Available online at **www.ijmrhs.com**

ISSN No: 2319-5886

International Journal of Medical Research & Health Sciences, 2017, 6(11): 58-66

Effect of Icon and Bond Type on Shear Bond Strength: An *In vitro* Study

Ahmed M Yousif AL-Mayali*

Lecturer, Orthodontic Department, College of Dentistry, University of Kufa Iraq

**Corresponding e-mail: ahmedalmayali@yahoo.co.uk*

ABSTRACT

Aim: *To investigate the differences in SBS of orthodontic brackets after applying a caries resin infiltrant and its relationship to the bond type used.* ***Materials and methods:*** *A total of 48 extracted upper premolar were divided to four groups, and the force required for debonding of brackets was recorded. Residual adhesive material was examined by light microscopy. Statistical analysis was performed included t-test and Chi-square test.* ***Result:*** *The highest bond strength (22.543 MPa) was get by use the caries infiltrant with self-etching bond. More residual adhesive was observed on infiltrated enamel surfaces.* ***Conclusion:*** *Acceptable bond strengths were obtained with Icon application as measured in vitro, producing the highest strength of all tested sample when compared with the other adhesive system without Icon.*

Keywords: Icon, Caries infiltrant, Shear bond strength, Bond type, Bracket

INTRODUCTION

White spot lesions (WSLs) is enamel demineralization and a serious iatrogenic complication during and after orthodontic treatment, WSL accruement has been reported to occur in up to 73% [1] of subjects treated with fixed orthodontic appliances. In most cases, this is due to oral hygiene being aggravated in presence of brackets and orthodontic wires [2,3].

The prevalence of WSLs after orthodontic treatment remains high, up to 97% [4]. The increased risk of WSLs development during orthodontic treatment is due to excessive plaque accumulation around fixed orthodontic appliances [5].

The teeth most affected by WSLs are the molars, upper laterals, lower canines, and premolars [6]. WSLs are visible as they are scattering light, instead of reflecting it, as is the case with sound enamel. The technique of WSL infiltration using low-viscosity light-curing resins (infiltrant) has been established as a new way to stopping or reducing progression of lesions [7,8]. Both long time screening and subsequent follow-ups, as well as case reports and *in vitro* research indicate a reduced visibility of infiltrated white-spot-lesions, as an additional positive side-effect, which is due to the similar refractive index of the infiltrant and sound enamel areas [9-11].

When the enamel area has been infiltrated by the infiltrating resin (Icon, DMG) and there is need for an adhesive procedure such as: bonding orthodontic brackets; once the infiltrant material will not be removed, there is a question about the bonding between the treated surface and the compatibility of this material to current bond systems [12,13].

The purpose of this study was to examine the SBS (Shear Bond Strength) of orthodontic bracket after application of Icon (caries resin infiltrant) and in conventional method and relationship to the bond type used.

MATERIALS AND METHODS

In this *in vitro* study, sixty-six freshly extracted sound human upper first premolars were collected from patients seeking of orthodontic treatment and rinsed with water [14,15]. Then stored in closed container containing 0.9% sodium chloride (normal saline) with 0.1% thymol to prevent dehydration and bacterial growth which change weekly, at room temperature [16-20].

Forty-eight extracted teeth were selected after being examined with 10x magnifying lens [16]. The selected teeth

were caries free, no enamel cracks or restorations and no surface irregularities or marked structural or developmental anomalies. The collected teeth were divided equally in to two groups each one containing 24 extracted teeth.

Control group (Con)

This contains twenty-four sound upper first premolars which were bonded using the bonding adhesive (3M, USA) and (Ortho Technology, USA) in conventional method.

Icon group (Icon)

This contains the caries resin infiltrant (Icon-Dry, DMG, Hamburg, Germany). The Icon-Dry was applied on the buccal surface of twenty-four sound upper premolars, followed by the application of the adhesive material.

Then each of two groups subdivided in to two other sub-groups containing twelve extracted teeth; first group using 7th generation self-etching bond and adhesive material (3M, USA) and the second group using total-etching bond and adhesive material (Ortho Technology, USA).

The roots of the teeth were serrated by diamond disk, made a retentive wedge shaped to increase the retention of the teeth inside the self-cured acrylic blocks, three teeth were fixed with 2 cm apart [18,21,22] and adjusted vertically using the surveyor (Dentaurum, Germany), the two L-shaped metal plates (7 cm length, 2.5 cm width, 2 cm height and 8 mm thickness) were painted with a thin layer of separating medium (Vaseline) and placed to form a mold around the vertically positioned teeth with the crowns protruding outside the mold. The powder and liquid of the self-curing acrylic resin (Vertex, Netherlands) were then mixed according to the manufacturer's instructions, and poured around the teeth to the level of cemento-enamel junction [23,24]. After setting has been completed, excess material was removed and polished then the teeth were stored in a patch containing normal saline solution with 0.1% thymol until bonding procedure [17].

The buccal surface of the teeth was cleaned with a rubber cup (Full Dent Prophy Cups, Switzerland) and non-fluoridated pumice for 10 s [25,26]. The teeth were then washed using running water for 10 s. and dried with oil free steam of air for another 10 s. This procedure was set to simulate the 'real life' clinical situation [24,27]. For Control group that using total-etching bond and adhesive material (Ortho Technology, USA). Phosphoric acid etching (37%) (Ivoclar, Vivadent) was used on the buccal surface of the crowns for 30 s. and then washed with water spray and dried with steam of air until the etched enamel appeared chalky [19,28,29]. while the control group that using 7th generation self-etching bond and composite material (3M, USA) no need for acid etching procedure.

Bonding procedure

1. Control group (Con)

A thin layer of light activated orthodontic adhesive paste (Ortho Technology, USA and 3M, USA) was applied to the Stainless steel orthodontic brackets (0.022 × 0.030-inch standard edge wise, Pinnacle, coarse mesh base with surface area=10.9068 mm^2. Ortho Technology, USA) [30]. Which was then placed onto the buccal surface of the tooth surface at the middle of the middle third of the buccal surface [19]. The excess adhesive was removed using dental probe before setting without disturbing the seated bracket [31-35]. The adhesive material was cured for 40 s [36,37] using LED light cure unit with wave length range 400-500 nm and light intensity more than 500 mW/cm^2 (Woodpecker Co., China). Where 10 s curing time was set for each of the four directions; mesial, distal, occlusal and cervical. The adjacent teeth were covered with opaque separator before curing to prevent the effect of the disseminated light [38]. After the completion of the bonding procedure, the teeth were stored in a patch containing normal saline solution with 0.1% thymol until testing procedure [17].

2. Icon group (Icon)

Applying Icon-Etch let, sit for 2 min. then Rinsing off with water for 30 sec., dry with oil and water free air, apply Icon-dry, let sit for 30 sec. and there by carry out visual inspection, then dry with oil and water-free air. Applying Icon-Infiltrant, let sit for 3 min. Dispense with air and light cure for 40 sec. Applying Icon Infiltrant, let sit for 1 min. remove excess then light cure for 40 sec. (according to the instructions of manufacturer). After that, light activated orthodontic adhesive material (Ortho Technology, USA and 3M, USA) was applied over the coated layer as described in group (Con). Shear bond strength test was done 24 hours after bonding procedure to allow for complete polymerization of adhesive [24,39,40]. The SBS testing was carried out using A Universal testing

machine (Laryee, WPW-50, 50 KN, China). The machine is connected to a Pentium IV computer using MAX-Test software, in the University of Technology. Each specimen was placed in the machine base parallel to the horizontal plan of the floor. The chisel rod was used in the testing machine, which perpendicular to the enamel/ bracket interface. This was done to provide a force in an occluso-gingival direction [26,41,42].

The crosshead speed was 0.5 mm/minute [43] and the highest magnitude of the load values were considered as the load of the bond failure. The failure load (in Newton) was divided by the base bonding area (10.9068 mm^2 in the study) to calculate the shear bond strength in MPa (N/mm^2).

Statistical Analysis

Statistical analyses were performed by using SPSS (statistical package of social science) program Version 21. In this study the following statistic methods used:

I. Descriptive statistics

1) Mean and standard deviation.

II. Inferential statistics

1) Independent sample t-test was done for comparison between different groups.
2) Chi-square to examine the differences among all the groups for the results of failure site.

RESULTS

The descriptive statistics of shear bond strength (MPa) and the effect of Icon application on the SBS from different companies were calculated.

T-test show that the mean value of the SBS were higher (significant) in group that using Icon as compare with the other group that don't used Icon for the same (3M) company. Also, the mean value of the SBS were higher (despite non-significant) in group that using Icon as compare with the other group that don't used Icon for the same (Ortho Technology) company as shown in Table 1.

Table 1 Descriptive statistics of SBS and the effect of Icon application on the SS of adhesive from different companies

Manufacturer	State	Descriptive statistics			Comparison		
		N	Mean	S.D.	t-test	d.f.	p-value
3M	Without Icon	12	17.343	4.432	-2.421	22	0.024*
	With Icon	12	22.543	5.977			
Ortho Technology	Without Icon	12	13.031	2.061	-1.3	22	0.207#
	With Icon	12	14.759	4.116			
*Significant; #Non-significant							

Descriptive statistics and comparison of SBS of adhesive of different companies in case of application and not application of Icon was calculated. Found that the mean value of SBS were higher (high significant) in group without Icon for 3 M company as compared with the other group without Icon for Ortho Technology company of adhesive composite material. Also found that the mean value of the SBS were higher (high significant) in group with Icon for 3 M company as compared with the other group with Icon for Ortho Technology company of adhesive composite material as shown in Table 2 and Figure 1.

Table 2 Descriptive statistics and comparison of shear bond strength of adhesive of different companies in case of application and not application of Icon

Manufacturer	State	Descriptive statistics			Comparison		
		N	Mean	S.D.	t-test	d.f.	p-value
Without Icon	3M	12	17.343	4.432	3.056	22	0.006**
	Ortho Technology	12	13.031	2.061			
With Icon	3M	12	22.543	5.977	3.716	22	0.001**
	Ortho Technology	12	14.759	4.116			
** Highly Significant							

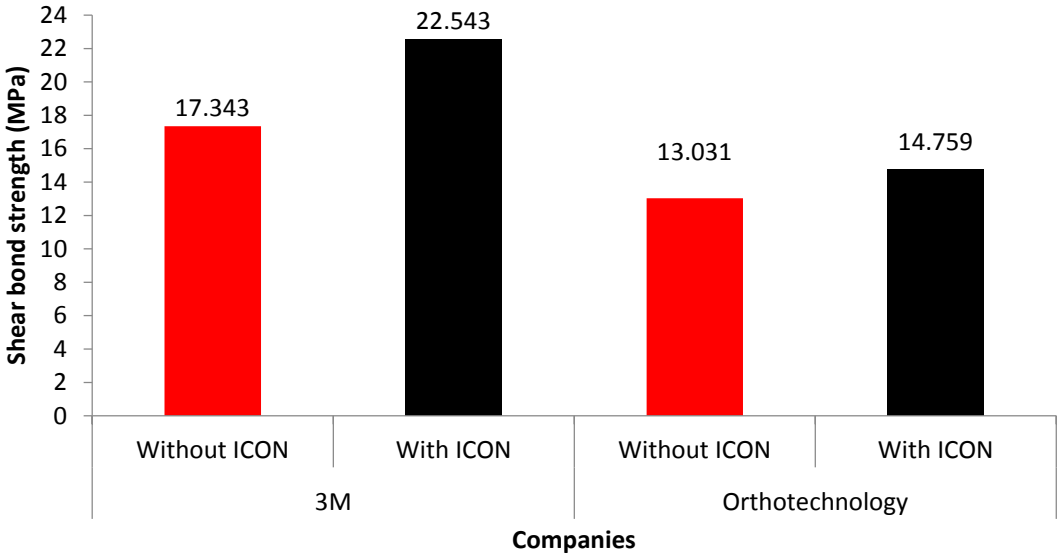

Figure 1 Comparison of shear bond strength of adhesive of different companies in case of application and not application of Icon

Regarding the adhesive remnant index there were significant difference among all groups, also there were significant difference between Ortho Technology subgroups. But there was no significant difference found between 3M subgroups.

Also found a significant difference between groups without Icon. But no significant difference found when using Icon (Tables 3 and 4, Figure 2).

Table 3 ARI score of different companies in case of application and not application of ICON

Score	Ortho Technology without Icon	Ortho Technology with Icon	3M without Icon	3M with Icon
I	1 (8.33%)	5 (41.67%)	7 (58.33%)	8 (66.67%)
II	9 (75%)	3 (25%)	5 (41.67%)	2 (16.67%)
III	2 (16.67%)	4 (33.33%)	0 (0%)	1 (8.33%)
IV	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (8.33%)
Total	12 (100%)	12 (100%)	12 (100%)	12 (100%)

Table 4 Comparison of ARI score of different companies in case of application and not application of Icon

Comparison	X^2 test	d.f.	p-value
Among all groups	19.529	9	0.021*
Between Ortho Technology groups	6.33	2	0.042*
Between 3M groups	3.352	3	0.340#
Effect of not using ICON	7.643	2	0.022*
Effect of using ICON	3.692	3	0.297#
*Significant; #Non-significant			

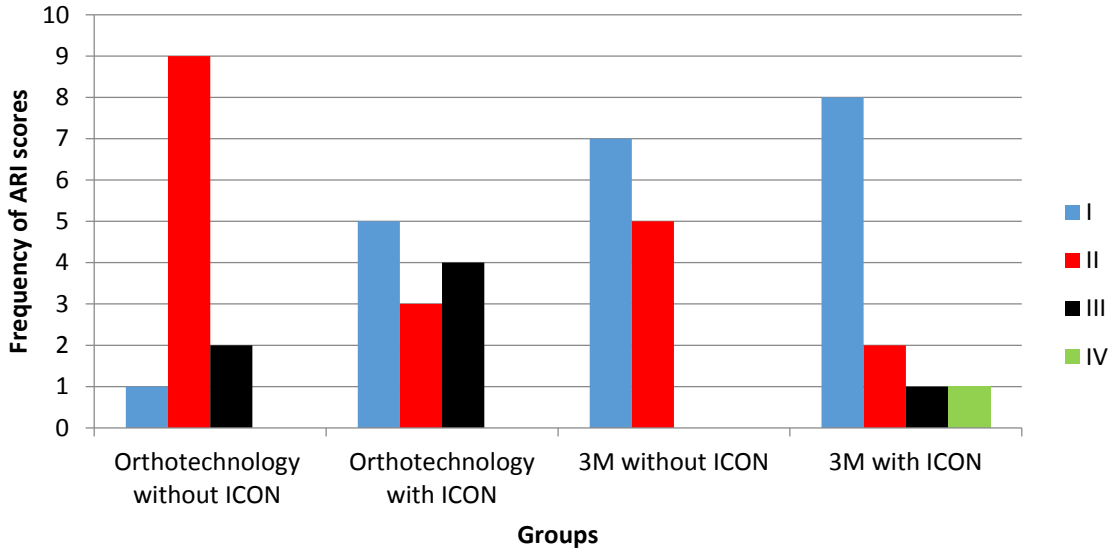

Figure 2 Frequency of ARI score of different companies in case of application and not application of Icon

DISCUSSION

The aim of this study was to analyses the differences is SBS between bracket bonding with Icon application and Bracket bonding in conventional method and its relationship to the bond type used.

The most frequently cited bond strengths for orthodontic brackets fall within the minimum range of 6 to 8 MPa [44] and the results obtained from the current study showed that the mean shear bond strength values of the tested materials were higher than the optimal limits.

The previous investigations did not reveal any disadvantages regarding bond strength or residual adhesive when healthy enamel surfaces were infiltrated therefore suggest that the entire tooth surface is covered with infiltration treatment [45-47].

The result shows a significant difference between the control group and the Icon group, the SBS for ICON group was higher than the other group without Icon.

The finding agrees with Ekizer, et al. claimed that there was a significant increase in SBS when Icon was used as a preconditioner during bonding orthodontic brackets onto enamel surfaces [48]. Additionally, Naidu, et al., found that there was a significant increase in SBS of specimens after Icon preconditioning [46]. Laura Mews Show a significant increase in SBS when the primer-adhesive system was applied to enamel in addition to the caries infiltrant [49]. But the finding disagrees with Montasser, et al. that show no significant difference between Icon and control group in SBS [50].

The Icon had a hydrophilic property which may enable their penetration into the tooth surface which results in a direct contact to this surface. This minimizes the effect of oxygen and increases the polymerization reaction which enhances the SBS [51].

Also, Shawkat, et al., claim that the high TEGDMA-based resin infiltrant content (triethylene glycol dimethacrylate), not only facilitates penetration but also induces the formation of a thicker oxygen inhibition layer on the surface. This layer may cause chemical bonding to the monomers [52].

The penetration time is an important factor to determining the rate of resin penetrates the gaps formed by etching [53]. Icon was the only resin with prolonged penetration time of 2 min. It may be suggested that this was also another factor increasing the SBS.

According to the results, the Icon can be applied on the tooth surface which does not negatively interfere on the bond between resin composite and enamel, it showed to be statistically superior to the other groups that were don't use Icon.

The penetration of self-etching bond (3M) with (3M) composite might be distinctly increased by etching with

hydrochloric acid during Icon preconditioning, resulting in significantly higher shear bond strength values. Even on sound enamel, preconditioning with the caries infiltrant system had positive effect on shear bond strength, probably as a result of the high wettability of the TEGDMA resin [54].

Overall, bond strength was not impaired but rather was enhanced by caries infiltrant preconditioning, confirming the results of previous studies which showed that caries infiltrant application increased SBS values of both etch-rinse and self-etching paste [45,47].

Adhesive remnant index scores

The adhesive remnant index was scored according to Wang, et al. [55]. Another relevant consideration besides bond strength is the residual adhesive upon debonding. The predominant finding after previous infiltration was the ARI score of I. This finding confirms that pre-treatment caries infiltration strengthens the structure of enamel and offers better stress distribution during shear bond testing.

The ARI indicated that, most of composite remained on the tooth after bracket debonding. This type of failure site suggested that either due to the weak link in the adhesive chain was occurred between the bracket base and the composite, this implies that resin penetrated the undercuts of the bracket base was unable to resist the shear stress when not fully cure this agree with the finding of Wang, et al., Fernandez, et al., and Üsümez, et al. [55-57] or due to strong bond between the adhesive interface and the enamel surface.

Also, filler reinforcement of composite increased bond strength, highly filled composite has advantage of great stiffness, strength, and good handling properties that prevent the bracket slippage away, but have disadvantage that decrease solubility of composite affect penetration into undercut of bracket base. Therefore, debonding occurred on the bracket-adhesive interface (adhesive fracture) with laser-structured base, which is consider as weak point in adhesive joint as reported by Faltemeier, et al. [58].

Using (3M) with Icon the score IV was 8.33%, the deeper enamel surface penetration by the adhesive, the greater the risk of enamel fractures this agrees with the finding of Bishara, et al., and Eminkahyagil, et al. [59,60]. Also, this may be due to the strong bond of adhesive to both the bracket base and the etched enamel surface, and strong bond within the adhesive itself, so with high value of shear strength applied to the bonded brackets during testing enamel detachment accrued, or may be due to variation in enamel structure and thickness of these teeth, this agree with the finding of Karam [61].

The failure site of metal brackets bonded with Ortho Technology without Icon were located at enamel-adhesive interface (score II is predominant). At enamel surface the adhesive failure might be due to demineralization depth were decreased. Because, the resin tags are thin, and less uniform, which is conductive to weaker bond [62,63].

As a result of the sealing effect on sound enamel and the stabilization of demineralized enamel, it is wise to use the caries infiltration before bracket fixation [46].

CONCLUSION

To summarize, pre-treatment Icon can affect bond strength as measured *in vitro*, producing the highest strength of all tested sample when compared with the other adhesive system without Icon.

REFERENCES

[1] Richter, Amy E., et al. “Incidence of caries lesions among patients treated with comprehensive orthodontics.” *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 139, No. 5, 2011, pp. 657-64.

[2] Bishara, Samir E., et al. “Enamel cracks and ceramic bracket failure during debonding *in vitro*.” *The Angle Orthodontist* Vol. 78, No. 6, 2008, pp. 1078-83.

[3] Heymann, Gavin C., and Dan Grauer. “A contemporary review of white spot lesions in orthodontics.” *Journal of Esthetic and Restorative Dentistry* Vol. 25, No. 2, 2013, pp. 85-95.

[4] Boersma, J.G., et al. “Caries prevalence measured with QLF after treatment with fixed orthodontic appliances: influencing factors.” *Caries Research* Vol. 39, No. 1, 2005, pp. 41-47.

[5] Willmot, Derrick. “White spot lesions after orthodontic treatment.” *Seminars in Orthodontics*. Vol. 14. No. 3. WB Saunders, 2008.

[6] Başaran, Güvenç, İlknur Veli, and Emine Göncü Başaran. "Non-cavitated approach for the treatment of white spot lesions: a case report." *International Dental Research* Vol. 1, No. 2, 2017, pp. 65-69.

[7] Tinanoff, N., et al. "Evidence-based update of pediatric dental restorative procedures: preventive strategies." *Journal of Clinical Pediatric Dentistry* Vol. 39, No. 3, 2015, pp. 193-97.

[8] Doméjean, Sophie, et al. "Resin infiltration of non-cavitated caries lesions: A systematic review." *Medical Principles and Practice* Vol. 24, No. 3, 2015, pp. 216-21.

[9] Paris, Sebastian, and Hendrik Meyer-Lueckel. "Masking of labial enamel white spot lesions by resin infiltration--A clinical report." *Quintessence International* Vol. 40, No. 9, 2009.

[10] Neuhaus, Klaus W., et al. "Late infiltration of post-orthodontic white spot lesions." *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie* Vol. 71, No. 6, 2010, pp. 442-47.

[11] Torres, Carlos Rocha Gomes, et al. "Effect of caries infiltration technique and fluoride therapy on the colour masking of white spot lesions." *Journal of Dentistry* Vol. 39, No. 3, 2011, pp. 202-07.

[12] Tay, Franklin R., et al. "Factors contributing to the incompatibility between simplified-step adhesives and chemically-cured or dual cured composites. Part I. Single-step Self-etching Adhesive." *Journal of Adhesive Dentistry* Vol. 5, No. 1, 2003.

[13] Gauthier, M. A., et al. "Oxygen inhibition in dental resins." *Journal of Dental Research* Vol. 84, No. 8, 2005, pp. 725-29.

[14] Habibi, Maryam, Tahereh Hosseinzadeh Nik, and Tabassom Hooshmand. "Comparison of debonding characteristics of metal and ceramic orthodontic brackets to enamel: An *in-vitro* study." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 132, No. 5, 2007, pp. 675-79.

[15] Vicente, Ascensión, and Luis Alberto Bravo. "Shear bond strength of precoated and uncoated brackets using a self-etching primer: An *in vitro* study." *The Angle Orthodontist* Vol. 77, No. 3, 2007, pp. 524-27.

[16] D'Attilio, Michele, et al. "Shear bond strength, bond failure, and scanning electron microscopy analysis of a new flowable composite for orthodontic use." *The Angle Orthodontist* Vol. 75, No. 3, 2005, pp. 410-15.

[17] Millett, Declan T., et al. "Bonded molar tubes-an *in vitro* evaluation." *The Angle Orthodontist* Vol. 71, No. 5, 2001, pp. 380-85.

[18] Polat, Omur, Ali Ihya Karaman, and Tamer Buyukyilmaz. "*In vitro* evaluation of shear bond strengths and *in vivo* analysis of bond survival of indirect-bonding resins." *The Angle Orthodontist* Vol. 74, No. 3, 2004, pp. 405-09.

[19] Bishara, Samir E., et al. "The effect of repeated bonding on the shear bond strength of a composite resin orthodontic adhesive." *The Angle Orthodontist* Vol. 70, No. 6, 2000, pp. 435-43.

[20] Bishara, Samir E., et al. "Comparison of bonding time and shear bond strength between a conventional and a new integrated bonding system." *The Angle Orthodontist* Vol. 75, No. 2, 2005, pp. 237-42.

[21] Murray, Stephen D., and Ross S. Hobson. "Comparison of *in vivo* and *in vitro* shear bond strength." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 123, No. 1, 2003, pp. 2-9.

[22] Gia, K. Yi, William J. Dunn, and Louis J. Taloumis. "Shear bond strength comparison between direct and indirect bonded orthodontic brackets." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 124, No. 5, 2003, pp. 577-81.

[23] Rajagopal, Rangaswamy, Sridevi Padmanabhan, and Janakirama Gnanamani. "A comparison of shear bond strength and debonding characteristics of conventional, moisture-insensitive, and self-etching primers *in vitro*." *The Angle Orthodontist* Vol. 74, No. 2, 2004, pp. 264-68.

[24] Drummond, J.L., et al. "Rebonding of orthodontic brackets. Part II, an XPS and SEM study." *Angle Orthodontist* Vol. 78, 2008, pp. 537-44.

[25] Bishara, Samir E., et al. "A new premixed self-etch adhesive for bonding orthodontic brackets." *The Angle Orthodontist* Vol. 78, No. 6, 2008, pp. 1101-04.

[26] Ostby, Adam Wade, et al. "Influence of self-etchant application time on bracket shear bond strength." *The Angle Orthodontist* Vol. 77, No. 5, 2007, pp. 885-89.

[27] Gronberg, Kimberly, et al. "Distance and time effect on shear bond strength of brackets cured with a second-generation light-emitting diode unit." *The Angle Orthodontist* Vol. 76, No. 4, 2006, pp. 682-88.

[28] Bishara, Samir E. *Textbook of Orthodontics*. WB Saunders, 2001, pp. 186-208.

[29] Katona, Thomas R., and Robert W. Long. "Effect of loading mode on bond strength of orthodontic brackets bonded with 2 systems." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 129, No. 1, 2006, pp. 60-64.

[30] Vorhies, A. Bronwen, et al. "Enamel demineralization adjacent to orthodontic brackets bonded with hybrid glass ionomer cements: An *in vitro* study." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 114, No. 6, 1998, pp. 668-74.

[31] Winchester, L. J. "Bond strengths of five different ceramic brackets: An *in vitro* study." *The European Journal of Orthodontics* Vol. 13, No. 4, 1991, pp. 293-305.

[32] McLaughlin, Richard P., John C. Bennett, and Hugo J. Trevisi. *Systemized Orthodontic Treatment Mechanics*. Elsevier Health Sciences, 2001. p. 68.

[33] Saleh H.H. "*A comparative study of the shear bond strength of different types of orthodontic adhesives (In vitro study)"*. 2004. University of Baghdad, Master Thesis.

[34] Al-Issa, A.A. "*The effect of repeated bonding on shear bond strength of different orthodontic adhesives"*. 2005. University of Baghdad, Master Thesis.

[35] Mahdi H.A. "*Evaluation of enamel surface damage after debonding using three different pliers (An in vitro study)"*. 2010. University of Baghdad, Master Thesis.

[36] Alexander, Stanley, A. "Effects of orthodontic attachments on the gingival health of permanent second molars." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 100, No. 4, 1991, pp. 337-40.

[37] Ewoldsen, Nels, et al. "Effects of enamel conditioning on bond strength with a restorative light-cured glass ionomer." *Journal of Clinical Orthodontics: JCO* Vol. 29, No. 10, 1995, pp. 621-24.

[38] Abdulameer A.G. "*Shear bond strength of different light-cured adhesives with metal and ceramic brackets: A comparative in vitro study"*. 2008. University of Baghdad, Master Thesis.

[39] McSherry, Patrick F. "An *in vitro* evaluation of the tensile and shear strengths of four adhesives used in orthodontics." *European Journal of Orthodontics* Vol. 18, No. 4, 1996, pp. 319-27.

[40] Cohen, Stephen M., et al. "Shear bond strengths of chemically and light-cured resin modified ionomers." *Journal of Clinical Orthodontics* Vol. 32, No. 7, 1998, pp. 423-26.

[41] Bishara, Samir E., et al. "Early shear bond strength of a one-step self-adhesive on orthodontic brackets." *The Angle Orthodontist* Vol. 76, No. 4, 2006, pp. 689-93.

[42] Bishara, Samir E., et al. "The effect of modifying the self-etchant bonding protocol on the shear bond strength of orthodontic brackets." *The Angle Orthodontist* Vol. 77, No. 3, 2007, pp. 504-08.

[43] Sonis, A.L. "Comparison of a light-cured adhesive with an auto-polymerizing bonding system." *Journal of Clinical Orthodontics: JCO* Vol. 22, No. 11, 1988, p. 730.

[44] Reynolds, I.R. "A review of direct orthodontic bonding." *British Journal of Orthodontics* Vol. 2, No. 3, 1975, pp. 171-78.

[45] Jia, Liuhe, et al. "Effect of caries infiltrant application on shear bond strength of different adhesive systems to sound and demineralized enamel." *Journal of Adhesive Dentistry* Vol. 14, No. 6, 2012.

[46] Naidu, Ewelina, et al. "Shear bond strength of orthodontic resins after caries infiltrant preconditioning." *The Angle Orthodontist* Vol. 83, No. 2, 2012, pp. 306-12.

[47] Wiegand, A., et al. "Adhesive performance of a caries infiltrant on sound and demineralised enamel." *Journal of Dentistry* Vol. 39, No. 2, 2011, pp. 117-21.

[48] Ekizer, Abdullah, et al. "Effects of demineralizaton-inhibition procedures on the bond strength of brackets bonded to demineralized enamel surface." *The Korean Journal of Orthodontics* Vol. 42, No. 1, 2012, pp. 17-22.

[49] Mews, Laura, et al. "Shear bond strength of orthodontic brackets to enamel after application of a caries infiltrant." *The Angle Orthodontist* Vol. 85, No. 4, 2014, pp. 645-50.

[50] Montasser, Mona A., and Mahasen Taha. "Effect of enamel protective agents on shear bond strength of orthodontic brackets." *Progress in Orthodontics* Vol. 15, No. 1, 2014, p. 34.

[51] Sano, Hidehiko, et al. "Relationship between surface area for adhesion and tensile bond strength-evaluation of a micro-tensile bond test." *Dental Materials* Vol. 10, No. 4, 1994, pp. 236-40.

[52] Shawkat, Essam S., et al. "Oxygen inhibition and incremental layer bond strengths of resin composites." *Dental Materials* Vol. 25, No. 11, 2009, pp. 1338-46.

[53] Meyer-Lueckel, Hendrik, et al. "Influence of application time on penetration of an infiltrant into natural enamel caries." *Journal of Dentistry* Vol. 39, No. 7, 2011, pp. 465-69.

[54] Paris, Sebastian, et al. "Penetration coefficients of commercially available and experimental composites intended to infiltrate enamel carious lesions." *Dental Materials* Vol. 23, No. 6, 2007, pp. 742-48.

[55] Wang, Wei Nan, Ching Liang Meng, and Tien Hsiang Tarng. "Bond strength: A comparison between chemical coated and mechanical interlock bases of ceramic and metal brackets." *American Journal of Orthodontics and Dentofacial Orthopedics* Vol. 111, No. 4, 1997, pp. 374-81.

[56] Fernandez, Leandro, and José A. Canut. "*In vitro* comparison of the retention capacity of new aesthetic brackets." *The European Journal of Orthodontics* Vol. 21, No. 1, 1999, pp. 71-77.

[57] Üşümez, Serdar, Tamer Büyükyilmaz, and Aliİhya Karaman. "Effect of light-emitting diode on bond strength of orthodontic brackets." *The Angle Orthodontist* Vol. 74, No. 2, 2004, pp. 259-63.

[58] Faltermeier, Andreas, et al. "Influence of filler level on the bond strength of orthodontic adhesives." *The Angle Orthodontist* Vol. 77, No. 3, 2007, pp. 494-98.

[59] Bishara, Samir E., et al. "The effect of variation in mesh-base design on the shear bond strength of orthodontic brackets." *The Angle Orthodontist* Vol. 74, No. 3, 2004, pp. 400-04.

[60] Eminkahyagil, Neslihan, et al. "Shear bond strength of orthodontic brackets with newly developed antibacterial self-etch adhesive." *The Angle Orthodontist* Vol. 75, No. 5, 2005, pp. 843-48.

[61] Karam L.M.K. "*Evaluation of shear bond strength of bonded molar tudes (In vitro comparative study")*. 2006. University of Baghdad, Master Thesis.

[62] Coups-Smith, K.S., P.E. Rossouw, and K.C. Titley. "Glass ionomer cements as luting agents for orthodontic brackets." *The Angle Orthodontist* Vol. 73, No. 4, 2003, pp. 436-44.

[63] Al-Khatib AR. "Consequences of employment self-etching primer adhesive in orthodontic practice." *Al-Rafidain Dental Journal* Vol. 4, No. 2, 2004, pp. 95-103.