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Consequences of employment self–etching primer adhesive in orthodontic practice

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ABSTRACT

The purposes of this study were to evaluate the shear bonding strength of stainless steel brackets bonded with self–etching primer adhesive system (Transbond^{TM} 3M Uniteck, Monrovia, California, USA), compared with same system which employ 35% phosphoric acid gel, sepa-rated primer and adhesive. Also to assess and compare clinically the brackets bond-ing failure rate after using the 2 different techniques in orthodontic patients and to examine bracket / adhesive failure mode by using modified adhesive remnant index (MARI). Fifty six extracted human premo-lars used in the laboratory part, they were divided into 2 groups (I and II), each one subdivided into upper first and second, lower first and second premolars; 7 for each subgroup. In the first group bonding was carried out by using the conventional technique (phosphoric acid / adhesive) wh-ile in the second one, the self–etching pri-mer was used. In the clinical part 15 pat-ients with upper and lower fixed applian-ces (central, lateral incisors, canines and premolars) with 13–16 years old. The fol-low up period extended into 12–15 mon-ths.

The statistical analyses in the laboratory (*in vitro*) part reported significantly lower but acceptable shear bond strength (8.69 and 8.42 MPa) for the upper first and second premolars, and 8.13 and 8.99 MPa for lower first and second premolars in comparison with the conventional groups (11.61 and 11.63 MPa) for upper first and second premolars, and 11.48 and 11.59 MPa for the lower first and second premolars as t–values were significant (2.69, 3.05 for the upper first and second premolars; 2.68, 2.45 for the lower first and second premolars) at $p < 0.05$ between study groups, but in the clinical trial no signi-

الخلاصة

هدفت هذه الدراسة إلى تحديد ومقارنة القوة القاصة للربط بين الحاصرات المعدنية لتقويم الأسنان وسطح الأسنان الخدي باستخدام اللاصق ذاتي الحمض لإحدى المجاميع مرة واللاصق غير ذاتي الحمض للمجموعة الأخرى (غير المعتمد على المزج). كذلك هدفت الدراسة إلى تحديد نسب فشل اللاصق سريرياً حيث أن الحاصرات تم لصقها على أسنان المرضى لمجموعة باستخدام اللاصق ذاتي الحمض ولمجموعة أخرى باستخدام اللاصق الاعتيادي. استُخدِم في الدراسة المختبرية ٥٦ سناً قُسِّمَت إلى مجموعتين (٢٨ سن لكل مجموعة)، استُخدِم للمجموعة الأولى اللاصق بالطريقة الاعتيادية وللمجموعة الثانية اللاصق ذاتي الحمض. ساهم في الجزء السريري ١٥ مريض من مرضى تقويم الأسنان تراوحت أعمارهم بين ١٣ – ١٦ سنة حيث وضِعَت الأجهزة الثابتة العلوية والسفلية بفترة متابعة استمرت من ١٢ – ١٥ شهراً.

لقد أشارت النتائج في الجزء المختبري من البحث إلى أن القوة القاصة للمجموعة التي استخدمت اللاصق ذاتي الحمض كانت ذات قيمة أقل احصائياً لكل من الضاحكين العلويين الأول والثاني وبمقدار ٨.٦٩ و٨.٤٢ ميكاباسكال وكذلك للضاحكين السفليين الأول والثاني (٨.١٣ و٨.٩٩ ميكاباسكال) بالمقارنة مع المجموعة التي استخدمت الطريقة الاعتيادية حيث كانت القيم ١١.٦١ و١١.٦٣ ميكاباسكال للضواحك العلوية الأولى والثانية و١١.٤٨ و١١٥٩ ميكاباسكال للضواحك السفلى الأولى والثانية، حيث أن قيم (t) كانت ٢.٦٩ و٣.٠٥ لكل من الضواحك العلوية الأولى والثانية و٢.٦٨ و٢.٤٥ للضواحك السفلية الأولى والثانية عند مستوى معنوية ٥% لمجاميع البحث.

ficant difference between the groups were recorded in relation to bonding failure rate as values of Z test of two proportions were ranged between 0.98 and 1.94, 0.00 and 1.94 for the upper and lower arches respectively, in spite of the higher percentages of failure rate for the self–etching primer adhesive group. The MARI reported higher frequencies at score 2, and score 3 for the control and experimental (self–etching primer) groups respectively.

It can be concluded that in spite of the lower bonding strength values for the self–etching primer adhesive, but the results appear to be acceptable and this adhesive is recommended to be used in orthodontic practice. In accompanied to that the residual adhesive amount were smaller than those of the conventional one so that less damage happened to enamel surface during debonding procedures.

Key Words: Self–etching primer, orthodontic adhesive.

لكن الجزء السريري من البحث أظهر عدم وجود أي فرق معنوي لمعامل السقوط للحاصرات بين مجاميع الدراسة حيث أن قيم (Z) كانت تتراوح بين ٠.٩٨ و١.٩٤ و٠.٠٠ و١.٩٤ بالتعاقب للفكين العلوي والسفلي، أما مقياس اللاصق المتبقي فقد أظهر أعلى تردد عند المقياس رقم ٢ والمقياس رقم ٣ لكل من الطريقة الاعتيادية وطريقة اللاصق ذاتي الحمض بالتعاقب.

يمكن الاستنتاج بأنه على الرغم من قلة القيم التي وجدت فيما يتعلق بطريقة اللاصق ذاتي الحمض بالمقارنة مع الطريقة الاعتيادية، إلا أن هذه القيم كانت مقبولة بالنسبة لأي لاصق يستخدم في تقويم الأسنان، بالإضافة إلى أن الأضرار التي سيحدثها على ميناء الأسنان سوف تكون أقل بالمقارنة مع الطريقة الاعتيادية. هذا الشيء الذي أثبتته القيم التي تتعلق بمقياس اللاصق المتبقي والتي كانت أعلى فيما يتعلق بالطريقة الاعتيادية وخاصةً بعد أن يتم رفع الحاصرات من الأسنان.

INTRODUCTION

The maintaining of sound, unblemished enamel surface after debonding of orthodontic brackets is a primary concern to the clinician.[1] Bond failure at the bracket adhesive interface or within the adhesive is safer than failure at the adhesive–enamel one, because enamel fracture and crazing have been reported at the time of bracket debonding.[2]

Historically, the direct bonding process has been complicated task, practitioners must first prophy the teeth with pumice slurry, rinse and dry, then the teeth must be etched with phosphoric acid solution or gel. The etchant is rinsed from the teeth being careful not to allow any contact with gingiva. The teeth are dried and then the primer and the adhesive applied.[3]

As a result of these long procedures, an alternative bonding systems have been tested so as to find whether a clinically useful bracket bonding strength could be obtained.[4] One of these systems are that which combined the steps of conditioning and priming into single step. Generally, these systems contain water, methacrylated phosphoric acid esters, phosphine oxide, stabilizer pavabenes and sometimes fluoride complex at their primer solution.[5,6]

These relatively new systems were used originally on dentin,[7] as the acidic part at the primer dissolves the smear layer and incorporates it into the mixture. Acidic primer solutions also demineralize the de-ntin and encapsulate the collagen fibers and hydroxyapatite crystals.[8] The adhe-sive resin component then diffuse into pri-med dentin, which produce a hybrid lay-er.[9] These new systems were also found to be effective when used in enamel bond-ing,[10] and appeared in markets as an orth-odontic self–etching adhesive system.

Orthodontists use the acid–etch bonding technique when attaching brackets to the enamel. These new systems have been assessed *in vitro*; the results were conflicting. In 1998, Bishara *et al*.[4] investigated the shear bond strength of stainless steel brackets that bonded with either acidic primer with lightly filled and highly filled adhesives in comparison with system that use 37% phosphoric acid

separated from the other two components, and found significantly lower but acceptable shear bond strength for acidic primer highly fill-ed adhesive (10.4 MPa) in comparison with those which used the conventional techniques (11.8 MPa), but for the lightly filled one (5.9 MPa). Other study[11] rep-orted an excessively reduced shear bond strength for the acidic primer (2.6 MPa) in comparison with conventional systems (10.4 MPa) or with the glass ionomer adh-esives (6.5 MPa) and stated that the pati-ents are better served by using phosphoric acid / composite resin adhesive system. On the other hand, Arnold *et al*.[12] reported that the increasing of application time of acidic primer from 3 seconds to 10 minut-es have an important role so as to extend appliance construction and working time. Also a non significant smaller shear bond-ing strength was noticed for the self–etch-ing primer adhesives, while others[13] fou-nd that one step self–etching primer pro-vide superior shear bond strength (18.6 MPa) in comparison with the traditional one (17.0 MPa).

Lastly, a new self–etching primer adhesive was provided in single foil pack which pressed and folded to combine ingredients into single mixture. The shear strength of stainless steel brackets of self–etching primer adhesive were compared to the conventional one (10.4 MPa) and appear to be lower but clinically acceptable (7.1 MPa).[14]

Little information were available about clinical bonding failure. Some investigators[15] found that bonding failure were 7.2%, and were significantly higher in mandible than maxilla, with second premolars showing the highest failure (23%) and indicated a significant negative correlation between complexity of appliance design and bond failure rate.

This study was undertaken to assess the shear bond strength of one of the self–etching primer adhesive systems, compared with the conventional technique (separate etching step) *in vitro*, then evaluate the bonding failure rate of stainless steel brackets that bonded in orthodontic patients by the self–etching primer adhesive and compare it with those bonded conventionally *in vivo*. Also estimation of adhesive / bracket failure mode was carried out.

MATERIALS AND METHODS

This study was divided into 2 parts. The first one was the laboratory task (*in vitro*), while the second was the clinical trial (*in vivo*).

In Vitro Division

In the laboratory part, a sample of 56 sound human first and second, upper and lower premolars, extracted for orthodontic purposes, were involved. The teeth were free from any restoration, no enamel cr-acks, no hypocalcification, especially on buccal surface, and not subjected to any pre–treatment agents. Each tooth was clea-ned from any tissue remnants and stored in solution of 70% ethyl alcohol.[16] Before bonding, the teeth were mounted in a pla-stic ring, each tooth was fixed in a glass slide, which placed on the base of dental surveyor (Quayle Dental Mfg Co, Sussex, England). The tooth was placed in an up-right position; the middle third of buccal surface was oriented to be parallel with the analyzing rod of the surveyor. The cold–cure acrylic resin (Medicus Cold Cure, DMP Ltd, EU) was poured around the tooth. After setting, the specimen was re-surveyed to ensure that crown position not changed, then each tooth was polished with non–fluoridated pumice and rubber prophylactic cup (JTC–Full Dent SA, Switzerland) for 10 seconds[1, 4, 11] using conventional handpiece (Belmont PNEU–MART, Japan), then washed by air and water stream for 30 seconds, and dried with an oil–free air compressor.[1, 4, 11]

The sample was divided into 2 main groups; each of 28 teeth. Group one received the phosphoric acid gel, primer and adhesive separately (conventional technique), while the second group for the self–etching primer and its adhesive. Each group was divided into four subgroups for the upper and lower, first and second premolars respectively. Each category consisted of 7 teeth.

The brackets were stainless steel 0.022", with 0 torque and angulation, double wing, mesh–back with total surface area range between 32.58 to 32.95 cm^2 for each one (Ultramintum, Dentaurum Co, Pforzheim, Germany). They were bonded

according to one of two protocols. In group I (control group), we used Transbond™ XT light cure adhesive system (3M Unitek Co, Monrovia, California, USA) which contain the adhesive composite and primer bottle; also the etching gel separa-tely. Twenty eight teeth according to their categories were etched with 35% phospho-ric acid gel as the middle region of the buccal surface received it for 15 seconds according to manufacturer's instruction; then thoroughly rinsed with water and dried until chalky white surface was appe-ared. The primer was applied on bracket base, bracket was lightly placed on tooth surface, pressed firmly to seat it, gently remove excess from around bracket base without disturbing bracket. Each side of bracket (mesial, distal, occlusal and gingival) was light cured by light cure unit (Quayle Dental Co, Sussex, England) for 20 seconds per side according to manufacturer's instruction. Meanwhile, group II was the self–etching primer group; we used the same adhesive composite but with self–etching primer (3M Unitek Co, Monrovia, California, USA). The same procedure was done until we reached bonding, the middle third of the buccal surface of each tooth received directly and only few drops of the self–etching primer for 3 seconds. The material was rubbed on tooth surface according to manufacturer's instruction. A gentle air burst is applied, then the adhesive was applied on bracket base, and the brackets were positioned and light cured as in the control group.

Each bracket was subjected to 300 gm of compressive force for 10 seconds[1, 4, 11] by using a dental surveyor arm. The load was placed over it and the rod of the sur-veying arm was positioned to be perpen-dicular to the bracket slot. All teeth were stored in distilled water at 37 ºC for 48 hours before debonding procedures.[1, 4, 11]

For shear strength measurement, a un-iversal compression machine (Electric Un-confined Compression Apparatus, Soil Te-st Co) was used. A steel rod with 1 end flatted was attached to the crosshead of the machine. The force was applied in occluso–gingival direction. The rod was parallel to the middle third of the buccal surface of the tooth at the interface between bracket and tooth. The crosshead speed was 0.5 mm / minute.[17] When the bracket was sheared the amount of force was recorded in kilograms. This was divided by surface area of bracket and converted to megapascal (MPa).

***In Vivo* Division**

The clinical trial was carried out on 15 male patients, with an age range of 13–16 years old. The study period was from 12–15 months, including upper and lower arch of each participant. Each arch was divided into right and left sides. The brackets' size is 0.022" for each of the central and lateral incisors, canines and premolars (which were either first or second according to the decision at extraction) were bonded in the right sides in accordance to the first protocol (conventional), while in the left sides the brackets were bonded in similar to self–etching primer adhesive group. The protocol was reversed in lower arch. Care was taken to avoid salivary contamination.

The treatment technique was the edgewise technique. Similar types of wires which were stainless steel multistranded 0.017", round 0.016", 0.018", rectangular 0.016"×0.022", 0.017"×0.025" (Ultramintum, Dentaurum Co, Pforzheim, Germany) were used in the study. Similar type of elastic power chain (Orthomatrix Omx Co, USA) used; throughout the study period. The initial arch wire placed 24 hours after brackets bonding. The patient was informed to come immediately when any bracket fail down. In case of any failure, the bracket was replaced by a new one that is bonded according to conventional technique.

After brackets being debonded, teeth and brackets were examined under 10× magnification. Any adhesive that remained after bracket removal was assessed accor-ding to the modified adhesive remnant index (MARI) and scored with respect to the amount of resin material that adhered to enamel surface.[18] The scale has range of 5 to 1 as following:

5: No composite remained on the enamel.
4: Less than 10% of composite remained on tooth surface.

3: More than 10% but less than 90% of composite remained on tooth surface.
2: More than 90% of composite remained on tooth surface.
1: All of the composite, with an impression of the bracket base remained on tooth surface.

Descriptive statistics that included the mean and standard deviation were calculated for each study group. Student's t–test was used to determine the significance between shear bond strength of brackets that bonded with conventional manner and those used self–etching primer in their bonding procedures.

The number and failure rate percentage were determined in the clinical part of study, with the use of Z–test of two proportions to determine whether significant differences were present between the groups. Significance for all statistical tests was predetermined at a probability value of less than 0.01 and 0.05.

RESULTS

***In Vitro* Division**

Student's t–test comparisons indicated that shear bond strength for the group that used self–etching primer in bracket bonding procedures were significantly lower than those used phosphoric acid and primer in separated manner. The highest t–value appeared for the upper second premolar category, while the smallest occurred for the lower second premolar. These findings are presented in Table (1).

Table (1): Comparison of shear bond strength (MPa) between group used conventional technique and group used self–etching primer

Technique		Upper Premolar n= 14 Teeth				Lower Premolar n= 14 Teeth			
		First n= 7		Second n= 7		First n= 7		Second n= 7	
		Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
I	Conventional	11.61	2.41	11.63	2.35	11.48	1.57	11.59	2.53
II	Self–etching	8.69	1.23	8.42	1.58	8.13	1.35	8.99	1.27
t–value		2.69*		3.05*		2.68*		2.45*	

* Significant at $p < 0.05$.
SD: Standard deviation.

Figure (1) depicts the results of MARI scores distributed among the groups of the laboratory experiment. It indicates a higher frequency of scores 3 and 4 for the groups that used self–etching primer compared to conventional one which fall in scores 2 and 1, as only 3 brackets from 28 one were recorded in score 3, no brackets recorded at score 5 for any of the study groups. Also, the statistical analysis between the study groups –as a total sample without subdivision– revealed a significant difference for the mean value of the control group (1.85 with standard deviation 1.98) from that of the experimental one (self–etching primer group) which was 3.00 with standard deviation 3.07. The t–value was 1.71 at $p < 0.01$. The mean val-ues of the study groups scores appeared in Table (2).

Table (2): Mean values of modified remnant adhesive index according to their groups in the laboratory part of the study

Technique		Upper Premolar				Lower Premolar			
		First		Second		First		Second	
		Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
I	Conventional	1.57	1.72	1.85	2.05	2.28	2.43	1.71	1.85

II	**Self–etching**	2.71	2.86	3.74	2.97	2.00	2.09	3.14	1.69

SD: Standard deviation.

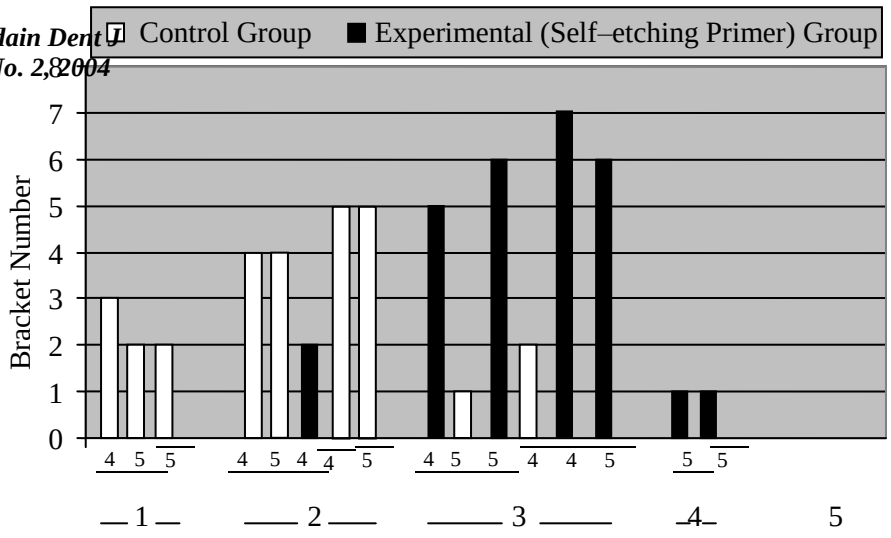

Figure (1): Frequency distribution of modified adhesive remnant index among study groups in the laboratory part

***In Vivo* Division**

The difference in failure rate between teeth received conventional technique and self–etching primer one for brackets of each tooth involved in the clinical work are shown in Table (3) which recorded a non significant difference among the groups of *in vivo* work, but the percentages of failure rate appeared to be higher in the experimental group (self–etching primer) than in the control one (conventional etching).

Table (3): Comparison of brackets failure rate percentages between study groups

Technique	**Teeth**							
	Upper Arch n= 15 Patients				**Lower Arch n= 15 Patients**			
	Central	**Lateral**	**Canine**	**Premolar**	**Central**	**Lateral**	**Canine**	**Premolar**
I Conventional	6.6	6.6	0	13.3	0	6.6	6.6	6.6
II Self–etching	0	13.3	20.00	20.00	0	0	2.00	26.6
Z–value	0.98	0.68	1.94	0.53	0.00	0.98	1.94	1.60

In relation to the clinical part again the frequency distribution of the MARI for the involved teeth (as total samples) for the study groups was presented in Figure (2) which indicated that self–etching primer gave a highest score at number 3, while the control group gave score 2 as a highest one. The t–test results indicated a highly significant difference (3.588, $p < 0.05$) between the control group (mean= 1.71, standard deviation= 1.91) and the experimental one (mean= 2.93, standard deviation= 3.09).

DISCUSSION

The traditional adhesive system used the enamel conditioner (37% H_3PO_4), primer solution and the adhesive resin in bon-ding procedures. The self–etching

adhes-ive system combine the conditioning and priming agents into single solution for the simultaneous use into both enamel and dentin.[7, 8]

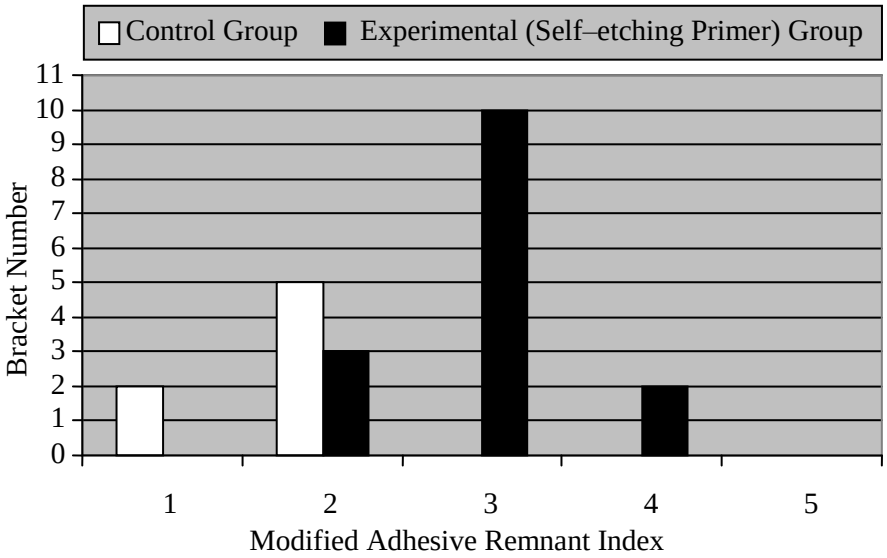

Figure (2): Frequency distribution of modified adhesive remnant index among study groups in the clinical part

The active ingredient in self–etching primer is the methacrylated phosphoric acid ester. Phosphoric acid and methacrylate group are combined into a molecule that etches and primes simultaneously.[19] One of its advantages is that the primer penetrates into the entire depth of the etch, ensuring an excellent mechanical interlock; then the phosphate group dissolves the calcium and removes it from the hydroxyapatite rather than being rinsed away. The calcium forms complex with the phosphate group and is incorporated into network. In this manner, the acid is neutralized.[19]

In this work, it was clear that the self–etching primer adhesive system would red-uce the number of procedural steps, dec-rease chair–side time, without compromis-ing outcome. This was in agreement with many investigators.[1, 14]

The early acidic primers were selectively compatible with certain adhesives, so that they either produced lower bond strength or needed more working time.[4]

The findings of this study indicated the use of self–etching primer adhesive produced lower but comparable shear bond strength in comparison with conventional one; as the authors[20, 21] recommended the clinically adequate shear bond strength to range 6–8 MPa for orthodontic purposes, so that the results of the laboratory work were in accordance with the investigators who used the same type of adhesive, the difference in values due to the experimental circumstances. The standard deviation gave the idea of how the observations are ranged between the largest and smallest values. In this work the standard deviations are in somehow large because the observations are scattered over a considerable distance about their mean values.

The present study evaluated also the performance of self–etching primer adhesive *in vivo*. The follow up period was extended into 12–15 months until most of the treatment procedures were finished. This type of adhesive provided acceptable results in comparison with the conventional adhesive, and appear to be an effective bonding agent throughout therapy period as different gauges of wires, elastic have been used which applied different orthodontic forces.

Furthermore, the amount of residual adhesive that being left on tooth surface after bracket failure or debonding found to be less than that left by the phosphoric acid / adhesive, but it is an important to know that successful bonding depends on conditioning of teeth, bonding material,

size, shape and quality of the attachment, type of teeth and lastly experience of operator.[22] All explain also the remarkable differences in bonding strength between study group which have assessed by MARI depend on the method of bracket removal.[23] In this study, the debonding force applied at the bracket base/ composite/ enamel interface. The results showed that the self–etching primer adhesive was advantageous which facilitate debonding procedures, enamel cleaning after appliance removal.

CONCLUSIONS

From this study, it was concluded that self–etching primer adhesive provided a clinically acceptable shear bond strength in comparison with the conventional one; MARI give another indication for the advantages of this adhesive as the amount of residual resin be less when compared with the other type. This adhesive will simplify the clinical handling of brackets bonding procedures.

However, it needs to be recommended that this study was carried out on one commercial type of self–etching primer adhesives; other studies are indicated to assess the other available self–etching primer adhesives in markets. Also care should be taken to explain clinical results due to the limited sample size, and more clinical studies with a larger sample sizes are required.

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