

Influence of Accelerated Staining and Bleaching Procedures on the Shear-bond Strength Orthodontic Adhesives

An *in vitro* study

ANCA MESAROS^{1*}, CAMELIA ALB¹, BOGDAN CULIC¹, MICHAELA MESAROS², MARIOARA MOLDOVAN³, LAURA BRU-CIFRE¹, MINDRA BADEA⁴

¹ Iuliu Hatieganu University of Medicine and Pharmacy, Faculty of Dental Medicine, Department of Dental Propaedeutics and Aesthetics, 32 Clinicilor Str., 400006, Cluj-Napoca, Romania

² Iuliu Hatieganu University of Medicine and Pharmacy, Faculty of Dental Medicine, Department of Paediatric Dentistry, 4 Louis Pasteur Str., 400349, Cluj-Napoca, Romania

³ Babes-Bolyai University Cluj-Napoca, Raluca Ripan Institute of Chemistry, 30 Fantanele Str., 400294, Cluj-Napoca, Romania

⁴ Iuliu Hatieganu University of Medicine and Pharmacy, Faculty of Dental Medicine, Department of Preventive Dentistry, 33 Motilor Str., 401135, Cluj-Napoca, Romania

The present study wishes to test the influence that procedures such as accelerated staining or bleaching might have on orthodontic adhesives. The test was done using 5 adhesive materials on 60 extracted human premolars. Adhesive remnant index was also studied by two methods, the classical and one using a CEREC 3D Red Cam. The result showed no evidence suggesting a statistical difference in the means of SBS between the commercial resin material groups but there was found to be important difference between them and the Vertise adhesive.

Keywords: shear-bond strength, orthodontic adhesives materials, adhesive remnant index, digital impression

The success of any fixed-appliance orthodontic treatment depends on multiple factors, most important of which being correct bracket placement and bonding together with the longevity of these accessories on the teeth. [1] Some types of beverage consumption together with some self-applied dental treatments, such as home-bleaching procedures, may affect the bonding properties of the brackets to the teeth. Bleaching agents contain solvents and other components which may increase the solubility or degradation of the orthodontic adhesives. Sometimes, remnants of the bleaching material interfere with the adhesion and clinical performance of the bonding material, resulting in decreased shear bond strength (SBS) of the brackets to enamel. It is essential to maintain the biomechanical stability of the bracket-adhesive interface, which transfers the force generated by the archwires to the teeth [2]. Bracket loss during orthodontic treatment is a common problem for orthodontists and requires additional in-office time and expense to replace the debonded brackets, as well as it may extend treatment time for patients in some cases [3, 4]. Another risk for the patient can be enamel loss during uncontrolled bracket de-bonding or during the removal of residual resin. The etching process can also induce irreversible changes to the enamel. In most cases, a re-bonded tooth has a weaker SBS than it had when it was initially bonded [5]. The effects of bleaching on the enamel surface and the subsequent effect of the composite resin on the SBS have been widely evaluated [6-16]. However, the results were very controversial. Some authors found no significant differences in SBS between bleached enamel and unbleached enamel [8, 9]. Then, others reported significant decreases in SBS when bleaching agents were applied [6, 7, 10-15]. Since fixed appliances facilitate the retention of bacterial plaque and

affect oral hygiene by making it more difficult, avoiding dental decay during treatment has also become a key issue for orthodontists. Therefore, an ideal orthodontic adhesive system should have sufficient bond strength to withstand untimely impact forces on bonded brackets and, at the same time, possess cariostatic properties [17]. Nowadays there are two types of adhesive material applied in orthodontic attachment bonding. They are resin base and resin hybrid glass ionomer base adhesives, but the properties these materials have can be quite different.

The objectives of this *in vitro* study were:

- to evaluate the shear bond strength (SBS) of 5 adhesives after being submitted to an accelerated staining or bleaching technique;

- to evaluate the failure mode of the 5 adhesives by comparing the classical ARI (Adhesive remnant index, described by Artun and Bergland, 1984) assessment with a new ARI method of assessment, one with a more clinical application.

The null hypotheses were as follows:

- there is no difference in SBS between the tested adhesives nor does the accelerated staining or bleaching techniques have any influence on the SBS;

- there is no difference in the failure mode of the adhesives due to the accelerated staining or bleaching techniques;

- there are no differences between the two different techniques used to assess the ARI.

Experimental part

Sample preparation

60 human premolars (30 mandibular and 30 from the maxilla) were selected from extracted teeth from patients aged 16 to 25 years and stored in a solution of 0.9% sodium

* email: mesaros.anca@umfcluj.ro



Fig 1. Accelerated staining/bleaching procedure

chloride. The storage time varied from 10 to 15 weeks. Tooth selection criteria included those with intact enamel, no pretreatment with chemical agents (for example, hydrogen-peroxide), no cracks, no lesions from the extraction forceps, and no caries or restorations. Teeth were cleansed of any soft tissue, and their roots were embedded in acrylic resin with a label bearing the code of each sample; therefore, only the crowns of the teeth remained exposed. Each tooth was embedded in its physiological implantation axis. Teeth surfaces were cleaned with a pumice-water paste in a rubber cup with a slow-speed hand piece for 30 s, washed for 10 s, and then air dried for 15 s.

The specimens were assigned to 5 groups ($n = 12$) according to the material used for bracket bonding. The selection of teeth within each group was randomized but each group had 6 upper premolars and 6 mandibular ones. The 5 different adhesive materials used for this study were:

- the resin base adhesive Light Bond (Reliance Orthodontic Products, Itasca, IL);
- the resin base adhesive Opal Bond MV (Opal Orthodontics, Ultradent);
- the resin self-etching composite Vertise (Kerr) - a commercial material with restorative indications, tested to search an eventual indication in bracket bonding
- the resin hybrid glassionomer adhesive Fuji Ortho LC (GC);
- an experimental resin hybrid glass ionomer material developed at the Raluca Ripan Institute of Chemistry (UBB).

60 standard edgewise stainless steel premolar brackets (0.022 X 0.028 inch slot) (GAC Orthodontic Products, New York, USA) were directly bonded to the labial surfaces of the teeth following the manufacturers bonding protocol for each of the materials. Afterwards all teeth were submitted to a thermo cycling procedure for 1,000 cycles at 5 degrees C and 55 degrees C with a dwell time of 20 s.

Staining procedure

Each group corresponding to an adhesive material was subdivided in 3 subgroups ($n=4$, 2 maxillary teeth and 2 mandibular) and each subgroup was submitted to a different procedure (fig 1):

- accelerated staining procedure using natural coffee: Coffee solution was prepared by boiling 30g of Turkish coffee in 250 mL of distilled water. Teeth were immersed in fresh coffee 8 hours per day for 14 consecutive days. Solutions were maintained at 37°C in an incubator and between coffee soaking times the samples were kept in distilled water;

- accelerated bleaching procedure: A commercial tooth whitening product -Opalescence 15% (Ultradent) - was used to simulate this procedure. A small amount of the product was applied daily, for 8 h, or 14 consecutive days. Between procedures, teeth were kept at 37°C in an incubator in distilled water;

- control Procedure: teeth were kept in distilled water at 37°C in an incubator for 14 days and the solution was changed twice a day.

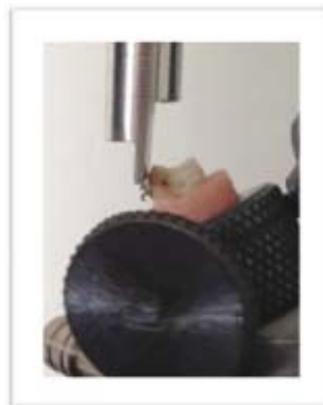


Fig 2. The knife-edged shearing blade for the SBS tests

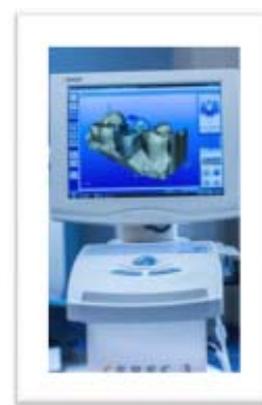


Fig 3. The CEREC 3D Red Cam

Shear Bond Strength (SBS) Test

After the accelerated staining/bleaching procedures, all samples were submitted to a Shear-Bond Strength test. The Machine of choice used for SBS testing was the LR5KPlus 5kN Universal Materials Testing Machine from Lloyd. In order to test the SBS, without touching the enamel and while using a crosshead speed of 1 mm/min, a knife-edged shearing blade was positioned parallel to both the labial surface and the bracket interface to allow the transmission of the force in the occlusogingival direction (fig 2.). The force applied at the time of fracture was recorded in Newton's (N) and converted to megapascals (Mpa) dividing the force by the bracket base area, which according to the manufacturer have a mesh base area of 0.115 cm².

Adhesive Remnant Index Assessment

Once the brackets had been debonded, the enamel surface of each tooth was examined using two methods:

- with a stereoscope (Nikon, Tokyo, Japan) at a magnification of 10x to determine the amount of residual adhesive remaining on each tooth;

- using digital impressions acquired using the Cerec 3D Red Cam, Sirona, Germany (fig 3). A digital impression of the labial surfaces of all teeth was obtained prior to bracket bonding, and a second one was obtained after de-bonding. The CEREC 3D RED CAM has an infrared, polarized, 840nm Light Source with a 680X480 pixels (=362.400 pixels) Low-Noise CCD sensor and offers a measuring technique by active triangulation. The images are acquired after drying the object and using the CEREC Optispray, Sirona – a coating spray of anti-reflex powder.

The same operator that interpreted the ARI (fig 4) scores with the first method did the readings by the second method within two weeks time distance in between methods. The ARI scores were recorded as described by Artun and Bergland in 1984 (18): 0 = no adhesive left on the tooth, 1 = less than half of the adhesive left on the tooth, 2 = more than half of the adhesive left on the tooth, 3 = all adhesive left on the tooth, with distinct impression of the button mesh.



Fig 4. Adhesive Remnant Index Assessment (with the CERC 3D Red Cam on the left and by classical method on the left)

Statistical Analysis

The resulting bond strengths of the three groups (control, coffee, bleach) were compared by a one-way analysis of variance (ANOVA). A chi-squared test was used to determine significant differences in the ordinal ARI scores. All statistical tests were run with a predetermined significance of $\alpha=0.05$ and were done using the statistical software (SPSS for Windows, version 13.0, SPSS, Chicago).

Results and discussions

The SBS means, expressed in MPa, and are shown in table 1. There was little difference between the mean and median bond strengths values. There was no evidence suggesting a statistical difference in the mean SBS between the commercial resin material groups (Opal Bond MV and Light Bond), however there was found to be an important difference ($p=0.0236$) between them and the Vertise adhesive, the latter having shown very low resistance to shear-bond stress. Also there were important differences found between the glassionomer type adhesives, the

Experimental one also having performed in a less satisfactory manner ($p=0.0048$). The Chi-squared test $\chi^2 = 109.673$ revealed important differences between SBS values corresponding to the same material but different immersion solution ($p<0.0005$).

Comparing the SBS of orthodontic brackets to teeth (with the five adhesive systems and three different immersion solutions) has showed that for each material there was a tendency that the values for the SBS of the teeth exposed to bleaching materials were smaller than for the teeth with brackets bonded with the same adhesive material but exposed to coffee or distilled water. However there was no statistical difference found between the SBS values presented by adhesive materials immersed in coffee and distilled water. ($p=0.21$).

The distribution and results of the ARI scores are illustrated in table 2. There was found a perfect match between the two methods of ARI assessment. The chi-squared test showed a highly significant difference between ARI scores of the Coffee and the other two groups. It appears that due to the immersion in coffee solution, there is a lower frequency of remnant adhesive on tooth.

The Coffee group showed less than half of the adhesive remaining in 95 per cent, indicating failure at the adhesive-bracket interface. Enamel fractures were not observed in any of the three groups.

Controversy exists in the literature regarding the effects of bleaching on the SBS of composite resins to the enamel; these results could be attributed to the variability in the bleaching agent concentrations associated with different bleaching protocols, as well as the amount of time allotted between the bleaching and bonding procedures [16].

In this study, the bleaching groups had lower SBS values than the control and coffee groups. This reduction could be explained by the high residual peroxide concentration at the enamel surfaces, as residual oxygen that is released from the bleaching agent may interfere with the infiltration of resin into the etched enamel [13, 19, and 20-22]. The

	Coffee (4/group)	Bleach(4/group)	Control(4/group)
Experimental	1.26775 MPa	0.68950 MPa	1.27325 MPa
FujiOrthoLC	7.17675 MPa	5.31850 MPa	6.69050 MPa
OpalBondMV	9.77825 MPa	6.71650 MPa	9.1800 MPa
LightBond	12,89125 MPa	8.89675 MPa	13.08150 MPa
Vertise	0.70750 MPa	0.36050 MPa	0.80200 MPa

Table 1
SHEAR BOND STRENGTH MEAN RESULTS

	0	1	2	3	n
Coffee	7	12	1	0	20
Experimental	2	4	4	0	6
FujiOrthoLC	2	3	3	0	5
OpalBondMV	1	2	2	0	3
LightBond	0	0	0	0	0
Vertise	2	3	1	0	6
Bleach	2	3	11	4	20
Experimental	1	2	2	1	6
FujiOrthoLC	0	1	2	0	3
OpalBondMV	0	0	1	0	1
LightBond	0	0	2	0	2
Vertise	1	0	4	3	8
Control	1	9	3	7	20
Experimental	0	1	1	2	4
FujiOrthoLC	0	1	0	1	2
OpalBondMV	0	2	0	1	3
LightBond	1	3	1	1	6
Vertise	0	2	1	2	5

Table 2
DISTRIBUTION FREQUENCY OF THE ADHESIVE REMNANT INDEX (ARI)

increased temperature and high peroxide concentrations used in the in-office bleaching procedures are designed to accelerate the reaction and produce an immediate effect, probably resulting in significant concentrations of residual peroxide on the tooth surfaces.

This result, bleaching groups had lower SBS values than the control and coffee groups may be related to the incomplete diffusion of the peroxide into the tooth structure immediately after bleaching. Furthermore, this fact might be associated with the presence of carbopol in the bleaching gel, an additive that thickens the bleaching material, improves adhesion, and prolongs oxygen peroxide release [9, 21].

A possible explanation for the low SBS on all groups' values is the effect of saliva on enamel remineralization after bleaching. Previous investigations have demonstrated that the immersion of *in vitro* specimens in distilled water, artificial saliva, or even saline solution results in a complete reversal of the reduced enamel bonds [8, 10, and 16].

Reynolds [1] suggested that minimum bond strengths of 6 - 8 MPa are adequate for most clinical orthodontic needs and are considered able to withstand masticatory and orthodontic forces. Our study has shown similar values only for the adhesive materials that are already on the market with this particular indication of bracket bonding.

Less residual adhesive after debonding would be beneficial for the clean-up procedure at the end of treatment: it would save both time and prevent iatrogenic enamel loss [18,22]. Although, the locus of bond failure is determined by a complex combination of contributory factors including the direction of the force applied, enamel pre-treatment, the adhesive itself, and the bracket type.

Bracket failure at the bracket-adhesive interface is advantageous as it leaves the enamel surface relatively intact. However, considerable chair time is necessary to remove the residual adhesive and may lead to potential damage to the enamel surface during the cleaning process. Nevertheless, when the brackets fail at the enamel-adhesive interface, less residual adhesive remains, but the probability of damage to the enamel surface increases[9].

Conclusions

Within the limitations of this *in vitro* study, the following conclusions were drawn.

The null hypothesis was not totally rejected. All the tested bleaching groups had reduced SBS of the brackets to the enamel, the Experimental material and Vertise showed the lowest bond strength values but there was observed a similarity between the two commercial resin-based adhesives (Opal Bond MV and Light Bond).

The majority of fractures were shown to be adhesive for the resin-based, occurring at the tooth-adhesive interface, but even more preminent in teeth that were soaked in coffee solution.

Analysis of ARI scores showed a statistically significant disparity, thus, the null hypothesis that there would be no difference in ARI scores between the groups was rejected.

The null hypothesis that there are no differences between the two different techniques used to assess the ARI is accepted, and in the future, the use of CEREC 3D Red Cam can be an alternative to stereoscopes.

Acknowledgements: The research is part of the PN-II-PT-PCCA-2011-3-2-1275 Contract nr 165/2012 research grant.

References

1. REYNOLDS I. R., BR. J. Orthod, nr **2**, 1975, p. 171-178
2. ELIADES T., BRANTLEY W. A., Eur J Orthod, nr **22**, 2000
3. OESTERLE L. J. , SHELLHART W. C., Am J Orthod Dentofacial Orthop, nr **133**, 2008, p.716
4. RAY S., LONDHE S., MITRA R., CHOPRA S. S., Orthodontics(Chic.)nr **13**, 2012,p. e181
5. BISHARA . S. E., OSTBY A.W, LAFFOON J., WARREN J.J., Angle Orthod nr **77**, 2007, p.711
6. MILES P. G., PONTIER J.P, BAHIRAEI D., CLOSE J., Am J Orthod Dentofacial Orthop, nr **106**, 1994, p. 371
7. CACCIAFESTA V., SFONDRINI M. F, STIFANELLI P, SCRIBANTE A., KLERSY C., Am J Orthod Dentofacial Orthop nr **130**, 2006, p. 83
8. UYSAL T., BASCIPTCI F. A, UÜMEZ S. SARI Z. , BUYUKERKMEK A., Am J Orthod Dentofacial Orthop nr. **123**, 2003, p.628
9. BISHARA S. E., OONSOMBAT C., SOLIMAN M. M., AJLOUNI R., LAFFOON J. F., Am J Orthod Dentofacial Orthop nr. **128**, 2005, p.755
10. TITLEY K. C.,TORNECK C. D., RUSE N. D, J Dent Res nr **71**, 1992, p.20.
11. TITLEY K. C., TORNECK C. D., RUSE N. D. , D. KRMEC, J Endod nr **19**,1993, p.112
12. ATTIN T. , HANNIG C., WIEGAND A.. ATTIN R, Dent Mater nr. **20**, 2004, p. 852
13. BULUT H., KAYA A.D., TURKUN M., Eur J Orthod nr **27** ,2005,p. 466
14. MULLINS . J. M., KAO E. C., MARTIN C. A., GUNEL E., NGAN P., Angle Orthod nr. **79**, 2009, p.777
15. BORGES A. B., RODRIGUES J. R. , BORGES A. L. S., MARSILIO A. R., Rev Odontol UNESP nr. **36**, 2007, p.77
16. NASCIMENTO G. C. R., DE MIRANDA C. A., MACHADO S. M. M., BRANDAO G. A. M., DE ALMEIDA H. A., SILVA C. M., Korean J Orthod nr. **43** ,2013, p. 242 .
17. MARGOLIS H. C, MORENO E. C., J Dent Res nr. **69** ,1990, p.606
18. RTUN J., BERGLAND S., Am J Orthod nr **85**, 1984, p. 333
19. OZOE R., ENDO T., ABE R, SHINKAI K., KATOH Y., Quintessence Int. nr. **43**, 2012, p. e60
20. BRESCHI L., MAZZONI A., DORIGO E. S., FERRARI M., J Adhes Sci Tech nr. **23**, 2003, p. 1053.
21. MOLDOVAN M., ALMASI A., PREJMEREAN C., MUSAT O., SILAGHI-DUMITRESCU L., NICOLA C., COJOCARU I., PASTRAV O., Mat. Plast.,**46**, no. **4**, 2009, p. 404
22. POPESCU R.G., MOREGA A., IORDACHESCU D., DEMETRESCU I.,Mat. Plast., **46**, no. **2**, 2009, p.140

Manuscript received: 7.05.2014