth. This will leads to more plaque and food accumulation in the oral cavity and hence these patients are in great risk of caries and therefore they need special oral care and advice (Yip *et al.*, 2009).

Today the consumption of carbonated beverages (soft drinks) has increased in all countries especially among children and adolescents (Michael, 2005; Yip *et al.*, 2009). Van Eygen *et al.*, (2005) investigated the short-term effect of soft drinks on enamel surfaces in vitro. They found that even a relatively short duration of immersion in Coca Cola (20 minutes) reduced enamel micro-hardness. Healthy enamel surface is one of the important factors for the retention of the brackets. The altered enamel surface due to erosion or enamel decalcification, caused by the acidity of carbonated beverages (Coca Cola) have a negative effect on the bracket retention against shearing forces (Oncag *et al.*, 2005).

The caries lesion begins with the demineralization of enamel. It is a dynamic alternating process of destruction and repair. This process is depends on the oral environment which in turn is affected by multiple factors such as diet, oral hygiene, type and duration of orthodontic treatment (Chang *et al.*, 1997). The prevalence of enamel demineralization (white spots formation) during and after orthodontic treatment can be very high. It ranges from 2% to 96% which depends on the duration of treatment and the use of oral hygiene measures by the patient (Mizrahi, 1982; Travess *et al.*, 2004).

In the oral cavity, changes in the mineral content of the teeth occur regularly. In normal conditions, the losses and gains of the mineral content of the teeth is balance out. However, if the balance shifted towards demineralization over a period of time, a carious lesion is form. This can occur due to a number of reasons. It is very important to detect and treat caries in the early stage in order to avoid the continuing loss of minerals from the enamel and to prevent the lesion from becoming a cavity.

Early caries diagnosis allows the lesion to be treated medically by applying remineralizing agents. Therefore, the use of different fluoride regimes remains the most used method for avoiding the appearance of new lesions and reducing the speed at which existing ones progress (Axelsson, 2000; Llena and Forner, 2008).

The World Health Organization has recommended the use of fluoridated mouth rinses as an alternative caries prevention and treatment (WHO, 1972; Navarro *et al.*, 2001). This is due to the fact that frequent uses of fluoride preparation with low concentration of fluoride such as toothpaste and mouth rinses have an anti-cariogenic effect (Navarro *et al.*, 2001).

1.2 Statement of Problem

White spots can appear on teeth during orthodontic treatment. This is due to early caries developing around the brackets. It is considered as important complications of orthodontic treatment. The fixed appliance therapy causes tooth cleaning more difficult and predispose a patient to plaque accumulation around brackets and near gingival margins. The appliances can also restrict the tongue from removing food debris from stagnant areas. These resulted in food debris and plaque accumulation in the oral cavity.

The reaction of oral bacteria, retained plaque and food debris resulted in acids formation in the mouth and hence prolonged exposure to these acids during orthodontic treatment can cause caries or enamel demineralization (Chang *et al.*, 1997). This can be a significant problem due to poor appearance of the teeth during and following orthodontic treatment. In severe cases cavities can develop which requires restorations.

The acidic exposure is influenced by the nature of diet, the content and frequency of acidic food and beverage consumption. The sugar in the diet is turned into acid. The acid is then produced by bacteria in the dental plaque which are not properly cleaned from around the orthodontic attachment during treatment. Therefore, it was recommended that the occurrence and severity of white spot lesion and dental caries can be reduced with the use of 0.05% of sodium fluoride mouth rinse on daily basis (Benson *et al.*, 2004).

Some studies indicated that carbonated beverages can increase the risk of caries in general or at least erosion, among patients undergoing orthodontic treatment (Yip *et al.*, 2009). Areas of defect due to erosion were detected on the enamel surface around the brackets in both the in vitro and in vivo study groups. This is due to the consumption of acidic soft drinks such as Coca Cola and Sprite. The consumption of acidic soft drinks such as Coca Cola and Sprite also has a negative effect on bracket retention against shearing force (Oncag *et al.*, 2005).

It has been found that the micro-hardness of composite resin which is the most popular material used as orthodontic adhesive remained stable up to one month of beverage exposure, but decreased significantly at the second month (Badra *et al.*, 2005). In addition, shear bond strength of orthodontic brackets can be reduced due to drinking of carbonated beverages (Oncag *et al.*, 2005). Furthermore, the increase in the temperature and exposure time will decrease the micro-hardness of human enamel during the consumption of soft drinks (Amaechi *et al.*, 1999; Eisenburger and Addy, 2003).

On the other hand, some studies shows that topically applied fluoride found in various oral hygiene products have low or no protective effect against enamel erosion and demineralization that caused by acidic challenges such as carbonated beverages (Hughes *et al.*, 2004; Kitchens and Owens, 2007; Lussi *et al.*, 2008; Bueno *et al.*, 2010). However, there are limited studies regarding the effect of fluoride mouth rinses on the shear bond strength of conventional resin based orthodontic adhesive composite.

In addition, currently there has been a steady increase in mouth rinses sales and usage, where some individuals using such mouth rinses up to six times per day (Moran, 1997; Pretty *et al.*, 2003). Media publicity of mouth rinses have also increased and any supermarket or pharmacy will provide the potential purchaser with a lot of options, many with claims of proven efficacy. Obviously, any solution with a low pH that is being used or arguably abused can cause erosion which was proved by some studies (Moran, 1997; Pontefract *at el.*, 2001; Pretty *et al.*, 2003).

1.3 Justification of the Study

Today, the prevalence and consumption of carbonated beverages is very high around the world (Michael, 2005; Yip *et al*., 2009). The ingredients of these carbonated beverages contain a large amount of sugar and acids and it has negative effects on the oral cavity. It is considered as risk factors to caries, erosion and white spots formation on the enamel.

The presence of fixed orthodontic appliance in the oral cavity can lead to formation of stagnation areas on tooth surface. This will prevent normal cleaning mechanism by saliva and cause difficulty in plaque removing by tooth brushing. Research done by Abdullah and Rock, (2001) showed the need for orthodontic treatment was 47.9% among the Malaysian children based on grades 4 and 5 of the dental health component (DHC) of Index of Orthodontic Treatment Need (IOTN). A large intake of carbonated beverages among children and teen ages, who were on the fixed orthodontic appliances therapy, put them at high risk of the enamel decalcification and white spots formation. This will lead to bad appearance of the tooth surface and hence affect the patient's aesthetics (Michael, 2005; Yip *et al.*, 2009). As well as towards progression of cavity.

On the other hand, carbonated beverages not only causes enamel decalcification but it may also cause weakening in the bond strength between the brackets and enamel surface (Oncag *et al.*, 2005; Ulusoy *et al.*, 2009). Failure in bond will lead to increase in treatment time and money.

To improve oral hygiene and to prevent white spots formation (enamel decalcification), the orthodontists normally prescribe the fluoride mouth rinses to patients on fixed appliance therapy. Fluoride has a bactericidal effect in the oral cavity. Its action is by diffusing into the oral bacteria as hydrogen fluoride (HF) molecules when plaque is acidified (Ekstrand *et al.*, 1996; Kwon *et al.*, 2008).

The caries preventive effect of fluoride on enamel is well established. The two major effects of fluoride action are: inhibition of demineralization at the hydroxyapatite crystal surfaces and enhancement of remineralization, resulting in arrest or reversal of caries lesions (Almqvist and Lagerlof, 1993).

The incorporating of fluoride into the dental apatite crystals has previously been considered to play a determining role in the inhibition of demineralization of the enamel. However, there are limited studies done before to evaluate the effect of fluoride mouth rinses (Colgate and Oral-B) on shear bond strength of conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek). There were some studies showed that mouth rinses with low pH values has an erosive effect on hard tooth structures (Moran, 1997; Pontefract *at el*., 2001; Pretty *et al*., 2003).

Consequently, the present study were designed to assess the enamel decalcification or white spots formation after exposure to Coca Cola beverage, Colgate, Oral-B mouth rinses and both together (Coca Cola plus mouth rinse) in cyclic manner. This study also measure of the shear bond strength and adhesive remnant index of the popular conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek) under the effect of carbonated beverage (Coca Cola), fluoride mouth rinses (Colgate and Oral-B) and both together (carbonated beverage and fluoride mouth rinses) in cyclic manner.

The selection of Coca Cola carbonated beverage was based on the fact that it has low pH value and it contains phosphoric acid. Phosphoric acid is used as acid etching agent during bonding procedures of orthodontic brackets. The Colgate and Oral-B mouth rinses which have the same fluoride concentration were selected due to their acidic nature but with different pH values and titratable acidity.

This study should help orthodontists to have good idea about the effect of carbonated beverages and fluoride mouth rinses on tooth surface and bonding of the orthodontic adhesive composite. This is to maximize the achieved benefit for orthodontic patients and raising the chance of minimum adverse effect on the facial appearance and oral health of the patient's teeth during and after orthodontic treatment. Figure 1.1 shows the conceptual framework of the study.

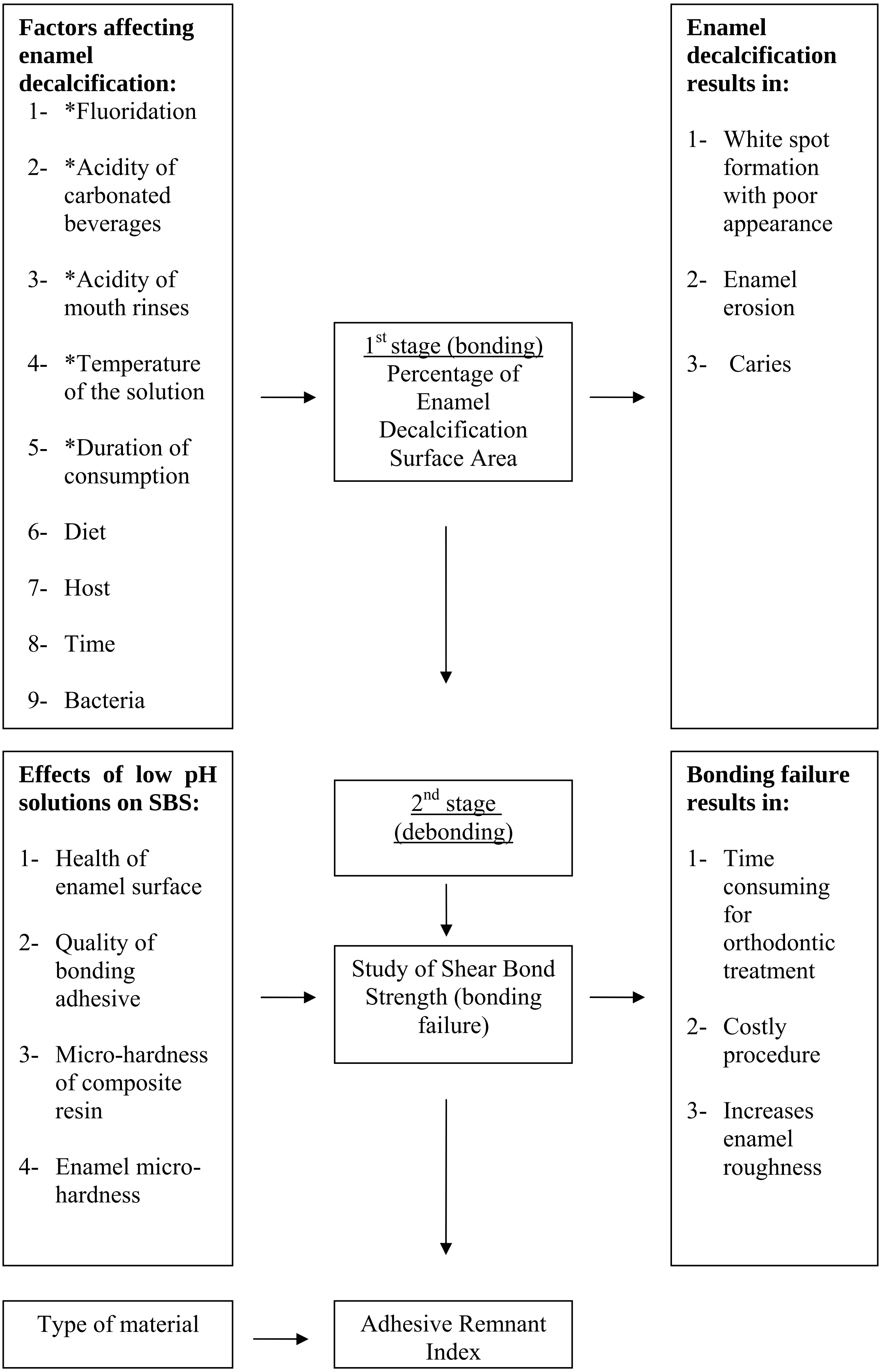

Figure 1.1 Conceptual framework of the study

* Variables studied

1.4 Objectives

1.4.1 General Objective

To study the effect of carbonated beverage (Coca Cola) and fluoride mouth rinses (Colgate Phos-Flur and Oral-B) on the enamel surface and the shear bond strength of conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek).

1.4.2 Specific Objectives

1. To determine and compare the percentage of enamel decalcification surface area of Control group, Coca Cola group, Colgate group, Oral-B group, Coca Cola plus Colgate group and Coca Cola plus Oral-B group.

2. To determine and compare the shear bond strength of conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek) of Control group, Coca Cola group, Colgate group, Oral-B group, Coca Cola plus Colgate group and Coca Cola plus Oral-B group.

3. To determine and compare the adhesive remnant index of conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek) of Control group, Coca Cola group, Colgate group, Oral-B group, Coca Cola plus Colgate group and Coca Cola plus Oral-B group.

1.4.3 Research Hypothesis

1. There is a significant difference in the percentage of enamel decalcification surface area between Control group, Coca Cola group, Colgate group, Oral-B group, Coca Cola plus Colgate group and Coca Cola plus Oral-B group.

2. There is a significant difference in the shear bond strength of conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek) between Control group, Coca Cola group, Colgate group, Oral-B group, Coca Cola plus Colgate group and Coca Cola plus Oral-B group.

3. There is a significant difference in the adhesive remnant index of conventional resin based orthodontic adhesive composite (Transbond XT, 3M Unitek) between Control group, Coca Cola group, Colgate group, Oral-B group, Coca Cola plus Colgate group and Coca Cola plus Oral-B group.

CHAPTER TWO

LITERATURE REVIEW

2.1 Bonding orthodontic brackets

In orthodontics, the used of bonding resins to enamel has been developed and widely used (Eminkahyagil *et al*., 2006). Bonding of orthodontic attachments to enamel surface eliminates the need for routinely place bands on all teeth (Proffit *et al.*, 2007). This established by Buonocore, (1955) that developed the basis of brackets adhesion to enamel surface using enamel etching technique. Since then, rapid development in product termed as adhesive resin, brackets and techniques has been occurred (Zachrisson and Büyükyilmaz, 2005). Van Meerbeek *et al*., (2003) classified adhesive systems into three groups according to the number of application steps and the interaction with dental structures:

- Etch and rinse (two and three-step) adhesives.
- Self etch (one and two-step) adhesives.
- Glass ionomer.

The conventional resin adhesive is the three-step etch and rinse adhesive. This type of adhesives still has the most favourable and most reliable long term performance (Van Meerbeek *et al*., 2003).

2.1.1 Composite resin

Composite resins have been widely used adhesives for orthodontic bonding procedures (Al Shamsi, 2007). The composition of the composite is based on the bisphenol A glycol dimethacrylate (Bis-GMA) monomer which is a viscous liquid. In order to render the resin suitable for formulating into a composite, a monomer with low viscosity is used, which is triethylene glycol dimethacrylate (TEGDMA). Consecutively to improve toughness, reduce water sorption and viscosity of composite resin, some manufacturers replace part or all of the Bis-GMA with urethane dimethacrylate (UDMA) (Brantley and Eliades, 2001).

The physical and chemical properties of the unfilled resin are improved by the addition of filler particles. Conventional composites contain particles (glass or ground quartz), of 10-30 micrometres diameter. These particles are treated with a saline coupling agent to enable bonding to occur between the particles and the resin. The conventional composites have filler particles of 80%. Micro-filled resins contain 50% fillers and have filler particles of 0.04 micrometres (μm) diameter or less. According to the type of inorganic filler, composite resins are classified as highly-filled composite or low-filled composite. The smaller the particle diameter, the less filler can be included into the matrix (Marcia and Michael, 2000).

In light cured composite systems, two components are involved in the initiating systems, namely a ketone and amine. The ketone and camphorquinone is sensitive to blue light at wavelengths in the region of 470 nanometre. Free radicals are produced which initiates the additional polymerization (Brantley and Eliades, 2001).

Transbond XT Light Cure Adhesive is used for bonding metal and ceramic brackets to tooth surfaces. It is available in both syringes and capsules. This adhesive uses light cure adhesive technology to provide additional working time to ensure accurate bracket placement. The Transbond XT contains 14% Bis GMA, 9% bisphenol A ethoxylated dimethacrylate (Bis EMA), and 77% fillers (silylated quartz and submicron silica); (Bishara *et al.*, 1997; 3M Unitek Orthodontic Products, 2008).

2.1.2 Bonding technique

There are two bonding techniques: direct and indirect techniques. The direct bonding technique refers to the direct attachment of orthodontic appliances to etched teeth using chemically and light cured adhesives. The indirect bonding technique, in which the brackets were first positioned on study casts and then transferred to the patient mouth using a custom tray (Sinha and Nanda, 2001). Direct bonding does not provide as accurate as a placement of brackets as indirect bonding. On the other hand, direct bonding is easier, faster and less expensive (because the laboratory fabrication steps are eliminated) (Proffit *et al.*, 2007). Direct bonding of orthodontic brackets is now routinely performed by orthodontists. Direct bonding adhesives provide clinically acceptable bond strength (Yamada *et al*., 2002).

The bonding procedure of orthodontic brackets is dependent on four main steps; cleaning, enamel conditioning, sealing and bonding. Failure to perform each of these steps may lead to problems which may compromise the desired result (Zachrisson and Büyükyilmaz, 2005).

2.1.2.1 Cleaning

Cleaning of the tooth surface before bonding is an important step. This process is aim at the removal of plaque and organic debris that covers the enamel surfaces. Rotary instruments are normally required for this procedure. A rubber cup or a polishing brush is regularly used in the cleaning process. Pumice prophylaxis did not appear to affect the bonding procedure negatively and cleaning the teeth may be recommended to remove plaque and debris that might remain trapped at the enamel-adhesive interface after bonding (Zachrisson and Büyükyilmaz, 2005).

2.1.2.2 Acid etching

Direct bonding brackets on etched enamel surfaces have been extensively evaluated in the orthodontic literatures and are reported to be clinically successful (Buonocore, 1955; Sadowsky *et al.*, 1990). Etching of the enamel surface with phosphoric acid leads to dissolution of the hydroxyapatite crystals producing micro-porosities into which fluid monomer can penetrate (Beech and Jalaly, 1980; Beech *et al.*, 1985).

Retief *et al.*, (1985) reported that the depth of etch and the amount of surface enamel lost during the etching procedure depends on the type of acid, its concentration, the duration of etching and the chemical composition of enamel. Studies indicate that longer etching time does not provide more retention and probably it might result in less retention due to the loss of surface structure (Powers *et al.*, 1997; Fricker, 1998). It was recommended to etch the enamel with 30-40% orthophosphoric acid liquid for 30 seconds before bonding of orthodontic brackets (Al Shamsi, 2007).

2.1.2.3 Sealants and adhesive

Sealants in orthodontic practice are needed to attain required bond strength and to improve resistance to micro-leakage. In contrast, some studies have concluded that the intermediate resin not increase the bonding strength but improve the wetability of the tooth surface that is necessary for proper adhesive bonding (Prevost *et al.*, 1982). Orthodontic adhesive material must have the following criteria: dimensional stability, flowability to penetrate the enamel surface, proper strength and easy to use clinically (Proffit *et al.*, 2007).

The light-initiated resins by now have become the most popular adhesives for the majority of orthodontists (Keim *et al.*, 2002). The use of light cured adhesives offer the advantage of extended, though not indefinite, working time. This in turn provides the opportunity for assistants to place the brackets, with the orthodontist following up with any final positioning. In addition, light cured adhesives are particularly useful in situations in which a quick set is required, such as when rebonding one loose bracket or when placing an attachment on an impacted canine after surgical exposure of the tooth (Zachrisson and Büyükyilmaz, 2005).

Moreover, light cured adhesives are also advantageous when extra-long working time is desirable. This may be the situation when difficult premolar bracket positions need to be checked and rechecked before the bracket placement is considered optimal (Zachrisson and Büyükyilmaz, 2005). Furthermore, the material is cured under metal based brackets by direct illumination from different sides and by trans-illumination because the tooth structure transmits visible light. A rapid polymerization happens when curing light is applied, producing nearly unlimited working time, allowing more precise bracket placement (Trimpeneers *et al.*, 1996).

2.1.2.4 Excess adhesive removal

It is usual clinical procedure to ensure that excess adhesive is removed after bonding of the orthodontic bracket. This is to prevent or minimize gingival irritation and plaque accumulation around the periphery of the bonding base. It is also reduces potential periodontal damage and the possibility of enamel decalcification. In addition, removal of excess adhesive can improve aesthetics, not only by providing a neater and cleaner appearance, but also by eliminating exposed adhesive that might become discoloured in the oral environment (Zachrisson and Büyükyilmaz, 2005).

2.1.3 Bracket types

The corrosion susceptibility of stainless steel brackets may lead to enamel roughness around the brackets which in turn may lead to plaque accumulation (Maijer and Smith, 1986; Matasa, 1998).

Bracket base design, may also lead to enamel decalcification around the margins of the bracket base which is smaller than the bracket wings. The use of the elastic ligatures around the bracket could lead to plaque accumulation. Although, those elastics are time saving, stainless steel wires are safer and more hygienic (Zachrisson and Brobakken, 1978; Forsberg *et al.*, 1991).

2.2 Bond strength testing

Bond strength is the force per unit area necessary to break a bonded assembly with failure taking place in, or near, the adhesive/adherent interface (SI, 2006). The variations in the enamel surface and bracket base nature, the thickness and continuity of the materials beneath the bracket and accuracy of the material mixing, as well as lack of standardization of experimental procedures can leads to wide variations of bond strength testing results (Bishara *et al.*, 2005). The use of shear loading is recommended in orthodontic bracket bond strength testing. This is because the relative simplicity of the experimental configuration and the presumably increased reliability of simulating the debonding that occurs during orthodontic treatment (Eliades and Brantley, 2000).

2.2.1 Factors that affecting bond strength testing

Orthodontic bonding materials are being constantly developed. The development of these materials has usually focused on the values of the bond strength as an indicator of its improvement (Al Shamsi, 2007). Therefore, the following factors could be considered during bond strength testing.

2.2.1.1 Tooth type and enamel surface nature

The common teeth used in bond strength studies are human premolar teeth, human incisors, bovine incisors, human molars and human deciduous molars (Al Shamsi, 2007). It would seem preferable to use premolars for all future studies, as these teeth are often extracted from patients for orthodontic purposes (Fox *et al.*, 1994). Mattick and Hobson, (2000) have shown that the nature of the etched enamel surface varies between different teeth. Hobson *et al.*, (2001) concluded that there were significant differences in bond strengths between different tooth types. It was suggested by Hobson *et al.*, (2001) that the future bond strength studies of surface enamel should use only one type of tooth or an equal number of different tooth types in order to achieve stratification. Linklater and Gordon, (2001) concluded that canine and premolar teeth exhibited significantly higher shear bond strengths and significantly lower probability of failure at given levels of applied stress, than incisor teeth.

2.2.1.2 Tooth surface preparation

Three ordinary steps are usually applied before bonding the brackets namely prophylaxis, surface etching, washing and drying. These steps are summarized into one term namely ‘‘prophylaxis’’.

Prophylaxis

Rotary instruments are needed for this procedure which includes either a rubber cup or a polishing brush. Many studies use pumice applied with a rubber cup (Winchester, 1991; Ulusoy *et al.*, 2009; Navarro *et al.*, 2010). The duration of prophylaxis has not been formalized, but commonly it varies from 15 to 30 seconds (Al Shamsi, 2007).

Acid etching

The acid concentration and the etching time are still controversial. The effects of variations in acid concentration have been evaluated in several studies. Some studies have reported that the shear bond strengths were not significantly influenced by acid concentration (Beech and Jalaly, 1980; Barkmeier *et al.*, 1987; Sadowsky *et al.*, 1990). Sadowsky *et al.*, (1990) found that reducing the etching time of 37% phosphoric acid from 60 to 15 seconds had no significant effect on the retention of bonded orthodontic attachments. Therefore, it is recommended to use 37% phosphoric acid solution for 30 seconds.

Washing

Washing with water is important to remove the etching material and any deposit from the enamel surface. However, insufficient rinsing will not totally remove the phosphoric acid which negatively affects the bond strength (Al Shamsi, 2007). Bishara *et al.*, (1995) has suggested that approximately 20 seconds of rinsing is enough.

Drying

Drying for 15 seconds with an oil-free air stream is necessary after washing to create a frosted appearance in the enamel. An oil-free air stream is preferable to avoid contamination of the freshly etched enamel (Al Shamsi, 2007).

2.2.1.3 Storage medium before debonding

Fox *et al.*, (1994) were giving the details of variety storage media that can be used between bonding and testing:-

- Water 37ºC for 24 hours.
- Water 37ºC (other times).
- Water room temperature for 24 hours.
- Water room temperature (other times).
- Saline 37ºC for 24 hours.
- Saline refrigerated.
- Water 37ºC for 1 week.
- Artificial saliva 37ºC for 24 hours.
- Acid phosphate buffer for times up to 1 week.

These storage mediums have no effect on the bond strength. They, also suggested that the timing between bonding and testing was probably not critical, as long as this period was not less than 24 hours.

2.2.1.4 Cross-head speed

There was a large variation of cross-head speeds reported when using the Instron testing machine. Alexandre *et al.*, (1981) tested at 0.05 inches per minute, Knoll *et al.*, (1986) and Winchester, (1991) tested at 2 mm per minute (mm/min).

The faster testing speeds tend to give decreasing bond strengths (Rider, 1977). Slowing the cross-head speeds from 5 to 0.5 mm/min significantly increased the mean shear bond strength from 7 to 12.2 MPa, an increase of by 57% (Bishara *et al.*, 2005).

Ulusoy *et al.*, (2009) and Navarro *et al.*, (2010) used cross-head speed of 1 mm/min in their study on the effect of carbonated beverages on shear bond strength of orthodontic adhesive composite.

2.2.1.5 Failure site

No failure is desirable but if failure is to occurs, the desirable failure site is between the adhesive and the enamel as this would make polishing much easier and less damage to the enamel surface (Zachrisson and Büyükyilmaz, 2005).

2.2.1.6 Quality of the materials

The failure mode of the adhesive can indicate the physical and chemical properties of the materials. If the adhesive failure is located in the adhesive interference, this may point to the wetting properties, or chemical reactions within the substrate. This is necessary to improve the bond strength. If there is a cohesive failure (a fracture in one of the materials to the side of the interface), this indicates that the physical properties of the material has limited the bond strength of the assembly (Al Shamsi, 2007). Failure mode observations indicates how the system is working and pointing out its weakest link (Oilo, 1993).

When comparisons were made between tooth surface appearances after debonding metal brackets attached with macro-filled (10 to 30 μm) and micro-filled (0.2 to 0.3 μm) adhesives, a difference occurred when the resin was scraped off with pliers. Possibly small filler particles may penetrate into the etched enamel to a greater degree than macro-fillers do. For instance, the holes corresponding to the dissolved enamel prism cores in the central etch type are 3 to 5 μm in diameter. On debonding the small fillers reinforce the adhesive tags. The macro-fillers, however, create a more natural break point in the enamel-adhesive interface (Zachrisson and Büyükyilmaz, 2005).

2.3 Enamel decalcification and erosion

The process of minerals losing from the tooth surface is called demineralization and the opposite process in which the tooth surface gaining minerals from the oral cavity is called remineralization. The demineralization process starts first in a sub-clinical lesion and leading to a white spot lesion formation. White spot appearance is the early visual sign of caries formation that can be detected clinically (ten Cate and Duijsters, 1982).

White spot lesion is best seen on a dried surface. The lesion shape is a small, opaque, chalky white area and the colour of the lesion distinguishes it from adjacent translucent sound enamel. The colour change is due to the increased porosity of the tissue, which change the way in which the light is scattered. If air drying reveals a white spot in the enamel, the change in enamel porosity is slight, but if the porosity is clinically visible as a white spot without air drying the porosity is larger. Some white spot lesions may remineralize and return either to normal or at least to a visually acceptable appearance. White spot lesions may also persist, resulting in an aesthetically unacceptable result. In severe cases, restorative treatment may be required as the demineralization process include the full thickness of the enamel and some of the dentine after the relatively hypermineralized surface layer is actually lost (Sudjalim *et al.*, 2006).

Dental erosion is defined as the progressive loss of hard dental tissue due to the chemical influence of extrinsic and intrinsic acids without bacterial involvement (Chunmuang *et al.*, 2007; Kitchens and Owens, 2007; Wang *et al.*, 2010).

The chemical's action results in decalcification of the enamel. The aetiology of erosion can be categorized into chemical, biological and behavioural factors. The two chemical parameters, pH and titratable acidity may explain the erosive potential of acidic food or drinks. Saliva is one of important biological factor in erosion protection, low salivary flow can results in inadequate rinsing and buffering of acids on the tooth surfaces. In addition, tooth structure and positioning in relation to soft tissues and tongue may be of particular significance. Behavioural factors can includes the manner by which dietary acids are introduced and kept in the mouth before swallowing; the timing of acidic consumption/exposure and daily work/pleasure/sport activities can all have a significant effect on the development and location of erosive tooth wear. If gastric symptoms are also present, especially when the patient has a psychological eating disorder such as anorexia nervosa or bulimia (Prietsch *et al.*, 2002; Young *et al.*, 2008), this can also contribute significantly to the enamel decalcification and erosive tooth wear.

Erosive lesion can appear as shallow, smooth and rounded areas on enamel tooth surface and possibly the dentine involvement in severe cases. Erosion patterns starting from as little as 100 microns of mineral loss can be visible to the naked eye. In cases with erosion due to a high ingestion of acidic food, the lesions usually appear on the labial surfaces and only occasionally on the lingual surfaces. In cases with chronic regurgitation, the lesions are more severe and are more often found on the lingual surfaces (Prietsch *et al.*, 2002).

2.3.1 Prevalence of enamel decalcification during fixed orthodontic treatment

Several clinical studies have confirmed the susceptibility of patients undergoing orthodontic therapy to dental caries (Chang *et al.*, 1997; Batoni *et al.*, 2001). As a result of the rapid plaque accumulation around the bonded brackets, decalcification and white spot lesions have occurred within a few weeks of wearing brackets (O'Reilly and Featherstone, 1987; Ashok and Ritu, 2006; Hoshang *et al.*, 2008). Melrose *et al.*, (1996) reported that early enamel carious lesions can develop in areas of plaque retention, associated with orthodontic attachments, in periods as short as 4 weeks.

The incidence of decalcification following a course of fixed appliance therapy that lasts approximately for 2 years, has been reported to be as high as 50% (Gorelick *et al.*, 1982; Artun and Brobakken, 1986; Ogaard, 1989). Many studies proved that the prevalence of decalcification following a course of fixed appliance treatment ranged between 2%-96% (Mizrahi, 1982; Mitchell, 1992). Actually, the carious formation is a dynamic alternating process of lesion progression and lesion repair. An earlier study found a correlation between the duration of treatment and the appearance of minor and deep demineralization. The probability of lesion formation in patients, who had fixed appliances for more than 2 years, was higher than those patients that had fixed appliance therapy for a year (Geiger *et al.*, 1988).

The progression of demineralization was not dependant on plaque volume but on differentiation of microflora which leads to a greater concentration of acid forming bacteria (Balenseifen and Madonia, 1970). Repetition of the cementing procedure, due to detachment of brackets or bands, produces more decalcification. Dincer and Erdinc, (2002) in an in vivo study found that "recemented teeth" showed more decalcification. However, this process is reversible process. Once the orthodontic treatment is completed, this will cause a change in the oral environment and the process of remineralization might out balance the process of demineralization. On the other hand, white spot lesions may stay and affect patient appearance, also in severe cases it may require restorative treatment. Multiple factors can affect the decalcification process during a course orthodontic treatment. These factors are patient's oral hygiene level, acidic drinks or food consumption and its quantity, frequency and acidity, also fluoride administration in the form of fluoridated water, fluoride mouth rinse, toothpaste and fluoride varnish (Sudjalim *et al.*, 2006).

2.4 Carbonated beverages

Carbonation process that used in carbonated beverages production occurs when carbon dioxide dissolved in water or an aqueous solution (Kitchens and Owens, 2007). Carbonated beverages or soft drinks is a drink that contains no alcohol and usually are sugary and consumed while cold. Soft drinks contain a high concentration of sucrose or fructose and a typical 12 fluid-ounce (375 ml) can of sugared soda contain approximately 10 teaspoons of sugar (Shenkin *et al*., 2003).

2.4.1 History of carbonated beverages

These drinks were developed in the latter half of the nineteenth century in USA. Before that time, drinks were used as refreshments are mostly well water, milk and at certain times of the year cordials, such as lemonade and dandelion and burdock. The latter were made out of water and extracts from different fruits. These drinks were very limited in their accessibility due to the fact that these fruits were seasonal fruits (Tahmassebi *et al.*, 2006).

Changes started to happen in the 1890s when entrepreneurs developed substitute drinks based on cola and sarsaparilla extracts. These drinks was based on cola extract, sarsaparilla and carbonated and believed to have medicinal properties. Shortly after that other very similar drinks were developed including Coca Cola and Pepsi Cola. Industrial production of these drinks together with the expansion of preservatives made so called 'soft drinks' more widely available, particularly in the USA. There is another important aspect, however, is that these soft drinks packaged in bottles and are free from contamination where as many natural water sources might not be. The widely available and reliable safe drinking water is only quite recent and still not common in many parts of the world. In addition to being safe, these drinks are also easily assimilated energy source (Tahmassebi *et al.*, 2006).

2.4.2 The increase in carbonated beverages (soft drinks) consumption

In the United States, dramatic increase in soft drinks consumption occurred over the past 50 years. The average consumption in 2002 is approximately 53 gallons per year or over 16 ounces per day, representing about 25% of the recommended daily fluid intake of 67 ounces (Shenkin *et al.*, 2003). The main increase in soft drinks