

## CHAPTER II

### LITERATURE REVIEW

The literature review is divided into four parts as follows:

#### 2.1 DENTAL PORCELAIN

#### 2.2 BONDING BRACKETS IN ORTHODONTICS

#### 2.3 PREPARATION OF PORCELAIN SURFACES FOR BONDING

#### ORTHODONTIC BRACKETS

#### 2.4 ADHESIVE RESIN FOR BONDING ORTHODONTIC BRACKETS

### 2.1 DENTAL PORCELAIN

Dental porcelain is a popular restorative material, used for restorations such as veneers, crowns, and bridges, to restore damaged or missing teeth, or to enhance the aesthetics of the natural dentition.

Porcelains are made of the mineral feldspar with some additions for color and translucency, and contain silica ( $\text{SiO}_2$ ) and alumina ( $\text{Al}_2\text{O}_3$ ) with small amounts of potassium oxide ( $\text{K}_2\text{O}$ ) and sodium oxide ( $\text{Na}_2\text{O}$ ) to control expansion.<sup>22</sup>

Two main types of ceramic systems are used for crown fabrication in modern dentistry.<sup>27</sup>

#### 2.1.1 Metal-ceramic systems

Materials in metal-ceramic systems are now substantially glassy and the  $\text{K}_2\text{O}$  content can be varied to accommodate the need to match the coefficient of thermal expansion of metal alloys used in dental metal-ceramic techniques. The increase in

$K_2O$  content allows a greater proportion of leucite crystals (coefficient of thermal expansion  $27 \times 10^{-6}/^{\circ}C$ ) which leads to the overall coefficient of thermal expansion rising to something in the order of  $13.5 - 15.5 \times 10^{-6}/^{\circ}C$ . Metal–ceramic porcelain can be classified in to three groups.

- a. Opaque porcelain: It is used to cover a metal substructure.
- b. Body porcelain: It covers opaque porcelain but is more translucent than opaque porcelain.
- c. Incisor porcelain: It is used as the outermost layer.

### **2.1.2 All-ceramics systems**

The ways to achieve high strength ceramics is by using two ceramic materials; one with a high strength but non-esthetic core, then veneered with low strength but esthetic porcelain.<sup>27</sup>

#### **2.1.2.1 Aluminous core ceramics**

The high strength ceramic core, which is composed of alumina crystals dispersed in a glassy matrix. One system is used to make alumina profiles that are then used as cores to build up ceramic superstructures for single tooth implants, CeraOne®, and the second is to make cores for conventional crowns, a process known as Procera®. Feldspathic-veneered porcelains are then fired onto this alumina core to provide the colour and form for the restoration.

#### **2.1.2.2 Slip –cast ceramics**

During the 1980's, Dr. Michael Sadoun and Vita Zahnfabrik, developed a slip casting system. The cast alumina was sintered and then infiltrated with a Lanthana-based glass. This provided a glass-infiltrated alumina core (In-Ceram®) on which a feldspathic ceramic could be baked to provide the functional form and the aesthetic

component of the restoration. In-Ceram has the highest flexural strength and fracture toughness of all the currently available dental ceramic systems. The system also has the greatest versatility for dental use of any metal free ceramic restorative material.

#### 2.1.2.3 Heat-pressed ceramics

##### a. Leucite based

Leucite has been widely used as a constituent of dental ceramics to modify the coefficient of thermal expansion. This is most important where the ceramic is to be fused or baked onto metal.

The recent introduction of the pressed-leucite-reinforced ceramic system, IPS Empress, features leucite in a different role. This material relies on an increased volume of fine leucite particles to increase flexural strength. Similar versions, using finely dispersed leucite grains to increase toughness and strength, and to modify wear rates to make them similar to enamel wear rates, are now available for metal-ceramic restorations.

##### b. Lithium silicate-based

Lithium silicate-based is a metal-free ceramic. The major crystalline phase consists of lithium disilicate and fluoro-apatite bases. An example of this type is Empress 2. It is indicated for a layered crown and 3-unit anterior bridge with one pontic.

#### 2.1.2.4 Machined ceramics

The development of glass ceramics by the Corning Glass Works in the late 1950s has led to the creation of a dental ceramic system based on the strengthening of glass with various forms of mica. The Dicor® crown system uses the lost wax

technique to produce a glass casting of the restoration. The casting is then heat treated or cerammed.

This procedure is designed to take place within the economic confines of a commercial dental laboratory. A second dental version was developed to be used for CAD/CAM dental procedures. This cerammed glass is provided in an already heat-treated state from the manufacturer. In this latter technique an optical scan of a prepared tooth is loaded into a computer and a milling system is used to produce the restoration. The restoration is then “bonded” to the remaining tooth structure using a dental BisGMA-based composite resin.

#### 2.1.2.5 Metal-reinforced systems

Metal-reinforced systems are similar to metal-ceramic systems, but use high-gold as a substructure. These systems rely on different ways of creating a thin coping onto which the ceramic is fired.

The driving force for these developments has been the immense difference in reliability between metal-ceramic systems and all-ceramic systems and a public perception that metal-free restorations are more aesthetic. The disadvantages of the metal ceramic systems include radiopacity, some questions around metal biocompatibility and lack of natural aesthetics; important features in today's consumer conscious dental market.

The chemical composition of porcelain constitutes a problem because many of these materials are similar in chemical formula, but there are differences in components, crystalline structure, particle size, sintering behavior, and micro-topography created by etching.<sup>20</sup> Most dental ceramics and metal ceramic crowns,

bridges, and veneers currently are made from different feldspathic porcelains containing from 10% to 20% aluminium oxide.<sup>11</sup>

## 2.2 BONDING BRACKETS IN ORTHODONTICS

Until the 1980s, the only practical way to fix an orthodontic attachment was to put it on a band that could be cemented to a tooth.<sup>28</sup> Bonding attachments, eliminating the need for bands, have many advantages since an orthodontic bracket has no interproximal component and, therefore, results in better periodontal health condition and less enamel demineralization.<sup>29,30</sup> Nowadays, teeth are banded less routinely than in the past.<sup>1</sup> Bonding concepts are challenged continuously by new developments and technical improvements. A continuous search is on for higher bond strength, better adhesives with simpler procedures.

In orthodontic treatment with fixed appliances, achieving a low bond failure rate should be a high priority objective because replacing loose brackets is inefficient, time-consuming, and costly. Over the years, various bonding materials have been developed in an attempt to increase bond strength to enamel and dentine surfaces.

Several generations of bonding materials were developed for restorative purposes and later were applied to orthodontics. Successful bonding in orthodontics requires careful attention to three components of the system: the tooth surface and its preparation, the design of the attachment base, and the bonding material itself.<sup>28</sup>

Previously, most of an orthodontic practice involved treating children and adolescents. However, a greater number of adults are now seeking orthodontic treatment.<sup>29,31</sup> Adult dentitions have been maintained with a variety of restorations, which include porcelain. Clinically, orthodontists are often faced with the difficulty

of bonding metal brackets to porcelain surfaces, since conventional acid etching is ineffective for etching porcelain surfaces for retention of orthodontic brackets. Banding is an alternative but is considered aesthetically unacceptable, particularly with anterior teeth, and banding is not possible on the abutment teeth of fixed bridges. Direct bonding of orthodontic brackets has removed some of the esthetic concerns. Progress in materials and techniques has shown that direct bonding of orthodontic attachments to porcelain is also possible.<sup>10</sup>

## **2.3 PREPARATION OF PORCELAIN SURFACES FOR BONDING ORTHODONTIC BRACKETS**

Since conventional acid etching is ineffective for etching porcelain surfaces for retention of orthodontic brackets, mechanical or chemical pre-treatment of the surface is essential for direct bonding to porcelain surfaces.<sup>1,2</sup> Techniques for bonding brackets to porcelain surfaces vary in terms of the surface preparation technique and the type of bonding agent used. The approaches that have been suggested to improve bond strength to porcelain surfaces can be grouped into three broad categories : mechanical, chemical, or a combination of these.<sup>24</sup>

### **Type of porcelain surface preparation**

#### **2.3.1 Mechanical treatment**

The purpose of mechanical alteration of the porcelain surface is to remove the glaze and roughen the surface to provide sufficient mechanical retention for the adhesive. This mechanical retention to the porcelain surface is achieved by two categories.

##### **1. Using a coarse diamond stone or green stone<sup>4,8,9,12,20</sup>**

Roughening the porcelain surface with a coarse diamond produced a random peeling appearance thus enlarging the porcelain surface area for bonding with shallow mechanical retention as revealed by SEM.<sup>8,9</sup> Even though roughened surface features suggested that mechanical retention might be expected but SEM examination of cross-sections of brackets bonded to glazed and deglazed porcelain surfaces of Nebbe *et al*<sup>10</sup> study revealed similar composite- porcelain interdigitation in both groups. Unfortunately, glaze removal by a bur may damage the porcelain surface; an additional disadvantage is a reduction of porcelain strength.<sup>18</sup>

## **2. Micro-etching (air abrasion or sandblasting)**<sup>2,11,22</sup>

Sandblasting with microscopic particles of aluminium oxide to remove glaze may be better than using burs since only a small amount of surface is removed and the procedure is more uniform.<sup>22</sup> Sandblasting is the quickest and easiest method of roughening the porcelain *in vitro*. However this procedure may be difficult to perform intra-orally.<sup>11</sup>

Although the changes introduced by these mechanical approaches may increased sufficiently bond strength for orthodontic purposes, they also cause irreversible surface damage to the porcelain.<sup>10,19,24</sup>

### **2.3.2 Chemical treatment**

#### **1. Hydrofluoric acid (HF)**

Hydrofluoric acid has been used successfully to etch the porcelain surface (glassy ceramics) and significantly increases the bond strength of orthodontic attachments.<sup>2,8,11,18,22</sup> The use of hydrofluoric acid to etch porcelain surfaces before bonding brackets may increase bond strength, since the action of hydrofluoric acid is to create a series of surface pits by preferential dissolution of the glass phase from the

ceramic matrix.<sup>18</sup> The etchant creates microporosities on the porcelain surface that achieve a mechanical interlock with the composite resin.<sup>1</sup> In a comparison of sandblasted surfaces to hydrofluoric acid-etched surfaces, Cochran *et al.*<sup>11</sup> showed that the etched samples had significantly higher bond strength. This result may have been due to the deep etching pattern produced by the hydrofluoric acid, which created greater mechanical retention for the resin.

Hydrofluoric acid must be used with great care, as it is extremely corrosive, and is capable of causing severe trauma to soft tissues.<sup>18</sup> The most commonly used porcelain etchant is 9.6% hydrofluoric acid in gel form.<sup>1</sup> Hydrofluoric acid is strong and requires bonding separately from other teeth and should be carefully used by isolation of the working area. The etching process require rinsing with high-volume suction and drying before bonding.<sup>11</sup> Another disadvantage of hydrofluoric acid is that the ceramic surface can lose its glaze and it becomes difficult for the clinician to restore the surface to its original lustre.<sup>24</sup>

## **2. Acidulated phosphate fluorides (APF)**

Acidulated phosphate fluorides have also been used to etch porcelain surfaces because they do not cause as much damage as hydrofluoric acid. Barossa *et al.*<sup>4</sup> studied potential use of APF for orthodontic bonding and revealed that APF was in effective in providing adequate and consistent bond strength for orthodontic purposes.

## **3. Phosphoric acid**

Phosphoric acid, at 37% concentration, does not etch porcelain and does not produce physical or topographical changes in the porcelain surface. Instead, the effect of phosphoric acid is to neutralize the alkalinity of the adsorbed water layer, which is



present on ceramic restorations in the mouth, thereby enhancing the chemical activity of any silane primer subsequently applied.<sup>17,18</sup>

#### **4. Silane coupling agent**

Another approach used to enhance bond strength to porcelain surfaces is by changing the nature of the surface, using a coupling agent such as silane.<sup>2,18</sup> In the late 1970s, Organosilane gained popularity in the fields of prosthodontics for porcelain repair, and in orthodontics for the direct bonding of attachments to porcelain.<sup>15</sup> The silane coupler forms a chemical bond with both the resin and the porcelain by forming a bridge between the two materials.<sup>24</sup> The action of the silane coupler performs two functions; the hydrolysable group of the coupler reacts with the inorganic dental porcelain, whereas its organofunctional group reacts with the resin and enhances adhesion. The portion of the silane molecule that is not adsorbed presents a free surface that is wetted easily by adhesive materials.<sup>24</sup> There are two main types of silane, depending on the first step of chemical reaction.

##### **Type of silane preparation**

##### **a) Prehydrolyzed form**

Prehydrolysed silane is easy to use, with a higher rate of hydrolysis than non-hydrolysed silane. However it has a shorter shelf life and is less stable in the container. Moreover, it is prepared in diluted solutions to avoid polycondensation of silanol upon storage. Silanol solutions condense over time, forming high molecular weight oligomers, becoming cloudy, and no longer acting as a coupling agent. Hydrolysed silane solution is very active. Silanol tends to form linear cyclic dimers, trimers, or tetramers through condensation. Hydrolysed silane is commonly available in single phase.

### b) Non-hydrolyzed form

Non-hydrolysed silane needs acid activation to cause hydrolysis. The major difference between the two forms of silane is that the prehydrolyzed silane is easier to use but generally has a shorter shelf life and is less stable in its container.<sup>3</sup> Furthermore, both silanes have limited shelf lives and require proper handling and storage according to the manufacturers' recommendations.

#### Action of silane

For a permanent chemical bond to form between the porcelain and the resin, a series of events must occur:<sup>3</sup>

#### 1. Hydrolysis of organosilane to form an organosilanol

This stage requires the presence of an acid (e.g., H<sub>3</sub>PO<sub>4</sub>, HF) to acidify the thick alkaline layer of water that adsorbs to the surface of the porcelain and lowers its bond energy and wettability. Furthermore, the acid reacts with the silane to form a silanol that is the chemically reactive form of the compound. This chemical reaction occurs rapidly and proceeds to completion.



(Organosilane)

(Silanol)

R = organic side chain

It is at this first stage that many of the commercially available organosilanes differ. The silanes can be purchased in either a prehydrolyzed or a nonhydrolyzed form.

## 2. Initial formation of oxane

Before a permanent covalent oxane bond is formed, the organosilane initially hydrogen-bonds to the mineral surface of the porcelain. This bond is weak and easily disturbed.

## 3. Condensation reaction to form permanent oxane bond

This process is slow and usually takes anywhere from 2 to 24 hours for bonds to develop and stabilize. The permanent covalent bond forms between silicon in the organosilane molecule and silicon dioxide or other alkaline oxides in the porcelain feldspathic glassy matrix. Since this reaction behaves like an ionic reaction with a constant equilibrium value, upon completion the reaction remains in equilibrium with the surrounding water.



(siloxane bond)

M = Si or other alkaline earth metal

Overall, organosilanes increase bond strength by performing two functions. First, they provide a chemical link between dental porcelain and composite resins; second, the organic portion of the molecule increases the wettability of the porcelain surface, thereby providing a more intimate micro mechanical bond.<sup>3</sup>

### Comparative finding with different porcelain surface treatment

Techniques for bonding brackets to porcelain surfaces vary in terms of the surface preparation technique and type of bonding agent used. Conflicting results exist in the literature on the effects of different conditioning methods and various adhesives. Mechanical approaches have increased bond strength for orthodontic

purposes but they also cause irreversible damage to the porcelain glaze and greater risk of porcelain fracture on de-bonding.<sup>2,10,18,19,24</sup> Some studies have reported that the promotion of microretention on the porcelain surface does not appear to be necessary for orthodontic purposes.<sup>8,20</sup> The removal of surface glaze by grinding reduces the transverse strength of the porcelain to half that when the glaze was present, and the glaze is effective in reducing crack propagation of the porcelain.<sup>10</sup>

The recommended procedure may involve using a hydrofluoric gel to condition the porcelain.<sup>1,4,7,8,16</sup> Etching with hydrofluoric acid has proved to be excellent throughout full routine orthodontic treatment periods.<sup>1</sup> However, the major disadvantages of hydrofluoric acid are the irreversible change in the porcelain surface that occurs even after the surface is cleaned and polished, and the hazard of a chemical burn to the gingival tissues.<sup>24</sup> More than that, most of the porcelain repair materials are not capable of restoring the original porcelain surface texture.<sup>8</sup>

Extreme care should be taken during intra-oral application of hydrofluoric acid because contact between the acid and soft tissues may cause severe tissue irritation.<sup>4</sup> Because of this potential danger, one may prefer alternative conditioning techniques.

The use of phosphoric acid in conjunction with silane has been used to bond porcelain surfaces because it does not cause as much damage as does hydrofluoric acid.<sup>2,10,17-21</sup>

The issue of bond reliability using organosilanes has been a concern in many previous studies in this area. Standard deviations have always had a tendency to be rather large.<sup>3</sup> Some studies show that application of silane alone, without application of hydrofluoric acid or surface roughening did not give sufficient bond strength to withstand occlusion force and that silane coating should be combined with surface roughening.<sup>4,7,9,13,15,16,22-25</sup>

## 2.4 ADHESIVE RESIN FOR BONDING ORTHODONTIC BRACKETS

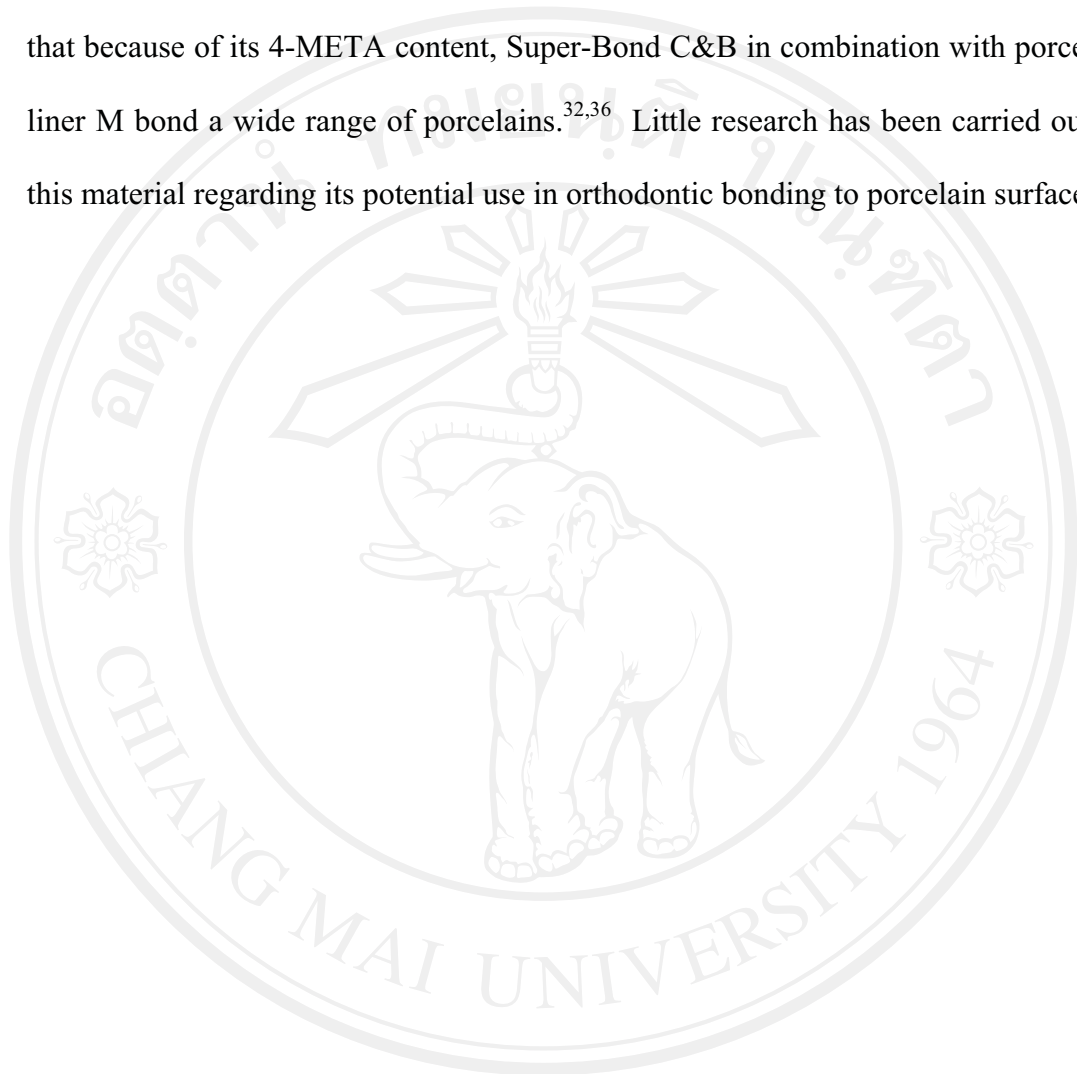
Two basic types of dental resins may be used for orthodontic bracket bonding.<sup>1</sup>

1. The acrylic resins based on self-curing acrylics which consist of methylmethacrylate monomer and ultrafine powder.
2. Diacrylate resins are based on the acrylic modified epoxy resin, bis-GMA or Bowen's resin.

Both types of adhesive exist in filled or unfilled forms. A fundamental difference is that resins of the first type form linear polymers only, whereas those of the second type may be polymerized also by crosslinking into a three-dimensional network. This crosslinking contributes to greater strength, lower water absorption, and less polymerization shrinkage. Acrylic or combination resins have been most successful with plastic brackets.<sup>1</sup>

Advances in restorative dentistry have led to the development of adhesive resins which have the capacity to adhere to ceramic as well as etched enamel.<sup>26</sup> Resin cements with reduced filler contents offer improved flow, increased surface wettability, and optimal positioning of the bracket. Super-Bond C&B (Sunmedical Co., Ltd., Shiga, Japan), a 4-methacryloxyethyl trimellitate anhydride (4-META)/methyl methacrylate (MMA) is an adhesive resin cement, which contains no filler<sup>32</sup> that has been used for bonding orthodontic brackets and has earned a reputation for strong bonding.<sup>33</sup> The 4-META is a bifunctional monomer exhibiting a hydrophobic methacrylate group and a hydrophilic aromatic anhydride group<sup>26</sup> and functions as a coupling agent, promoting adhesion to composite resins, enamel, dental alloys and ceramic powders.<sup>34,35</sup> Before porcelain is bonded using a resin cement, it is recommended the surface is treated with a silane-based coupling agent. Porcelain

liner M (Sunmedical Co., Ltd.) is a silane-based coupling primer. When liquids A and B are mixed, their methoxyl groups quickly hydrolyze. Researchers have reported that because of its 4-META content, Super-Bond C&B in combination with porcelain liner M bond a wide range of porcelains.<sup>32,36</sup> Little research has been carried out on this material regarding its potential use in orthodontic bonding to porcelain surfaces.



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