Margin Assessment and Fracture Resistance of Adhesively Luted Ceramic Crowns

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Abstract: Objectives: The aim of this study was to investigate the effect of different adhesive systems on the vertical marginal gap distance and the fracture resistance of lithium disilicate based crowns.
Methods: Forty premolars were prepared to receive forty e-max crowns. The crowns were divided into 4 groups (N=10 each) according to the adhesive luting systems. Group (U): using RelyX Unicem resin cement (self-adhesive system). Group (V): Variolink II (total-etch system). Group (GU) and group (GV): application of G-bond (self-etch) on dentin preceded previously used adhesive systems. A stereomicroscope was used to record the vertical marginal gap distance before and after cementation. The crowns were subjected to cyclic loading and fracture resistance test. Data were statistically analyzed using One-way Analysis of Variance (ANOVA) SPSS 15.0. A scanning electron microscope was used to qualitatively examine the dentin/resin interface. Results: Groups (GU) (67.6 ± 5.8 µm) and (GV) (68 ± 6.4 µm) recorded the significantly lowest vertical marginal gap, followed by group (V) (82 ± 6.8 µm). Group (U) showed the highest marginal inaccuracy (114 ± 6.4 µm). Group (GU) recorded the significantly highest fracture resistance (2840.5 ± 3.8 N), followed by group (GV) (2411.3 ± 3.3 N) and group (V) (2365.8 ± 3.6 N). Group (U) showed the lowest results (2270.9 ± 3.4 N). Conclusions: Ceramic restorations luted with total-etch system offer better vertical marginal gap distance and fracture resistance than restorations luted with self-adhesive system. Treatment of the dentin surface prior to the application of the bonding system is efficient. [Journal of American Science. 2010;6(11):264-273]. (ISSN: 1545-1003).

Keywords: Adhesives, marginal gap, fracture resistance, all-ceramics

1. Introduction

Success of any indirect dental restorations depends on many factors among them the cementation techniques and procedures. Dental cement must act as a barrier against microleakage, holding the tooth and restoration together mechanically and/or chemically. The behavior of the cement and bonding systems is complex and partly depends on the properties and quality of the component parts of each system.[1] An ideal dental adhesive should be able to wet, infiltrate dentin and provide a durable bond between the unhomogenicity of enamel and dentin and the restoration.[2] The permeability of dentin to adhesive agents depends on the resin infiltration of both dentinal tubules and intertubular dentin, however, resin infiltration into intertubular dentin can occur only if the mineral phase of dentin is removed by acid conditioners.[3] Knobloch et al 2007, reported a résumé of the modification done through the bonding agent generations.[4] Total-etch technique including dry and wet techniques, rely on etching the dentin and removal of the smear layer. This technique involves a separate etch and rinse step followed by priming and application of the bonding resin, it is said to be a time consuming technique.[5] Self-etching technique rely on etching the dentin using non rinse acidic monomers that simultaneously condition and prime, in one step, incorporating the smear layer within the hybrid layer so that it becomes one single layer.[6] RelyX Unicem (3M ESPE, Seefeld, Germany) the self-adhesive, universal resin cement without surface pretreatment has been introduced. It is based on a novel initiation technology using new monomer and filler. The organic matrix consists of newly developed multifunctional phosphoric acid methacrylate, which, can react with the basic fillers in the luting cement and the hydroxyapatite of the hard tooth tissue. This cement quickly neutralizes during the curing process, to switch from a hydrophilic to a hydrophobic state. This unique switch allows the material to adapt to the tooth structure while in the hydrophilic state, yet provide for ongoing dimensional stability with the restoration after converting to the hydrophobic matrix.[7]

Today operators have the choice between water based and resin based cements, which can be used with or without adhesives.

They should however choose the most efficient system i.e. pretreatment of the dentin surface is advisable.[8] A strong bond has been reported to improve marginal adaptation and increases fracture resistance of the tooth and the restoration.[9]

An increased demand for aesthetic restorations makes ceramic the material of choice as anterior and posterior restorations. Consequently, all-ceramic crown may be considered an alternative restoration for highly esthetic areas.[10] Several types of all-ceramic materials have been developed for posterior crowns, including castable ceramics, leucite-reinforced ceramics, lithium disilicate, aluminum oxide ceramics, and zirconium oxide ceramics.[11,12] Several factors influence the compressive strength testing of a clinical ceramic crown, such as preparation design, ceramic material, crown thickness, method of luting, cyclic loading, and thermal cycling.[13] The majority of failures of all ceramic crowns are initiated at the inner surface of the crown where it is subjected to maximum tensile stress and this is intensified by the presence of flaws and cracks.[14] Resin luting agents providing durable resin bonds significantly strengthen ceramic materials by “healing” minor surface defects.[15] Adhesive resin cements must have the ability to bond to both tooth structure and restoration, otherwise, poor bond quality at either the ceramic-cement or dentin-cement interface can significantly reduce the fracture resistance.[13]

The purpose of this study was to investigate the effect of the adhesive bonding system (total-etch versus self-etch) on the vertical marginal gap distance and the fracture resistance of lithium disilicate based crowns and to evaluate the effect of dentin pre-treatment preceding each cement on the results.

2. Materials and Methods

1- Sample preparation:

Forty recently extracted caries free maxillary first premolars of similar size were collected and stored in water in a refrigerator to avoid dehydration until used. The teeth were embedded in acyclic resin blocks (Meliodent, Bayer Dental, Newbury, UK) up to 2mm below the cemento-enamel junction. To secure the tooth in the resin block, a hole in the root was drilled where an orthodontic wire was placed and protruded for mechanical interlocking within the resin. Using an industrial lathe machine, the teeth were prepared for all ceramic preparation with standardized dimensions of 6 degrees angle of convergence.[16] The preparation had 5mm occluso-cervical height, 3mm occlusal diameter, 6mm cervical diameter, 1.2 mm shoulder finish line and 130 degrees occlusal angle.

2- Crowns construction:

A total number of forty crowns were constructed. For the purpose of standardization, two counter dies (stainless steel) were constructed, one counter die provided 0.8mm space for core construction and the other provided 1.2mm space for veneer application. Forty impressions of the prepared teeth were made with polyvinyl siloxane impression material (Imprint II, 3M, ESPE, Minnesota, USA) using custom made trays and poured into stone dies (Degussa, AG, Frankfurt, Germany). The stone dies were trimmed, and die spacer was applied (Vita zahnfabrik, Bad Sackingen, Germany) followed by separating medium application (Bego, Bremer, Bremen, Germany). Direct wax pattern (Schuler-dental, Gmbh & Co, Koln, Germany) was made on the stone dies. Waxed crown samples were constructed, and then the first counter die was applied to provide 0.8mm space for core construction. Verification of the thickness was performed using a caliper. Spruing, investing using E-max Press Vest Speed investment (Ivoclar, Vivadent, Schaan, Liechtenstein) and wax elimination following manufacturer’s instructions was performed. E-max Press ingots medium opacity (Ivoclar, Vivadent, Schaan, Liechtenstein) were heat pressed in the EP 600 furnace (EP600 Combi, Ivoclar, Vivadent, AG FL-9494, Schaan, Liechtenstein) following manufacturer’s instructions forming the full thickness core. The cores were replaced onto the dies for full thickness veneering application, using the second counter die which provides 1.2mm space for veneer application (0.4mm thickness). The E-max Ceram veneering (Ivoclar, Vivadent, Schaan, Liechtenstein) was mixed, then applied conventionally and fired according to the manufacturer’s direction. Adjustment to the final 1.2mm thickness was verified prior to over glaze at 750˚C. Finally, the samples were ultrasonically cleaned in an ultrasonic bath (Vitasonic, Vita Zahnfabrik, Bad Sackingen, Germany) for five minutes and then examined carefully for any crack or defect. The fitting surface of the E-max crowns was etched for 2 minutes with hydrofluoric acid (Ivoclar, Vivadent, Schaan, Liechtenstein) then silane treated (Monobond-S, Vivadent, Schaan, Liechtenstein) according to the manufacturer recommendation.

3- Samples assignment:

The forty crowns were assigned to 4 groups (N = 10 each) according to the adhesive luting systems employed. Table (1) shows the different systems used, their main components and application protocols.

Group (U): Self-etch system:

The self-adhesive approach was employed using RelyX Unicem resin cement (U) according to the manufacturer's instruction to lute the ceramic crowns.

Group (V): Total-etch system:

The dentin was etched with 35% phosphoric acid for 15 seconds, rinsed, gently air dried, and followed by Excite DSC bonding agent application (Ivoclar, Vivadent, Schaan-Liechtenstein). Variolink II resin cement (Ivoclar, Vivadent, Schaan, Liechtenstein) was mixed according to the manufacturer's instructions and applied to the internal walls of the crowns for cementation.

Group (GU):

An application of G-bond (G) on untreated dentin preceded the use of RelyX Unicem resin cement (U) for luting the crowns.

Group (GV):

It consisted of the application of G-Bond (G), the self-etch adhesive, on untreated dentin according to the manufacturer's instructions, and then Variolink II resin cement was used for cementation of the crowns.

4- Ultrasonic cementation of the crowns:

An ultrasonic seating tip (Sonic Flex, KaVo, America Corporation, Lake Zurich, IL, USA) was used to seat the crowns on the dentin surface. The ultrasonic unit was set at a power 2 and was turned on each time for five seconds to minimize the up heating of the tip. The total ultrasonic seating time was 30 seconds,[17] where pressure was applied on several points of the surface. Then light curing was done multidirectional according to the manufacturer's instructions. The cemented crown samples were stored in distilled water for 24 hours at room temperature, and then subjected to 500 thermal cycles between 5°C and 55°C with dwell time of 30 seconds.

Vertical marginal gap distance assessment before and after cementation:

A stereomicroscope (SZ-PT-Olympus, Tokyo, Japan) was used to measure the vertical marginal gap in microns at the tooth/ceramic interface for the ceramic crowns being non-luted which recorded a mean marginal gap of 58 µm. The cemented crown samples were examined for vertical marginal gap distance after cementation, to monitor the interfacial vertical marginal gap distance in microns at the tooth/ceramic interface multiple measurements were made at eight different regions of the crown circumference. This is done to compare between the 4 groups regarding the effect of different adhesive systems on the marginal gap.

Fracture resistance test after cyclic loading:

All samples were individually and vertically mounted in the lower fixed compartment of a computer operated materials testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, Hampshire, UK) with a load cell of 5 kN and data were recorded. The samples underwent pre-loading in a cyclic manner (10000 cycles).[18] The load was cycled between a specified minimum 30 N to prevent lateral dislocation of load applicator and a maximum 300 N, this reflects normal occlusal and chewing forces.[19] This testing protocol was based on previous reports of physiological load levels during chewing (clinical realistic). The rate of cyclic loading was a compromise between physiological chewing rates (masticatory cycle 0.8-1.0 , approximately 1 Hz).[20] A layer of rubber was placed between the loading tip and the occlusal surface of the crown samples to achieve homogenous stress distribution and minimization of the transmission of local force peaks.

After load cycling, the crowns were then statically compressively loaded until fracture at a cross head speed of 1mm/min with the same steel rod, which had been used in cyclic pre-loading procedure placed centrally at the occlusal surface of the crowns. The load-deflection curves were recorded with computer software (Nexygen; Lloyd Instruments Ltd). The compressive load required to cause fracture was recorded for each specimen in Newtons.

Statistical analysis:

Data were presented as mean and standard deviation (SD) values. Paired t test was used to compare vertical marginal gap before and after cementation. One-way Analysis of Variance (ANOVA) was used to compare between the 4 groups regarding the effect of different adhesive systems on the mean fracture resistance and marginal gap distance of the four groups. Tukey's post-hoc test was used for pair-wise comparison between the means when ANOVA test was significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS 15.0 (Statistical Package for Scientific

Studies for Windows. SPSS, Inc., Chicago, IL, USA.)

Visual examination for the mode of fracture:
All specimens were visually examined to determine the mode of fracture.

Scanning electron microscopic examination at dentin/resin interface:

For morphologic evaluation of the dentin/resin interfaces by SEM (Jeol, XL, Phillips, Holland), eight mandibular premolars were collected. The teeth were prepared by sectioning the crown perpendicular to the long axis of the tooth using a low speed diamond disc under water coolant to remove occlusal enamel and expose a flat dentinal surface. The teeth were then embedded in self-cured acrylic resin, using a cylindrical Teflon mold, such that the long axis of the tooth was perpendicular to the surface of the mold. The dentinal surfaces were abraded with 360/grit silicone carbide paper under running water to create a flat, uniform, smooth dentinal surface. The teeth were selected as representative samples for each group with its prementioned protocol of adhesive application to the dentin surface but without the crowns. A split Teflon mold was used (with a central hole of 3mm diameter and 2mm depth) for resin cement application. Representative samples (two teeth) for each of the 4 groups were sectioned longitudinally through the dentin-resin interface perpendicular to the bonded surface of each tooth, using a low speed rotary cutting machine under copious water coolant. After the surfaces were polished with soflex polishing discs, they were immersed in 6-mol/liter hydrochloric acid (HCl) for 30 seconds to demineralize any minerals within the hybrid layer that was not protected by resin infiltration. This was followed by rinsing the specimens with water for one minute. The specimens were then immersed in 1% sodium hypochlorite (NaOCl) for 10 minutes to dissolve all exposed collagen beneath the hybrid layer, and then thorough rinsing with water was performed for 5 minutes.[21] The specimens were dehydrated in ascending concentration of alcohol, subjected to critical point drying and then all specimens were gold sputtered. The hybrid layer and the resin tags at dentin/resin interfaces of these specimens were observed with SEM at magnification 1000 X.

3. Results

The means, standard deviation values and results of paired t-test presented in Table 2, revealed that there was a statistically significant increase in mean gap distance after cementation in all groups.

Vertical marginal gap distance after cementation for the four groups

The means, standard deviation values and results of ANOVA and Tukey's tests are presented in Table (3). Group (U) showed the statistically significant highest mean gap distance. This was followed by group (V). There was no statistically significant difference between group (GU) and group (GV), which showed the statistically significantly lowest means gap distance.

Fracture resistance

The means, standard deviation values and results of ANOVA and Tukey's tests are presented in Table (4). Group (GU) showed the statistically significantly highest mean fracture resistance. This was followed by group (GV) then group (V). Group (U) showed the statistically significantly lowest mean fracture resistance value.

Visual mode of failure

Visual examination of all groups showed a longitudinal fracture through the crown continuous with the tooth structure. Figure 1 is a representative sample showing the longitudinal fracture.

Scanning Electrons Micrograph

Scanning electron micrograph for self–etch adhesive approach group (U) presented in Figure 2a revealed indistinct resin tag formation. Typical well-formed resin tags were not prominent. G-bond application to dentin prior self-etch adhesive system in group (GU), presented in Figure 2b, resulted in increased resin tag formation which are connected with resin infiltrated dentin surface. Long, thick coagulated pattern was evident. Total-etch approach of group (V), Figure 2c, revealed the presence of hybrid layer with numerous long, tubular resin tags forming a bundler appearance. They are connected with resin infiltrated dentin surface in a rough pattern, resinous lateral branches connecting adjacent resin tags. A gap free attachment at the interface was evident. G-bond application to dentin prior to Variolink (GV), presented in Figure 2d, resulted in increased resin tag formation in a bundler appearance. They are connected with resin infiltrated dentin surface. Resinous branches with long, thick coagulated pattern were evident.

Table 1: The components and application protocols of the dentin adhesive system

Adhesive system (Manufacturer)	Main component	Application protocol
RelyX Unicem resin luting cement (3M ESPE, Seefeld, Germany)	Methacrylated phosphoric ester, dimethacrylates, inorganic fillers, fumed silica, stabilizers and initiators.	(Self-adhesive approach) the cement was supplied in a capsule, which was activated and mixed for 10 seconds using Rotomix (3 M ESPE)
Variolink II resin luting cement(Ivoclar, Vivadent, Schaan, Liechtenstein)	Urethan Dimethacrylate (UDMA) and Bis phenol Glycedial methacrylate (BisGMA), inorganic fillers barium glass filler and silicon dioxide filler, Ytterbium triflouride, catalysts stabilizers and pigments.	2 paste system (total-etch approach) Base: Urethane dimethacrylate, Catalyst: Dimethacrylates.
Exite (Ivoclar, Vivadent, AG FL-9494 Shaan/Liechtenstein)	2-Hydroxyethylmethacrylate (HEMA), dimethacrylates, phosphoric acid acrylate, silicon dioxide, initiators and stabilizers in an ethanol solution	Apply to moist dentin for 10 seconds. Dry gently for 1-3 seconds. Light cure for 20 seconds.
G-Bond (GC corporation, Tokyo, Japan)	Methacryloyloxyethyl Trimellitate (4-MET), phosphoric ester monomer, UDMA, acetone and camphorquinone	Apply to entire dried surface. Leave undisturbed for 10 seconds. Dry thoroughly under maximum air pressure for 5 seconds. Light cure for 10 seconds.

Table 2: The means and standard deviation values of paired t-test of the vertical marginal gap distance in micrometers before and after cementation

	U	**V**	**GU**	**GV**
Before cementation	58 ± 6.7			
After cementation	114 ± 6.4	82 ± 6.8	67.6 ± 5.8	68 ± 6.4
***P*-value**	**<0.001***	**<0.001***	**<0.001***	**<0.001***

*: Significant at P ≤ 0.05

Table 3: Mean and standard deviation of the vertical marginal gap distance in micrometers of the different groups after cementation

Group U (RelyX Unicem)		Group V (Variolink with Excite)		Group GU (RelyX Unicem with G-bond)		Group GV (Variolink with G-bond)		*P*-value
Mean	SD	Mean	SD	Mean	SD	Mean	SD	
114 [a]	±6.4	82 [b]	±6.8	67.6[c]	±5.8	68 [c]	±6.4	<0.001*

*: Significant at P ≤ 0.05, Means with different letters are statistically significantly different according to Tukey's test

Table 4: Mean and standard deviation of the fracture resistance in Newton of the different groups

Group U (RelyX Unicem)		Group V (Variolink with Excite)		Group GU (RelyX Unicem with G-bond)		Group GV (Variolink with G-bond)		*P*-value
Mean	SD	Mean	SD	Mean	SD	Mean	SD	
2270.9 [d]	±3.4	2365.8 [c]	±3.6	2840.5 [a]	±3.8	2411.3 [b]	±3.3	<0.001*

*: Significant at P ≤ 0.05, Means with different letters are statistically significantly different according to Tukey's test

Figure 1: A representative longitudinal fracture for one specimen.

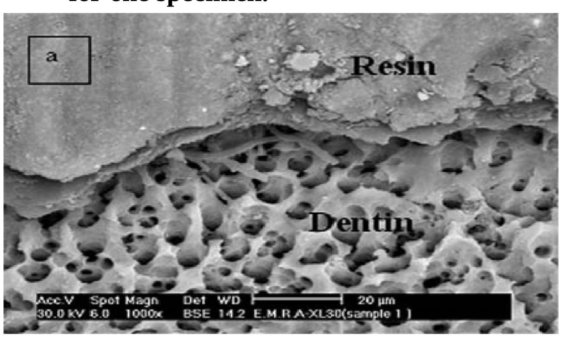

Figure 2a: SEM micrograph X 1000 of dentin/resin interface of group (U).

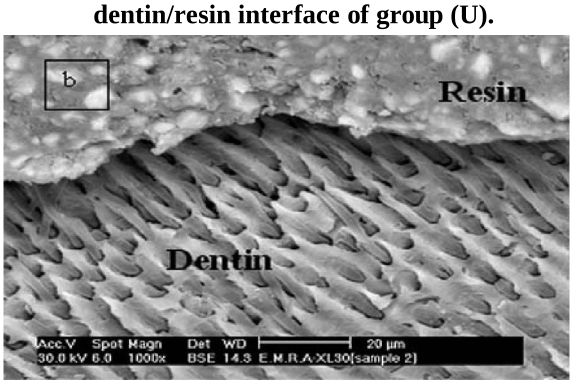

Figure 2b: SEM micrograph X 1000 of dentin/resin interface of group (GU)

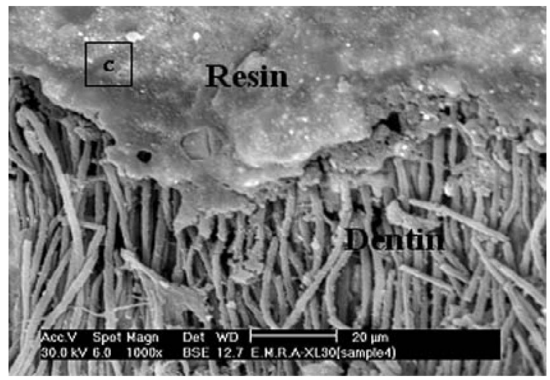

Figure 2c: SEM micrograph X 1000 of dentin/resin interface of group (V).

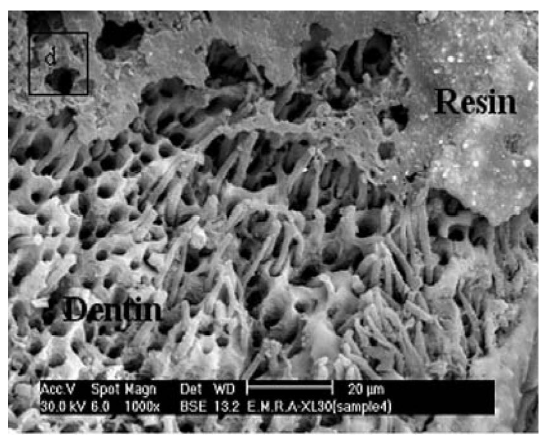

Figure 2d: SEM micrograph X 1000 of dentin/resin interface of group (GV)

4. Discussion:

Natural teeth have been used in this study, which are difficult in standardization as they show a large variation depending on age, and anatomy. Several studies used steel or resin dies for the fracture testing of crowns as they include standardized preparation and identical physical quality of materials used. However, prepared teeth made of steel or resins do not reproduce the real force distribution that occurs on crowns cemented on natural teeth. Dentin has a lower elastic modulus than steel; therefore, the inner crown surface shows a greater shear stress every time the tooth is subjected to deformation. [10] In natural teeth no uniform force distribution is expected between ceramic and tooth structure due to their different moduli of elasticity.[22] However if they are well bonded together they will act as one unit i.e. the stronger part strengthening the weaker part. This bonding is realized by the type and the efficiency of the bonding system. In this study, the bonding was done with several systems to investigate efficiency. To begin with, all crowns were silanated before cementation to improve the adhesion between the ceramic crowns and the luting systems.[23] Ultrasonic cementation technique was selected in this study to benefit from the acoustic energy applied to increase the flow of the luting cement with subsequent decrease in its viscosity (thixotropy). This acoustic energy results in decreasing the number and size of the voids in the luting cement, hence, increasing the adaptation of the material. Moreover, any medium or object in the path of an ultrasonic beam is subjected to a radiation force, which tends to push the luting cement in the direction of the propagating waves. This may cause redistribution and aggregation of the filler particles of the cement leading to optimum particle size distribution.[17] All the bonding systems used in this study were dual cured cements, their polymerization reaction is chemically and photo-initiated. This ensures higher conversion rate of curing, leading to better mechanical properties, i.e the force will be distributed over a large area, as the whole assembly: the crown, the adhesive and the tooth structure would act as one unit.[24] This was confirmed by the visual mode of fracture where the failure was within the long axis of the crown and the tooth structure, which may demonstrate effective adhesive systems on the fracture resistance (Figure 1). From the limitation of this research, is that lateral forces were not duplicated. Axial loading was only applied in the testing method which interprets the presence of longitudinal failure mode. Actually, the forces existing in the clinical situation are multidirectional so by utilizing other testing method using chewing simulators, other fracture modes may be available.

The fracture resistance of the dentin-ceramic bonded system is affected by many factors among them are the composition of the restorative material, as well as the composition, the consistency and the flow properties of the bonding system. The used ceramic system is a new core glass ceramic material "E-max-press" containing lithium disilicate crystal as a strengthening agent. The ceramic crowns restoring the teeth showed a high fracture resistance values for all groups in varying degree. All groups had the same restorative material and were done with a similar controlled design. The only different parameter was the bonding system. The bonded interface can be the weakest area of tooth-colored restorations if it is exposed to the oral cavity i.e. increased marginal gap distance. Improving the bonding durability of luting resins to dentin and to the restoration leads to the reinforcement of brittle restorations and the longevity of bonded restorations in fixed prosthodontics.[25]

Comparing the results of the gap distance before cementation, all groups were insignificantly different from each other with an acceptable gap distance of approximately 58 ± 6.7 µm.[26]

After cementation, the magnitude of gap differed with the different groups i.e. the introduction of the bonding system and the cement. RelyX Unicem showed the highest gap distance (114 ± 6.4 µm) with the lowest fracture resistance (2270.9 ± 3.4 N). This may be due to several factors: 1- the high viscosity of the RelyX Unicem noticed during application, due to the presence 9% amount of fillers, which lead to high film thickness. For effective chemical bonding, the distance between the adhesive and substrate must be less than few Angstroms. Increase in adhesive thickness is susceptible to large amount of voids preventing intimate contact between the tooth structure and the bonding system (Figure 2a), which may help in initiating crack. The bulk properties of the tooth substrates (dentin) and restorative substrate (ceramic) are much stronger than the bond strength of the cement/restorations. Therefore, cracks that form generally remain in the bonded interface zone. As cracks grow, they contribute to stress concentrations or stress redistributions within the substrates. The final failure may often extend for short distances through portions of tooth structure or restorative material explaining the accelerating failure rate.[27,28] In addition, the presence of voids at the interface can lead to bending of the restoration under force application, which will accelerate failure of the restoration. The more the resin thickness the more contraction stresses of the bonding system, the less the maturing bond to walls. As long as the polymerizing material can flow before reaching the gel point, contraction stress can be dissipated. This suggests that a thin layer of resin bonded to the ceramic surface may, in some situations, act to reinforce the ceramic material, i.e. there will be no gap between the restoration/cement/tooth structure, the force induced is a compressive force. 2- RelyX Unicem is a self-etch adhesive maintaining the smear layer on the dentin preventing the adhesion between dentin and the adhesive (Figure 2a).[29] Since the self-etch approach uses acidic adhesive co-monomers, which dissolve the inorganic phase of dentin, and simultaneously primes and infiltrates the dentin matrix without removing the smear layer, it leads to fewer exposed collagen fibrils.[30] Adhesive stability is related to the effective coupling of the co-monomers with the infiltrated substrate.[31] 3- The pH of the acid used in any adhesive system is related to its success in bonding with dentin. RelyX Unicem contains phosphoric acid ester with higher pH than phosphoric acid acrylate used for the total-etch technique of the Variolink II and Excite system, as reported by the manufacturer, and therefore it has a lower bonding capacity.

Variolink II with Excite adhesive bonding system gave better vertical marginal gap distance and better fracture resistance than RelyX Unicem. Variolink II is a total-etch contributing to complete removal of the smear layer with dentin. Moreover, etch-and-rinse adhesive system is applied directly on the demineralized dentin collagen. The maintenance of the structural integrity of these structures during and after etching should greatly improve the final stability of the hybrid layer, as the collagen in the dentin matrix is preserved (Figure 2c).[32]

Treatment of dentin with G-bond improved the gap distance between the restoration, the tooth structure, and the fracture resistance. G bond was applied for groups GU and GV before the application of the RelyX Unicem and Variolink II. The values of fracture resistance were higher and significantly different for the pretreated groups than for the untreated groups (Table 4). This may be due to the presence of 4MET (methacryloyloxyethyl Trimellitate) formulated with fillers in the G-bond system .These components produce nano particles responsible for the formation of extremely thin layer of nano interaction zone containing insoluble calcium compound with dentin characterized by the exposure of little amount of collagen fibrils.[33] According to the adhesion-decalcification concept, the less soluble the calcium salt of an acidic molecule, the more intense and stable the molecular adhesion to a hydroxyapatite-based substrate.[34] In addition, the absence of HEMA (Hydroxy Ethyl Methacrylic acid) in group (U) rendered the bonding system less sensitive to water uptake. HEMA creates a hydrogel within the hybrid layer and adhesive resin in some cases. The hydrogel may provide a channel for water permeation that has the potential to affect the durability of bonds. Thus, HEMA free adhesives have been proposed as RelyX Unicem and G-Bond. The omission of HEMA from the adhesive blends has been considered advantageous in removing water, separating it from the other components upon solvent evaporation.[35] Figures 2b and 2d for the treated dentin with G-bond, showed increased resin tags formation in a bundler appearance, which are connected with resin infiltrated dentin surface. Resinous branches with long, thick coagulated pattern were evident after the application of the G-bond system. Although the present investigation may be rather close to the clinical situation, the prospective clinical trial remains the final instrument to definitely answer the raised question regarding the appropriate adhesive system to enhance the fracture resistance and marginal fidelity of E-max crowns.

CLINICAL IMPLICATIONS: Within the limitation of this study total-etch adhesives are more preferred than self-etch adhesives for luting all -ceramic crowns. However, treatment of dentin surface prior to the application of any bonding agent is of great importance to enhance the fracture resistance and marginal fidelity of E-max ceramic crowns.

5. Conclusion

From the present study, the following can be concluded:

1- Bonded ceramic restorations with total-etch system offer better vertical marginal gap distance and fracture resistance than bonded restorations with self-adhesive system.
2- Treatment of the dentin surface, with all in one self–etch adhesive, prior to the application of the bonding system is very efficient.
3- The bonding system affects the vertical marginal gap distance and the fracture resistance of all- ceramic restorations.

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