SHORT- AND LONG-TERM BOND STRENGTHS OF A GOLD STANDARD TWO-STEP SELF-ETCH ADHESIVE SYSTEM TO DENTIN: A PRELIMINARY STUDY

Altın Standart İki Aşamalı Self-Etch Bağlayıcı Sistemin Kısa Dönem ve Uzun Dönem Dentine Bağlanma Dayanımları: Bir Ön Çalışma

Safa TUNCER¹, Neslihan TEKÇE², Dial PASHAEV³, Mustafa DEMİRCİ¹, Canan BAYDEMİR³

Received: 06/07/2014
Accepted: 23/02/2015

ABSTRACT

Purpose: The aim of this study was to investigate the micro tensile bond strength of a self-etch adhesive system following 1 year storage in water.

Materials and Methods: 10 sound human molar teeth were used for micro tensile bond strength test. Two-step self-etch dentin adhesive (Clearfil SE Bond®) was applied to the flat dentin surfaces according to the manufacturer’s instructions. Composite blocks (Z-250; 3M ESPE) of 5 mm in height have been prepared by using layering technique. Teeth were stored in water for 24 hours at 37°C and longitudinally sectioned to obtain dentin sticks of 1 mm². Randomly selected samples from half of the teeth were immediately subjected to micro tensile test and the remaining specimens were tested after 1 year storage in water. Bond strengths were calculated in megapascal (MPa).

Results: Means and standard deviations of the Clearfil SE Bond® micro tensile bond strength values were, respectively, 37.31 ± 13.77 MPa and 24.78 ± 2.99 MPa after 24 h and 1 year of storage in water. The difference was statistically significant (p=0.031).

Conclusion: Long-term storage in water decreased the micro tensile bond strength values of the two-step self-etch adhesive which has been accepted as the gold standard in bond strength tests.

Keywords: Microtensile bond strength test; two-step self-etch adhesive; degradation; water aging

ÖZ

Amaç: Bu çalışmanın amacı, iki aşamalı bir self-etch dentin bağlayıcı sistemin 1 yıl suda bekletme sonucunda bağlanma dayanımlarındaki değişimini inclemektir.

Gereç ve Yöntem: Mikro-gerilim bağlanma dayanımları testi için 10 adet gömük üçüncü molar dişi kullanılmıştır. Düz dentin yüzeylerine iki aşamalı self-etch (Clearfil SE Bond; Kuraray) sistem uygulanmış ve tabakalama yöntemi ile 5 mm yükseklikte kompozit bloklar (Z-250; 3M ESPE) oluşturulmuştur. Restore edilen dişler 24 saat 37°C suda bekletildikten sonra uzun aksar paralel olarak kesilmiştir ve 1 mm²’lik dentin çubukları oluşturulmuştur. Rastgele seçilen 5 diş ait çubuklar 24 saat sonra, kalan 5 dişin hazırlanmış çubuklar ise 1 yıl 37°C suda bekletildikten sonra çekme testine tabi tutulmuştur. Elde edilen bağlanma dayanımı değerleri megapascal (MPa) olarak kayit edilmiştir.

Bulgular: Bağlanma dayanımı değerleri 24 saat sonunda ortalaması 37.31 ± 13.77 MPa, 1 yıl suda bekletme sonunda ortalaması 24.78 ± 2.99 MPa olarak tespit edilmiştir. Suda bekletme sonucunda Clearfil SE Bond bağlanma dayanımı değerlerindeki azalma istatistiksel olarak anlamlılık göstermiştir (p=0.031).

Sonuç: Bağlanma testlerinde altın standard olarak kabul edilen iki aşamalı bir self-etch bağlayıcının suda uzun dönem bekletilmesi, bağlanma dayanım değerlerinde azalma neden olmuştur.

Anahtar kelimeler: Mikro-gerilim bağlanma dayanımı testi; iki aşamalı self-etch bağlayıcı; yıkm; suda yaşlandırma
Introduction

The most important factor that determines the clinical performance of dental restorations is their resistance to biodegradation. Biodegradation concept is related to resin matrix, filler composition and the interface. Chemical and mechanical degradations occur in the components of the interface over time (1, 2). Generally these morphological changes in the adhesive structure are seen in the long term. During chemical degradation, components of the interface hydrolyze due to the effects of saliva, bacterial enzymes or water content in dentin (3, 4), which results in plasticizing of the resin (2, 5, 6). Short- and long-term bond strength tests should be performed to evaluate time-dependent degradation of the dentin adhesives (7).

To determine long-term efficiency of the adhesive, its short-term efficiency must first be established (2, 7). Although bond strengths of dentin adhesives are usually evaluated in the short-term or during the first 24 hours, more clinically relevant studies or those that include sample aging protocols are also required. Findings of experimental studies which have been designed to measure the short-term bond strength of the adhesive does not always correlate with real clinical observations. Therefore, in addition to short-term experiments, long-term studies that bear more resemblance to clinical conditions must also be carried out (2, 7).

In self-etching adhesive systems, inorganic phase of the dentin is dissolved by the acidic monomer instead of the phosphoric acid. As a result, monomer infiltrates the collagen network with the help of the solvent and hydrophilic components. When collagen network is completely surrounded by the monomer, it is protected against the degradation. Also, chemical reaction of the functional monomer has additional positive effects on the bonding. However, inadequate infiltration of the resin causes nanoleakage. Incomplete removal of water from the environment is associated with the presence of hydrophilic resin monomers. Water-tree formation is observed after an average of 1 year of water aging. The formation of the water trees can occur with slow absorption of water at the bonding interface. Aging of the interface depends on the water intake and the increase of porous regions in the hybrid layer (5, 8).

Clearfil SE Bond® is a self-etch adhesive which demonstrates high performance in in vitro and in vivo studies (9-12). It is considered as the gold standard for studies on adhesion research and is therefore frequently used as a control group (9, 13-15). The aim of this study was to compare bond strength of the Clearfil SE Bond® system after 24 hours and 1 year of water storage.

Materials and Methods

Sample characteristics and preparation

10 impacted third molar teeth were used in this study. Periodontal tissues were cleaned using a scalpel and teeth were stored in 0.5% Chloramin T solution (Merck KGaA, Darmstadt, Germany) for 1 week. At the end of this period, solution was replaced with distilled water, stored in a refrigerator at 4°C and renewed periodically to prevent bacterial growth. All extracted teeth were used in the experiments within 6 months. Specimens were randomly allocated into two groups of equal size, which are described as the short-term (24 hours in water storage) and the long-term (1 year in water storage) groups. Teeth were glued to acrylic resin blocks with sticky wax and the occlusal enamel surface of each tooth was removed using a slow-speed diamond saw (Isomet, Buehler Inc., Lake Bluff, IL, USA) under water lubrication to expose flat superficial dentin, which was then polished with wet 600-grit silicon carbide paper to create a uniform surface and smear layer.

Clearfil SE Bond® (Kuraray Medical Inc., Okayama, Japan) was applied to dentin surfaces of teeth in each group according to the manufacturer’s instructions. Next, teeth were completely encircled with tofflemire matrix, a composite core buildup was made in three layers of maximally 2-mm thickness to a height of 5 mm, using a microhybrid resin composite (Filtek Z 250, A2 Shade, 3M ESPE, St. Paul, MN, USA) (Table 1). Each increment was light cured with a quartz-tungsten halogen curing unit (Bisco VIP Dental Curing Light, Schaumburg, IL, USA) for 20 seconds. Light intensity output was checked with a dental radiometer (Hilux® Ledmax Light Curing Meter, Benlioglu Dental Inc., Ankara, Turkey). After completing the composite blocks, teeth were placed in a drying oven at 37°C for 24 hours and glued to acrylic blocks parallel to their long axis by using sticky wax. Teeth were then sectioned with above mentioned precision saw to obtain 1 mm thickness dentin slices. In the next step, acrylic block was removed from the instrument, tooth axis was rotated 90° and again fixed to the block for cutting. Thus, 1 mm² sticks were obtained, which consisted of 5 mm of dentin and 5 mm of composite material. Same bonding and cutting procedures were followed for teeth in 1 year of water aging and 24 hours groups. The sticks from 5 teeth were stored for 1 year in water which changed periodically.
Table 1. Brand names, manufacturers, contents and operating instructions of the composite filling material and two-step dentin bonding agent which were used in this study. MDP; 10-methacryloyloxydecyl dihydrogenphosphate, HEMA; hydroxyethylmethacrylate, bis-glycidyl methacrylate; Bis-GMA, urethane dimethacrylate; UDMA, glycol dimethacrylate; BIS-EMA, CQ; Camphorquinone.

| Material                  | Manufacturer                        | Contents                                                                 | Operating instructions                      |
|---------------------------|--------------------------------------|--------------------------------------------------------------------------|---------------------------------------------|
| Clearfil SE Bond®         | KURARAY Medical Inc., Okayama, Japan  | Primer: MDP, HEMA, hydrophilic dimethacrylate, N-Diethanol p-toluidine,   | Apply one layer of primer. Wait for 20 s.   |
| (two-step, self-etch dentin bonding) |                        | HEMA, N-Diethanol p-toluidine, water. Bond: MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, CQ, N-Diethanol p-toluidine, Silanate-cooled silica. | Dry with mild air and apply bond. Remove excess bond with gentle air flow. Polymerize with light for 10 s. |
| Filtek Z 250®             | 3M ESPE Inc., St. Paul, MN, USA      | BIS-GMA, UDMA, and BIS-EMA resins 60% by volume, 0.01-3.5µm diameter zirconia/silica filler. | Apply material into the cavity in 2 mm layers. Polymerize with halogen light device for 20 s. |

Bond strength testing

Bonded sticks were attached to a modified device for microtensile testing with cyanacrylate resin (Zapit Dental Ventures of North America, Corona, CA, USA) and subjected to a tensile force in a microtensile testing machine (Micro Tensile Tester Bisco Inc., Schaumburg, IL, USA) at a crosshead speed of 0.5mm/min. until fracture occurs. Values obtained from the samples at fracture points were recorded separately for short- and long-term groups and expressed as MegaPascal (MPa).

Fracture surfaces were examined under stereomicroscope (Olympus® SZ61, Munster, Germany) at X30 magnification. Fracture surfaces were classified separately as:

- Adhesive/Mix, (fracture from resin/dentin interface or any amount of fracture from surrounding tissues (composite or dentin) in addition to adhesive surface
- Cohesive dentin
- Cohesive composite (16-18).

Statistical Analysis

SPSS Statistics 21 for Windows® (IBM Inc., Chicago, IL, USA) and G*Power version 3.1.9.2 (Kiel University, Kiel, Germany) softwares were used to compare variables and to determine study power, respectively. Since Kolmogorov-Smirnov normality test showed that the data did not meet the requirements of normal distribution, non-parametric Mann Whitney U test was used to compare medians of study groups. The proportions of the categorical variables for each fracture type in short- and long-term groups were compared with Fisher’s and Yates’ Chi Square tests. The confidence interval was set to 95% and p < 0.05 was considered as statistically significant.

Results

46 sticks were obtained from 5 teeth which were treated with Clearfil SE Bond® and stored in water for 24 hours. Number of sticks per tooth and minimum, maximum and mean bond strength values obtained from these sticks for each tooth are presented in Table 2. Median (minimum-maximum) bond strength of 46 sticks which were obtained from teeth treated with Clearfil SE Bond® agent was found to be 33.59 (26.70-60.40) MPa (Table 3).

Table 2. Number of sticks, minimum, maximum, median and mean values of bond strengths for each tooth after 24 hours and 1 year of water storage which were obtained from 5 teeth treated with Clearfil SE Bond®. Statistical analysis.

| Duration | Tooth number | n | Minimum value (MPa) | Maximum value (MPa) | Median value (MPa) | Mean value (MPa) |
|----------|--------------|---|---------------------|---------------------|--------------------|------------------|
| 24 hours | 1            | 9 | 22.2                | 51.6                | 44.0               | 38.5             |
|          | 2            | 7 | 35.5                | 77                  | 65.5               | 60.4             |
|          | 3            | 13| 12.9                | 53.2                | 41.1               | 33.6             |
|          | 4            | 9 | 11.7                | 46                  | 24.6               | 26.7             |
|          | 5            | 8 | 12.9                | 40                  | 32.5               | 27.6             |
| 1 year   | 1            | 11| 7.7                 | 46.8                | 22.6               | 27.5             |
|          | 2            | 8 | 21                  | 54.7                | 25.1               | 27.3             |
|          | 3            | 11| 6                   | 37.1                | 24.2               | 22.4             |
|          | 4            | 12| 7.7                 | 57.7                | 22.8               | 25.9             |
|          | 5            | 14| 8.9                 | 41.5                | 19.8               | 20.9             |
56 sticks were obtained from 5 teeth which were treated with Clearfil SE Bond® and stored in water for 1 year. Number of sticks per tooth and minimum, maximum and mean bond strength values obtained from these rods for each tooth are presented in Table 2. Median (minimum-maximum) bond strength of 56 dentin rods which were obtained from teeth treated with Clearfil SE Bond® agent was found to be 25.88 (20.90-27.50) MPa (Table 3). Comparison between the micro tensile bond strengths of teeth which were stored in water for 24 hours and 1 year revealed that the bond strength values after 24 hours were significantly higher and there was a significant time-dependent decrease in bond strength (p=0.031). When values obtained for 24 hours and 1 year (for all sections) groups are considered together, the study power was calculated as 0.95. Adhesive/Mix type fractures constituted the highest percentage of failures in sticks which were prepared from samples treated with Clearfil SE Bond® after 24 hours and 1 year. Adhesive/Mix type fractures were observed in 52.2% of the samples stored in water for 24 hours and in 82.2% of the samples stored in water for 1 year (p=0.002) (Table 4).

Table 3. Means, standard deviations (SD), medians, minimum and maximum bonding strength values of the samples after 24 hours and 1 year of water storage.

|                  | 24 hours | 1 year  |
|------------------|----------|---------|
| Mean ± SD (MPa)  | 37.31±13.77 | 24.78±2.99 |
| Median (MPa)     | 33.59    | 25.88   |
| Minimum (MPa)    | 26.70    | 20.90   |
| Maximum (MPa)    | 60.40    | 27.50   |

Discussion

Clearfil SE Bond® is one of the most frequently used adhesives in laboratory studies and are considered as gold standard in terms of bonding capability. Shirai et al. (19) and Toledano et al. (20) have reported that the functional monomer 10-methacryloyloxydeoxyldihydrogenphosphate (10-MDP) in Clearfil SE Bond® has the highest chemical bonding potential with hydroxyapatite and hydrolytic stability among other monomers. Toledano et al. (20) also associated the high bond strength of Clearfil SE Bond® to the high percentage of monomer 10-MDP content found in this material. In our study, mean micro tensile bond strength value for Clearfil SE Bond® was 37.31 ± 13.77 MPa after 24 hours. Our findings were in accordance with those of Van Landuyt et al. (21) who had reported dentin bond strength of Clearfil SE Bond® as 40.5 MPa after 24 hours, Proença et al. (22) 42.7 MPa, Sadek et al. (23) 40.4 MPa, Inoue et al. (24) 40.8 MPa, Kenshima et al. (25) 40.7 MPa, Lodovici et al. (26) 33.8 MPa, Yeşilyurt et al. (27) and Van Landuyt et al. (28) 35.1 MPa. Fillers are added to adhesive systems to improve bond strength. Presence of filler in the material enables the application of relatively thick adhesive layer. According to a hypothesis, this relatively thick adhesive layer acts as stress breaker and it tolerates shrinkage stresses (16, 19). High bond strengths observed with Clearfil SE Bond® in our study could have been influenced by its MDP content, as well as being an adhesive resin which contains fillers (particle-filled). 24 hours bond strength of Clearfil SE Bond® was found to decrease from 37.3 MPa to 24.7 MPa after 1 year of water storage and this difference was statistically significant (p=0.031). In accordance with our findings, Toledano et al. (7) have reported that the micro tensile bond strength of Clearfil SE Bond® at 24 hours had decreased from 40.8 MPa to 20.6 MPa after 1 year of water storage. In our study, significant decrease in the bond strength of Clearfil SE Bond® after 1 year could be related to the storage conditions, such as sectioning samples to form sticks. Preparing samples as sticks could have shortened the water diffusion distance which, in turn, could
have led to direct contact of water with the interface. Such conditions could result in rapid decline in bond strength. Armstrong et al. (29) also showed that the bond strength values of samples prepared with Clearfil SE Bond® at 1 month decreased significantly from 47.7 MPa to 21.6 MPa after 15 months of water storage. Akın et al. (30) reported that the mean bond strength of samples at the end of 24 hours was 30.05 MPa which decreased to 26.13 MPa after 6 months of water storage. Clearfil SE Bond® is a two-step (primer and bond) self-etch system with hydrophilic material properties. Torkabadi et al. (31) related the decrease in the bond strength values of hydrophilic adhesive systems after 1 year of water storage to the water absorption of 2-hydroxyethyl methacrylate (HEMA) which diminishes mechanical strength of the resin.

Hashimoto et al. (32) suggested the hydrolysis process as the main cause of damage at the resin/dentin interface. Hydrolysis is the water absorption of resin from inter-fibrillar spaces in the hybrid layer. Water absorbed in resin can be found in two forms such as free water between polymer chains or as water attached to polymer chains (31). Water penetrating the interface by hydrolysis disrupts covalent bonds and creates empty spaces in hybrid layer by causing detachment of filler particles from the resin. Thus, the mechanical properties of the resin start to decline and the polymer swells (5, 6). Clinical relevance of this reaction is the time-dependent decrease in the resin-dentin bond strength (33). Water intake of the polymer depends on hydrophilic properties of the bonding agent. Water absorption capability of the structure is proportional to the hydrophilic characteristics of the material. Hydrophilic components such as HEMA, increase water uptake of the bonding agent and enables water molecules to migrate from dentin layer to the adhesive layer (31). Methacrylate monomers modified with carboxylic or phosphoric acid groups can also increase water uptake. Hydrophobic monomers such as bis-glycidyl methacrylate and methyl methacrylate are the main components which decrease the water uptake (34). Hashimoto et al. (32) reported that they did not observe time-dependent decrease in the bonding strength values when samples are stored in mineral oil instead of water. Yiu et al. (6) investigated 5 experimental bonding agents that have different hydrophilic characteristics. After preparation, authors have stored their samples either in water or mineral oil for 1, 3, 6 and 12 months. They reported the hydrophilicity of the resin as the most important factor that determines the percentage of water absorption and have found that long-term water storage declined bonding strength of 5 experimental bonding agents. In addition, they also suggested that long-term storage of samples in mineral oil instead of water could stabilize, or even increase, the tensile strength of hydrophilic resin mixture over time (6).

Most frequent type of failure on the sample surfaces in our study was adhesive/mix fracture both in 24 hours and 1 year groups. Also, percentage of such mechanical failures was observed to increase drastically after 1 year water storage, when compared to that of 24 hours group. In many studies, failures at the fracture surfaces of stick shaped samples have been classified under three main categories, namely the adhesive/mix, cohesive dentin and cohesive composite type of fractures (16-18, 26, 35, 36). Reis et al. (35) reported that it would be very difficult to distinguish between adhesive and mix types with naked-eye observation, as well as stereomicroscope. Authors have therefore suggested to combine adhesive and mix fracture types. Same approach was also used in this study. Samples having adhesive or mix fracture surfaces were grouped and analyzed as a single entity (35, 36). Cohesive fractures and pre-test fractures were not included in statistical analysis (37). Meerbeek et al. (13) have suggested that pre-test fractures should be excluded from statistical analysis. Otherwise, pre-test fracture values, usually accepted/assumed as 0 or 5 MPa, would decrease the mean bond strength of the dentin bonding system and such conditions could not reflect the real performance of the adhesive agent.

Conclusion

Long-term water storage of the two-step self-etch dentin bonding system which is considered as the gold standard in mechanical tests, have caused significant decrease in the bond strength values. Therefore, there is a need to develop new dentin bonding agents which provide more mechanical stability in long-term bonding strength tests and can be used as gold standard.

Source of funding

None declared

Conflict of interest

None declared
References

1. Sano H. Microtensile testing, nanoleakage, and degradation of resin-dentin bonds. J Dent Rest 2006;85(1):11-14.
2. De Munck J, Landuyt KV, Peumans M, Poitevin A, Lambrechts P, Braem M, Van Meerbeek B. A critical review of durability of adhesion to tooth tissue: Methods and results. J Dent Res 2005;84(2):118-132.
3. Tay FR, Pashley DH. Have dentin adhesives become too hydrophilic? J Can Dent Assoc 2003;69(11):726-731.
4. Hashimoto M, Ohno H, Kaga M, Endo K, Sano H, Oguchi H. In vivo degradation of resin-dentin bonds in humans over 1 to 3 years. J Dent Res 2000;79(6):1385-1391.
5. Amaral FL, Colucci V, Palma-Dibb RG, Corona SA. Assessment of in vitro methods used to promote adhesive interface degradation: a critical review. J Esthet Restor Dent 2007;19(6):340-354.
6. Yiu CK, King NM, Pashley DH, Suh BI, Carvalho RM, Carrilho MR, Tay F. Effect of resin hydrophilicity and water storage on resin strength. Biomaterials 2004;25(26):5789-5796.
7. Toledano M, Osorio R, Osorio E, Aguilera FS, Yamauti M, Pashley DH, Tay F. Durability of resin-dentin bonds: effects of direct/indirect exposure and storage media. Dent Mater 2007;23(7):885-892.
8. Cenci MS, Venturini D, Pereira-Cenci T, Piva E, Demarco FF. The effect of polishing techniques and time on the surface characteristics and sealing ability of resin composite restorations after one-year storage. Oper Dent 2008;33(2):169-176.
9. Mine A, De Munck J, Cardoso MV, Van Landuyt KL, Poitevin A, Kuboki T, Yoshida Y, Suzuki K, Lambrechts P, Van Meerbeek B. Bonding effectiveness of two contemporary self-etch adhesives to enamel and dentin. J Dent 2009;37(11):872-883.
10. Peumans M, De Munck D, Van Landuyt K, Lambrechts P, Van Meerbeek B. Five-year clinical effectiveness of a two-step self-etching adhesive. J Adhes Dent 2007;9(1):7-10.
11. Loguerocio AD, Lorini E, Weiss RV, Tori AP, Picinatto CC, Ribeiro NR, Reis A. A 12-month clinical evaluation of composite resins in class III restorations. J Adhes Dent 2007;9(1):57-64.
12. Yuan Y, Shimada Y, Ichinose S, Tagami J. Effect of dentin depth on hybridization quality using different bonding tactics in vivo. J Dent 2007;35(8):664-672.
13. Van Meerbeek B, Peumans M, Poitevin A, Mine A, Van Ende A, Neves A, De Munck J. Relationship between bond-strength tests and clinical outcomes. Dent Mater 2010;26(2):100-121.
14. De Munck J, Van den Steen PE, Mine A, Van Landuyt KL, Poitevin A, Opdenakker G, Van Meerbeek B. Inhibition of enzymatic degradation of adhesive-dentin interfaces. J Dent Res 2009;88(12):1101-1106.
15. De Munck J, Shirai K, Yoshida Y, Inoue S, Van Landuyt K, Lambrechts P, Suzuki K, Shintani H, Van Meerbeek B. Effect of water storage on the bonding effectiveness of 6 adhesives to Class I cavity dentin. Oper Dent 2006;31(4):456-465.
16. Reis A, Albuquerque M, Pegoraro M, Mattei G, Bauer JR, Grande RH, Klein-Junior CA, Baumhardt-Neto R, Loguerocio AD. Can the durability of one-step self-etch adhesives be improved by double application or by an extra layer of hydrophobic resin? J Dent 2008;36(5):309-315.
17. Mena-Serrano A, Garcia EJ, Loguerocio AD, Reis A. Effect of sonic application mode on the resin-dentin bond strength and nanoleakage of simpliﬁed self-etch adhesive. Clin Oral Investig 2014;18(3):729-736.
18. Tekçe N, Demirci M, Tuncer S, Uysal Ö. Effect of Different Application Techniques of All-in-One Adhesives on Microtensile Bond Strength to Sound and Caries-Aﬀected Dentin. J Adhesion 2015;91(4):245-261.
19. Shirai K, De Munck J, Yoshida Y, Inoue S, Lambrechts P, Suzuki K, Shintani H, Van Meerbeek B. Effect of cavity conﬁguration and aging on the bonding effectiveness of six adhesives to dentin. Dent Mater 2005;21(2):110-124.
20. Toledano M, Osorio R, Ceballos L, Fuentes MV, Fernandes CA, Tay FR, Carvalho RM. Microtensile bond strength of several adhesive systems to diﬀerent dentin depths. Am J Dent 2003;16(5):292-298.
21. Van Landuyt KL, Kanumilli P, De Munck J, Peumans M, Lambrechts P, Van Meerbeek B. Bond strength of a mild self-etch adhesive with and without prior acid-etching. J Dent 2006;34(1):77-85.
22. Proença JP, Polido M, Osorio E, Erhardt MC,
Aguilera FS, Garcia-Godoy F, Osorio R, Toledano M. Dentin regional bond strength of self-etch and total-etch adhesive systems. Dent Mater 2007;23(12):1542-1548.

23. Sadek FT, Goracci C, Cardoso PE, Tay FR, Ferrari M. Microtensile bond strength of current dentin adhesives measured immediately and 24 hours after application. J Adhes Dent 2005;7(4):297-302.

24. Inoue S, Koshiro K, Yoshida Y, De Munck J, Nagakane K, Suzuki K, Sano H, Van Meerbeek B. Hydrolytic stability of self-etch adhesives bonded to dentin. J Dent Res 2005;84(12):1160-1164.

25. Kenshima S, Reis A, Uceda-Gomez N, Tancredo LL, Filho LE, Nogueira FN, Loguercio AD. Effect of smear layer thickness and pH of self-etching adhesive systems on the bond strength and gap formation to dentin. J Adhes Dent 2005;7(2):117-126.

26. Lodovici E, Reis A, Geraldeli S, Ferracane JL, Ballester RY, Filho LE. Does adhesive thickness affect resin-dentin bond strength after thermal/load cycling? Oper Dent 2009;34(1):58-64.

27. Yeşilyurt C, Bulucu B, Koyutürk A. Adezif sistemlerin derin ve yüzeyel dentine mikrotensile bağlanma dayanımları üzerine etkileri. Ataturk Univ Dış Hek Fak Derg 2007;41(4):13-20.

28. Van Landuyt KL, Mine A, De Munck J, Jaecques S, Peumans M, Lambrechts P, Van Meerbeek B. Are one-step adhesives easier to use and better performing? Multifactorial assessment of contemporary one-step self-etching adhesives. J Adhes Dent 2009;11(3):175-190.

29. Armstrong SR, Vargas MA, Fang Q, Laffoon JE. Microtensile bond strength of a total-etch 3-step, total-etch 2-step, self-etch 2-step, and a self-etch 1-step dentin bonding system through 15-month water storage. J Adhes Dent 2003;5(1):47-56.

30. Akin GE, Hergüner-Siso Ş, Akin H. Termal siklus ve suda bekleşmenin kendinden asılti adezivlerin dentine mikrogerilim bağlanma dayanımları üzerine etkileri. Atatürk Üniv Dışhek Fak Derg 2012;22(2):125-131.

31. Torkabadi S, Nakajima M, Ikeda M, Foxton RM, Tagami J. Bonding durability of HEMA-free and HEMA-containing one-step adhesives to dentine surrounded by bonded enamel. J Dent, 2008;36(1):80-86.

32. Hashimoto M. A review- micromorphological evidence of degradation in resin-dentin bonds and potential preventative solutions. J Biomed Mater Res B Appl Biomater 2010;92(1):268-280.

33. Breschi L, Mazzoni A, Ruggeri A, Cademaro M, Di Lenardo R, De Stefano Dorigo E. Dental adhesion review: aging and stability of the bonded interface. Dent Mater 2008;24(1):90-101.

34. Hosaka K, Nakajima M, Takahashi M, Itoh S, Ikeda M, Tagami J, Pashley DH. Relationship between mechanical properties of one-step self-etch adhesives and water sorption. Dent Mater 2010;26(4):360-367.

35. Reis A, Grandi V, Carlotto L, Bortoli G, Patzlaff R, Rodrigues Accorite Mde L, Dourado Loguercio A. Effect of smear layer thickness and acidity of self-etching solutions on early and long term bond strength to dentin. J Dent 2005;33(7):549-559.

36. Reis A, Grande RH, Oliveira GM, Lopes GC, Loguercio AD. A 2-year evaluation of moisture on microtensile bond strength and nanoleakage. Dent Mater 2007;23(7):862-870.

37. Perdigão J, Munoz M, Sezinando A, Loque-Martinez I, Staichak R, Reis A, Loguercio A. Immediate adhesive properties to dentin and enamel of a universal adhesive associated with a hydrophobic resin coat. Oper Dent 2014;39(5):489-499.

Corresponding Author:
Safa TUNCER
Department of Restorative Dentistry
Faculty of Dentistry Istanbul University
34093- Capa-Fatih-Istanbul / TURKEY
Phone: +90 212 414 20 20 / 30354
e-mail: safatuncer@gmail.com