T.C.

İSTANBUL YENİ YÜZYIL UNIVERSITY

HEALTH SCIENCES INSTITUTE

DEPARTMENT OF ORHODONTHICS

COMPARISON OF SHEAR BOND STRENGTH AND BONDING TIME OF METAL FLASH-FREE ORTHODONTIC BRACKET

MASTER OF THESIS

ALİ M. A. BENAROS

Supervisor

Prof. Dr. Mustafa Haluk İŞERİ

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ACCEPTANCE AND APPROVAL

T.C. ISTANBUL YENI YUZYIL UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

This study which was conducted within the framework of the Orthodontic Department was accepted by the jury as a Master thesis.

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Prof. Dr. Mustafa Haluk İŞERİ

Orthodontic Department

Istanbul Yeni Yüzyıl University

Prof. Dr. Gökmen KURT

Orthodontic Department

Bezmialem Vakıf University

Yrd. Doç. Ayşe BAHAT YALVAÇ

Orthodontic Department

Istanbul Yeni Yüzyıl University

Abstract

Purpose: The purpose of this in vitro study is to compare the shear bond strength and bonding time between metal flash-free brackets and conventional metal brackets. Remaining adhesive following removal of orthodontic brackets was also assessed.

Materials and Methods: Forty five intact human premolars (N =45, n = 15 per group) were selected and randomly divided into three groups. Group1: Smart clip brackets used as control group, Group 2: Smart clip APC II flash-free adhesive coated brackets used as first experimental group, Group 3: Smart clip APC plus adhesive coated brackets used as second experimental group. The bonding time was calculated after the teeth were prepared until the brackets placed in the ideal position in seconds. Shear bond strength (SBS) for each sample was measured. Samples were then examined under X 8 magnification light microscopy to assess the remaining adhesive. The shear bond strength, bonding time and remaining adhesive of each group were statistically compared using t-test $p<0.05$.

Results: The mean bonding time of smart clip group (**40.1140**) had significantly difference when compared with APC II group (**31.0560**) (**p=0.00**), and did not show significant difference when compared with the smart clip APC plus (**39.5431**) group (**p=0.638**).

The mean shear bond strength of smart clip group had significantly higher mean shear bond strength value (**11.25120**) when compared with APC II (**9.42347**) and APC plus (**8.42867**) group (**p=0.00 , p=0.00** respectively).

The mean residual adhesive of smart clip group (**1.73**) did not show significant difference when compared with APC II group (**1.93**) (**p=0.558**). The mean ARI of smart clip group had significantly higher mean ARI value (**1.73**) when compared with APC plus (**0.87**) group (**p=0.033**).

Conclusions: APC flash-free adhesive coated bracket systems had shear bond strength clinically acceptable. The APC flash free adhesive system is able to decrease the time needed for orthodontic bracket bonding. More adhesive remaining on the bracket appear to be favorable to save chair time during debonding but increase the risk of enamel surface damage due to enamel fracture on bracket removal.

Key words: Flash free bracket; Shear bond strength; Bonding time; adhesive residual index

Dedication

This thesis is dedicated to:

my mother,

she always encouraged and inspired me. Without her I wouldn’t have ever achieved what I did. She has always supported me with her best wishes,

my wife and children,

they always cheering me up and stood by me through the good and bad times.

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To my mother, Fatima, I would like to first and foremost thank you for the amazing love and support you have given me throughout the years. Thank you for encouraging me endlessly to pursue higher education and explaining to me how through education and knowledge comes enlightenment and humility.

I also would like to thank all of the orthodontic staff for educating me.

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1. Literature review

1.1. Introduction

In 1955, Buoncore introduced the acid-etching bonding technique and the concept of resin bonding has been developed to apply enamel in dentistry, including the intertwining of orthodontic brackets (1,2). Before 1970, the interrelationship between orthodontic brackets has some advantages, including ease of placement and removal, minimal soft tissue irritation and gingivitis, minimal risk of decalcification with loose band, and being more aesthetic (3). Various materials and methods are being continuously developed for bonding brackets, but in some cases the problem of decalcification is still being developed (4). Low PH environment, increase retention sites for food particles and streptococcus mutants (5, 6).

The intertwining of the orthodontic brackets on the dental surfaces has improved with the advent of new products with excellent adhesive properties. Traditional system of orthodontic bracket bonding need to use of a three-step procedure includes three separate of enamel conditioner, a priming agent and resin adhesive. (Self-priming primers) try to limit the three steps to two steps, effectively reduce chair time and increase the cost effect resulting in increased comfort and potentially reducing costs to the patient (7). Although designed to be used in reducing operative bonding procedures, SEPs/adhesives have been used to successfully bond of orthodontic brackets with shear bond strength (SBS) value similar to those of conventional acid-etch.

The three main components to be considered for sufficient orthodontic bonding are the dental surface (morphology, Preparation of enamel) and individual orthodontic base attachment (mechanical and material properties), bonding of material itself (shear bond strength, material composition) (3). A wide range of resins that are light activated, chemically, and filled resins and other cements are available for orthodontics.

The main objective is to achieve a sufficient marginal seal and less bonding material around the bracket to avoid caries or white spot lesion under the arch and in its periphery.

Until recently, while tying the orthodontic bracket the practitioner has to remove excess resin or bonding material immediately after placing the attachment using the positing instrument or a dental probe before curing of material.

In 2014, 3M and unitek (Monrovia, Calif ornia) create APC Flash-Free system (APC flash-free adhesive-coated appliance system), as a try to eliminate the need to remove Flash.

The system can be applied to any orthodontic bracket base during the manufacturing process. When pressing the enamel surface, the transparent and low viscosity resin forms a guiding border on the edges of the bracket (4).

1.2. Enamel feature, structure and formation.

1.2.1 Enamel feature:

Enamel is the hardest substance in the human body and contains the highest proportion of minerals, 96%, with water and organic substance compose the rest (8).

The primary mineral is hydroxyapatite, which is crystalline calcium phosphate (9). Enamel is formed on the tooth while the teeth develop inside the gums, before that it explodes in the mouth. Once fully formed, it does not contain blood vessels or nerves.

In humans, enamel difference in thickness on the surface of the teeth, often more thickness on the cusp, up to 2.5 mm, and less thickness on its border with cement the surface is not good shape at cement enamel junction (CEJ) (8).The normal color of enamel differs from light yellow to Gray (bluish) white. On the edges of the teeth where there is no dentine underlying the enamel, color sometimes has white or slightly transparent tone, easily can be seen on the upper incisors. Since the enamel is semi-transparent, enamel strongly affects the appearance, the large amount of minerals in the enamel accounts do not only for its strength but also for its fragility (8). Enamel does not contain collagen, as found in other hard tissues like dentine and bones, but the enamel contain two unique classes of proteins: amelogenins and enamelins (8).

1.2.2 Enamel structure:

The basic enamel unit is called an enamel rod. Measuring 4-8 microns in diameter, the enamel rod, formally called the enamel prism, is a tightly packed block of hydroxyapatite crystals in a structured pattern (8).

In the cross section, it is best to compare with a keyhole with a head or head oriented toward the crown of the tooth, or the tail, oriented toward the tooth root.

Both enamel cells (cells that begin forming enamel) and Tomes processes (acone-shaped process at the distal secretory end of the ameloblasts) affect the crystals. Enamel crystals in the head of the enamel rod are oriented parallel to the long axis of the rod. When found in the tail of the enamel rod, the crystal orientation diverges slightly (65 degrees) from the long axis (8).

The arrangement of enamel rods is more clearly understood than its internal structure. Enamel rods are found in rows along the tooth and within each row, and the long axis of the enamel rod is generally perpendicular to the primary dentine.

In permanent teeth, enamel rods near the cement enamel junction (CEJ) tilt slightly towards the root of the tooth. Understanding the direction of enamel is very important in restorative dentistry, because unsupported enamel of dentine is vulnerable to break.

The area around the enamel rod is known as interred enamel. Inter enamel rod has the same configuration as enamel rod (8).

1.2.3 Enamel formation:

Formation of amylogenesis, or enamel formation, occurs after the creation of the first dentine by enamel cells which known as ameloblasts, an amylogenesis is two phases (8).

The first phase produces partially mineralized (about 30%) enamel. Once the full width of this enamel is deposited, the second phase includes large flow of additional materials and water to achieve more than 96% mineral contain.

This mineral flow makes the shape of the crystals, during the first phase grow wider and thicker. This complex process is under cellular control, and associated cells undergo major morphological changes throughout amylogenesis, reflecting its physiological evolution (8).

1.3 Preparation of tooth surface:

1.3.1 Prophylaxis

Enamel cleaning before acid etching is necessary for direct preparation and indirect repairs, and incisions (10,11). The discoloration and plaque accumulation are removed by dental prophylaxis with pumice powder or paste and rotating brush or a cup of rubber (12).

There are other prevention techniques, such as airflow and bicarbonate jet polishers, which are faster and more efficient, but they can damage tissue and surface contamination (13,14).

Even in patients with good oral hygiene, it is always necessary to remove the invisible acquired pellicle with dental prophylaxis.

The pellicle acquired is organic flake and sham, without cells, which covers cleaned tooth surfaces in a few minutes (15).

Acquired pellicle is important in tooth decay (16), especially in the demineralization /reminelization of enamel surface. The acquired pellicle is important with respect to the enamel surface response to the bacterial acid exhibit (17,18).

1.3.2 Acid etching technique

During the 32nd annual meeting of the International Dental Association Research in 1955, (1). Buonocor suggested that use of 85% phosphoric acid solution resulted in an adhesion of the acrylic resin bonded to enamel that lasted 1070 hours to deboned when stored in water (1).

Similar to other conceptual and technologic innovations, this procedure was introduced in dentistry before and after 10 years the bonding mechanism was described (20), Bis-GMA-based adhesive systems and composite resins were developed and the first clinical application, were developed as a pit and fissure sealant (21,22). Chemotherapy by acid etching reinforces enamel topography, changing it from a low-reactivity surface to a surface more susceptible to adhesion.

Removal of metals is selective due to the morphology of the prisms. The difference in arrangement of prism crystals causes acidity to have higher metal removal capacity in some microorganisms. After instrumentation of cavity depending on the angulation of the prism, demineralization can be greater at the prism head or at the periphery. These features are respectable known as type I and acid type II patterns of acid etching. This feature is important in understanding the foundation of etching eliminates approximately 10 μm of enamel surface and creates a porous formality layer (5 μm to 50 μm deep) (23).

The free surface energy is multiplied,(24) as a result, the viscous liquid resin low-contact to the surface and is attracted to the interior of these microsporocytes created by conditioning through the noodles (poetic attraction) (25). Therefore, the resin markers in the microsporocytes of the enamel are conditioned after it is sufficient polymerization, providing resistance, long-lasting bonds by micromechanical interlocking with this tissue (20, 26, 27).

1.3.3 Etching time

When the enamel etching was made in 1955, the recommended time was 30 S for 85% phosphoric acid (1). Then at the time of its first clinical use, was extended to 60 seconds (20,22).

In 1984 it was decreased to 30 seconds the application stayed until today (28,29). Some writers recommend reducing the etching time to15 seconds when 32% to 40% phosphoric acid is used (30).

Most manufacturers have recommended adhesive systems 15 seconds it saves time without compromising the appearance of adhesive limit. Reducing etching time from 30 to 15 seconds over 3 advantages: First, because conditioning acid causes loss of surface tissue, it is recommended that the minimum dental structure is resolved; therefore, the minimum time should be applied (31).

The difference between 15-second and 30-second application time of phosphoric acid on the enamel solution is very small. chemical reaction of conditioning happens quickly and, as mineral components are lost, acidity is decreased by Caching. Secondly, when one is dealing with cavities involving dentine and enamel, the expansion of the etching technique into dentine (also called total etching technique) is controversial because time should not be longer than 15 seconds in dentine, however this is the minimum time required to achieve proper enamel bonding (32). It has been suggested that the conditioning time is reduced to 15 seconds which are sufficient to create an enamel retentive surface with no difference in enamel etching pattern, (33) or bond decline power to enamel (29).

Studies in the laboratory have shown that 15-second conditioning time is also enough for orthodontic adhesion procedures, the third advantage is the preserve of chair time.

The etching time is sufficient as 15 seconds when using 32% to 40% phosphoric acid to achieve proper bond strength when it is applied to enamels surfaces (37,35).

1.3.4 Etchant Concentration

When the etching technique was extended to dentine (total etch technique), manufacturers included a low concentration of acid conditioners in adhesives perhaps because of lack of information, knowledge or marketing, and systems which presumably will cause less aggression on pulp tissues (36).In the early 1991, it was common to find etchant such as 10% phosphoric acid, 10% malic acid, 10% citric acid, 2.5% oxalic acid, 2.5% nitric acid. Some of these acids do not result in a typical dull white crystalline appearance adapted but some studies show that this does not adversely affect the immediate enamel adhesive bonding to instrumented enamel (35).

However, other research shows a significant reduction in bond strength. due to lack of long-term clinical evidence on bonding robustness to enamel using those less aggressive conditioner, the previous use of 32% to 40% phosphoric acid conditioner is still the best option to obtaine the expected correlation to enamel surface (37).

1.4 Orthodontic cements and adhesives

The bonding of orthodontic brackets to dental enamel was an important issue since the introduction of direct bonding in orthodontics. Since then, many new bonding agents have been developed such as composite resin and conventional glass ionomer cement, modified glass ionomer cement and modified composite (compomers) with a differet polymerization mechanism such as chemically, light or dual treatment (38).

New adhesives, adhesive resins, and hybrid cement combination offer improved physical and clinical benefits, but there are obvious differences in clinical indications and contraindications for each category of materials (39).

Composite resin is one of the most commonly used adhesives in orthodontic bonding although they provide sufficient bonding strength and are easy to handle. It adheres to the tooth enamel only by microtesion requiring dry field and the amount of fluoride release was not found to be enough for anticaries effects.

Resin modified glass ionomer cement is another type of cement with improved properties possessing some of good qualities of compound resins as well as some properties that make it very desirable to orthodontic bonding as fluoride release properties. This can be regenerated by local application of fluoride as well as the ability to provide satisfactory bond strength to the enamel while the bonding is preformed in the presence of moisture. In addition to micromechanical lock with enamel surface irregularities they provide chemical bonding resulting in superior bonding strenght (38), with an understanding of the features, benefits, and limitations, the practitioner can be choose the material wisely to obtain optimal results.

1.4.1 Ideal Requirements Of Orthodontic Adhesive

The orthodontic adhesive must be able to enable the bracket to remain bonded to enamel for a full period of treatment and allow easy removal of the brackets when that is needed without any harmful on the enamel surface and less discomfort to patient (40,41).

The adhesive should be non-irritating to the mucousmembrane of the mouth, allowing sufficient long working time positioning the brackets while placing quickly enough for the patient comfort, provide a simple way to apply, a convenient way to treat and has fluoride – potential release (42).

1.4.2 Glass ionomer cement

Glass ionomer cements were introduced by Wilson and Kent as material for restorative treatment, and later became available as cement (46).

First generation Of GICs consists of aluminosilicate glass powder and an alkenoate acid liquied, setting reaction of GICs considered acid base reaction (43).

The second generation of GICs investment companies incorporate a freeze acid as dried powder blended with glass and is mixed with distilled water (43). Original glass ionomer cement (GICs) were water-based substances developed by acid- base reaction between a poly alkenoic acid and afluroaluminosilicate glass materials. Attempts to enhance physical properties have been made by add any of the metal particles (silver or gold), by fusion process resulting acement (ceramic, metal) (44). However, there are problems associated with handling characteristics.

Accurate dispensing of the liquid component is difficult, resulting in inaccurate powder: fluid / water ratios, which are prone to moisture pollution during the setup reaction.

These can negatively affect on physical properties set of materials while the development of coated cement has helped, these are more expensive than hand-mixed cement and likely wastage (43).

1.4.3 Zinc poly-carboxylate cement

In the pursuit of an adhesive luting agent that strongly bonding to the structure of teeth, zinc polycarbxylate and twist cement as adhesive bond to the dental structure (45). Polycarboxylate cement is a product reaction of zinc oxide and a polycarboxylate acid solution.

The carboxylic group is spaced along the polycarboxylic acid chain chelate to calcium in enamel and dentin, resulting in a chemical bond between cement and tooth. Cement polycarboxylate was the first chemical adhesive as with zinc-phosphate cement, the mixing technique takes time to cement the teeth like to master because the incorporation of zinc oxide powder in the viscous relatively poly carboxylate acid is difficult (39).

This orthodontic cement was created with main advantage which is chemical adherence to enamel and the treatment properties was flawed, due to poor bonding strenght, viscosity solubility, and short working time (43).

1.4.4 Zinc-phosphate cement

Zinc phosphate cement is one of the oldest cement sealers and has been widely used as band cement in the last century (45).

Zinc phosphate cement is the product reaction of zinc oxide and phosphoric acid solution. When set, zinc-phosphate cement is relatively dimensions stable including low solubility in oral fluids.

The cement components must be mixed properly to ensure that the acidic base the reaction can proceed optimally resulting in good and minimal physical properties effects on oral tissues. Mixing powder / liquid cement product is sensitive technique (39).

Ideally, zinc phosphate cement should be kept cool during mixing. Zic-phosphate was widely used for band lutting for a large part of the last centary. It has high compressive strength, but suffers from low tensile strength and high solubility, resulting in micro-leakage and demineralization (43).

1.4.5 Resin modified cement

The use of "metal reniforced" GICs appeares to be diminshing following the introduction of high powder input: ratio of liquid products.

In early 1990 through the addition of conventional water to produce soluble "resin modification" GICs (RM-GICs). The purpose of adding resin was to enhance physical properties and reduce the sensitivity of the water balance to traditional GICs (46).

Resin modified glass ionomer cement is a hybrid material of traditional glass ionomer cement with a small addition of resin-treated light or self-curing resin thus the exhibition properties superior to conventional glass ionomer materials, it has the advantage of both adhesion to the tooth structure, and fluoride release hardened by visible light, powder and liqued capsulate of RMGIC simplify mixing procedures with triturator (47,48).

Although a limited amount of resin monomer can be added to the polyalkenoic acid solution, polymerization of the resin monomers hastens the initial hardening of RMGICs without interfering significantly with the acid-base setting reaction, the fluoride release, or chelation of carboxyl groups to metal and tooth surface. In addition to the chemical bonding of RMGICs, resin monomers penetrate surface irregularities to produce micro-mechanical interlock after polymerization (39).

1.4.6 Resins

Newman (1965) was the first person to use epoxy resin to bonding stainless steel between brackets and enamel (49).

Resin cement is mainly low viscosity. It consists of resin monomers and inert fillers. As with RMGICs, polymerization can be either light or chemically activated, or dual activation. Light activated resin adhesives are always one material stored in opaque packages. Resin component is single component convenient because it is not necessary to mix and thus eliminate the technical variables (39).

Chemically cured systems are available as two pastes or as powder and liquid. The systems use both mechanisms which are chemotherapy as well as light therapy and several referred to as dual treatment systems.

Resin cement is insoluble in oral liquid. They do not contain any water gel and do not show any fluoride release or recharging, the resin bonding to tooth surface by interlock mechanism.

The strength between enamel and brackets depends on many factors including bonds, type of enamel conditioners, acid concentrations and duration of etching and bonding agent (primer), bracket material, base design and oral environment (45).

1.4.7 Compomers

The poly acid –modified composite resin or compomers, are a single component systems consist of aluminosilicate glass in the presence of carboxyl modified resin monomers and light activated traditional resin monomers. Although alkaline glass and carboxyle components are packaged in the same container, purportedly reaction does not occur as acid base preparation because the water is absent from compostion (39).

This material is moisture sensitive and packed in moisture proof packages. The setting starts after activating of light (polymerization image) of acidic monomers to change to rigid materials.

The material group absorbs water from the saliva, allowing the delayed acid base reaction. This reaction releases fluorides and other remineralizing ions from aluminosilicate glass. Because of the absence of water in the formula, the material is not self-adhesive such as traditional glass ionomer or hybrid ionomer.

The bonding to the tooth surface is by mechanical interlock, acid etching and other surface treatments are required prior to bonding and the bonding surfaces must be dry (45).

1.4.8 Three-step adhesive (total etching system)

They require acid etching (enamel and dentin rinse and dry, and use a priming agent adhesive as steps to follow before putting composite).

Once the tissue are demineralization, primers must transform the hydrophilic dental surface into hydrophobic surface, so that the bonding of adhesive resin is achieved, to do this, agents contain monomers that can polymerized with the hydrophilic properties, dissolved in acetone, water and / or ethanol. These agents carry monomers through the etched tissue (50).

Adhesive systems containing volatile organic compounds such as ethanol and acetone on their ability to remove the remaining water. This makes it possible to penetrate microporosites induced by acid etching enamel, inside the open dentinal tube and through the nano-space in the collagen network of dentin . Thus, complete tissue infiltration can be achieved if such a tissue been previosuly watted water mainly by HEMA and Polyalkenoic acid.

The mechanism of action of these materials is based on the fact that water evaporates after application and the surface is air- dried , thus increasing thehydroxyethyle methacrylate concentration (HEMA). The principle of different volatilities of solvent and solute is very important. Water has a much higher steam pressure than HEMA. This allows keep them, as solvent, water, evaporates in the drying phase, the priming for the procedure ends with dispersion using air stream to remove the solvent leaving a shiny and homogeneous layer on the surface. In the third step, the bonding agent is applied, which will chemically correlate with hydrophobic. composite resin, then applied. One of the advantages of a three-step system is its ability to achieve the bond strength necessary for enamel and dentin. The main drawback is that the technique is very sensitive given the many clinical steps to follow fot their application, and the risk of over-wetting or over drying the dentin during rinsing and drying after the etching acid has been applied (51,52).

1.4.9 Two-step adhesive

The adhesion mechanism of these systems is the same as that of their three steps, but more sensitive technique this system require apply wet adhesive technique as a priming step does not occur. Independently. wet tissue should be kept in the dentin case to prevent the demineralizine collagen from collapse, thus prevents the infiltration of incomplete adhesive. However, it is very difficult for the doctor to reach the optimum degree of moisture, which is why the technique is a sensitive system (53).

The clinical techniqe of system is simplified, to some extent reduced the working time. Two procedures are described:. Frist, the primer and adhesive come together in one package and comes separately. The main drawback of this system is acid rinse with water and then dry. However, the dentin must remain wet after etching, which is difficult to standardize clinically given the lack of stability of the demineralized matrix (54).

The primer now has monomers acid etching agent, thus preparing dental tissues for adhesion.

The main advantage of this system is elimination of rinse phase also surface of the dentin is already ready to receive adhesive agent (53).

1.4.10 One Step All-in-One Adhesives

These systems combine three functions of acid etching, priming and adhesion in one stage. The main advantage is that they are easy to apply and they are no need to surface rinse, only drying is necessary for uniform spread product before polymerization (53).

Technology of adhesive system is simplified, making it possible to maintain acidic water monomers, organic solvents and water in one solution.

The components necessary to activate the process of dentin demineralize and running the system (54). Solvents such as acetone or alcohol are retained in solution, but once dispensed solvent evaporation begins this leads to separation phase with forming multiple drops and inhibition of oxygen. There is also a lower degree of conversion, which enhances the hydrolytic dig bond regeneration systems in restorative dentistry, affecting the ability of bonding in the adhesive interface (55, 56).

1.5 Orthodontic Bracket Design

1.5.1 Metal brackets

The first metal bracket of stainless steel have been milled and drawn on the cold and has perforated bases into which the adhesive can flow (57). Stainless steel brackets do not attach chemically with adhesive in the adhesive base but interface by mechanical interlocking (58).

The original metal pads contained only one row of holes along the outer margin of the inner surface was relatively large and smooth unable to contribute to its retention. This design was subsequently changed base to the network foil bracket, which produced the largest bond strength (59) and less accumulation of plaque (60). The top has been foiled into a solid metal support, this point named gobbets.

The adhesive is prone to breakage in areas adjacent to these sites. Maijer and Smith (1988) Suggested that gobbets lead to stress concentrations in adjacent resin, resulting in less bond strength (60).

1.5.2 Bracket base morphology

The formations of the orthodontic bracket base have been contemplated effect on the bond failure mode and have an effect on the enamel surface damage during removal of bracket. The base can provide mechanical retention. The most common for metal brackets, mesh welded to the base of the bracket to form the structure (61). Welded mesh of bracket base is not without disadvantages; clinically flexible pads, especially those fine network size. These easily deform and bend away from the teeth surface, resulting in soft injury and effect on the mechanical retention (59). On deboning the components of network-based brackets tend to separate, leaving mesh wire attached to the teeth (62). Mixed replace the solder as a technique to connect the foil mesh to the bracket base, and prevent network branches from being flattened during assembly. Brackets manufactured as separate components have weakness between bracket and base (63). The bond strength of the foil mesh brackets is affected by diameter of wire mesh, also number and size of opening per unit area. The free size available affects resin penetration, which also depends on the filler size (59). The microscope detects the air blanks in the adhesive / base interface, perhaps caused by polymerization shrinkage or by air intrapimentation during bracket placement. The effect of base of the bracket morphology and orthodontic bonding agent on adhesion strength that the adhesive had a significant impact on bond strength and that certain base designs may improve penetration or adhesive improved light penetration processing (64). The literature provides conflicting reports on the impact of using different designs have a retentive base bracket on shear bond strength. Shear bond strength test of two metal brackets, one with a single – mesh bracket base and the other with double - mesh bracket using Trans bond XT Adhesive St ©. The shear bond strengths for both test groups were similar and the adhesive Remnant Index (ARI) comparison indicated that both bracket types and similar bracket failure modes. These results indicated that single and double mesh bracket base have comparable shear bond strengths and bracket failure modes (19). Although the ceramic brackets offer better aesthetics, concerns have been raised as to an increased risk of enamel surface damage on debonding, although Wang et al. (1997) found no statistical difference in bonds strengths between ceramic and metal bracket. Enamel detachment was found only when there was chemically coated base on the ceramic bracket and consequently higher bond strengths. Some ceramic brackets use a silane coupler as a chemical mediator between the bracket base and the adhesive resin (65). Silane treatment of a smooth ceramic bracket base unites the silica component of bracket with the composite resin to produce a chemical bond (65).

Manufacturers sometimes apply textured to ceramic bracket, such as Transcead © 1000 (3Munitek). The bond strength is lower than silane but higher than stainless steel. And it has been suggested the material microcrystalline retentive of ceramic brackets provides stronger interlock opportunities between bracket and adhesive than does of metal foil (66). Comparison properties of metals and ceramic brackets concluded that the risk of enamel damage when deboning mechanically-ceramic bracket have maintained no greater risk when deboning metal bracket (67). The challenge is to develop a relationship between orthodontic attachments and enamel that are strong enough for survival treatment but can be broken for deboning without damage to the surface of enamel (19).

1.5.3 Adhesive pre-coated brackets

Fox et al. (1994) stressed the importance of standardization in bond strength testing. In order to unify the compound quantity on the braket base use for adhesive pre-coated brackets (APC) is to be employed in the present (68). Pre-coated composite used is a copy of the Transbond XT © (3M untik), modified to give increased viscosity. It can be used along with the Transponder © Plus Selfetching (TPsEP). The APC brackets are originally designed try to save chair time by allowing faster and easier bonding measures. Advantages for APC on traditional light activated systems are: quality and consistent quantity of cured light adhesive (69), easier cleaning up, reduce waste, improved infection control, improved inventory control. In addition improve control of both arch and paste with the use of APC is called to improve bond strength and thus reduce clinical failure rate. Feature of the light curing adhesives are they provide orthodontic with ample time to place the braket on the enamel surface thoroughly before polymerization. A disadvantage of the light-cured approach is the time it takes to expose bonded bracket to the light (70). Only a few studies have evaluated the bond strength of APC braket. Birnie et al. (1995) compared the shear bond strenght in vivo and vito of metallic APC brackets with that identical brackets bonded with Transbond © XT and found no statistically differences between the two (71). Sfondrini et al (2002) reported a much higher strength of bonds with non-APC-based braces, cured with a halogen light curing unit (70), a finding supported by the results of similar work (Bishara et al., 1997; Suna & Rock, 1999; Ash & 1996) (72, 73,74). Bishara et al. (1997) proposed that increased viscosity of the adhesive used on APC brackets, when compared with the retention mesh listed in the metal bracket base, may significantly reduce shear bond strength. According to this result, the manufacturer modified the adhesive used for pre-coateing (APC1 to APC2). It appears that the duration and intensity of light exposure is critical to the shear bond strenght of APC brackets (72). Birnie et al. (1995) used a long light-curing time (30 s) that suggested by the manufacturer (71). Sunna and Rock (1999) found that APC brackets cured for 40 seconds with a halogen unit had similar bond strenght to uncoated brackets bonded strenghts with Transbond XT when light-curing was increased from 20 to 40 seconds (73). IP and Rock (2004) reported that the use of plasma light granted time savings are worthwhile when interconnecting orthodontic braket, while producing bonds of equal strength to those found with quartz halogen lights (75). Reynolds (1975) suggested aclinically acceptable shear bond strenght to be in the order of 6-8MPa (59). Even light-curing for 20 seconds with the micro-xenon light produced clinically accptable bond strenghts of both uncoated nd pre-coated brackets. The reduced curing time achieved by means of the micro-xenon light represents a great advantage for both the pateint and the clinician (70).

1.6 Bond strength testing

Literature contains a large number of experental studyes on bond strenght test and results were quoted by manufacturers to support their products. Howerver, little attention has been paid to the details of the testing procedures used. Fox and Mc Cabe (1994) published a critique of bond strength testing in orthodontics, which revealed a great variation in the methods used (76). Van Noort et al. (1989) and Rueggeberg (1991) both suggested the need for standardization of test procedures for the measurement of bond strengths, to allow valid comparisons to be made between different bonding agents (77,78).

Hobson and McCabe (2002) investigated the relationship between enamel etch characteristics and resin-enamel bond strength. 28 patients had the buccal surfaces of teeth etched and replicated for examination under the scanning electron microscope. No statistical difference was found in etch patterns between upper and lower teeth. However mean bond strength varied significantly between different tooth types, with the lowest bond strength found on the upper first molar and the highest on the lower first molar (79). Shear bond strength with SEP has been compared with conventional two stage bonding systems in laboratory studies. Brackets bonded with the SEP were found to have a significantly lower mean shear bond strength compared with those bonded with a conventional two-stage adhesive system (Bishara et al., 2002; Aljubouri et al., 2003) (19) (80). However following the application of mechanical stress, the mean survival times for brackets bonded with either the SEP or the conventional two-stage bonding systems were similar (Aljibouri et al., 2003) (80).

1.7 Adhesive remnant system

Artun and Bergland were use adhesive residue indicator system (ARI) to assess the amount of adhesive left on the teeth after de-brackets.

The system was developed on the basis of a pilot study of 20 extracted teeth by using the following criterias: 0: No adhesive left on the tooth; 1: less than half of the left adhesive on the tooth; 2: more than half of the left adhesive on the tooth; 3: all adhesive left on the teeth with a clear impression of the arc mesh. Adhesine remnant index is important because it is an important factor to consider when choosing orthodontic adhesive (81).

2. MATERIALS AND METHODS

2.1 Power calculation

In our study, power analysis was performed to determine the number of samples. The sample size was found to be 14 for each group in the analysis of the power analysis performed with G * power 3.1 program and in the sample width analysis performed by taking 0.80 power value in 2 study groups (alpha error probability = 0.05). A total of 45 samples was included in this study and divided in to 3 groups each group 15 samples.

2.2 Specimens preparation:

Forty five teeth upper and lower premolar teeth, which extracted for orthodontic treatment were prepared and randomly separated into 3 groups each group contain 15 teeth. These teeth are extracted relatively frequently in severe crowding orthodontic cases, making them easy to obtain. All of the teeth were collected from the Orthodontic Department of Istanbul Yeni Yüzyil University, Dental Faculty. After extraction of the teeth, the teeth samples were placed in water which is distilled and thymol crystals to inhibit bacterial growth, Samples were placed within dark place at 37°C (fox et al, 1994) (76).

The criteria for teeth samples were as following:

- Labial surface of enamel is intact.
- All samples were place in distilled water immediately after extraction
- No caries, no crake, no any enamel defect.

All teeth examined by normal light conditions to assessment suitability of inclusion criteria. The root of each tooth samples were catted 1mm under the cement-enamel junction by use motorized circular saw with water for coolant, and then placed in distilled water to avoid dehydration. The crowns which catted were placed in self-curing orthodontic acrylic resin, the labial of catted crown placed parallel and projection supra to the border of the cylinder. Samples then placed in distilled water to avoid enamel dehydration.

2.3 Bracket selection

1- Smart clip (SL3) (3M unitek, Monrovia, California) brackets were used in the first group as the control group (Group 1).

2- Smart clip APC II flash-free adhesive bracket (SL3) (3M unitek, Monrovia, California) brackets were used in the second group as the first experimental group (Group 2).

3- Smart clip APC plus adhesive bracket (SL3) (3M unitek, Monrovia, California) brackets were used in the third group as the second experimental group (Group 3).

2.4 Enamel surface preparation and bracket placement

Preparation of enamel surface for bracket bonding was as the following direction:

1- The labial surfaces of enamel were polished by pumice slurry by using rubber cup for 10 seconds.

2- Washed by air/water sparing for 15 second then dehydrated by compressed air for 10 seconds.

3- All brackets were prepared from 3M unitek with same base.

4- The labial surface of control and first experimental groups were prepared by using traditional etching protocol.

5- The labial surfaces of second experimental were prepared by using Transbond plus self-etching primer (3M unitek) for 5 seconds, followed by a soft bust of dry air to thin the primer.

6- All adhesive resin polymerized by used an ortholux luminous curing (3M unitek) with instant of 1600 mm/cm for 6 seconds mesial and 6 seconds distal.

7- Bonded teeth were placed in distilled water at 37°C for 24 hour to allow polymerization of bonding material.

A- Group 1 – phosphoric acid etch, primer, Smart clip metal bracket

The labial surface of enamel was etched for 30 second with 37% ortho-phosphoric acid by using a brush, then the etching surface washed for 15 second with water and dried by oil-free compressed air until the etched enamel surface had a frosty appearance. Transbond XT primer (3M Unite, Monrovia, California) was applied to etched enamel surface followed by a stream of oil-free compressed air to ensure that thin layer of primer remained before light curing for 20 seconds. Transbond XT composite was applied on the base of smart clip bracket, then applied directly to the primed enamel surface and placed in ideal position (mesio-distal and occluso-gingival) with a consistent force. The excess adhesive was removed from around the bracket by right angle probe and bonding material polymerized by ortholux luminous curing for 6 seconds mesial and 6 seconds distal to the brackets.

B- Group 2 – phosphoric acid, primer, Smart clip APC II Flash-free adhesive bracket

The samples for Group 2 were prepared as for the Group 1. A premolar smart clip APC flash-free bracket, pre-coated with Trans bond XT was applied and bonded directly to the tooth surface.

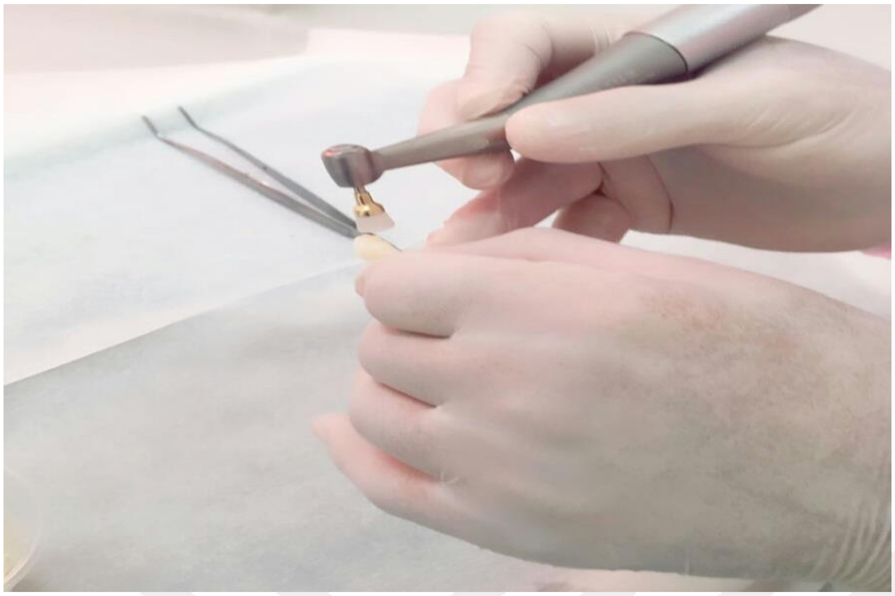

Figure 2.1: Polishing buccal surface of tooth.

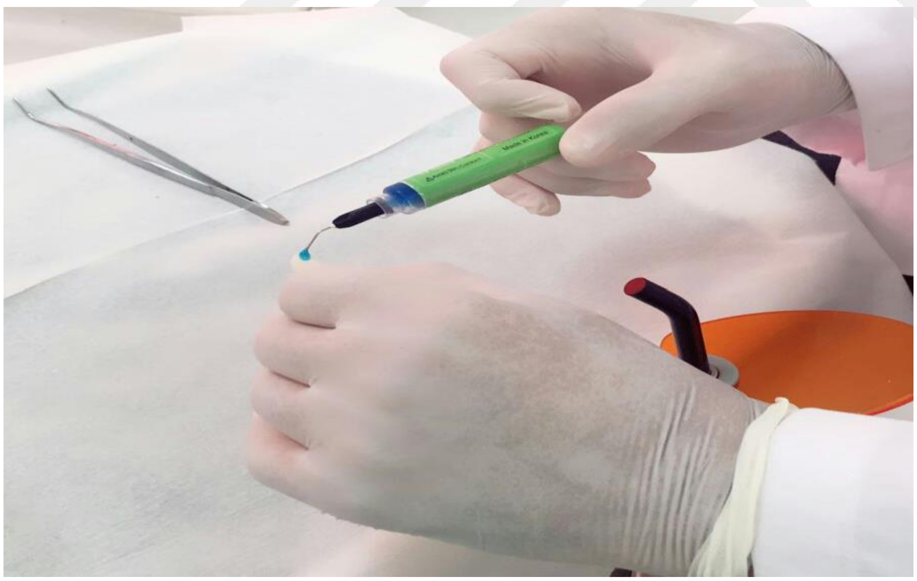

Figure 2.2: Etching of prepared tooth surfaces with 37% phosphoric acid.

Figure 2.3: Washing surface of tooth from acid and dry it.

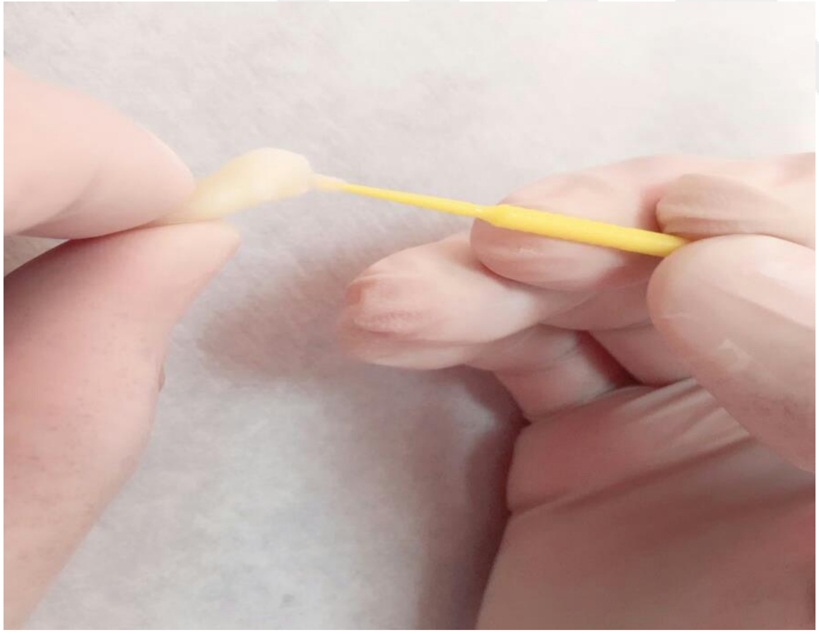

Figure 2.4: Apply Transbond XT primer on etched surface.

Figure 2.5: Curing primer for 20 secods.

Figure 2.6: Placing the bracket in ideal position after Transbond XT composite was applied on the bracket base and then excessise composite was removed.

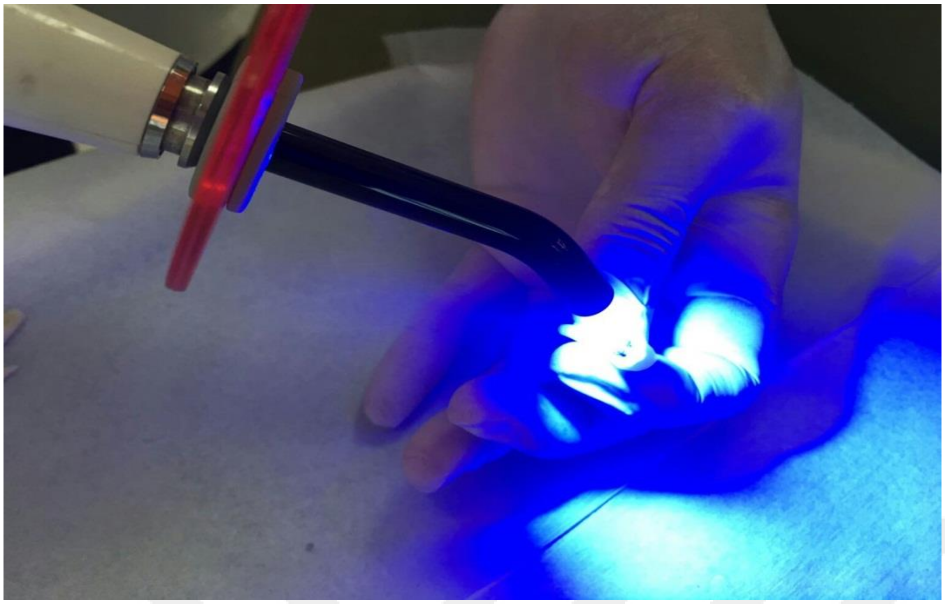

Figure 2.7: Polymerizing adhesive for 6 seconds mesial and 6 seconds distal of the brackets.

C- Group 3 – Self etching primer, Smart clip APC plus flash-free adhesive bracket

The labial surface of enamel was dried, Trans bond plus self-etching primer (SEP) (3M Unitek, Monrovia, California) was activated using thumb pressure against the sequenced punches in the dispending sheath, then SEP was applied to enamel surface by the use applicator brush provided. This was rubbed into enamel surface for 15 seconds with the micro brush. The stream of oil-free compressed air then used to disperse the solution into a thin film and allow evaporation of the carrier solvent, leaving a glossy enamel surface. A new sheath and applicator was used for each sample.

A premolar smart clip APC plus pre-coated with Trans bond XT adhesive was applied directly to the prepared enamel surface and placed in ideal position (mesio-distal and occluso-gingival).

Figure 2.8: Drying enamel surface of tooth.

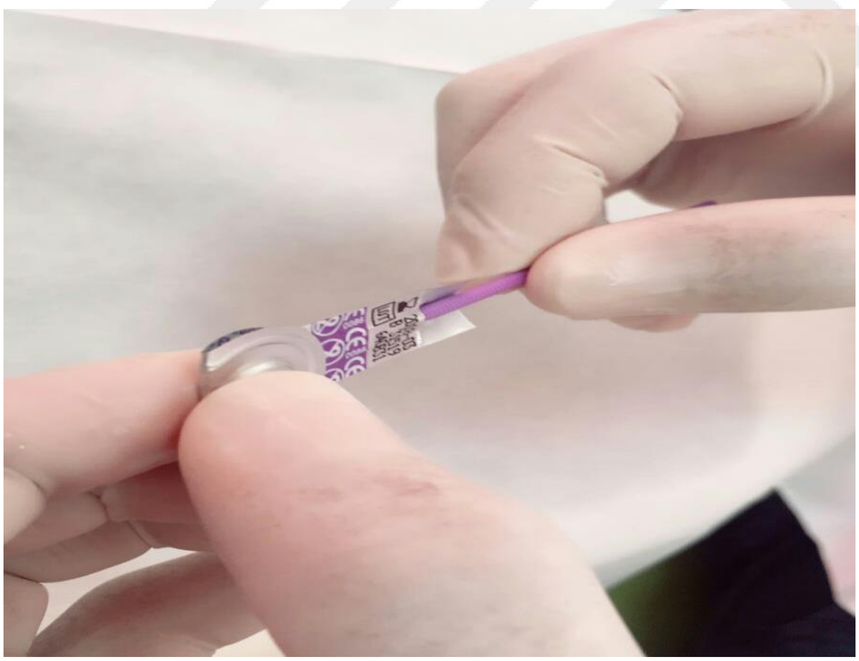

Figure 2.9: Trans bond plus self-etching primer activing by thumb pressure against the sequenced punches in the dispending sheath.

Figure 2.10: SEP was applied to enamel surface for 15 seconds.

Figure 2.11: Placing APC plus pre-coated bracket in ideal position.

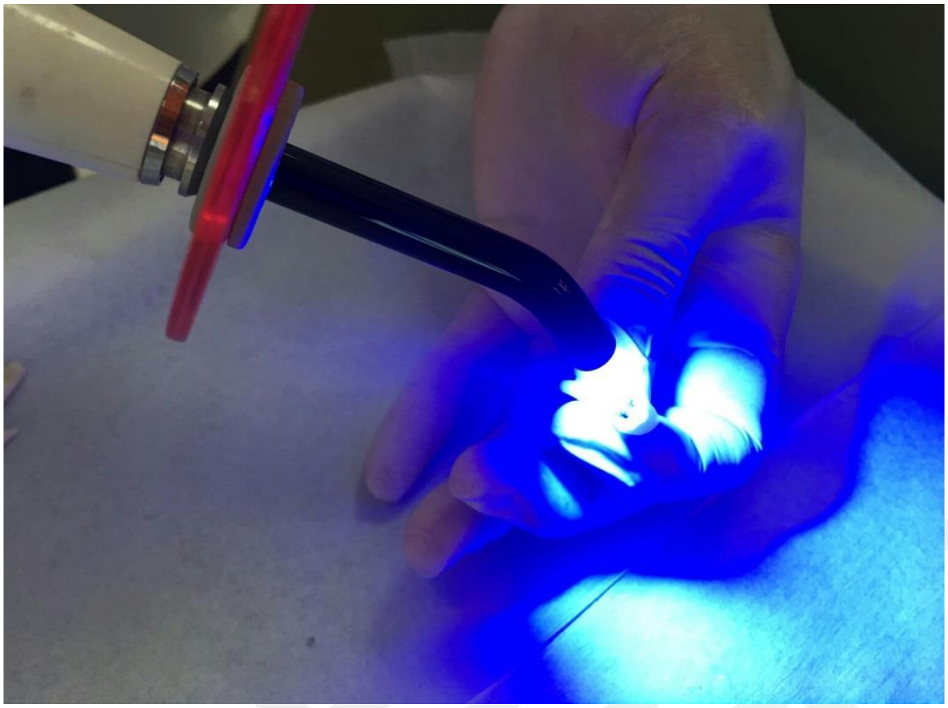

Figure 2.12: Polymerizing adhesive material of APC bracket for 6 second mesial and 6 seconds distal sides.

Table 2.1 Test groups

GROUP	DESIGNATED ETCH	PRIMER	ADHESIVE	BRACKET TYPE
1	Phosphoric acid (37%)	Trans bond XT	Trans bond XT	Smart clip SL3
2	Phosphoric acid (37%)	Trans bond XT	Trans bond XT	SL3 APC II
3	None	Trans bond SEP	Trans bond XT	SL3 APC PLUS

2.5 Measurement of bonding time

The bonding time calculated by a main observer by use a stopwatch. The time was calculated after the teeth were prepared and the brackets were placed in ideal position by the practitioner. Total time was calculated in seconds.

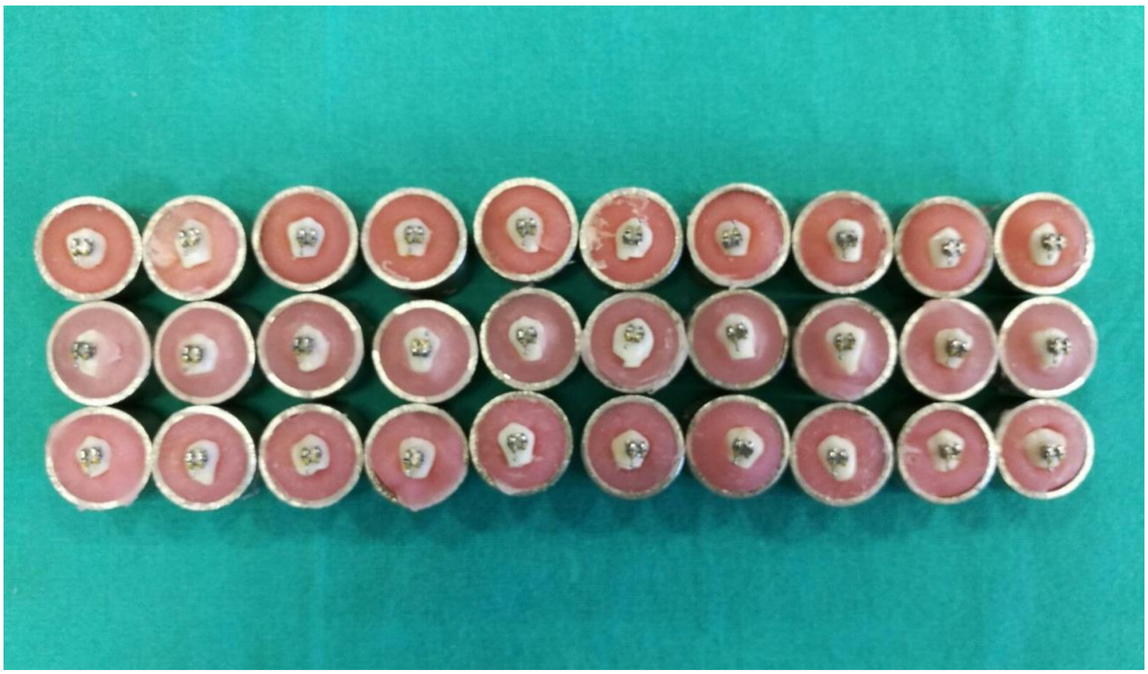

Figure 2.13: Mounting all specimens in acrylic resin.

2.6 Bond strength testing

Each brass cylinder with its embedded specimen was assembled in customized jig in the lower cross head of the Instron Universal testing machine (Model 3345, Instron Inc., Canton, Massachusetts, USA). The jig had a cylindrical hole (8 mm radius) into which each brass cylinder was fitted. The brass cylinder could be adjusted in both a rotational and in-out direction, enabling shear forces to be directed at right angles to the long axis of the bracket body. Specimens were mounted purposely to direct the applied force occluso - gingivally and parallel to the labial tooth surface. The blade was perpendicularly oriented to the bracket base and an occluso-gingival force was applied at a crosshead speed of 5mm/min. This distance was fixed for each specimen; an increase in distance from the tooth would increase the bond strength (Katona, 1997) (93). During testing procedures the Instron had a 2 KN load cell and cross-head speed of 1.0mm / min (Sunna and Rock, 1999) (73). Bespoke Merlin software electronically connected to the Instron machine recorded the results of the load applied at failure in Kg and Newton and this data was subsequently converted to MPa.

$$MPa = \frac{\text{Load (mass) (kg)}}{Bracket\ base\ area}\ X\ gravitational\ acceleration\ \ constant\ (9.81)$$

1 Kg = 9.81 N

1 MPa = N / mm2

The bracket base size for each bracket type was determined by taking the average sum of the widths and lengths of 10 brackets measured using digital calipers, accurate to 0.01 mm. It is impossible to apply a pure shear load to a bracket, due to an unavoidable inherent bending moment. The term ‘shear–peel’ is used in the literature to acknowledge this phenomenon (Katona, 1997) (93). In vivo, varied forces are exerted onto the brackets and stress distributions generated within the adhesive are complex (combination of shear, tensile and compressive force systems).

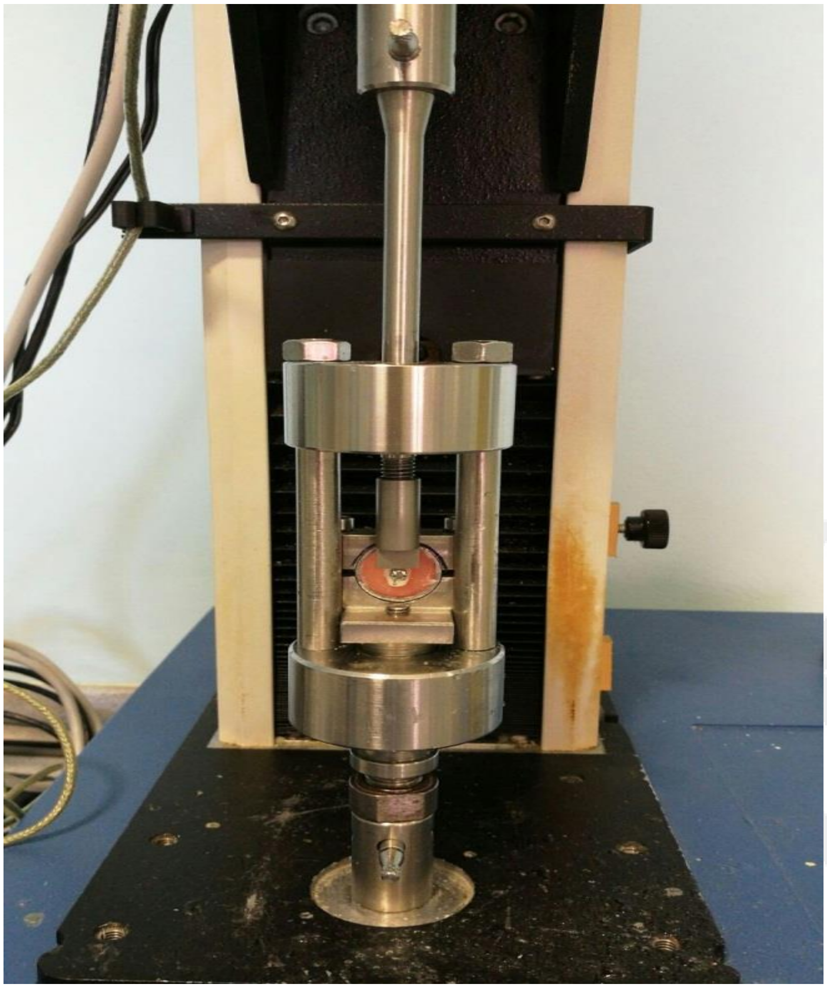

Figure 2.14: Testing the shear bond strength by universal testing machine.

2.7 Enamel surface examination after deboned

After deboning of tooth samples were finished, samples placed in de-ionized water within dark place at 10 ℃. The brackets and teeth surface were inspected by using a digital microscope under 8 × magnifications. Artun, and Bergland was evaluated the residual index on enamel and bracket by using modified ARI (table) (81). All samples were examined by this way.

Table 2.2 ARI (Artun and Bergland, 1984)

0	No adhesive left on the tooth
1	Less than half of the adhesive left on the tooth
2	More than half of the adhesive left on the tooth
3	All adhesive left on the tooth, with distinct impression of the bracket mesh

2.8 Statistical analysis

Statistical calculations were performed with SPSS (statistical package for the social sciences) (2008) statistical software program for windows. Independent t-test was used to assess for a statistically significant difference in mean values between test groups for bonding time, shear bond strength and residual adhesive. Equal variance t-test was performed during the evaluation qualitative data. Statistical significance level was established at $p<0.05$

Figure 2.15: Used materials.

Figure 2.16: Intact premolar teeth.

Figure 2.17: Instruments used during the preparation.

3. Results

The mean bonding time of smart clip group (40.1140) showed significant difference when compared with APC II flash free group (31.0560) and did not show significant difference with APC plus (39.5431) (p=0.000 and p=0.638 respectively). Tables 3.1, 3.2, 3.3 and figure 3.1.

Table 3.1: Mean bonding time (seconds) of the control and experimental groups.

Bonding Time	N	Mean	Std. Deviation	Std. Error Mean
Group 1	15	40.1140	3.42782	.88506
Group 2	15	31.0560	2.98323	.77027
Group 3	15	39.5433	3.12716	.80743

Table 3.2: Comparison of bonding time between groups one and two.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
BONGR1	Equal variances assumed	.931	.343	7.720	28	.000	9.0580	1.17330	6.65459	11.46141
	Equal variances not assumed			7.720	27.477	.000	9.0580	1.17330	6.65253	11.46347

Table 3.3: Comparison of bonding time between groups one and three.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
BONGR2	Equal variances assumed	.651	.427	.476	28	.638	.5707	1.19803	-1.88338	3.02472
	Equal variances not assumed			.476	27.767	.638	.5707	1.19803	-1.88431	3.02564

The mean shear bond strength of smart clip group had significantly higher mean shear bond strength value (11.2512), compared with APC II (9.42347) and APC plus (8.42867) groups (p=0.00 and p=0.00 respectively). Tables 3.4, 3.5, 3.6 and figure 3.2.

Table 3.4: Mean shear bond strengths (Newton) of the control and experimental groups.

SBS	N	Mean	Std. Deviation	Std. Error Mean
Group 1	15	11.25120	1.428943	.368952
Group 2	15	9.42347	1.019121	.263136
Group 3	15	8.42867	1.016503	.262460

Table 3.5 Comparison of shear bond strength between groups one and two (Newton).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
SHERGR1	Equal variances assumed	2.570	.120	4.033	28	.000	1.82773	.453173	.899450	2.756016
	Equal variances not assumed			4.033	25.315	.000	1.82773	.453173	.894994	2.760473

Table 3.6: Comparison of shear bond strength between groups one and three (Newton).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
SHERGR2	Equal variances assumed	2.414	.131	6.234	28	.000	2.82253	.452781	1.895054	3.750013
	Equal variances not assumed			6.234	25.280	.000	2.82253	.452781	1.890538	3.754529

The mean residual adhesive of smart clip group (1.73) did not show significant difference compared to APC II group (1.93) (p=0.558). The mean ARI of smart clip group was significantly greater than APC plus (0.87) group (p=0.033). Tables 3.7, 3.8, 3.9 and figure 3.3.

Table 3.7: Mean ARI (0-3) of the control and experimental groups.

ARI	N	Mean	Std. Deviation	Std. Error Mean
Group 1	15	1.73	.884	.228
Group 2	15	1.93	.961	.248
Group 3	15	.87	.640	.165

Table 3.8: Comparison of ARI between the groups one and two (0-3)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
RESGR1	Equal variances assumed	.502	.485	-.593	28	.558	-.20	.337	-.891	.491
	Equal variances not assumed			-.593	27.805	.558	-.20	.337	-.891	.491

Table 3.9: Comparison of ARI between groups one and three (0-3).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
RESGR2	Equal variances assumed	5.020	.033	3.076	28	.005	.87	.282	.290	1.444
	Equal variances not assumed			3.076	25.516	.005	.87	.282	.287	1.446

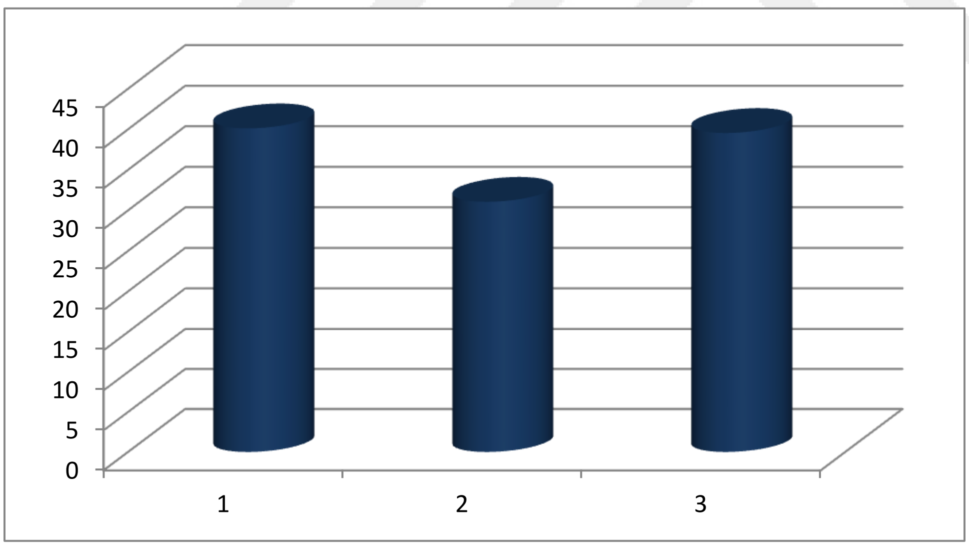

Figure 3.1: Bar-chart of bonding time in seconds between three study groups.

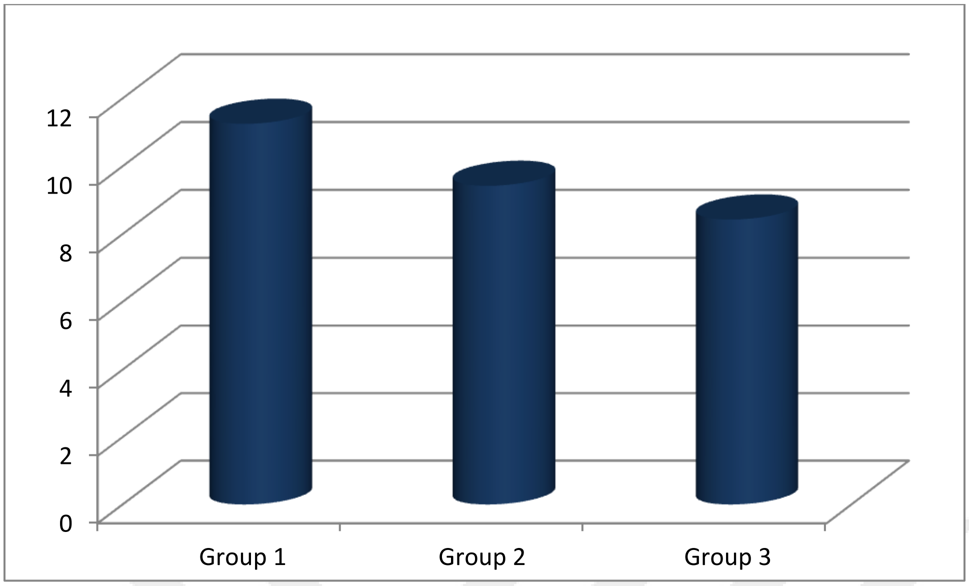

Figure 3.2 : Bar-chart of shear bond strength in MPa between three study groups.

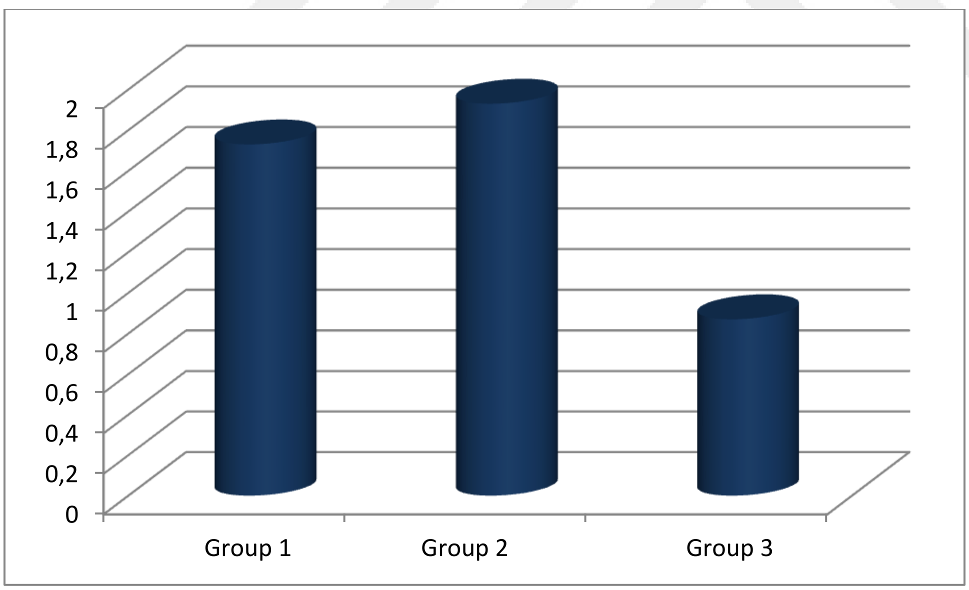

Figure 3.3: Bar-chart of ARI (0-3) between three study groups.

5. Discussion

Bond strength of orthodontic brackets has been studied extensively, with a wide range of data and publications. The ideal orthodontic bond should ensure that the bracket remains attached to the tooth surface for the duration of treatment, withstanding orthodontic and orthopedic forces. Moreover the attachment should be easily removed without damage to the tooth surface at the end of treatment (59).

A key point for minimizing bracket loss and achieving an optimal marginal integrity is the interface between the tooth surface and bracket base. Furthermore, the tighter the seal between the bracket-adhesive-enamel, the less micro leakage of plaque bacteria is possible with a reduction of demineralization and white spot lesions (82, 83).

The elimination of steps during the new bonding procedure minimizes the probability of contamination because the etchant and the sealant are applied simultaneously without an intermediary step of washing and drying the tooth between these two procedures. Furthermore, having the adhesive precoated to the bracket base reduces an additional step and also provides a uniform thickness of the adhesive layer between the bracket and the tooth surface. The clinician has to decide whether the time and steps saved during the bonding procedure as well as decreasing the chances of contamination balances the increased cost incurred when using the new bonding systems. To reduce chair time both for the patient and the practitioner, multiple innovations have been brought to the orthodontic community. With regard to the bonding process of conventional brackets, not only orthodontic adhesive and self-etching priming systems but also high-quality light-curing devices have to be mentioned (84).

For time saving purposes, not only the bonding procedure is interesting but also debonding and cleaning up remaining resin off the tooth surface is crucial for an efficient and optimum work flow. The more adhesive that remains on the base of the bracket, the less removal time is needed, and the procedure appears safer and easier (85,86).

The introduced flash-free adhesive system was significantly able to reduce the time that was needed to position the bracket.

The sites of failure within the bracket-adhesive enamel complex can occur within the bracket, between the bracket and the adhesive within the adhesive and between the tooth surface and the adhesive (87).

In our study, we aimed to evaluate and compare the shear bond strength and bonding time of flash-free metal orthodontic brackets. In this study using human teeth instead of artificial teeth, we have increased the variability of the bond strength; in addition the use of human teeth more closely approximates a clinical situation with respect to tooth architecture and morphology. Also the selection of teeth of similar sizes and shapes was performed before testing to decrease possible variations and errors. The extracted teeth should be stored on storage media until further processing; the storage medium maintenances the chemical, physical and mechanical properties of extracted teeth also avoid dehydration of tooth. Dehydration of tooth dentine does not appear to weaken strength and toughness of dentine, it tends to decrease flexibility and increase stiffness of dentine and affected on the outcomes of the results. The revision of the literature 1999 to 2002, indicated formaldehyde, ethanol, chloramine, freezing, water, distilled water, saline solution and thymol as the major storage media utilized for natural human teeth. In our study the storage media for extracted teeth was distilled water, which considered as one of the best storage medium capable of reassuring adequate results concerning to the enamel and dentine characteristics. Silva et al. (2006) compared the effect of the storage time and type of storage on bond strength of extracted tooth. They showed that extracted teeth stored in distilled water provided less variation in bond strength values (88).

The preparation of enamel surface requires polishing, then rinsing with air/water and dried with a steam of oil free compressed air. Kimura et al (2004) had reported that cleaning the tooth surfaces have a higher surface energy that is amenable to bonding (89). In our study, the labial surface of enamel was polished with no fluoride of pumice because fluoride on the surface can lower the surface energy of the adherent, decreasing the ability of the adhesive to spread.

Aasenden et al (1972) had reported that the fluoride deposits in hydroxyapatite to form fluor apatite might affect the bond strength (90). Also, Garcia-godoy et al (1991) had reported that the topical application of fluoride can interfere with etching effect of phosphoric acid on enamel surface resulting in reduced bond strength of dental resins (91).

In this study, we used two different etching protocols for enamel preparation. A conventional etching and primer technique to show the effect of etching protocol type on the bonding time and bond strength of brackets. The materials used for surface preparation and adhesive were Trans bond plus self-etching primer and Trans bond XT light cured adhesive and primer. All materials has been widely used in orthodontic clinics.

Bishara et al (2004) had reported that self-etching primer and adhesive systems provide significantly lower but clinically acceptable shear bond strength when compared with a conventional etching and primer technique bonding brackets with Trans bond XT adhesive paste (3M Unitek, Monrovia, Calif) (92).

In our study we selected a new type of bracket (flash-free precoated bracket) to evaluate bonding time and bond strength and compared this with conventional one if the result of shear bond strength clinically acceptable mean we can use the main advantage of this bracket in the clinic (reduce bonding steps).

All adhesive resin polymerized by using an ortholux luminous curing system (3M unitek) with instant of 1600 mm/cm for 6 seconds mesial and 6 seconds distal sides of the brackets. The ortholux luminous light with a combination of high intensity LED lamp and 8 mm light guide optimized for orthodontic bonding and efficient curing time.

An important method used to measure the shear bond strengths of different orthodontic brackets which were bonded to extracted teeth, is the compressive fracture resistance test by universal testing machine. There are advantages and disadvantages to such testing and its relevance to clinical practice is questionable. In vitro shear bond strength testing does not exactly replicate the clinical situation; however, it does give an indication of potential or anticipated bond strength in vivo. In reality, potential loading would be complex with the following acting as stresses on the enamel-adhesive and adhesive-bracket interfaces: Multi-directional loading during function such as eating and stress introduced by application of orthodontic force, (ligature of an arch wire).

Recommendation for standardization of bond strength testing was introduced by Fox et al (1994). However the following problem would arise an in vitro investigation: Enamel surface structures of extracted teeth may differ from in vivo due to desiccation during storage and bracket removal by using shear force only (68).

In our study, the mounted specimen were placed inside an adjustable vice for shear bond strength (SBS) testing in push pull instron Universal testing machine. Test was accomplished by using a chisel edge mounted on crosshead of the testing machine. Each tooth was orientated such that the chisel was parallel to the bracket base and equidistant to both incisal tie-wings. The chisel-type working tip was positioned in the occluso-gingival direction in contact with the bracket-enamel junction, producing a shear force at the bracket-tooth interface until the bracket deboned.

In our study, the speed of the cross head was set at 1 mm/min, load was determined using 2 KN load cell and recorded by the attached computer. The same de-bonding procedure was performed for all of the study samples.

Axial loading that we did in our study may represent occlusal forces with the point of application at the same distance from the bracket/ resin interface in all cases, helping to make the method of testing more reproducible. Katone et al (1997) reported that increase in distance from cross head of the instron universal testing machine to occlusal tie wing of bracket would increase the bond strength (93).

Instron Universal machine was used for measuring shear bond strength since it is accurate and widespread. This machine is capable of delivering a controlled and measured force to the bonded bracket via its moving crosshead. As was suggested, testing to failure in shear was quoted in Newtons and converted to MPa by dividing the value in Newton by the surface area of the bracket base.

SBS should be within an optimum range between 5.8 MPa-13.5 MPa to be supposedly “clinically acceptable” as recommended by Rossouw (Rossouw, 2010) about 10 MPa as mean value (94).

In our study after de-bonding, the teeth and brackets were examined under 8 magnifications to evaluate the amount of resin remaining on the tooth.

Bracket failure at either of the two interfaces, bracket-adhesive interface or enamel-adhesive interface, has its own advantages and disadvantages (Bishara et al., 2007) (95). Failure at the bracket adhesive interface is advantageous as it indicates good adhesion to the enamel and is safer to deboned (Berk et al., 2008) (96). However, considerable chair time (Khoroushi et al., 2007) (97) is needed to remove the residual adhesive, with the added possibility of damaging the enamel surface during the cleaning process (Justus et al., 2010) (98). Also more enamel loss during cleaning is reported (Bishara et al., 2000)(99). In contrast, when failure occurs at the enamel-adhesive interface, less residual adhesive remains on the enamel and less chair-side time is needed for cleaning. However failure at this interface may cause enamel fracture while de-bonding (Berk et al., 2008) (96).

Before performing mechanical tests, specimens have to be embedded in self-polymerizing acrylic resin; stainless steel cylinder can be used as model for resin. The teeth have been embedded in acrylic resin blocks to simulate cortical bone, the cemento-enamel junction of teeth should be situated approximately 2 mm above the level acrylic resin to simulate bone crest.

In our study, the bonding time of control group showed significant difference when compared with first experimental group and did not show significant difference compared to second experimental group.

The bonding time of our study was comparable to bonding time reported by Moon young leea, Georgios Kanavakis 2006, when compare bonding time of bonding of manual Trans bond XT adhesive and flash free clarity advanced ceramic bracket. (100).

The bonding time of the APC flash free group was faster compared with the other two groups. The results of the study indicate that the total time saved per tooth using the APC flash free bracket was 9.058 seconds, totally 135.87 seconds when bonding 15 teeth. Having adhesive precoated to the bracket base reduce an additional step.

Moritz Foersch et al in 2016 analyze the clinical and laboratory properties of APC flash free orthodontic adhesive, was significantly reduced the time needed for the bonding process due to less excess resin material for the flash free group (101).

In our study, SBS of manual Trans bond XT adhesive group was significantly greater than that of other two groups.

Mean shear bond strength varied between test groups. In ascending order, the lowest mean shear bond strength was 8.428 Mpa for group 3, APC plus brackets bonded with SEP. The second lowest mean bond strength was 9.42347 Mpa for group 2 APC II flash free bracket with etch and primer. Trans bond bracket bonded with etch and primer had the highest mean bond strength of 11.2512 Mpa.

The bond strength of three study groups ranged between 8 and 11 Mpa which is sufficient for orthodontic purposes.

The bond strength of first group was less than bond strength reported by Reddy et al in 2013 (102) but comparable with bond strength reported by Zielinski et al (2014) (103).

Light microscopy, under x 8 magnification, was used to examine enamel surfaces. ARI scores provided a qualitative assessment of the tooth surface after debonding. Alternative methods include quantitative analysis using a miniaturized Boley gauge (Brown and Way, 1978) (104), scanning ruby laser digitizer (Quick et al., 1992) (105), non-contacting laser probe (Al Shamsi et al., 2007) (106) or a 3D laser profilometer (Lee and Lim, 2008) (107).

In this study the greatest number of ARI score 1 occurred in all study groups, indicated that less than half of adhesive remain on tooth surface. In clinical terms, less adhesive following debond decrease the amount of chair time need for remove it. However it might but increase the risk of enamel surface damage due to enamel fracture on bracket removal. On the other hand, use of tungsten carbide burs for adhesive removal lead to enamel damage.

In our study the mean residual adhesive of manual adhesive group (1.73) did not show significant difference compared to APC II group (1.93) (p=558). The mean ARI of smart clip group had significantly greater mean ARI value (1.73) when compared with APC plus (0.87) (p=0.033). Overall, the mode of bracket failure among the three groups was favorable with a reduced risk of enamel fracture during the bonding procedure.

Grünheid et al had reported that a significant difference between the ARI scores of conventional and flash-free adhesive (108).

Clinicians should remember that this was an in vitro study and the results are not necessarily as those that would be obtained in the oral environmental. In addition, more research is needed to determine the shear bond strength of this new integrated system over a longer time period as well as after thermo cycling.

Future studies could use dyes to help quantify the adhesive around the bracket base and clinically measure and evaluate decalcifications or white spot lesions around brackets bonded with the flash free system.

5. Conclusions

1. The results of the present investigation showed that APC flash-free brackets had shear bond strength clinically acceptable.
2. Reducing the number of steps during bonding, clinicians can save time as well as reduce the potential for error and contamination during the bonding procedure, no need to clean up excess adhesive with APC flash-free bracket system able to decrease the time of bonding.
3. The lower ARI scores (more adhesive remaining on the bracket) appear to be favorable to save chair time during debonding but increase the risk of enamel surface damage due to enamel fracture on bracket removal.

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