An Analysis of Incisive-Bracket Bond Resistance in Orthodontics. III

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The third part of the study is oriented toward emphasizing the effect of aggressive media on mechanical behaviour of orthodontic systems. As the incisive teeth are suffering the largest loads during feeding this study is focused on accidental failure of incisive-bracket systems after their use in a manner not recommended by doctors. As in the previous two articles the bovine rib is used to simulate the teeth but in this case the orthodontic systems are tested in aggressive conditions meaning the systems are employing to bite from apples considering that the apples are containing enough acids to chemically affect the bond between incisive and bracket – one hand and, on the other hand, they are enough hard peeled in order to mechanically load the orthodontic system. Another aspect concerns with the fact that apples are most eaten fruits in Romania, especially in schools, and being about kids a failure of orthodontic system caused by inattention is more probable. Forty teeth were prepared for this study and twenty of them were new while the other twenty were used before for other studies and the brackets were newly mounted. The number of bites was set after an analysis regarding the human feeding behaviour namely by considering that a normal person or a normal kid might eat three apples a day. The shear strength of orthodontic system was determined in accidental conditions if the system did not fail during the biting part of tests.

Keywords: orthodontics, adhesive, bracket, shear strength.

Measuring the shear bonding strength of a bracket-polymer-tooth system had been reported by many authors as a difficult task. Researchers – both from orthodontics and mechanics – pointed out the fact that the measuring design has to take into account too many factors such as geometry of tooth, polymerization conditions, working time of the system, *p*H of saliva, regular diet, and alimentation habits and so on. Generally all the measuring attempts are carried out *in vitro* as long as there are not available sensors and instruments to be used for *in vivo* conditions. All the reported results are obtained in laboratory conditions using various equipments, sensors and techniques [1,2] on separate teeth [3-6] or teeth systems [7-9].

The nature of the forces directed onto orthodontic brackets in the mouth is likely to be a combination of shear, tensile and torsion. The bond strength of bracket - adhesive - enamel system in orthodontic bonding varies and depends on factors such as the type of adhesive, bracket base design, enamel morphology, appliance force systems and the clinician's technique. In vitro studies are unable to produce the same conditions as the ones present in oral cavity when fixed appliance is in place. Effects of forces that are loaded onto teeth during mastication, bad habits, pH of saliva, type of food and drinks consumed during treatment, oral hygiene are only the small fraction of all the influences that are present in the mouth during orthodontic treatment. The universal testing machine used in vitro studies is capable of producing only pure debonding forces (shear, tensile or torsion) not the combination of them and other conditions are not possible to simulate. In addition, the rate of loading for the universal testing machine is constant, whereas the rate of loading for in vivo debonding is not standardized or constant [10].

The study and evaluation of the adhesive potential of a specific bonding system are complicated, as there are multiple variables that can influence the survival or longevity of the bracket-enamel interphase. The two primary tests used for evaluating the strength of the orthodontic adhesives measure shear and tensile bond strengths. In the shear test, the force is directed parallel to the long axis of the tooth and as closely as possible to the bracket-tooth interface [9].

There are many factors that can cause bond failure of orthodontic brackets, including the multifactorial nature of the oral environment which causes pH fluctuations, as well as the complex cyclic loading of chewing, alcohol-containing fluids, temperature variations, and food consistency, all of which make it difficult to specifically determine the reasons for failure and some of this factors had been studied apart [10-19]. When considering each of these factors, the true effectiveness and performance of any particular bracket-bonding system in in vitro studies become questionable when different studies are compared. However, if studies are performed under standardized testing conditions, they may generate more reliable information that may be useful in future studies.

Experimental part

Materials and methods

For this study metal brackets Avex MX Opal from Opal Orthodontics by Ultradent had been used and Transbond™ Plus Self Etching Primer and Transbond™ PLUS Color Change Adhesive from 3M Unitek to ensure the brackets positioning on teeth.

Forty samples were prepared for this study. Twenty of them had been used in previous studies such as the brackets were reinstalled on them and twenty are at the first bracket installation as it might be seen in figure 1. Thinking the study in this manner is in accordance with the dental medical practice since the patients are required to visit the doctor's cabinet within one month after the

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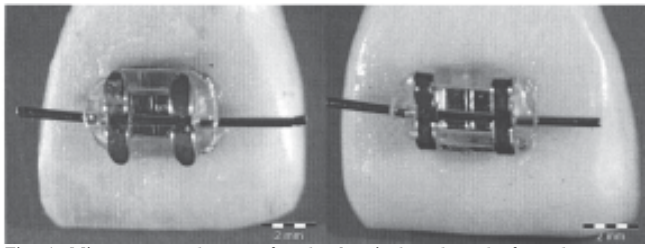

Fig. 1. Microscope photos of orthodontic brackets before the tests. Left replaced bracket. Right newly mounted bracket

installation of orthodontic systems. Of course this visit is meant for fine tuning of the orthodontic system especially for tension of the arch wire. For this test all the brackets were provided with small parts of arch wire to simulate also the in plane (bonding plane) shearing of the bracket which is affecting the bond strength.

Performing the tests both on re-used systems and new systems concerns with the viability of re-use of the same brackets after they are accidentally debonded. After the previous tests the brackets surfaces and bond surfaces were cleaned of debris of polymer material. But it has to be assumed that in dental cabinet conditions is difficult to proceed for a complete cleaning. In other words it is almost impossible to remove all the hardened polymer debris both from bracket surface and from dental surface. In these conditions it is expected that the shear resistance of repaired orthodontic systems to be lower than the one of new systems.

Results and discussions

For all the systems – human incisive shaped bovine rib with polymer fixed bracket and arch wire – it was thought a test in a high aggressive media. The two sets of orthodontic systems (one set of twenty of repaired systems and one set of twenty of new systems) were randomly distributed into eight groups of five. From each set of twenty the first group of systems were kept as reference systems i.e. they were not used to simulate bites. The other groups were used to bite from apples for 200, 400 and 600 times. There were chosen hard peeled apples of *Grannie Smith* sort available in Romanian market, which also presents a high acidity.

The number of bites was established taking into account the fact that a normal person can eat three apples a day and for each apple two bites are direct ones – against medical recommendations but normal taking into account the alimentary habits. In this case two sets of simulating orthodontic systems (one of old systems and one of new ones) were employed to realize 200 bites. For the other four sets (two of re-used systems and two of new systems) 400 and, respectively 600 bites were realized. 600 bites are corresponding to an alimentation containing three apples a day without taking into account the medical recommendations (there were considered 5 to 6 hard bites for each apple – the ones that involves the incisive teeth) while 400 are corresponding to a negligent alimentation (3-4 hard bites) into a regime containing three apples a day.

During the tests each orthodontic system is suffering both a mechanical load due to the interaction between the apple and the bracket with effects on polymer bond and an acid attack from apple acids also at the polymer bond level. It is expected that shear resistance of brackets – measured in accidental debonding conditions – to decrease with the increase of the bites number. The results of the tests are offering just general conclusions because the shear resistance of the orthodontic systems is not

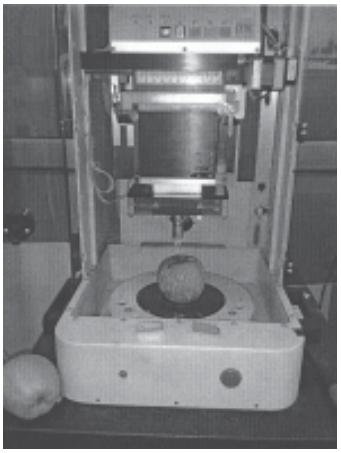

Fig. 2. Universal testing machine from CTR

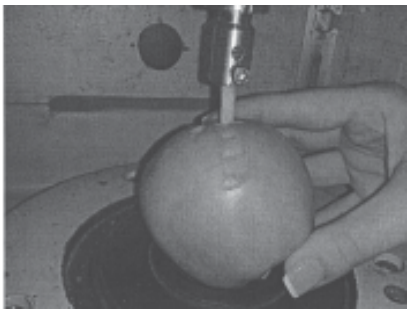

Fig. 3. Bite simulation

depending only on exploitation conditions but also on bracket fixing process itself. It is also expected that the acid attack is mostly affecting the polymer – bracket interphase with consequences at the level of fracture area namely most of the polymer will remain on the dental surface leading to a high ARI quotient.

For this study each tooth simulator was gripped on a universal testing machine from CTR (fig. 2 and 3.) and the machine was set to execute an oscillatory movement on a vertical plane. Both for descending part and the ascending part of the cycle representing the bite the speed of the orthodontic system was of 50mm/s and the amplitude of the movement was of 15mm, This values are fitting the values which are obtained in the case of natural processes of biting and chewing. Also the natural curvature of the bovine bone contributes to the complexity of the simulation by introducing a soft rotation, proper to the natural movement during the bite.

After all the incisive-bracket systems supported the planned number of bites they were tested for shear resistance in accidental conditions. We assume that accidental conditions are representing an accidental bite on very hard media such as peach kernel or apricot kernel. These conditions were described in the first two parts of the study.

There was just a system which failed during the test procedure. This system is showed in figure 4. and it can be seen that the failure is placed between bracket and polymer adhesive and almost the entire amount of adhesive remained on the dental surface. An explanation of this behavior could be connected with a late installation of the bracket on applied polymer fact that explains the absence of interphase between polymer and bracket.

The sample labeled 40 having an opposite behaviour is showed in figure 5. and it is noticeable that almost the entire amount of polymer remained on the bracket surface such as the dental specialists are expecting. This sample is tested for accidental debonding without being loaded before by biting from apple being part of reference set of systems.

The debonding mode according to ARI (adhesive remnant index) by means of qualitative analysis of

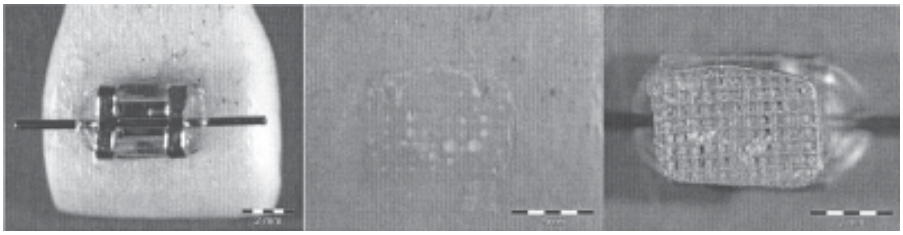

Fig. 4. Sample no.14. Aspect of the system before the test (left). Images of bone surface and bracket surface after debonding

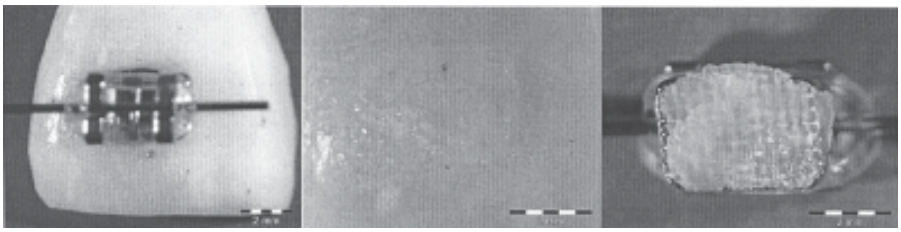

Fig. 5. Sample no.40. Aspect of the system before the test (left). Images of bone surface and bracket surface after debonding

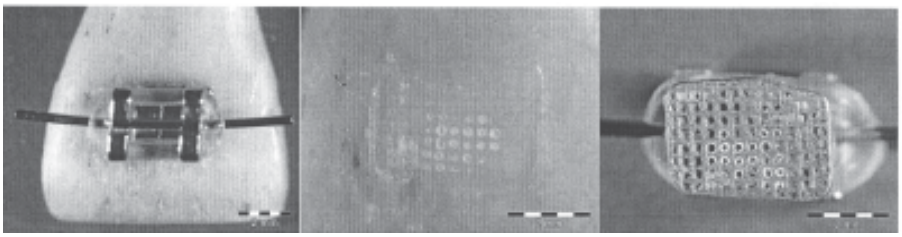

Fig. 6. Sample no. 12 scoring 3 in ARI (more than 90% of the adhesive remained on the tooth)

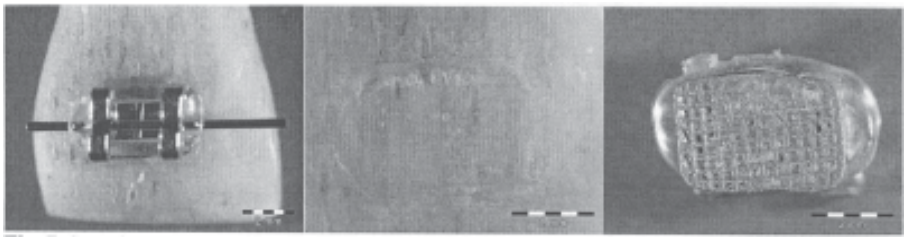

Fig. 7. Sample no. 17 scoring 3 in ARI (more than 90% of the adhesive remained on the tooth)

microscope [22] shows for all the samples variations between sample no. 40 (fig. 5.) and sample no. 12 (fig. 6.) or sample no. 17 (fig. 7.). Both last two systems are from the set of remounted brackets signifying that in this case the polymer remains mostly on the dental surface. That could be explained as a consequence of improper cleaning of bracket surface before it is remounted on the dental surface and taking into account the fact that usually the epoxy resins are not adhering to epoxy surfaces. However there are samples with variable ARI quotients belonging to the second set of samples, the one of new mounted brackets such can be seen in fig. 8 for the sample labeled 34 or fig. 9 for sample no. 35.

The shear resistance values are showed in table no. 1 where **a** denotes repaired systems and **b** denotes new systems, the second digit represents the number of bites (0 for reference samples, 1 for 200 bites, 2 for 400 bites and 3 for 600 bites) and the last digit is number of sample into the test set. The number in parentheses represents the sample labeling and is 1 to 20 for repaired systems and 21 to 40 for new systems. It might be noticed that the lowest value corresponds to the sample labeled 14 (a33) the one that failed during the apple test and it was not tested for accidental debonding while the highest value corresponds to the sample labeled 40 (b05) a sample that was tested for accidental debonding without being tested on apple as it belongs to reference set.

Generally the average values of shear resistance are lower in the case of repaired systems than in the case of new systems, as it can be easily noticed from table 1. There is an exception in the case of 400 bites test when the average value for repaired systems is a little higher than the one corresponding to new systems but that cannot be explained as a consequence of orthodontic system-apple interaction but as a result of bracket installation.

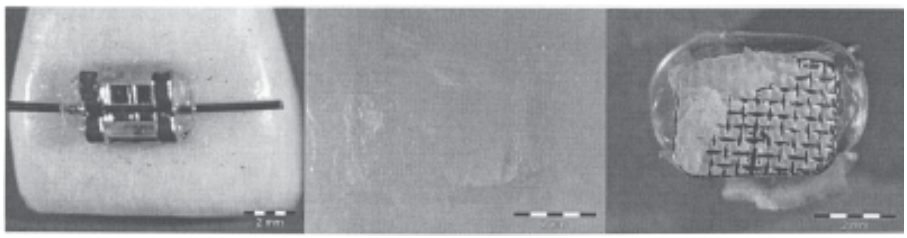

Fig. 8. Sample no. 32 scoring 2 in ARI (more than 50% of the adhesive remained on the tooth)

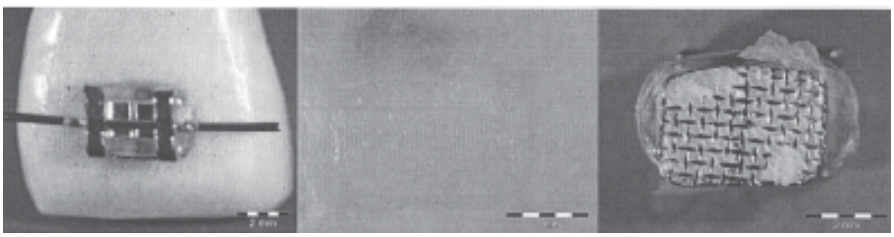

Fig. 9. Sample no. 34 scoring 2 in ARI (more than 50% of the adhesive remained on the tooth)

Sample	a01 (01)	a02 (04)	a03 (08)	a04 (12)	a05 (15)		b01 (27)	b02 (31)	b03 (36)	b04 (37)	b05 (40)	
Force [N]	7.19	38,9	36.5	55.8	85.4	**44.8**	80.7	54.4	96.8	92.4	167.3	**98.3**

Sample	a11 (05)	a12 (10)	a13 (11)	a14 (17)	a15 (20)		b11 (21)	b12 (22)	b13 (29)	b14 (33)	b15 (39)	
Force [N]	63.8	35.2	71.1	125.2	64.3	**71.9**	86.3	77.7	95.2	99.2	51.1	**81.9**

Sample	a21 (02)	a22 (06)	a23 (09)	a24 (13)	a25 (19)		b21 (23)	b22 (26)	b23 (30)	b24 (34)	b25 (38)	
Force [N]	123.9	108.0	108.8	7.6	93.5	**88.4**	104.2	72.2	82.9	79.5	98.6	**87.5**

Sample	a31 (03)	a32 (07)	a33 (14)	a34 (16)	a35 (18)		b31 (24)	b32 (25)	b33 (28)	b34 (32)	b35 (35)	
Force [N]	77.1	61.9	0	143.0	45.1	**65.4**	88.8	115.9	90.0	109.4	32.0	**87.2**

Table 1
SHEAR RESISTANCE VALUES

Conclusions

Simulating orthodontic systems had been realized using bovine rib bone and metal brackets Avex MX Opal from Opal Orthodontics by Ultradent. The brackets had been fixed on the human incisive shaped bovine rib bone with Transbond™ Plus Self Etching Primer and Transbond™ PLUS Color Change Adhesive from 3M Unitek. There were used two sets of simulating orthodontic systems one of 20 repaired systems and one of 20 new systems. In the case of the first set both brackets and bovine rib bone had been used for other tests and each bracket was replaced on the same bovine rib bone after the surfaces were cleaned and the polymer debris was removed. Five repaired systems and five new systems were randomly chosen as reference and they were tested for accidental debonding without other tests. The other systems were also randomly distributed into three sets which were employed to realize 200, 400 and respectively 600 bites in a highly acid hard peeled apple available in the Romanian market.

The apple biting is reducing the shear resistance of orthodontic systems in accidental debonding conditions especially in the case of repaired systems meaning that the system resistance is influenced both from the mechanical loading during the bite and the acid attack at the bone-polymer and bracket-polymer interphases. Generally, in the case of repaired systems the entire amount of polymer is remaining on the dental surface denoting a higher efficiency of acid attack at the bracket-polymer interphase level.

In the case of new orthodontic systems the shear resistance is decreasing for apple tested systems but it seems that the number of bites is not influencing the mechanical parameter.

Regarding the ARI quotient in the case of repaired systems almost all the systems are scoring 3 (more than 90% of adhesive remained on dental surface) while for new systems the ARI quotient varies from 1 to 3.

Analyzing the results of the tests and the microscope images of systems before accidental debonding tests it seems that the bracket position on the tooth is influencing the shear resistance of orthodontic systems and it would be interesting such an analysis. Also, regarding repaired orthodontic systems with the same bracket re-installed on the same tooth an analysis regarding the influence of re-installing conditions on shear resistance is required.

References

1. MATEI, M., CIORTAN, S., CIRCIUMARU, A., Mat. Plast., **51**, no. 3, 2014, p. 267
2. MATEI, M., CIOTAN, S., CIRCIUMARU, A., Mat. Plast., **51**, no. 3, 2014, p. 313
3.. ELSAKA, S. E., HAMMAD, S. M., IBRAHIM, N. F. (2014), Evaluation of stress developed in different bracket-cement-enamel systems using finite element analysis with in vitro bond strength tests, Progress in Orthodontics, no. 15, http://www.progressinorthodontics.com/content/15/1/33.
4. MÁRTHA, KRISZTINA, OGODESCU, A., ZETU, IRINA, OGODESCU, EMILIA, GYERGYAY, RÉKA, PĂCURAR, MARIANA, Mat. Plast., **50**, no. 3, 2013, p. 208.
5, RASTELLI, MARCIA CRISTINA, COELHO, U., ORELLANA JIMENEZ, E. E., Evaluation of shear bond strength of brackets bonded with orthodontic fluoride-releasing composite resins, Dental Press J Orthod, No. 15(3), p. 206-213.
6.SCOUGALL-VILCHIS, R. J., ZÁRATE-DÍAZ, C., KUSAKABE, S., YAMAMOTO, K., (2010), Bond strengths of different orthodontic adhesives after enamel conditioning with same self-etching primer, Australian Orthodontic Journal, vol. 26, No. 1, p. 84-89.
7. BADAWI, H. M., TOOGOOD, R. W., CAREY J. P. R., HEO, G., MAJOR, P. W. (2009), Three-dimensional orthodontic force measurements, American Journal of Orthodontics and Dentofacial Orthopedics, vol. 136, no. 4, p. 518-528.
8. FERČEC, J., GLIŠIĆ, B., ŠĆEPAN, I., MARKOVIĆ, E., STAMENKOVIĆ, D. ANZEL, I., FLAŠKER, J., RUDOLF, R., (2012), Determination of Stress and Forces on the Orthodontic System by Using Numerical Simulation of the Finite Elements Method, Acta Physica Polonica A, vol. 122, No. 4, 2012, p. 659-665.
9.MARKOVIC, EVGENIJA, GLIŠIC, B., ŠCEPAN, IVANA, MARKOVIC, D., JOKKANOVIC, V., Bond Strength of Orthodontic Adhesives, Metalurgija – Journal of Metallurgy, UDC:611.314:616-089.23.08=861.
10. GREENLAW, R., WAY, D. G., KHADRY, A. G. (1989), An in vitro evaluation of a light-cured resin bonding systems, American Journal of Orthodontic and Dentofacial Orthopedics, vol. 96, p. 214.
11. GUZMAN, U. A., JERROLD, L., VIG, P. S., ABDELKARIM, A. (2013), Comparison of shear bond strength and adhesive remnant index between precoated and conventionally bonded orthodontic brackets, http://www.progressinorthodontics.com/content/14/1/39.
12. RAMOS DOS SANTOS, A. A., MELO PITHON, M., CARVALHO CARLO, F. G., LEMES CARLO, H., SILVA GUEDES DA LIMA, A., DOS PASSOS, T. A., LACERDA-SANTOS, R. (2013) Effect of time and pH on physical-

chemical properties of orthodontic brackets and wires, Angle Orthodontist, http://dx.doi.org/10.2319/032914-234.1.
13. OSTBY, A. W., BISHARA, S. E., DENEHY, G. E., LAFFOON, J. F., WARREN, J. J. (2006), Effect of self-etchant pH on the shear bond strength of orthodontic brackets, doi: 10.1016/j.ajodo.2006.07.039.
14. OMID KHODA, M., HERAVI, F., SHAFAEE, H., MOLLAHASSANI, H. (2012), The Effect of Different Soft Drinks on the Shear Bond Strength of Orthodontic Brackets, Journal of Dentistry, Teheran University of Medical Sciences, vol. 9, no. 2, p. 145 - 149.
15. ALSULAIMANI, F. F., (2014), Effect of Lactic Acid Etching on Bonding Effectiveness of Orthodontic Brackets after Water Storage, http://dx.doi.org/10.1155/2014/719608
16. LUPAN, I., SACHDEV, S., SANNOUFI, E., (2011), Optimizing adhesion of orthodontic brackets to fluorised teeth, Romanian Journal of Oral Reahabilitation2, vol. 3, no. 1, p. 19-22.
17. ULUSOY, Ç., M□JDECI, A., GÔKAY, O. (2009), The effect of herbal teas on the shear bond strength of orthodontic brackets, European Journal of Orthodontics, vol. 31, no. 4, p. 385-389.
18. HUSSIEN, A. H., AL-MULLA, A. (2010), The effect of food simulants on corrosion of simulated fixed rthodontic appliance, J Bagh College Dentistry, vol. 22, no 1, p. 68-75.
19. IMMERZ, I., PROFF, P., ROEMER, P. REICHENEDER, C., FALTERMEIER, A. (2012) An investigation about the Influence of Bleaching on Shear Bond Strength of Orthodontic Brackets and on Enamel Colour, http://dx.doi.org/10.5402/2012/375849.
20. BRONWEN VORHIES, A., DONLY, K. J., STALEY, R. N., WEFEL, J. S. (1998) Enamel demineralization adjacent to orthodontic brackets bonded with hybrid glass ionomer cements: An in vitro study, Am J Orthod Dentofacial Orthop, no. 144 (6), p. 668-674.
21. ZIDAN, O., HILL, G. (1986), Phosphoric acid concentration: enamel surface loss and bonding strength, J Prosthet Dent, no. 55 (3), p. 388-392.
22. BURCAK CEHRELI, S., POLAT-OZSOY, O., SAR, C., EVREN CUBUKCU, H., CEHRELI, Z. C., A comparative study of qualitative and quantitative methods for the assessment of adhesive remnant after bracket debonding, European Journal of Orthodontics, http://ejo.oxfordjournals.org

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