A COMPARISON OF THE ENAMEL DEMINERALIZATION INHIBITION AND SHEAR BOND STRENGTH OF TWO ORTHODONTIC RESINS

by

JAMES HENRY ALLEN

JOHN O. BURGESS, COMMITTEE CHAIR
ANDRE’ FERREIRA
P. LIONEL SADOWSKY

A THESIS

Submitted to the graduate faculty of the University of Alabama at Birmingham, in partial fulfillment of the requirements for the degree of Master of Science

BIRMINGHAM, ALABAMA

2009
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JAMES HENRY ALLEN

DENTISTRY

ABSTRACT

White spot lesions (WSLs) left on the teeth after orthodontic treatment are a huge compromise to the esthetic outcome of a treated case. Patient compliance with oral hygiene instruction is often low and thus WSLs occur in a large proportion of finished cases. Amorphous calcium phosphate (ACP) has recently emerged as a viable alternative to fluoride therapy in preventing enamel demineralization by promoting remineralization. ACP has been added as filler in an orthodontic bracket adhesive with the expectation of preventing WSLs in poorly compliant patients. The purpose of this study was to compare the enamel demineralization inhibition and shear bond strength of an ACP filled orthodontic bracket adhesive and a conventional adhesive.

Ninety previously extracted human 3rd molar teeth were divided into three groups of thirty. Within each group, half the teeth were bonded with brackets using the ACP filled adhesive and the other half were bonded with brackets using the conventional adhesive. After creating a 2mm window around the bracket, Group 1 was submerged in an acidic gel for ten days. Demineralization depth and shear bond strength were recorded. Groups 2 and 3 were stored in distilled water for ten days and 24 hours respectively after which the brackets were fractured and the shear bond strengths were recorded. The study found that teeth bonded with the ACP filled adhesive had a 29.8% reduction in demineralization depth when compared to the conventional adhesive. The average shear bond strength of the ACP filled adhesive (5.5 MPa) was significantly less
than the conventional adhesive (18.5 MPa) in all three treatment groups. In conclusion, there was significantly less demineralization with the ACP filled adhesive but the low bond strengths greatly increase the risk of clinical bond failures.

Keywords: WHITE SPOT LESIONS, AMORPHOUS CALCIUM PHOSPHATE, ORTHODONTICS, SHEAR BOND STRENGTH, ESTHETICS
ACKNOWLEDGMENTS

I would like to thank Dr. John Burgess, Dr. Lionel Sadowsky, Dr. Andre Ferreira, and Ms. Sandre McNeal for their guidance during the thesis process. I would like to thank 3M Unitek for supplying the brackets and Bosworth Company for providing the Aegis Ortho used in the study. A special thanks to Dr. Deniz Cakir, Preston Beck, and Ian Mugisa for all their help in the lab during the project. Finally, I would like to thank my fellow 3rd year residents for all of your support and friendship. Although I am looking forward to graduating, I will miss our time together immensely.
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LITERATURE REVIEW

White Spot Lesions and Orthodontics

The traditional goals of orthodontic treatment have always been function, esthetics, stability and longevity, but not necessarily in that order. In our society, great emphasis is placed on appearance. Orthodontists play a significant role in assisting patients in achieving their esthetic goals. An attractive appearance gives individuals an advantage in life.¹ This is important in our ever increasing competitive world where first impressions are all important. Tooth shape, tooth proportionality, gingival heights, incisal edge relationships, smile arc and buccal corridors are some of the smile components that create optimal esthetics.² Discolorations on the tooth surface known as “white spot lesions” detract from the optimal esthetic goals of treatment outcomes. White spot lesions have a white frosty appearance that often appear in the shape of a ring circling the position the bracket occupied on the tooth during orthodontic treatment. As the demineralization producing these lesions occurs slowly, white spots lesions are often not noticed by the patient until the orthodontic appliances have been removed from their teeth. These white marks left behind on the teeth compromise the esthetic expectations of both the orthodontist and more importantly the patient.
White spot lesions (WSLs) have been defined as a subsurface enamel porosity from carious demineralization that presents as a milky white opacity when located on smooth surfaces. Since enamel translucency is directly related to its mineral content, the optical properties of demineralized enamel are different from adjacent sound enamel. The porous enamel scatters light differently and clinically results in a frosty white appearance. White spot lesions occur frequently and can be found in 50% to 96% of orthodontic patients compared to 11% to 24% of untreated controls. WSLs are more often seen on maxillary lateral, mandibular canine and premolar, and first molar teeth and are often found on the gingival aspect of the bracket and under loose fitting bands where oral hygiene is more difficult. In a scanning microscope study, Gwinnett and Ceen showed that bacterial accumulation was greatest at the resin/enamel interface and the most important factor in plaque accumulation was the surface area of composite resin exposed. Gwinnett and Ceen stated that normal wear of the resin matrix constantly exposes filler particles which contribute to a persistently roughened surface, and this predisposes the resin surface to a rapid attachment and growth of oral microorganisms. Lim et al. studied bacterial adhesion to various orthodontic raw materials and reported that bacteria adhered most to orthodontic adhesives because the roughened surface provides protective niches for bacterial colonization. Another scanning microscope study revealed that bacterial accumulation was constantly detected in a ten micrometer gap at the resin enamel interface due to the polymerization shrinkage of the composite. Auxiliaries such as Class II correctors, power chains, underlaces, o-ties and intrusion arches can also increase the number of potential plaque harboring areas. Studies have shown that fixed orthodontic appliances not only induce a rapid increase in the volume of
dental plaque, but such plaque has a lower pH than that in non-orthodontic patients. There is a rapid shift in the composition of the bacterial flora of the plaque following the introduction of orthodontic appliances with an increase in the amount of *Streptococci mutans*. A rigorous oral hygiene regimen is needed to overcome this new environment challenge. Most orthodontic offices take great care in instructing the patient on proper oral hygiene home care. This usually consists of proper brushing and flossing techniques and frequencies along with the use of a fluoride toothpaste and mouth rinse. Often an anti-cariogenic diet is recommended to reduce the intake of fermentable carbohydrates. Despite these efforts, patient compliance remains an issue. Weinstein et al. studied 70 dental patients with a high plaque index and instructed them in proper oral hygiene procedures. At 24 weeks only 13 percent had reduced plaque levels compared to their starting values. If patient compliance is poor, the accumulation of plaque soon triggers the demineralization process which ultimately results in WSLs.

Enamel is the most highly mineralized and hardest substance in the body. The primary mineral component is hydroxyapatite (HAP) which is a crystalline calcium phosphate with the formula $\text{Ca}_{10}(\text{PO}_4)_{6}(\text{OH})_2$. Naturally, enamel is in a constant flux of demineralization and remineralization depending on the pH of the oral environment. Bacterial plaque accumulating around orthodontic appliances metabolize fermentable carbohydrates and produce lactic acid that lowers the pH of the local environment. Arneberg and coworkers showed that the plaque pH in orthodontic patients following a sucrose challenge could fall as low as 4 in the upper incisor region. When the pH dips below the critical pH (5.5) of the enamel, calcium and phosphate ions dissolve out the enamel and flow into the plaque fluid and saliva. This demineralization occurs until the
plaque fluid becomes saturated with respect to calcium and phosphate. If this frequently occurs, the demineralization/remineralization balance is interrupted and net demineralization is seen. Demineralization can occur and become clinically evident within four weeks after appliance placement which is typically the length of time between orthodontic appointments.\textsuperscript{15} White spot lesions development is considered an iatrogenic effect of fixed orthodontic treatment and can be subject to litigation. Recognizing and documenting poor oral hygiene before irreversible changes occur and instituting an effective remedy, which may very well result in termination of treatment, is the orthodontist’s responsibility. Continuing treatment under unfavorable conditions, such as poor oral hygiene, can leave oneself open to charges of supervised neglect.\textsuperscript{16} Orthodontists, therefore, must monitor and take the responsibility of WSL prevention.

Compliance Dependant Based Modalities for White Spot Lesion Prevention

\textit{Manual Products}

Proper patient education is the first step in preventing enamel demineralization. The patient must understand that daily plaque removal is required to control WSLs. The easiest and least expensive method of plaque removal is mechanical debridement with toothbrushes and dental floss. Patients must be trained in proper brushing and flossing techniques. Patients may be spending adequate time, yet still achieving unsatisfactory results with poor oral hygiene technique. Electric toothbrushes can be utilized and have been shown to help patients become more proficient at removing plaque.\textsuperscript{17} Sharma and
Barnes have shown that water jets are an effective adjunct to toothbrushes and result in better plaque removal in orthodontic patients.\textsuperscript{18,19}

\textit{Fluoride Products}

In addition to mechanical plaque removal, there are products available which require patient compliance that can be recommended for home use such as fluoride dentifrice and fluoride mouthwash. Fluoride is effective in preventing dental caries. Addition of fluoride to the public water system was one of the great public health successes of the 20\textsuperscript{th} century and is considered the single most effective public health measure for preventing tooth decay. Fluoride incorporates into the surface enamel to form fluoroapatite which makes the enamel less soluble and more resistant to acid attack. Sodium fluoride, sodium monofluorophosphate, stannous fluoride, amine fluoride or acidulated phosphate fluoride are the different forms of fluoride that are incorporated into the topical fluoride products. It is not recommended that the fluoride concentration be below 0.1\% for orthodontic patients.\textsuperscript{20} Antiplaque fluoridated dentifrice has been shown to be more effective than fluoride only dentifrice at preventing demineralization around appliances bonded with composite material.\textsuperscript{21} O’Rielly and Featherstone\textsuperscript{22} found that fluoride dentifrices alone were not able to stop enamel demineralization in non-compliant orthodontic patients. Arneberg et al.\textsuperscript{14} discovered that the plaque pH and plaque fluoride levels are proportional in orthodontic patients with the fluoride reservoir quickly becoming depleted at low pH. Thus the fluoride effect is limited when the pH drops below 4.5 and the solubility product of fluoroapatite is exceeded. A systematic review of the literature by Chadwick\textsuperscript{6} concluded that the use of topical fluorides in addition to
fluoride toothpaste should reduce the incidence of decalcification in orthodontic patients. Another systematic review of the literature from the Cochrane Clinical Trials Register (Jan 2004), MEDLINE (1966 to December 2004), and EMBASE (1974 to December 2004) concluded that there is little evidence as to which method or combination of methods is most effective to deliver fluoride and recommended the best practice for orthodontic patients is daily rinsing with 0.05% sodium fluoride mouth rinse. However, Geiger and coworkers showed that less than 15% of patients rinsed with fluoride mouth rinse as they were instructed.

*ADA Foundation Amorphous Calcium Phosphate (ACP)*

Although fluoride has been the mainstay in caries prevention, calcium phosphates provide an alternate approach to preventing enamel demineralization by promoting remineralization. Calcium phosphates have a significant medical and dental history since they are components of normal hard tissues such as enamel, dentin and bone and are therefore very biocompatible. In 1920 Albee reported that a ‘triple calcium phosphate’ compound used in a bony defect promoted new bone formation. In 1963, Posner was credited with first discovering a precipitate that formed an amorphous pattern in his laboratory when trying to make apatite. A year later, investigators under the direction of Posner first reported amorphous calcium phosphate (ACP) as a component of human hard tissues. ACP is one of many calcium phosphates and has gained attention in dental research. ACP, because of its high solubility and rapid conversion to HAP in aqueous environments, possesses characteristics suitable for enamel remineralization. The American Dental Association Foundation’s Paffenbarger Research Center (PRC) is
leading many research efforts in developing ACP and licensing it for commercial use. The PRC’s formulation of ACP has demonstrated remineralized enamel lesions. The first product on the market utilizing this technology was Enamelon toothpaste which was introduced in 1999. It consisted of a dual compartment container where calcium and phosphate were kept separated until squeezed out of the tube at which time they reacted to form ACP which precipitated onto the tooth surface. Currently this technology has been added to several products such as toothpastes and whitening agents. Unfortunately these products require patient compliance. Since the PRC’s ACP is highly soluble, it quickly washes away and must be frequently reapplied to provide benefit. This low substantivity has lead to the development of other technologies with the aim of providing a delivery vehicle that will provide a sustained release of ACP to the tooth.

**CPP-ACP (Recaldent)**

Recaldent (Bonlac Bioscience International Pty Ltd, Melbourne, Australia) is a technology that uses casein phosphopeptides (CPP), a milk protein, to stabilize ACP in solution. The multiple phosphoseryl residues of CPP bind to forming nanoclusters of ACP, preventing growth to the critical size requiring phase transformations to HAP. Casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) is incorporated into supragingival dental plaque by binding onto the surfaces of bacteria cells and the intercellular plaque matrix causing significant increases in plaque levels of calcium and phosphate. This increased level of calcium and phosphate helps maintain a supersaturated enamel interphase with the tooth surface depressing enamel demineralization and enhancing enamel remineralization. CPP-ACP solutions, when
applied to molar teeth of rats, reduced caries by 55% compared to controls. In a human in situ enamel demineralization study, a 1.0% CPP-ACP solution used twice daily produced a 51% reduction in enamel mineral loss. The addition CPP-ACP to sugar free chewing gums, resulted in a dose related increase in enamel remineralization. At the high end, 56.4mg of CPP-ACP produced a 152% increase in enamel remineralization relative to the control gum. A chewing gum and mouthrinse study demonstrated that CPP-ACP increased plaque levels of calcium and phosphate and that significant levels remained 3 hours after application. Although CPP-ACP has demonstrated substantivity and positive results with respect to enamel remineralization, patient compliance remains an issue in the success of these products.

Non-Compliant Modalities for White Spot Lesion Prevention

Fluoride Products

There are several modalities available to help protect the patient from white spot lesions that require much less patient compliance. These products come in the form of topical applications applied by the dental professional or adhesive materials used to bond orthodontic appliances. Fluoride varnish can be applied by the orthodontist and results in prolonged contact and subsequent release of fluoride to the tooth structure. Ogaard et al. showed a 48% reduction in the depth of naturally occuring enamel lesions treated with the fluoride varnish Duraphat (Colgate Oral Pharmaceuticals Inc., Canton, MA). Todd et al. reported 50% less enamel demineralization with a single application of Duraflor (Pharmascience Inc., Montreal Canada) to teeth bonded with orthodontic
appliances. Demito showed that two applications of Duraflor promoted a 38% reduction in the mean lesion depth adjacent to orthodontic brackets. Although varnishes are effective in reducing demineralization, they require repeated applications and discolor teeth which is often objectionable to the patient. A prospective trial comparing a fluoride releasing sealant (Reliance M5 Protection Plus) with a control showed no significant difference in the amount of enamel demineralization. Another fluoride releasing sealant (ProSeal; Reliance Orthodontic Products, Itasca, IL) released fluoride ions for 17 weeks in an in vitro study. In addition, it had the ability to be recharged with topical applications of acidulated phosphate fluoride. An in-vitro study conducted by Hu and Featherstone demonstrated that enamel demineralization was significantly less in teeth treated with ProSeal than in teeth treated with fluoride varnish or unfilled sealants. A more recent study showed that ProSeal reduced enamel demineralization by 92% over untreated controls and provided significantly more protection than a fluoride varnish or unfilled sealant. Although ProSeal has been shown to protect against WSLs, the resin has to be removed with a bur when orthodontic appliances are removed and resin tags remain in the enamel which can cause unesthetic staining and compromise future whitening results.

Glass ionomer cements (GIC) release fluoride and have been used as orthodontic adhesives for their demineralization preventative affects. Although GICs provide a fluoride reservoir capable of sustained release with the ability to be recharged with fluoride, their lower bond strength compared to composite resins produced more clinical debonds which limited their popularity. To improve the physical characteristics of GICs, light-activated resins were incorporated into the mix to give it added strength.
Resin-modified glass ionomer cements (RMGI) have improved bond strengths while providing the fluoride release of GICs, and thus are more widely used as orthodontic adhesives.\textsuperscript{42,43,44} Gorton et al. \textsuperscript{45} conducted an \textit{in vivo} study comparing the demineralization around orthodontic brackets bonded with a RMGI with the demineralization around brackets bonded with a conventional composite resin. Subjects in the study also used a fluoridated toothpaste. The conclusion reached after a 4 week period was that the RMGI significantly reduced the prevalence and severity of enamel demineralization. Sudjalim et al. \textsuperscript{46} bonded twenty extracted human 3\textsuperscript{rd} molar teeth with a RMGI and twenty extracted human 3\textsuperscript{rd} molar teeth with a light-cured resin control. Each group was subjected to topical applications of either CPP-ACP (TM with Recaldent), NaF 9000 ppm gel, or a combination of CPP-ACP and NaF gel. The test specimens were immersed in a demineralizing solution for 96 hours and removed for additional topical treatments every 4 hours. Sudjalim concluded that the use of RMGI would significantly reduce the development of enamel demineralization. Further, he found that the topical application of both the CPP-ACP and NaF in combination with the RMGIC provided the most protection against enamel demineralization and recommended this protocol for at risk orthodontic patients.

Fluoride releasing composite resins and compomers, a hybrid of glass ionomer and composite resin, have the ability to prevent enamel decalcification. In a \textit{in-vivo} study, Millet et al. \textsuperscript{47} reported that 20\% of fluoride releasing compomer bonded teeth were affected by decalcification while 26\% of control teeth were affected. Sonis et al. \textsuperscript{48} demonstrated in a prospective clinical trial no decalcification on teeth bonded with a fluoride releasing composite resin while the 12.6\% of the control teeth experienced
decalcifications. Similarly, Underwood et al.\textsuperscript{49} following a split mouth clinical study concluded that an experimental fluoride-exchanging resin held promise as a clinically useful orthodontic adhesive as it demonstrated significantly less demineralization compared with a control. Conversely, a systematic review by Derks et al.\textsuperscript{50} reported that fluoride-releasing bonding materials have no significant effect in the preventing WSL demineralizations.

\textit{Development of ACP Filled Composites}

Amorphous calcium phosphate has been incorporated as fillers into dental resin-based resorative materials to take advantage of its ability to remineralize dental hard tissues. ACP has been marketed as a “smart” material because it has been shown to release higher levels of calcium and phosphate under acidic conditions.\textsuperscript{51,52} However, ACPs high solubility weakens the resin in which it is filled due to the voids left behind after the ACP leaches out of the polymer matrix.\textsuperscript{53} Mechanical properties were improved by introducing glass-forming elements during the preparation of the ACP filler which permitted a stronger interaction with the surrounding resin matrix. These modified ACP fillers not only improved the mechanical properties, they also produced a more sustained release of calcium and phosphate at levels required for HAP formation.\textsuperscript{54,55} Artificial lesions created on bovine incisors recovered 38\% of lost mineral when covered with an ACP-containing composite.\textsuperscript{26} Langhorst et al.\textsuperscript{56} created artificial enamel lesions by submersing teeth for 72 hours in a 4 pH demineralizing solution at 37\degree C. The teeth were then cycled through a demineralization and remineralization scheme for 1 month.
Quantitative digital image analysis of matched areas from contact microradiographs taken before and after treatment indicated higher mineral recovery with ACP composites compared to a commercial orthodontic F-releasing cement (14.4% vs. 4.3%, respectively), while the control specimens showed an average of 55.4% further demineralization. Park et al. 57 demonstrated similar mechanical improvements with glass modified ACP and suggested its use as a base and liner material under dental restorations. Skrtic et al. 58 studied the effect of combinations of seven different resin matrices and three types of ACP fillers on the release rates of calcium and phosphate. Skrtic concluded that UDMA, a urethane di-methacrylate resin, appears to have advantages over Bis-GMA and highly carboxylated monomer systems such as PMGDMA in producing higher ion release rates. UDMA also has reduced water sorption and polymerization shrinkage thus enhancing the strength of the resin matrix. 59 With the systematic improvements in mechanical and ion release properties, Skrtic advocated ACP-filled composite resins for use as orthodontic bracket adhesives. Now the orthodontic profession had a potential non-compliant WSL prevention product that offered an alternative to fluoride therapy.

Aegis Ortho Studies

In March 2004, Aegis Ortho became the first available ACP-containing orthodontic adhesive to receive Food and Drug Administration approval. The proprietary formula of Aegis Ortho utilizes a UDMA resin base along with a mix of various fillers including ACP. To date, no published studies on the ability of Aegis Ortho to prevent...
enamel demineralization. The studies involving Aegis Ortho have been more concerned with its mechanical properties in order to establish its validity as an orthodontic adhesive. Using 30 freshly extracted human third molars, Dunn et al. 60 compared the shear bond strength (SBS) of Aegis Ortho and a conventional resin-based composite adhesive (Transbond XT, 3M Unitek). Each tooth was bonded with two brackets - one bonded with Transbond XT and the other bonded with Aegis Ortho. After bonding, the specimens were stored in water at 37 degrees C for 24 hours and then tested for shear bond strength. The results showed that Aegis Ortho failed at significantly weaker SBS values than did Transbond XT, 1.2 MPa and 10 MPa respectively. Foster et al. 61 compared the SBS of Aegis Ortho with a conventional composite resin (Transbond XT, 3M Unitek) and a resin-modified glass ionomer cement (Fuji Ortho LC, GC America Inc, Alsip, III). Each adhesive was used according to manufacturers’ instructions to bond brackets on 20 premolars. The teeth were mounted in acrylic and stored at 37°C for 40 hours prior to debonding. Foster’s results showed that there was a statistically significant difference in SBS values between Aegis Ortho and Transbond XT, 6.6 MPa and 15.2 MPa respectively. There was no statistical difference between Aegis Ortho and Fuji Ortho LC although Aegis Ortho values were lower, 6.6 MPa and 8.3 MPa respectively. Uysal et al. 62 tested the shear bond strength of lingual retainers bonded with Aegis Ortho and a conventional lingual retainer composite (Transbond-LR, 3M Unitek). Uysal concluded that Aegis Ortho had a significantly reduced bond strength when compared to conventional composite resin cements. Although the shear bond strengths were significantly lower than the composite resin controls, they were in the range of what has been reported as being clinically acceptable.63,64,60 Tavas et al. 63 reported that shear/peel
strengths of orthodontic brackets should be 5.9 MPa within 24 hours. In another study Reynolds\textsuperscript{64} determined that the clinically acceptable minimum bond strength values for direct orthodontic bonding systems are 5.9-7.8 MPa.

Present Study

Bosworth Company’s bonding protocol for previous studies\textsuperscript{60,61,62} did not include the use of a primer. Bosworth Company has since changed the bonding protocol for Aegis Ortho to include their self-etching primer, Aqua Bond. The present study was designed to test the SBS of orthodontic brackets bonded with Bosworth Company’s new bonding protocol for Aegis Ortho and compare the values to the SBS values of the industry standard, Transbond XT. Due to the “smart” characteristics of the ACP containing products, the bond strength after submersion in a low pH demineralizing solution was also tested to determine if an acidic environment deteriorated the bond strength. Since there have been no published studies of the demineralizing inhibition capabilities of Aegis Ortho, this study compared enamel lesion depth adjacent to orthodontic brackets bonded with Aegis Ortho and Transbond XT after a demineralizing treatment. The intensions of this study were to test the bond strength and demineralization prevention capability of a relatively new product that has the potential to be a tool for combating white spot lesions in non-compliant patients.
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White spot lesions (WSLs) left on the teeth after orthodontic treatment are a huge compromise to the esthetic outcome of a treated case. Patient compliance with oral hygiene instruction is often low and thus WSLs occur in a large proportion of finished cases. Amorphous calcium phosphate (ACP) has recently emerged as a viable alternative to fluoride therapy in preventing enamel demineralization by promoting remineralization. ACP has been added as filler in an orthodontic bracket adhesive with the expectation of preventing WSLs in poorly compliant patients. The purpose of this study was to compare the enamel demineralization inhibition and shear bond strength of an ACP filled orthodontic bracket adhesive and a conventional adhesive.

Ninety previously extracted human 3rd molar teeth were divided into three groups of thirty. Within each group, half the teeth were bonded with brackets using the ACP filled adhesive and the other half were bonded with brackets using the conventional adhesive. After creating a 2mm window around the bracket, Group 1 was submerged in an acidic gel for ten days. Demineralization depth and shear bond strength were recorded. Groups 2 and 3 were stored in distilled water for ten days and 24 hours respectively after which the brackets were fractured and the shear bond strengths were recorded. The study found that teeth bonded with the ACP filled adhesive had a 29.8% reduction in demineralization depth when compared to the conventional adhesive. The average shear bond strength of the ACP filled adhesive (5.5 MPa) was significantly less than the conventional adhesive (18.5 MPa) in all three treatment groups. In conclusion, there was significantly less demineralization with the ACP filled adhesive but the low bond strengths greatly increase the risk of clinical bond failures.
INTRODUCTION

In today’s society, esthetics is probably the most important reason patients seek orthodontic treatment. Much emphasis has been placed on identifying esthetic smile components to aid the orthodontist in delivering a beautiful smile. Sarver et al. ¹ advocates identifying and recording the positive attributes of a patient’s smile during the initial exam so that treatment planning will not negatively affect those attributes. The natural translucency of the patient’s enamel is a characteristic that should not worsen with orthodontic treatment. However, white spot lesions (WSLs) often develop around orthodontic appliances during the treatment period resulting in un-esthetic opacities that lead to patient dissatisfaction. WSLs have been defined as a subsurface enamel porosity from carious demineralization that presents as a milky white opacity when located on smooth surfaces.² Since enamel translucency is directly related to its mineral content, the optical properties of demineralized enamel are different from adjacent sound enamel. The porous enamel scatters light differently and clinically results in a frosty white appearance. It has been reported that anywhere from 50% to 96% of orthodontic patients get WSLs during treatment.²,³,⁴ WSLs are more often seen on maxillary lateral, mandibular canine and premolar, and first molar teeth.⁵,⁶ They are often found on the gingival aspect of the bracket and under loose fitting bands where oral hygiene is more difficult. Studies have shown that there is a rapid shift in the composition of the bacterial flora of plaque following the introduction of orthodontic appliances resulting in an increase in the amount of acidogenic Streptococci mutans which are strongly associated with enamel demineralization.⁷ It has also been demonstrated that there is a rapid increase in the volume of dental plaque after the placement of fixed orthodontic
appliances and this plaque has a lower pH than plaque found in non-orthodontic patients.\textsuperscript{8,9} Naturally, enamel is in a constant flux of demineralization and remineralization depending on the balance of the oral environment. Net demineralization results when poor oral hygiene efforts fail to remove the plaque that has accumulated around the orthodontic appliances. Each time fermentable carbohydrates are consumed, the acidogenic plaque around the appliances produce lactic acid that causes a dip in pH below the solubility threshold of enamel. When this occurs, calcium and phosphate diffuse out of the enamel disrupting the ordered arrangement of enamel crystals which produce enamel translucency. This process can occur with WSLs becoming clinically evident within four weeks, a typical orthodontic appointment interval.\textsuperscript{10}

Patient compliance with proper oral hygiene and a low cariogenic diet is crucial in preventing white spot lesions. It is the responsibility of the orthodontist to teach the patient how to effectively clean around the appliances and to monitor the patient’s oral hygiene at each office visit. Fluoride therapy has been the predominant treatment utilized in caries prevention and is incorporated in many products such as toothpastes, gels and mouth rinses designed for at home use by the patient. Fluoride incorporates into the surface enamel to form fluoroapatite which makes enamel less soluble and more resistant to acid attack. The recommended fluoride concentration is above 0.1% for orthodontic patients and the best daily practice for preventing enamel demineralization is using a fluoride dentifrice along with a fluoride mouth rinse.\textsuperscript{5,10,11} However, Geiger and coworkers\textsuperscript{12} showed that less than 15% of patients rinsed with fluoride mouth rinse as they were instructed. O’Rielly and Featherstone\textsuperscript{13} concluded that fluoride dentifrices
alone were not able to stop enamel demineralization in non-compliant orthodontic patients.

In-office applications of fluoride releasing products have been utilized in an attempt to reduce the effects of poor patient compliance. These products include elastomerics, varnishes, sealants, resin modified glass ionomer cements and adhesives that are applied to or adjacent to the enamel and have shown the ability to reduce enamel demineralization. These products are designed to provide a constant source of fluoride to the tooth; however, Arneberg et al. reported that plaque pH and plaque fluoride levels are proportional in orthodontic patients with the fluoride reservoir quickly becoming depleted at low pH. Arneberg showed that the plaque pH in orthodontic patients following a sucrose challenge could fall as low as 4 in the upper incisor region. The fluoride effect becomes limited when the pH drops below 4.5 and the solubility of fluoroapatite is exceeded.

Amorphous calcium phosphate (ACP) provides an alternative to fluoride in regards to preventing enamel demineralization and has gained much attention in the dental research community over the past decade. ACP is an important intermediate in the formation of the main mineral component of enamel, hydroxyapatite (HAP). ACP possesses characteristics suitable for enamel remineralization because of its high solubility and rapid conversion to hydroxyapatite in aqueous environments. ACP has been incorporated in many desensitizing and whitening products with the unofficial claim of reducing enamel demineralization. To increase ACP’s substantivity it has been packaged with casein phosphopeptides (CPP) which are milk proteins that stabilizes ACP in solution by slowing its conversion to HAP. This CPP-ACP combination is marketed
as Recaldent (Bonlac Bioscience International Pty Ltd, Melbourne, Australia). CPP-ACP is incorporated into supragingival dental plaque by binding to the surfaces of bacteria and various components of the intercellular plaque matrix causing significant increases in plaque levels of calcium and phosphate. This increased level of calcium and phosphate helps to maintain a state of supersaturation with respect to enamel mineral, thereby depressing enamel demineralization and enhancing enamel remineralization.\textsuperscript{26,27,28,29,30} Although CPP-ACP has a clinical history of success when used frequently, patient compliance is still an integral part of its clinical effectiveness.

Amorphous calcium phosphate has been incorporated as a filler in dental resin-based restorative materials to take advantage of its ability to remineralize dental hard tissues.\textsuperscript{31,32} ACP has also been marketed as a “smart” material because it releases higher levels of calcium and phosphate ions under acidic conditions.\textsuperscript{33,34} This property, in theory, makes an ACP filled resin a great choice in dental applications where poor oral hygiene persists. However, ACPs high solubility results in voids in the resin after the ACP dissolves out of the polymer matrix leading to weakening of the resin.\textsuperscript{35} Initially, ACP filled resins were advocated in non-stress bearing conditions such as bases or liners under dental restorations.\textsuperscript{36} ACP filled resins were recommended for use as orthodontic adhesives to prevent enamel demineralization adjacent to orthodontic brackets after improvements in mechanical properties were made.\textsuperscript{25,37,38}

In March 2004, Aegis Ortho (Harry J. Bosworth Co., Skokie, Ill) became the first available ACP-containing orthodontic adhesive to receive Food and Drug Administration approval. The proprietary formula of Aegis Ortho utilizes a UDMA resin base along with a mix of various fillers including ACP. To date, there have been no published
studies on the ability of Aegis Ortho to prevent enamel demineralization. The studies involving Aegis Ortho have been more concerned with its mechanical properties in order to establish its validity as an orthodontic adhesive. Dunn et al.\textsuperscript{39} compared the shear bond strength (SBS) of Aegis Ortho and a conventional resin-based composite adhesive (Transbond XT, 3M Unitek). They reported that Aegis Ortho had significantly lower shear bond strength than did Transbond XT, 1.2 MPa and 10 MPa respectively. Dunn concluded that Aegis Ortho did not have suitable mechanical strength for use as an orthodontic bracket adhesive. Foster et al.\textsuperscript{40} compared the SBS of Aegis Ortho with a conventional composite resin (Transbond XT, 3M Unitek) and a resin-modified glass ionomer cement (Fuji Ortho LC, GC America Inc, Alsip, III). Foster’s results concluded that Transbond XT with a 15.2 MPa bracket bond strength was statistically greater than the 6.6 MPa produced by Aegis Ortho. There was no statistical difference between Aegis Ortho and Fuji Ortho LC although Aegis Ortho values were lower, 6.6 MPa and 8.3 MPa respectively. Although the shear bond strengths of Aegis Ortho were significantly lower than the composite resin controls, they were in the range (5.9-7.8 MPa) of bonds that are clinically acceptable.\textsuperscript{39,41,42} The original bonding protocol for Aegis Ortho did not call for the use of a priming agent. After low SBS were reported for Aegis Ortho, the Bosworth Company changed the bonding protocol for Aegis Ortho by adding their self etching primer, Aqua Bond.

Patient compliance remains a hinderance to the effectiveness of proven techniques and products in preventing white spot lesions. The present \textit{in vitro} study is designed to evaluate a new orthodontic product intended to prevent white spot lesions with little or no patient compliance. For the purposes of the present study, the null hypotheses assumed
that there were no statistically significant differences in (1) the depth of demineralization adjacent to orthodontic brackets bonded with Aegis Ortho and Transbond XT and 2) the mean shear bond strengths of orthodontic brackets bonded with Aegis Ortho and Transbond XT under various treatment conditions. Therefore, the specific aims of the present in vitro study were 1) to bond brackets following manufacturer’s instructions to human third molar teeth using either an ACP-filled resin (Aegis Ortho) or a traditional composite (Transbond™ XT), fracturing them at 24 hours and 10 days to compare bracket shear bond strengths and modes of failure, 2) to demineralize enamel in a 2 mm unprotected window around the bracket for 10 days and measure the lesion depth at 0.5mm from the bracket base, comparing Aegis Ortho and Transbond™ XT, and 3) to determine if the increased release of ACP-filler at low pH decreases bond strength.

MATERIALS AND METHODS

Study Design

Ninety extracted human third molar teeth were collected. The teeth were inspected under 10x magnification and were free of visible opacities, decalcifications, fractures, or peculiar morphology. The teeth were stored in 10% sodium hypochlorite for approximately two months prior to the study. Three groups of thirty teeth were established based on the treatment conditions under which the teeth were to be tested. The three groups were further randomly assigned to two groups of fifteen teeth each depending on the bonding adhesive to be used for adhering the brackets (.018-in MBT Victory Series, 3M Unitek, Monrovia, CA) (Table 1).
Table 1

Study design

<table>
<thead>
<tr>
<th>Treatment Condition Groups</th>
<th>Aegis Ortho</th>
<th>Transbond XT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1: 10 Day Demineralization (n = 30)</td>
<td>n = 15</td>
<td>n = 15</td>
</tr>
<tr>
<td>Group 2: 10 Day H2O Storage (n = 30)</td>
<td>n = 14</td>
<td>n = 15</td>
</tr>
<tr>
<td>Group 3: 24 Hour H2O Storage (n = 30)</td>
<td>n = 15</td>
<td>n = 15</td>
</tr>
</tbody>
</table>

In group 1, the thirty teeth were cleaned and the mesiobuccal cusp of each tooth was pumiced with fluoride free flour pumice for 10 seconds, rinsed with sterile water, and dried with oil/moisture free air. A two millimeter by seven millimeter piece of protective barrier tape was placed on the tooth at the approximate occlusal aspect of the bracket position. The purpose of the tape was to eliminate any variables due to the different bonding protocols that might affect the demineralization study. In the order of random assignment, the brackets were bonded to the extracted teeth according to manufacturer’s instructions. The teeth bonded with Transbond XT were conditioned with 37% phosphoric acid for 30 seconds, rinsed with sterile water for 10 seconds, and dried with oil/moisture free air until the enamel had a frosty appearance. A thin coat of Transbond XT primer (3M Unitek) was applied and photopolymerized for 10 seconds. Transbond XT light-cured adhesive paste (3M Unitek) was then applied to the base of the bracket and the bracket was placed on the mesiobuccal cusp parallel to the long axis of the tooth. Under magnification, the bracket was placed on the tooth adjacent to the barrier tape and excess bonding material was removed with an explorer. The adhesive was
photopolymerized for 20 seconds on the mesial aspect of the bracket and 20 seconds on 
the distal aspect of the bracket using an Ortholux™ LED curing light (3M Unitek) with a 
power density of 1000 mW/cm. The teeth bonded with Aegis Ortho were conditioned 
with 35% phosphoric acid (Harry J. Bosworth Co., Skokie, Ill) for 30 seconds, rinsed 
with sterile water for 10 seconds, and dried with oil/moisture free air. A self-etching 
primer, Aqua Bond (Harry J. Bosworth Co.), was then rubbed onto the enamel surface for 
15 seconds. The teeth were rinsed with sterile water for 10 seconds and dried with 
oil/moisture free air. Aegis Ortho light-cured adhesive paste (Harry J. Bosworth Co., 
Skokie, Ill) was applied to the base of the bracket and the bracket was placed on the 
mesiobuccal cusp parallel to the long axis of the tooth. Under magnification, the bracket 
was placed adjacent to the barrier tape and excess bonding material was removed with an 
explorer. The adhesive was photopolymerized for 20 seconds on the mesial aspect of the 
bracket and 20 seconds on the distal aspect of the bracket using an Ortholux™ LED 
curing light (3M Unitek) with a power density of 1000 mW/cm². The tape was removed 
from all 30 teeth in group 1 and any residual adhesive residue removed with alcohol. The 
teeth were coated with a clear acid resistant nail varnish (Revlon, New York, NY) leaving 
a 2 millimeter circumferential window of unprotected enamel adjacent to the bracket. 
The demineralizing solution was prepared by buffering a 1M solution of 85% lactic acid 
with a 1M solution of sodium hydroxide to make a stock solution of pH 4.5. A calibrated 
sensION2 pH/ISE meter (Hach Company, Loveland, CO) was used to measure the pH. 
Thirty grams of medium viscosity Carboxymethyl Cellulose (Sigma-Aldrich Co., St. 
Louis, MO) were added to 500 mls of stock solution and stirred with a kitchen mixer 
until a gel like consistency was attained. A final pH of 4.5 was confirmed with the pH
meter. The bracketed teeth were completely submerged in the demineralizing solution and stored at 37°C for 10 days. In groups 2 and 3, the teeth were bonded in random order similarly to group 1 with the omission of the two millimeter by seven millimeter piece of protective barrier tape since these groups were not to undergo demineralization treatment. Group 2 was stored in distilled water at 37°C for 10 days. Group 3 was stored in distilled water at 37°C for 24 hours.

At the conclusion of the respective treatment times, the teeth in all three groups were mounted in acrylic cylinders and positioned in the Instron testing machine. A shear force was applied at the bracket/tooth interface using a sharp chisel-shaped rod attached to the upper platen of the universal testing machine (Model 5565, Instron, Norwood, MA) at a crosshead speed of 0.5mm per minute until bracket failure. The bracket bond strengths (N) were recorded for all teeth and after dividing by the cross-sectional area of the bracket base, the bond strength in MPa was calculated. Each tooth was then inspected under magnification and the mode of failure recorded.

The teeth in group 1 were then removed from the acrylic cylinders and sectioned buccolingually through the bonding sites using an Isomet low speed saw (Model 1180, Buehler, Lake Bluff, IL). The sections were stained with methylene blue dye so that the enamel lesions could be accurately observed and measured at 300x using a digital microscope (Keyence, VHX-600 series, Woodcliff Lake, NJ). At a distance of 0.5 mm from the occlusal aspect of where the bracket was bonded, the depth of each enamel lesion was measured in µm.
Statistical Analysis

A two-way ANOVA analysis was used to compare the shear bond strengths of the resin groups and treatment groups. A one factor ANOVA analysis was also used to compare the demineralization depth between the two resin groups. The modes of failure were analyzed using a Chi-square test. Statistical significance for all tests was determined at p<.05. All analysis was done using SAS version 9.1 (Cary, NC).

RESULTS

The mean enamel lesion depths from group 1 are listed in Table 2. The mean lesion depth of enamel bonded with Aegis Ortho at a distance of .5mm from the bracket base was statistically less than the mean lesion depth of enamel bonded with Transbond XT (p < .0006). Due to enamel fracture during the shearing of brackets in the Transbond XT group, five samples were unable to be sectioned and lesion depth accurately measured.

Table 2

Mean lesion depths (µm)

<table>
<thead>
<tr>
<th>Resin Group</th>
<th>Mean Lesion Depth (µm)</th>
<th>Std Dev.</th>
<th>P &lt; .0006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aegis Ortho (n=15)</td>
<td>51.80 ±13.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transbond XT (n=10)</td>
<td>73.25 ±12.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
There was a statistically significant difference in the mean shear bond strengths between brackets bonded with Aegis Ortho and brackets bonded with Transbond XT (Table 3). The Aegis Ortho bonds failed at statistically lower SBS values in every treatment group than the Transbond XT bonds.

Table 3

*Shear Bond Strengths (MPa)*

<table>
<thead>
<tr>
<th>Resin Group</th>
<th>Tx Group 1: 10 Day Demineralization (MPa ± Std Dev)</th>
<th>Tx Group 2: 10 Day H2O Storage (MPa ± Std Dev)</th>
<th>Tx Group 3: 24 Hour H2O Storage (MPa ± Std Dev)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aegis Ortho</td>
<td>5.26 ± 3.61</td>
<td>4.64 ± 2.21</td>
<td>6.52 ± 1.68</td>
</tr>
<tr>
<td>Transbond XT</td>
<td>17.09 ± 6.05</td>
<td>21.21 ± 7.32</td>
<td>17.28 ± 5.63</td>
</tr>
<tr>
<td>P-value</td>
<td>&lt; .001</td>
<td>&lt; .001</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

There were no statistically significant differences in the bracket SBS values between the treatment groups in teeth bonded with Aegis Ortho. There was a statistically significant difference in bracket SBS values between the treatment groups in teeth bonded with Transbond XT with treatment group 2 SBS producing statistically higher values than treatment groups 1 or 3 (p-values < .024 and < .031 respectively).

There was a statistically significant difference in the mode of failure between the two resin groups (p < .0001). The Aegis Ortho group failed 93.18% at the resin/enamel interface with zero enamel fractures. The Transbond XT group failed 33.33% at the resin/enamel interface, 31.11% at the resin/bracket interface, and 35.56% within the enamel.
Table 4

*Mode of Failure*

<table>
<thead>
<tr>
<th>Mode</th>
<th>% failure at resin/enamel</th>
<th>% failure at resin/bracket</th>
<th>% failure within enamel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aegis Ortho</td>
<td>93.18</td>
<td>6.82</td>
<td>0</td>
</tr>
<tr>
<td>Transbond XT</td>
<td>33.33</td>
<td>31.11</td>
<td>35.56</td>
</tr>
</tbody>
</table>

**DISCUSSION**

White spot lesions adjacent to orthodontic brackets are a major concern to the orthodontist and the patient. These lesions can progress to frank cavitations requiring dental restorations if left untreated. WSLs naturally regress in size after orthodontic appliances are removed, but the enamel will never recover its original translucency. Therefore, it is most important to prevent WSLs rather than attempt to treat them after they occur. Unfortunately most currently available methods of preventing WSLs require patient compliance. Patients with WSLs have proven to be non-compliant and are unlikely to comply with further preventive methods. Orthodontists therefore seek methods of preventing WSLs that do not require patient compliance.

Amorphous calcium phosphate (ACP) has recently been incorporated as a filler into a composite resin matrix. This product is marketed as the orthodontic adhesive Aegis Ortho (Harry J. Bosworth Co., Skokie, Ill). There have been no referred publications reporting the effectiveness of Aegis Ortho in preventing enamel demineralization adjacent to orthodontic brackets. However previous studies have shown that ACP filled composite resins have the ability to remineralize artificially created enamel lesions. Skrtic et al. \[^{31}\] created artificial enamel lesions and covered them
with an experimental ACP composite. After cycling them through a
demineralization/remineralization sequence, measurements showed that 38% of lost
mineral was regained in lesions under the ACP composite. Langhorst et al. 32 created
artificial enamel lesions and covered them with an ACP composite. The teeth were then
cycled through a demineralization/remineralization protocol for 1 month. Quantitative
digital image analysis of matched areas from contact microradiographs taken before and
after treatment indicated higher mineral recovery with ACP composites compared to a
commercial orthodontic F-releasing cement (14.4% vs. 4.3%, respectively), while control
specimens showed an average of 55.4% further demineralization. While these studies
showed positive results, they measure mineral recovery of previously created enamel
lesions that are covered with an ACP composite. This is not what happens in an
orthodontic clinical scenario where the demineralization occurs adjacent to the composite
and the starting point is sound enamel. Clinically the ACP first leaches out of the
composite matrix into the plaque biofilm where it then diffuses into the tooth to form
HAP. In my study, sound enamel adjacent to orthodontic brackets was subjected to 240
continuous hours of demineralization solution at pH 4.5 with no cycling protocol. The
lesion depth was measured 0.5mm from the composite pad which is clinically where most
WSLs occur. The results showed that human molar teeth bonded with Aegis Ortho had a
29.82% reduction in demineralization depth compared to teeth bonded with Transbond
XT (p = .0006). The mean lesion depth of enamel bonded with Aegis Ortho was
51.80µm while the mean lesion depth of enamel bonded with Transbond XT was
73.25µm. This study was not designed to mimic the oral environment, but to detect if
Aegis Ortho could reduce demineralization on adjacent enamel under continuous acid
attack. Therefore, the clinical effect of Aegis Ortho in the present study could be underestimated due to the conditions of the study.

Glass fillers are added to composite resins to increase strength, decrease polymerization shrinkage, add esthetic properties, and provide a coefficient of thermal expansion similar to tooth structure. A silane coupling agent is used to chemically bond the organic resin and the inorganic filler. Poor or no bonding of the filler to the resin matrix causes the filler to act as porosity in the composite and lowers fracture toughness and flexural strength of the composite resin. The primary purpose of the ACP filler in Aegis Ortho is to leach out of the polymer matrix so it can provide calcium and phosphate for enamel remineralization. This makes an ACP filled composite inherently weaker than conventional glass filled composites. Although many improvements have been made in the mechanical properties of ACP filled composites leading to the introduction of Aegis Ortho, initial bond studies of Aegis Ortho showed unfavorable results compared to conventional composites. The bonding protocol for Aegis Ortho during these studies did not include the use of a primer. A self etching primer (SEP), Aqua Bond (Harry J. Bosworth Co., Skokie, Ill), was added to the bonding protocol of Aegis Ortho since these study results were published. Unpublished data from Bosworth Company reported an average bracket shear bond strength value after a two hour water storage at 37°C that was statistically similar to Transbond XT (3M Unitek) (9.8 MPa vs 10.2 MPa; p>0.05). These results were not confirmed by the results of the present study. The mean SBS values of Aegis Ortho in all treatment groups were significantly lower than the mean SBS values of Transbond XT (Table 3). Group 3 (24 hour water storage) exhibited the most similar test conditions to the previous studies by Dunn and Foster.
The 24 hour mean SBS for Aegis Ortho in the present study was 6.5 MPa which was greater than Dunn’s 1.2 MPa for Aegis Ortho implying that the Aqua Bond primer in the present study improved the bond numbers. This conflicts with the mean bracket SBS reported by Foster with Aegis Ortho of 6.6 MPa which implies no additional benefit from the Aqua Bond. Erickson et al (2008) stated that the acidic monomers in self-etching primers (SEP) can remove some of the etched enamel structure created by the conventional etch, and the scrubbing action can also damage the etched enamel rods resulting in shallower resin tags and weaker bond strengths. SEM images taken at 3000x of the different etched surfaces in the present study show a more ordered arrangement of enamel rods in the conventionally etched enamel, whereas the enamel rods appear to be less orderly in the pre-etch, SEP enamel. This could account for some of the reduced bond strength of Aegis Ortho. Perhaps Bosworth Company should use a conventional priming agent as an alternative to the SEP. SEM images taken at 50x and 500x show cracks in the composite surface of polished Aegis Ortho discs where the filler particles disrupt the polymer matrix. This results in less available bonding surface and provides diffusion channels for deeper penetration of water and bacterial enzymes that are known to degrade the polymeric chain integrity. The reduced bonding area available, diffusion channels for greater water sorption, and etch pattern all contribute to the low SBS values and the mode of bond failure being 93.2% at the resin/enamel interface.

ACP has been marketed as a “smart” material because it produced increased levels of calcium and phosphate ions at lower pH levels. In the present study, there was no statistical difference in the mean SBS values of Aegis Ortho submerged in demineralization solution at pH 4.5 for 10 days (group 1) compared to Aegis Ortho stored
in water for 10 days (group 2). This suggests that the increased release of ACP filler at lower pH has no effect on the bond strength of the material. This could be due to the small amount of exposed surface area of composite around the perimeter of an orthodontic bracket compared to the surface area of composite under a bracket bonded to the enamel surface. Perhaps more time is needed to see the effects of lost filler on bond strengths.

Clinical bond failures of orthodontic brackets result in emergency office visits, extend the overall treatment time, and add to the expense of the orthodontic treatment. Tavas et al. reported that shear/peel strengths of direct bonded adhesives should develop 5.9 MPa within 24 hours. Reynolds determined that the minimum bond strength values in direct orthodontic bonding systems that are clinically acceptable are 5.9-7.8 MPa. While the mean SBS of the Aegis Ortho in groups 1 and 2 were slightly below these numbers, the group 3 values of Aegis Ortho were within the minimally acceptable range. Linklater et al. studied patterns of bond failures in vivo and determined that maxillary anterior teeth had the least amount of bond failures at around 2%. Since the maxillary anterior teeth comprise the esthetic zone where WSLs have the largest negative esthetic impact, orthodontists should consider using Aegis Ortho in the maxillary anterior region despite its lower shear bond strengths especially in higher caries risk patients.

CONCLUSIONS

Under the conditions of the present study, the following conclusions are made:
1. Aegis Ortho reduces enamel lesion depth by 29.82% compared to a traditional composite resin bracket adhesive when subjected to an acid challenge.

2. The mean shear bond strength associated with Aegis Ortho was significantly lower than the traditional composite resin control.

3. The increased release of ACP-filler at low pH does not significantly reduce the mean shear bond strength of the material.

4. Orthodontists should consider bonding maxillary anterior teeth with Aegis Ortho for increased WSL protection on at risk patients where compliance issues are anticipated.

REFERENCES


GENERAL CONCLUSIONS

The aim of the present study was to evaluate the shear bond strength of an ACP filled composite resin designed to provide protection against demineralization around orthodontic brackets. The study also measured the depth of enamel demineralization around an orthodontic bracket when subjected to a continuous acid assault. The results showed that the enamel lesion depth adjacent to the ACP filled resin was reduced by 29.82% over the lesion depth adjacent to a traditional composite resin bracket adhesive. The mean shear bond strength associated with Aegis Ortho was significantly lower than the traditional composite resin control. The increased release of ACP-filler at low pH does not significantly reduce the mean shear bond strength of the material. Since bond failure rates are typically low in the anterior, orthodontists may consider bonding maxillary anterior teeth with an ACP filled composite resin for increased WSL protection on at risk patients where compliance issues are anticipated.
GENERAL LIST OF REFERENCES


