Comparison of clinical bond failure rates and bonding times between two adhesive precoated bracket systems

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Objective: To compare the clinical bracket failure rate and bonding time differences between Adhesive Precoated Flash-Free (APCF) and Adhesive Precoated Plus (APCP) bracket systems. **Methods:** Thirty-three patients (7 male and 26 female) with a mean age of 17.2 ± 3.6 years and permanent dentition were included in the study. Total of 660 brackets were bonded by 1 operator with the use of a split-mouth design, and bracket failure rates were observed over 6 months. Bracket bonding time of each group was also evaluated. Bracket failure rates were evaluated by means of chi-square test. One-way analysis of variance (ANOVA) and Tukey honestly significant difference tests were used to evaluate the bonding time differences between groups. **Results:** The overall, APCF, and APCP bracket failure rates were 1.21%, 1.81%, and 1.51%, respectively. Chi-square test revealed significant differences ($P<0.01$) between groups in bracket failure rates. The upper left APCP group showed significantly ($P<0.05$) more failure than the other groups. One-way ANOVA test ($P<0.001$) showed statistically significant bonding time differences between groups. Bonding time of APCF brackets was significantly shorter than the bonding time of APCP brackets for the same quadrants. Chi-square test did not reveal significant differences ($P>0.05$) between groups according to adhesive remnant index scores. **Conclusions:** Compared with APCP brackets, APCF brackets can reduce the bonding time without increasing bracket failure rate. (Am J Orthod Dentofacial Orthop 2019;155:523-8)

The procedure of bonding orthodontic materials to the enamel surface consists of several steps and has significantly evolved since its introduction. Today, new materials are being used. These new orthodontic materials are reducing procedure times without reducing the bond strength of the brackets.[1,2] In 1992, a new-generation bracket system called Adhesive Precoated (APC) brackets was introduced.[3] Each bracket is individually packaged, and bracket bases are prepasted with optimal amount of adhesives.[4] According to Cooper et al,[5] APC offers some advantages over the conventional system, such as consistent quality and quantity of adhesive, easy debonding, reduced adhesive wastage, improved asepsis, and better control of inventory.

Features of APC brackets have been developed over the years. The APC Plus (APCP) system has provided better tolerance to humidity and has a fluoride-releasing adhesive. The color change property of the adhesive helps the practitioner when cleaning up the flash by providing a visual marker of adhesive placement.[6] Conventionally, the flash needs to be removed before polymerization of the adhesive to avoid the gingival irritation and plaque accumulation.[7] Studies aimed to reduce the excessive flash adhesive led to the development of different systems. The APC Flash-Free (APCF) appliance system, introduced in 2014, contains a low-viscosity resin applied to the bracket base, eliminating the need to remove excessive adhesive.[8] When pressed on the enamel surface, the transparent resin spreads out and conforms to the surface, creates a channeling border at the edges of the bracket,[2,8] and creates a seal to reduce microleakage.[9]

The APCF system offers some advantages, such as less chair time for bonding and a better concentration on bracket positioning. The manufacturer claims less than 2% bond failure and a reliable bond.[10,11] To date, few in vitro studies have evaluated the bonding time, shear bond strength, microleakage, adhesive remnant after debonding procedure, morphology of excessive adhesive, and bracket-adhesive-tooth interface of the APCF

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system.[2,4,8,9] However, in vitro studies are not able to imitate real oral environments.

Therefore, the aim of this first in vivo study was to compare bond failure rates and bonding time differences between APCF and APCP brackets.

MATERIAL AND METHODS

Ethical approval was obtained from the Regional Research Ethics Committee (approval number 2015/32), and the patients and parents gave their written consents for participation.

A total of 32 patients (mean age 17.2 ± 3.6 years) (26 female, mean age 17.1 ± 3.6 years, 6 male, mean age 17.3 ± 3.9 years) with complete permanent dentitions and Angle Class I or mild Class II malocclusions were selected. All of the patients required fixed orthodontic therapy without extractions. Patients with enamel defects, hypoplasia, or restorations on the buccal surfaces of the teeth were not included. The distribution of the brackets and characteristics of the patients included in the study are presented in Table I.

A total of 660 0.018-inch-slot APC Clarity Advanced ceramic brackets (330 APCP, 330 APCF; 3M Unitek) were bonded according to a split-mouth design. If a patient's bonding started with the upper right quadrant with the use of APCF brackets, another patient's bonding started from the upper left quadrant with the same bracket. Thus, failure rates and required chair time for APCP and APCF brackets were evaluated in all alternating quadrants. Eight groups were studied: URAPCF: APCF brackets bonded to the upper right quadrant; ULAPCP: APCP brackets bonded to the upper left quadrant; LLAPCF: APCF brackets bonded to the lower left quadrant; LRAPCP: APCP brackets bonded to the lower right quadrant; URAPCP: APCP brackets bonded to the upper right quadrant; ULAPCF: APCF brackets bonded to the upper left quadrant; LLAPCP: APCP brackets bonded to the lower left quadrant; and LRAPCF: APCF brackets bonded to the lower right quadrant.

Before bonding the brackets, buccal surfaces of the teeth were pumiced, washed with a spray, and dried with compressed air. All bonding procedures were carried out by the same clinician for standardization of the operator variable.

In all quadrants, teeth were etched with the use of 37% phosphoric acid etchant (3M ESPE, Saint Paul, Minn) for 30 seconds, then rinsed and dried. After the etching protocol, a thin uniform coat of primer (Transbond XT Primer; 3M Unitek) was applied. After the etching and primer application procedures, APCP and APCF brackets were immediately positioned on the enamel surface. Excessive adhesive around the APCP brackets was removed with the use of a scaler. However, excessive adhesive around the APCF brackets was not removed, in accordance with the manufacturer's instructions. Bonding time of each group was recorded with the use of a stopwatch. Because it was similar for both groups, the time used for etching, washing, drying, and primer application was not recorded. The stopwatch was started when taking the first bracket from the carrier box in the group and stopped when the polymerization of the last bracket was finished. The initial wire placed in all patients immediately after the bonding was 0.012-inch nickel-titanium (NiTi), followed by suitable combinations of round and rectangular NiTi and stainless steel wires as treatment proceeded. Only first-time failures were recorded, and adhesive remnant index (ARI) was used to visually determine the bond failure interface.[12] A new bracket was immediately bonded to the enamel and this new bracket was excluded from the study. Bond failures were monitored for 6 months.

The chi-square test was used to compare bond failure rates and ARI scores. Kruskal-Wallis test was used to evaluate bond failure rate differences between groups. One-way analysis of variance (ANOVA) and Tukey honestly significant difference (HSD) test were used to evaluate bonding time differences between groups. All statistical analyses were performed with the use of the SPSS 15 (SPSS, Chicago, Ill) at the 5% level of significance.

Table I. Patient characteristics

Group	*Number*	*%*	*Total*
Distribution of patients by gender			32
Male	6	18.7	
Female	26	81.3	
Number of brackets			660
APCP	330	50%	
APCF	330	50%	
Distribution of bracket types by gender			660
Female (APCP)	260	39.30%	520
Female (APCF)	260	39.30%	
Male (APCF)	70	10.60%	140
Male (APCP)	70	10.60%	
Distribution of bracket types by teeth			100%
Upper incisor (APCP)	66	10.00%	
Lower incisor (APCP)	66	10.00%	
Upper canine (APCP)	33	5.00%	
Lower canine (APCP)	33	5.00%	
Upper premolar (APCP)	66	10.00%	
Lower premolar (APCP)	66	10.00%	
Upper incisor (APCF)	66	10.00%	
Lower incisor (APCF)	66	10.00%	
Upper canine (APCF)	33	5.00%	
Lower canine (APCF)	33	5.00%	
Upper premolar (APCF)	66	10.00%	
Lower premolar (APCF)	66	10.00%	

RESULTS

The descriptive statistics and results of ANOVA test comparing the bonding time of orthodontic brackets are presented in Table II. The shortest and longest bonding time was obtained from the LRAPCF (4.91 ± 0.59 min) and ULAPCP groups (6.36 ± 0.45 min), respectively. ANOVA showed significant (F = 17.167; *P* <0.001) bonding time differences between groups. According to the Tukey HSD test (Table III) results, bonding time of APCF brackets was significantly shorter than that of APCP brackets in the same quadrants. No significant bonding time differences were found between the APCF groups. There were no significant bonding time differences between the APCP groups except between LLAPCP and ULAPCP (*P* <0.05).

The overall bond failure rate obtained from the study was 1.51%. A total of 10 bond failures were recorded in both groups in the total population of 660 brackets during the 6-months period: 4 in APCF brackets (1.21%) and 6 in APCP brackets (1.81%; Table IV). Nine maxillary brackets and 1 mandibular bracket failed: 4 of the brackets (3 APCP, 1 APCF) failed within the first 3 months, and the other 6 (4 APCP, 2 APCF) within the second 3 months. Only 1 canine bracket, in the ULAPCF group, failed. All of the other failed brackets were premolar brackets. The chi-square test (Table IV) showed significant differences in terms of bond failure rate among the groups (χ^2 = 24.783; *P* = 0.0008). The ULAPCP group showed significantly higher bracket failure rate (6 brackets) than other groups according to the Kruskal-Wallis test (*P* <0.05; Table V).

Results of the chi-square analysis of the ARI scores are presented in Table VI. No significant differences were found among the groups (χ^2 = 1.667; *P* = 0.435).

DISCUSSION

To date, although a limited number of in vitro studies[4,8] were found, clinical bond failure rates of APCF brackets had not been evaluated. Therefore, in the present in vivo study, clinical bond failures and bonding times of APCP and APCF brackets were evaluated with the use of a split-mouth design. Because the split-mouth design allows the patients to become their own control group, it was the best way to compare the clinical performance of orthodontic materials. However, for example, bonding an APCF bracket to the upper left quadrant in all patients would prevent evaluating the clinical performance of the same bracket in the upper right quadrant. Therefore, 8 groups were studied to evaluate both the clinical performance of each bracket and the bonding performance of the clinician in all of the quadrants.

Table II. Descriptive statistics and ANOVA test results

		Bonding time (min)					ANOVA	
Group	*n*	*Mean*	*SD*	*SE*	*Min*	*Max*	*F*	*P*
URAPCF	16	5.13	0.48	0.12	4.22	6.37	17.167	<.001
ULAPCP	16	6.36	0.45	0.11	5.51	7.20		
LLAPCF	16	4.84	0.53	0.13	4.20	6.07		
LRAPCP	16	5.86	0.63	0.15	4.51	7.10		
URAPCP	17	6.23	0.53	0.12	5.47	7.24		
ULAPCF	17	5.03	0.55	0.13	4.10	6.20		
LLAPCP	17	5.68	0.84	0.20	4.04	7.05		
LRAPCF	17	4.91	0.59	0.14	4.26	6.28		

Group abbreviations as in Table I.

Some studies[13,14] reported that most bonding failures occurred within the first 3-6 months. Sunna and Rock[15] and Kula et al[16] evaluated bonding failures for 1 year and reported that most failures occurred within the first 90 days or 6 months, respectively. O'Brien et al[17] reported that the possible causes of bracket failures in the first 6 months may be due to factors such as failures in the bracket adhesive interface at the initial stages of treatment, patient inexperience, and extreme occlusal forces.

Results of the present study showed significant differences in bonding times between groups (*P* <0.001). Bonding time of APCF brackets was significantly shorter than that of APCP brackets for the same quadrants. Although bonding time depends on different factors (operator experience, patient's compliance, bonding materials, etc), this was an expected result owing to the elimination of the excessive adhesive removal procedure for APCF brackets. These results indicate that an average of 4.22 minutes can be saved per patient with the use of APCF brackets. This can be considered an advantage because of increased patient comfort and reduced contamination risk. Lee and Kanavakis[4] used extracted human maxillary premolars and reported 30.7, 39.2, and 41.8 seconds mean bonding times for APCF, conventional, and APCP brackets, respectively. They reported that the bonding time could be 2.8-3.7 minutes shorter with the use of APCF brackets. Foersch et al[8] evaluated bonding times of APCP and APCF brackets in the mandible and maxilla with the use of typodonts and reported significant differences, with time-saving effects of 64.25% in the mandible and 42.3% in the maxilla with the use of APCF brackets. Results of the present study are similar to those studies of Lee and Kanavakis[4] and Foersch et al,[8] because bonding time for APCF brackets in both studies was significantly shorter than for APCP brackets. However, it should be kept in mind that in vivo studies are not directly comparable with in vitro studies.

Table III. Multiple comparison results of bonding times (P values)

Group	URAPCF	ULAPCP	LLAPCF	LRAPCP	URAPCP	ULAPCF	LLAPCP	LRAPCF
URAPCF		0.000*	0.864 (ns)	0.017†	0.000*	1.000 (ns)	0.145 (ns)	0.958 (ns)
ULAPCP			0.000*	0.257 (ns)	0.999 (ns)	0.000*	0.029†	0.000*
LLAPCF				0.000*	0.000*	0.984 (ns)	0.002‡	1.000 (ns)
LRAPCP					0.611 (ns)	0.003‡	0.990 (ns)	0.000*
URAPCP						0.000*	0.131 (ns)	0.000*
ULAPCF							0.037†	0.999 (ns)
LLAPCP								0.005‡

*P <0.001; †P <0.05; ‡P <0.01.

Table IV. Chi-square test results and distribution of falling brackets by groups and teeth

	Failure Rate				
	n			%	
Group	Incisor	Premolar	Total		Chi-square
URAPCF	0	1	1		24.783 P = 0.0008
ULAPCP	0	6	6		
LLAPCF	0	0	0		
LRAPCP	0	0	0		
URAPCP	0	0	0		
ULAPCF	1	1	2		
LLAPCP	0	0	0		
LRAPCF	0	1	1		
APCF	1	3	4	1.21	
APCP	0	6	6	1.81	
Total	10			1.51	

Group abbreviations as in Table I.

Table V. Results of the Kruskal-Wallis test

Group	n	Mean rank	Multiple comparisons (P <0.05)	Kruskal-Wallis
URAPCF (1)	80	329.63	2	1.1077 P = 0.0008
ULAPCP (2)	80	350.25	1, 3, 4, 5, 6, 7, 8	
LLAPCF (3)	80	325.5	2	
LRAPCP (4)	80	325.5	2	
URAPCP (5)	85	325.5	2	
ULAPCF (6)	85	333.26	2	
LLAPCP (7)	85	325.5	2	
LRAPCF (8)	85	329.38	2	

Group abbreviations as in Table I.

At the end of the 6-month observation period, bond failure rates of the APCF and APCP groups were 1.21% and 1.81%, respectively. These results indicated that the bond failure rate of both were below suggested limits and therefore clinically acceptable.[18] In the literature, in vivo studies about different APC and conventional brackets presented variable results. Ash and Hay[13] reported that APC brackets had less bond failure than

Table VI. Frequency distribution and result of the chi-square analysis of adhesive remnant index (ARI)

	ARI score					
Bracket type	0	1	2	3	Chi-square	
APCP	1	4	1	0	1.667	P = 0.435
APCF	2	2	0	0		

ARI scores: 0, no composite left on enamel surface; 1, less than half of composite left; 2, more than half of composite left; and 3, all of composite left.

conventional brackets, whereas some studies showed no difference between them.[14,15,19] Verstrynge et al[20] compared APC and conventional brackets with the use of a split-mouth system and reported no bond failure of APC brackets. Unfortunately, we can not compare our results with other studies, because no study evaluated the clinical bond failure rate of APCF brackets. However the manufacturer claimed <2% bond failure rate for APCF brackets, which is similar to our results.[10,11]

In the present study, the ULAPCP group showed significantly (P <0.05) more bracket failure rate than the other groups. Sunna and Rock[15] reported more bond failure in the left side than the right side and they thought it could be related to a right-handed operator, which can allow better moisture control and vision in the right side. Our operator was right-handed. In addition, adhesive composition differences between APCP and APCF brackets might be affected by operator-related bonding conditions. APCF adhesive is softer than the APCP adhesive, making it easier for the orthodontist to place, press, and adjust the bracket on the enamel surface during bonding. More viscous adhesive in the base of APCP brackets complicates adjustment of the correct bracket position, therefore both the bonding time and contamination risk increases. Indeed, in the context of oral pH–related conditions, chewing forces, temperature variations, contamination risk, and diet differences between patients, it is difficult to determine the causes of bonding failure of brackets.[21-24] After the observation period, only 1 incisor bracket failed. All of the other failures were for premolar brackets, similarly to the results of other clinical studies.[15,17,23] The greater extent of aprismatic enamel and increased masticatory loads in posterior teeth compared with anterior teeth might be other reasons for increased premolar bracket failure rates.[16,25] On the other hand, bonding in the premolar region is more difficult and time consuming owing to poor visualization and access, which may be considered as another cause of increased bracket failure.

Foersch et al[8] reported average ARI scores of 2 and 2.8 from the APCF and APCP brackets, respectively. According to Lee and Kanavakis,[4] mean ARI scores were 3.6 and 1.3, respectively, for APCF and APCP brackets. In the present study, mean ARI scores for APCF and APCP brackets were 1.16 and 2, respectively, and no significant difference ($P > 0.05$) was found between groups. Differences between the ARI scores may be attributed to the differences between in vivo and in vitro study designs. The ARI scores are important in assessing the failure type and bonding time of a failed bracket. Less adhesive left on the enamel surface requires less removal time. However, it might cause enamel fracture while debonding the brackets. Clinically, it is the authors' experience that removing the resin adhesive remaining on the enamel surface of a failed APCF bracket is easier than removing the adhesive remaining from a failed APCP bracket, which may be attributed to the adhesive composition differences between the 2 types. However, further studies are needed to prove this hypothesis.

CONCLUSION

Based on the results of the present clinical study, the following conclusions can be drawn:

1. The failure rates of APCP and APCF brackets are clinically acceptable.
2. Bonding an APCF bracket is easier and faster than an APCP bracket, and it is possible to save 4.22 minutes for a full mouth bonding.
3. APCF brackets can be effectively used in clinical practice without increasing the failure rates.
4. To evaluate the long-term effects of flash adhesive around APCF brackets on enamel surface and microbial flora, larger sample-sized long-term clinical microbiologic studies are needed.

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