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Research Article

Evaluation of Shear Bond Strength of Ceramic Laminate Veneers After Cementation with Different Types of Resin Cements. (An *In-Vitro* Study)

Ahmed Mohamed Elmarakby[1]*, Rymah Abdulaziz Alrashed[2], Riyadh Mohammed Albadr[3], Ali Mohammed Alfareh[3], Atheer Faihan Almutairi[2], Fahad Nayif Aldawood[2] and Lujain Shaher Altouri[2]

[1]Lecturer of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University, Assiute Branch, Egypt and Assistant Professor at Restorative Dental Science, Alfarabi Colleges for Dentistry and Nursing, Riyadh, Saudi Arabia

[2]General Dental Practitioner, Saudi Arabia

[3]BDS (KSU), One Year Fellowship in Advanced Esthetic Dentistry (Genona Uni), Working at MOH, Saudi Arabia

***Corresponding Author**: Ahmed Mohamed Elmarakby, Lecturer of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University, Assiute Branch, Egypt and Assistant Professor at Restorative Dental Science, Alfarabi Colleges for Dentistry and Nursing, Riyadh, Saudi Arabia.

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Abstract

Objectives: This study was designed to evaluate the shear bond strength and gap formation of ceramic laminate veneers after cementation with different types of adhesives\resin cements.

Material and Methods: Buccal surface of 55 extracted premolars were prepared for receiving the same number of ceramic laminate veneers disks. Specimens were divided into five groups (n = 11), according to the adhesive\resin cementation system. Distribution of groups was as follow: G1: Adper Single Bond 2/RelyX ARC in etch-and-rinse strategy, G2: Single Bond Universal/RelyX Ultimate in self-etch strategy, G3: Panavia F2.0 ED primer II Liquid A and Liquid B\Panavia F2.0, G4: Exite DSC\Variolink II and G5: One-Step\ Duolink. In each group, nine veneer disks were randomly evaluated for Shear Bond Strength test; while two veneer disks were evaluated for gap formation by Scanning electron microscope.

Results: All adhesives\resin cementation systems revealed different degrees of de-bonding and gap formation. The highest Shear Bond Strength values (MPa) were observed with One-Step\Duolink (Bisco), followed by Panavia F2.0 ED PRIMER II Liquid Aand Liquid B\Panavia F2.0 then Adper Single Bond 2\RelyX ARC in etch-and-rinse strategy. Poor performance was detected with Single Bond Universal\RelyX Ultimate in self-etch strategy then Exite DSC\Variolink II when they compared to other types.

Conclusions: Within the limitation of this study, it was revealed that the luting agent chemical composition determines the adhesive characteristics. Surface treatment for tooth substrate and veneer fitting surface play a significant role in formation of gap and enhancement of de-bonding.

Keywords: *Luting Cement; Ceramic Laminate Veneers; Adhesive Strategy; Shear Bond Strength*

Introduction

At this time, it became clear that the possibility for achieving aesthetic tooth restorations with a better smile for the patients can be done in easier way. This can be achieved through laminate veneer technique. Use of the most conservative tooth preparation techniques and the proper application of the adhesives are the basis for the clinical success of ceramic laminate veneers cases [1]. Of course, with the improvement of dental preparation techniques and with the rapid development of ceramic materials and their wide varieties, ceramic laminate veneers have become an undisputed choice for both the patient and the dentist as they can provide a beautiful aesthetic shape while maintaining the remaining tooth structure in a healthy state. It can also provide the patient with an attractive smile with a little preparation of teeth or sometimes with no dental preparation at all [2,3]. There is no doubt that the ceramic laminate veneers represent a revolution in restorative dentistry since it came to light few decades ago [4,5]. In fact, both dentists and ceramic technician need a good knowledge about the extensive collections of materials and techniques in relation to modern ceramic veneers to obtain the best treatment plane for those patients need this type of conservative cosmetic treatment. It should be noted that many clinical studies have proven that if the dentist of better clinical experience and good information met with a skillful technician with a professional craftsmanship, the results

of obtaining excellent ceramic laminate veneers are strongly increased [6,7]. There is no doubt that the main reason that many clinical studies have been considered the ceramic veneers is the best choice among the other alternatives of teeth restoratives is their preservation of aesthetics for a long time without a clear discolored effect [8-12]. On the other hand, the other studies, which had a different view, showed that there are a number of reasons that may lead to failure of ceramic veneers. These reasons can be summarized in a: the wrong selection of the case to be treated (such as those patients suffered from aggressive periodontitis), b: improper tooth preparation (enamel over-reduction combined with unnecessarily remove of dentin) that later on lead to a severe sensitivity to the pulp. c: incorrect application of adhesives and resin cement when misused by the dentist. All previous mentioned reasons play roles in the failure of the ceramic veneers [13,14]. However, if the restricted rules are followed when selecting the appropriate cases for making the ceramic laminate veneer as well as the good application of the adhesives and resin cements in addition to the proper teeth preparation, the resulting ceramic veneers will outperform the resin composite veneers [7,13]. Some clinical studies recorded percentages of cases that showed a failure in the ceramic veneers. The fracture of tooth structure recorded 6%, caries recurrence 6%, weak periodontal support 12.5%, poor luting cement and improper retention 12.5%, lack of desirable mechanical properties of veneer 31%, and Loss of esthetics 31% [15-19]. It is known that the weakest points of indirect tooth restorations is the proper application of adhesives and resin cements to make a good bond between tooth substrate and ceramic veneers. The rate of success or failure of these indirect restoration is closely related to how to deal with those adhesives and luting agents [20,21]. It is not logical to rely entirely on the success of obtaining strong bonding between teeth and ceramic veneers on bonding with enamel even if most studies have confirmed the high bond strength between enamel and adhesives. Enamel is not the only component of the teeth that facing the ceramic veneers to obtain a high bond strength. An additional dentin bond is important not only for enhancement and improvement the over-all bond strength but also to stop or decrease the postoperative hypersensitivity [22-23,25,26]. The latest trend in dental adhesives is universal bonding. Some examples are Scotchbond Universal (3M ESPE), Prime and Bond Elect (Dentsply Sirona), Clearfil Universal Bond (Kuraray), All-Bond Universal (Bisco) and others. The main advantage of that categories are their capability to be used in all application modes. This is to say they can be used in etch and rinse mode, selective enamel etching mode and self-etching mode. Another advantage is their ability not only to make a reliable bond between tooth substrates (Enamel and Dentin) and resin composites but also can make chemical bonding to other substrates such as zirconia or ceramics [27]. During preparation of teeth for receiving the porcelain laminate veneer, Most of the preparation margins are exposed to the oral environment. This may cause marginal leakage and dissolution of the luting agent [28,29]. This study was designed to evaluate the characteristics of adhesive bonding of five dual cured resin luting agents used for cementation of porcelain laminate veneers prepared with IPS Empress II E-Max Press.

Materials and Methods

A total number of fifty five human extracted premolar teeth were selected for this study. The selected teeth were extracted for orthodontic reasons. Teeth were caries free, did not undergo previous restorative treatment and have no cracks or developmental anomalies. Teeth were then immersed in distilled water and stored in an incubator (37^0C) until the next step of experiment. A rectangular block of stainless steel with dimensions of 30 mm x 10 mm x 25 mm has been prepared. A metal plate with a diameter of 30 mm x 15 mm x 2 mm with a circular hole of 4 mm in diameter was prepared in the center. On the top of the stainless steel block the plate was exactly fit. With a self-curing acrylic resin material, a special tray has been made to make an impression of stainless steel block. A polyether impression material (Impregum 3M ESPE) has been used to take an impression for the block. 4th type of improved stone has been used for pouring the impression. On a stone block, a central part of the 2 mm width was marked then a die spacer in two coats was painted at this area [30]. This resembled what happened in clinical conditions. After mold has been dried, the circular opening was directed to the mold stone block. Wax patterns were made from the (Bego) wax slices in the circular opening. Circular wax patterns have been sprued with the help of a 3 mm diameter spruce wax. The entire association was invested in fire resistant investment materials (phosphate bonded refractory type). For at least three hours until complete setting, the invested ring was kept aside without disturbance and then inserted into preheating furnace. In an investment ring, the ceramic ingots (E-max press) were placed. Inside the investment ring, the plunger has been kept in its predetermined position. The assembly was moved to the E-Max press furnace (Ivoclar Vivadent). The ceramic discs were recovered after the process of their cooling has been taken place. For roughing of the internal surface of veneers, sandblasting was performed followed by fishing and polishing. Fifty-five ceramic disks were prepared in the above ways. A stainless steel metal block of 25 mm x 20 mm x 25 mm has been prepared. A rectangular depression was performed to be suitable for the universal testing machine which will be used later during the shear bond test. Materials used in this study were collected in table 1.

Material trade Name	Category	Batch No. Manufacturer
Phosphoric Acid	Acid etch for tooth substrates	4762A2 3M ESPE
Hydrofluoric acid	Acid etch for veneer fitting surface	55083 3M ESPE
Adhesive Adper Single Bond 2	Etch-and-rinse adhesive system	4763 B 3M ESPE
Adhesive Single Bond Universal	Self-etching adhesive system	166926B 3M ESPE
Panavia F2.0 ED PRIMER II Liquid A and Liquid B	Etch-and-rinse adhesive system	1298 k Kuraray
Exite DSC	Etch-and-rinse adhesive system	7602 IV Ivoclar Vivadent
One-Step	Etch-and-rinse adhesive system	23985 B Bisco
Resin cement Relyx ARC	Resin cement	R04407 3M ESPE
Resin cement RelyX Ultimate	Resin cement	R265388 3M ESPE
Panavia F2.0	Resin cement	7654 L Kuraray
Variolink II	Resin cement	3332 IV Ivoclar Vivadent
Duolink	Resin cement	98043 B Bisco

Table 1: *Materials used in this study.*

Premolar selected for this study were mounted in a manner that keeping an exposed area above the cemento-enamel junction. Buccal surfaces were prepared flat for made a window design but within a depth not exceed enamel thickness. Any teeth had exposed dentin in their veneer preparation were discarded. For more confirmation of that step, samples were examined under stereo- microscope (Figure A1-A3) with (x 40) magnification. Using 37% phosphoric acid (3M ESPE) for fifteen seconds, all buccal surfaces of premolars were etched, rinsed, gently dried then treated with corresponding luting agent. Adhesive system recommended by the same manufacturer was used in this study to reduce incompatible chemical effect between them. Hydrofluoric acid (3M ESPE) for one minute was used for etching prepared porcelain disks that representing the laminate veneers, washed for fifteen seconds, then air dried for the same time. Silane coupling agent (3M ESPE) was then applied and finally resin cement was used to make a durable strong bond between prepared buccal surfaces of premolars and porcelain disks that representing the laminate veneers. Groups in this study were designed as the follow:

- **Group 1:** Adper Single Bond 2/RelyX ARC in etch-and-rinse strategy (3M).
- **Group 2:** Single Bond Universal/RelyX Ultimate in self-etch strategy (3M).
- **Group 3:** Panavia F2.0 ED PRIMER II Liquid A and Liquid B\Panavia F2.0 (Kuraray).
- **Group 4:** Exite DSC\Variolink II (Ivoclar Vivadent).
- **Group 5:** One-Step\Duolink (Bisco).

(1) (2) (3)

Figure A1-A3: *(1) LLoyid Universal testing machine, (2) Specimens undergone shear bond strength testing and (3) Stereomicroscope and digital camera connected to it.*

In a sample holder under 1 KG weight for 30 minutes all specimens were kept. In distilled water for 24h, Specimens of all adhesive systems were preserved to simulate what has happened in the oral environment. The shear bond test has been performed with the Universal testing machine (LLoyid Instron U.S.A.). The specially designed chisel was fabricated with specific dimensions compatible with the selected Universal testing machine. The maximum applied load at the de-bonding was measured. The shear bond strength values were calculated in Mpa and inserted into SPSS® software, examined and analyzed by three way ANOVA and Tukeys student post-hoc test (α = .05). Two sample from each group of were selected randomly for scanning electron microscopic analysis to revealed gap formation. The comparison between the mean shear bond strength of all groups is done by Scheffe's multiple-comparison test. Chi-square test was applied to statistically evaluate the mode of fractures.

Results

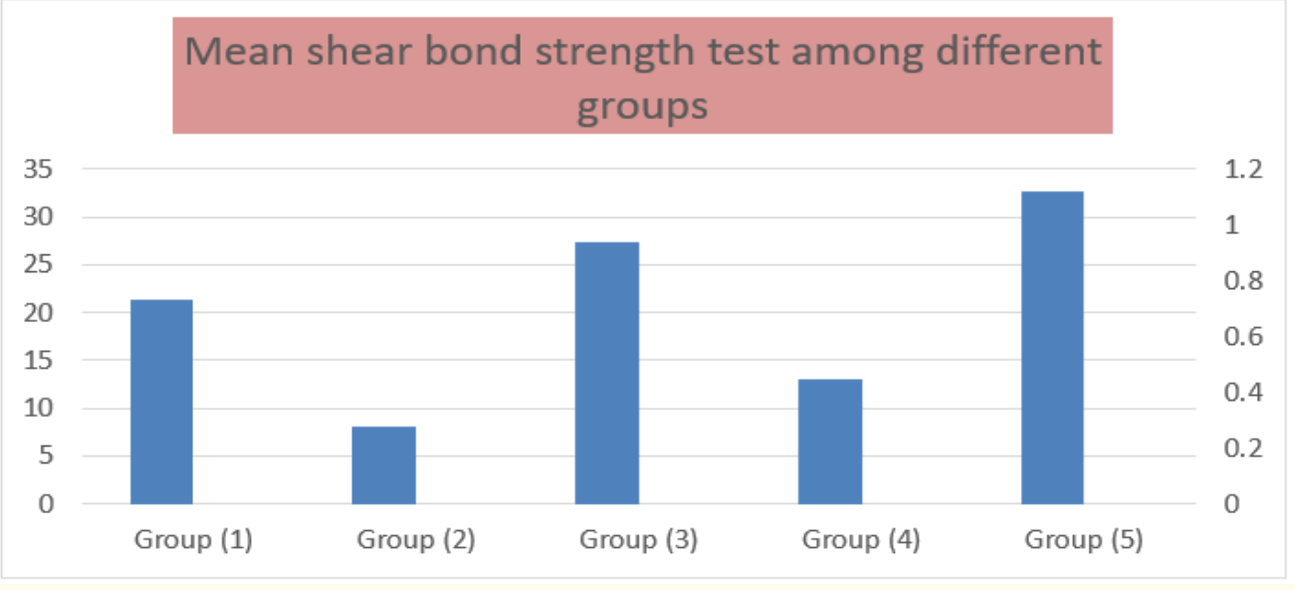
Appropriate tests were performed for accurate statistical analysis. To compare the shear bond strength values of five resin luting agents used in this study, Analysis of Variance test (ANOVA) was used. The results of ANOVA test are shown in table 2. Arrangement the groups from the highest shear bond strength values to the lowest was as follow:

- **Group 5:** One-Step\Duolink (Bisco): The shear bond strength value of this group ranged from (31.1006 M pa to 34.2032) Mpa with mean 32.73 Mpa.
- **Group 3:** Panavia F2.0 ED PRIMER II Liquid A and Liquid B\Panavia F2.0 (Kuraray): The shear bond strength value of this group ranged from (25.1557 Mpa to 28.5693 Mpa with mean 27.37 Mpa.)
- **Group 1:** Adper Single Bond 2/RelyX ARC in etch-and-rinse strategy (3M): The shear bond strength value of this group ranged from (20.2988 Mpa to 22.369 Mpa) with the mean 21.309 Mpa.
- **Group 4:** Exite DSC\Variolink II (Ivoclar Vivadent): The shear bond strength value of this group ranged from (11.1429 Mpa to 16.2385 Mpa) with the mean 12.96 Mpa.
- **Group 2:** Single Bond Universal/RelyX Ultimate in self-etch strategy(3M): The shear bond strength value of this group ranged from (8.4359 Mpa to 9.5406 Mpa with the mean 8.11 Mpa).

The p-value ≥ 0.005. This analysis revealed that the results were statistically significant. The comparison between the mean shear bond strength of all the groups is done by Scheffe's multiple-comparison test. The highest mean shear bond strength value was shown in Group 5 followed by Group 3, Group 1, and Group 4. The lowest mean value of shear bond strength was shown by Group 2 as shown in table 3. The mode of fractures occurred at different interfaces was observed under stereomicroscope figure A and results seen in table 4. Chi-square test was applied to statistically evaluate the mode of fractures. The p-value was ≥ 0.00005 which was highly significant. This analysis explains that Group 5 and Group 3 are at less risk of getting fractured whereas the remaining groups are at higher risk.

Specimens\Groups	Group 1	Group 2	Group 3	Group 4	Group 5
1	20.3685	9.4484	25.1557	12.4965	31.8471
2	20.2988	8.8507	27.4996	11.6107	32.1656
3	21.1557	9.5406	28.5786	12.4955	33.1213
4	21.5729	9.3284	27.4682	11.1429	32.1698
5	21.7226	8.8507	28.5693	13.1274	32.1324
6	22.369	8.2173	25.2556	12.4965	31.1006
7	22.122	8.0718	25.4324	13.3446	34.2032
8	21.732	8.4359	25.3324	11.6107	32.1752
9	22.369	8.5446	28.7683	16.2385	34.1021

Table 2: *Shear bond strength testing of different groups used in the study.*



Graph : *Bar chart represents the mean shear bond strength among different groups used in this study..*

Group	Number of samples	Range	Mean
Group (1)	9	20.2988 Mpa to 22.369 Mpa	21.309 Mpa.
Group (2)	9	8.4359 Mpa to 9.5406 Mpa	8.11 Mpa
Group (3)	9	25.1557 Mpa to 28.5693 Mpa	27.37 Mpa
Group (4)	9	11.1429 Mpa to 16.2385 Mpa	12.96
Group (5)	9	31.1006 M pa to 34.2032	32.73 Mpa

Table 3: *Scheffe's multiple comparison test.*

Group no. (n = 11 in each group)	Cohesive fracture		Adhesive Fracture	
	In Luting agent	In porcelain	In porcelain and luting agent interface	At tooth and luting agent interface
Group 1	1	2	5	3
Group 2	7	1	2	1
Group 3	1	2	6	2
Group 4	4	1	3	3
Group 5	1	1	7	2

Table 4: *Mode of fracture in luting agents.*

SEM analysis

The scanning electron microscopic study was performed at the fractured interface of representative samples from each group of luting agents. This analysis was performed because magnification is (1000x) and it is possible to focus the beam to a spot, and not to image the specimen. Different gaps formed between enamel surface and different adhesive\luting resin cements used in this study were observed in figures 1-5.

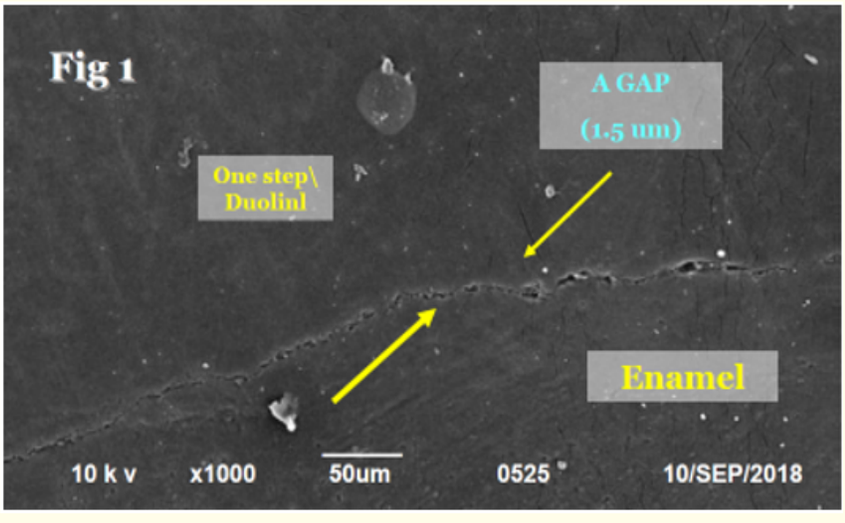


Figure 1: *A gap (1.5 um) between enamel and veneer disk when one step\Duolink resin cement was used.*

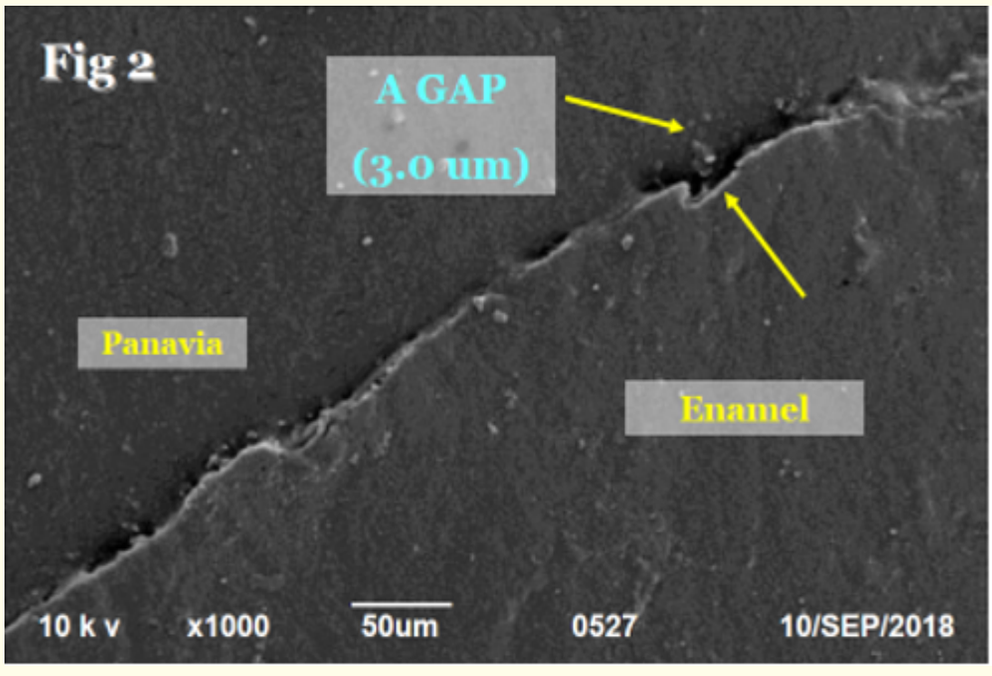


Figure 2: *A gap (3.0 um) between enamel and veneer disk when Panavia ED\Panavia resin cement was used.*

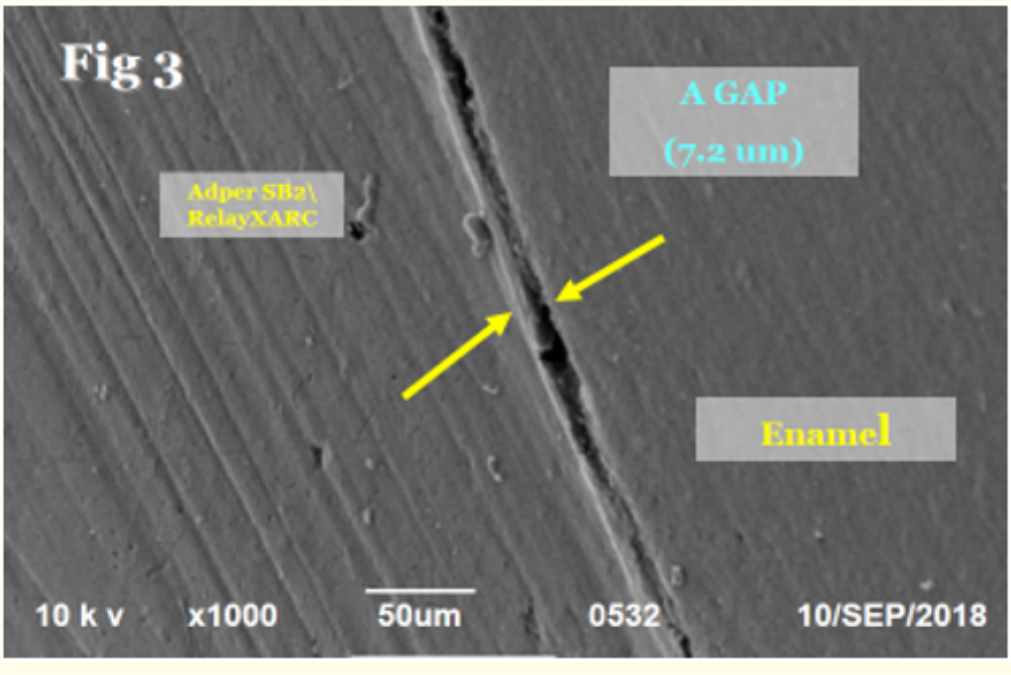


Figure 3: *A gap (7.2 um) between enamel and veneer disk when Adper SB2\Rely XARC resin cement was used.*

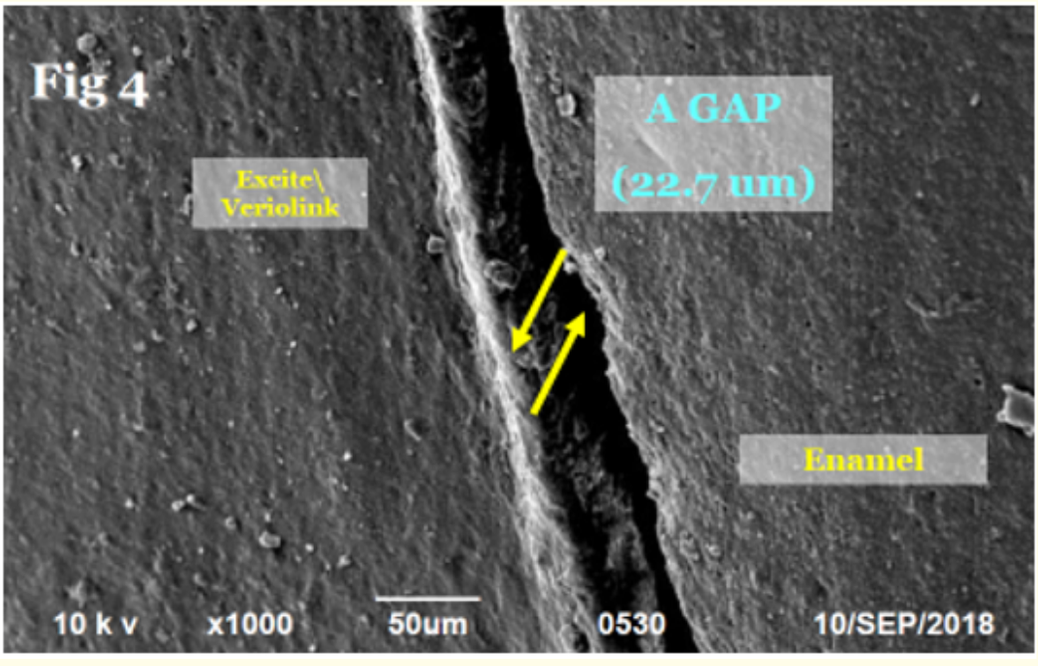


Figure 4: *A gap (22.7 um) between enamel and veneer disk when Excite\Veriolink resin cement was used.*

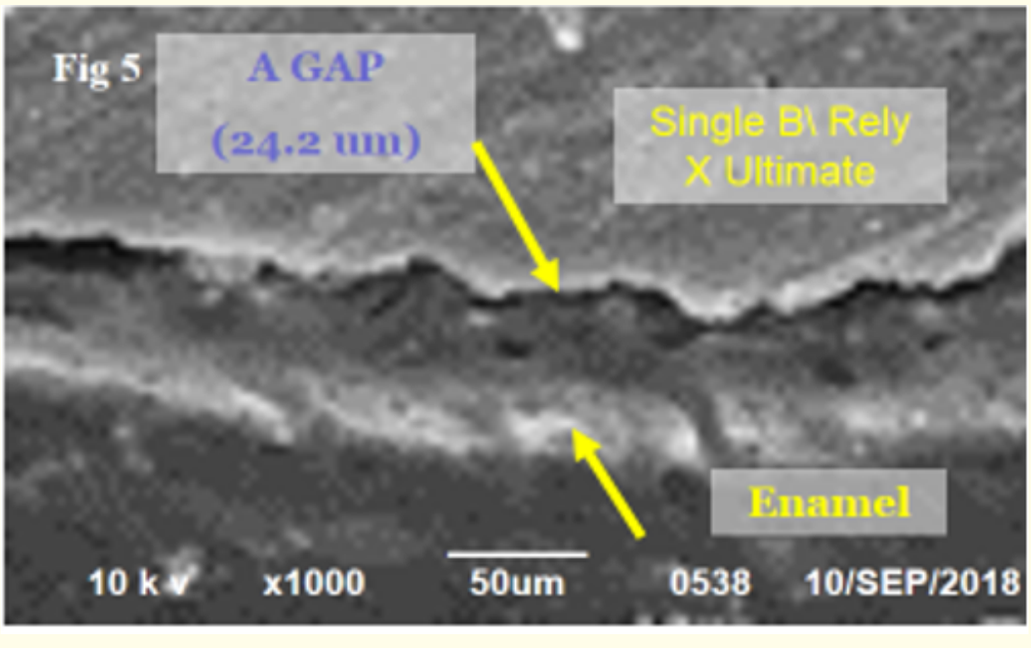


Figure 5: *A gap (24.2 um) between enamel and veneer disk when Single B\Rely X Ultimate resin cement was used.*

Discussion

Bailey LF and Chen JH., *et al.* were concluded that good surface treatment of porcelain laminate veneers and nature of adhesive system and luting agent and their chemical composition play an important role in making a durable bond between the tooth substrates and the indirect restoration [31-33]. In the present *in vitro* study, all manufacturer's instructions have been strictly followed to ensure a successful adhesive bonding of the laminates veneers fabricated from E-Max Press to tooth substance. Enas H., *et al.* [34] concluded that storage media and storage conditions had no significant effect on the shear bond strength of dentin of extracted teeth to esthetic restoration so a storage media in this study was the distilled water. High shear bond strengths were produced when porcelain surface was etched with hydrofluoric acid then silane coupling agent was used for enhancing bond strength between porcelain laminate veneers bonded to etched enamel or resin composites [35-39]. The fracture resistance of all-ceramic materials can be increased when using adhesive luting agents that can inhibit propagation of cracks by penetrating into the irregularities of the restoration's internal surface then all blanks could be filled and closed [40-43]. Although stresses at the restorations interface are so complex, many studies clarified that forces working perpendicular or parallel to the tooth surface can be measured when it have been identified as primarily tensile or shear types of stresses [44-46]. As application of the previous rule, shear bond tests were performed in the present study for measure bonding of resin luting cements and adhesive systems that used for complete bond between tooth substrate and the ceramic material. The highest mean shear bond strength value was shown in Group 5: One-Step\Duolink (Bisco) followed by Group 3: Panavia F2.0 ED PRIMER II Liquid A and Liquid B\ Panavia F2.0 (Kuraray), Group 1: Adper Single Bond 2/RelyX ARC (3M) and Group 4: Exite DSC\Variolink II (Ivoclar Vivadent). The lowest mean value of shear bond strength was shown by Group 2: Single Bond Universal/RelyX Ultimate in self-etch strategy (3M). These results shown in table 2. No significant differences were observed in failure mode or type of fracture frequencies among the test groups except Group 2: Single Bond Universal/RelyX Ultimate in self-etch strategy (3M). This is in agreement with results of the study of Özcan M [47]. The study was designed to measure the effect of surface conditioning methods on the bond strength of luting cement to ceramics. In the current study most of the failures in all groups of luting agents are adhesive at the cement/veneer interface except in Group 2: Single Bond Universal/RelyX Ultimate in self-etch strategy (3M) where the cohesive failures in the luting agent are clear i.e. occurred in 8 samples out of 11 as seen in table 4. The relation between shear bond strength and failure mode was explained by the study of P Samimi and Filsoufi K [48]. They concluded that the luting agent with lowest SBS (Shear bond strength) value could exhibit the greatest tendency for cohesive fractures in the luting agent. The values shown by G 2: Single Bond Universal/RelyX Ultimate in self-etch strategy (3M) are in agreement with this conclusion. On contrast, higher shear bond strength and lower cohesive failure were found among the other luting agents groups used in this study. G 5: One-Step\Duolink (Bisco) has produced the highest SBS value. The scanning electron microscopic analysis of this group revealed that most of the failures are adhesive in nature. The statistical analysis of mode of fracture failure indicates that G 2: Single Bond Universal/RelyX Ultimate in self-etch strategy (3M) is at higher risk of fracture and Group 5: One-Step\Duolink (Bisco) followed by Group 3: Panavia F2.0 ED PRIMER II Liquid A and Liquid B\Panavia F2.0 (Kuraray) are at the least risk. It was clear in this study that adhesive system that used in self etch strategy produced poor performance regarding shear bond strength. Buccal surface preparation was confined to enamel thickness and any tooth that their preparation penetrate dentin surface was discarded. Better performance of self-etch strategy always detected when it applied to dentin surface as it decrease technique sensitivity, but weak acid incorporated in component of self-etch adhesive system neither able to remove smear layer completely nor selective demineralized enamel substrate.

As mentioned before, chemical composition of resin cement luting agent play an important role in making a durable bond between the tooth substrates and the indirect restoration [31-33]. Group 1: Adper Single Bond 2/RelyX ARC (3M), and Group 4: Exite DSC\Variolink II (Ivoclar Vivadent) and Group 2: Single Bond Universal/RelyX Ultimate in self-etch strategy (3M) are the monomer matrix composed of Bis-GMA and TEGDMA polymer. Panavia F2.0 contains 10, metha acryloxydecyl hydrogen phosphate. The chemical composition of One-Step\Duolink (Bisco) can explain the reason of its highest value regarding SBS. The enhanced bond strength of this luting agent can be attributed to its proprietary amine free redox system. This is resistant to acidic monomers within air inhibited layer of the light cured adhesive agents. However, further *in vivo* studies are necessary to confirm to give more clarifications about that subject.

Conclusion

This *in vitro* study was designed to evaluate the shear bond strength of five different types of duel cured resin luting agents used for make a durable bond between tooth substrate and porcelain laminate veneers. within the limitation of this study, One-Step\Duolink (Bisco) is the best luting agent for luting of porcelain laminate veneers fabricated with IPS Empress II i.e. E.-Max Press (Lithium disilicate

based ceramic material). good surface treatment of porcelain laminate veneers and nature of adhesive system and luting agent and their chemical composition play an important role in making a durable bond between the tooth substrates and the indirect restoration.

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