Effects of Flash-Free Bonding Technique on Plaque Retention and Development of White Spot Lesions: A Randomized Clinical Trial

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ABSTRACT
Objective: To compare the effects of use of Flash-Free (FF) and conventional bonding techniques of brackets on plaque retention and development of white spot lesions (WSL) in-vivo.

Materials and Methods: Maxillary incisors of 20 randomly selected patients were used. Plaque accumulated around the brackets were collected 2 and 6 weeks after bonding and bacterial load was determined by ATP-driven bioluminescence. Labial surfaces of the maxillary incisors were scanned using Canary System™ to evaluate enamel demineralization. Number of spontaneously debonded brackets were counted during the first 6 months of treatment.

Results: No significant differences were found in plaque formation and retention between brackets bonded using FF and conventional adhesive. No significant difference in enamel demineralization was observed around the brackets bonded using FF technique and conventional technique during the same study period. Demineralization of enamel surfaces was detected in the mesiofacial and distofacial surfaces of the maxillary incisors. Failure rates of 5.26% and 0% were observed for brackets bonded using FF and conventional technique during the first 6 months, respectively.

Conclusion: WSL were observed in the mesiofacial and distofacial surfaces of maxillary incisors. Use of flash-free brackets did not minimize plaque retention or enamel demineralization of maxillary incisors during the first 6 months of orthodontic treatment. FF brackets failed more often than conventional brackets during the first 6 months of treatment.

INTRODUCTION

One of the side effects of orthodontic treatment with fixed appliances is development of white spot lesions (WSL) around orthodontic brackets. WSL could develop as early as one month after placement of orthodontic appliances. Prevalence of WSL is variable and is reported to be between 2% to 96% depending on the definition of WSL, method of diagnosis, and study design, with maxillary incisors and first molars having the highest prevalence of WSL.

WSL create esthetic problems after completion of orthodontic treatment and areas of decalcification may persist for many years, post-treatment. A number of treatment options to address WSLs have been proposed, but these treatment options may place a financial burden on patients with lengthy treatment time and/or less than ideal outcomes; therefore, prevention of WSLs is of great interest to clinicians.

WSL develop as a result of prolonged retention of dental plaque around fixed orthodontic appliances. Presence of elastomerics, metals, and adhesive resin margins increase plaque accumulation on appliances. Bracket type and method of ligation have been shown to influence the plaque retention. Poor oral hygiene is a risk factor for development of WSL during orthodontic treatment.

During bonding of an orthodontic bracket, certain amount of adhesive flash (AF) is expressed alongside the boundary between the bracket and surface enamel. If this AF is not removed adequately during the bonding procedure before polymerization, this rough surfaces could potentially act as a plaque retentive factor and promote development of WSL. Even though, complete removal of AF during orthodontic bonding is desirable, clinicians frequently leave AF behind after bracket bonding.

The amount of AF remains after bonding could be reduced either by minimizing amount of flash produced during the bonding procedure by modifying the adhesive properties/bonding technique or incorporating a visual marker into the adhesive to facilitate AF clean-up. Addition of a coloring agent to orthodontic adhesive to assist visualization of the AF did not result in the reduction the amount of AF around the brackets. Purpose of a recently introduced flash-free adhesive coated appliance system (APC™ Flash-Free Adhesive Coated Appliance System, 3M Unitek, Monrovia, CA) is to eliminate the need for AF clean-up during bonding procedure. A recent in vitro study demonstrated a significantly less AF around the brackets bonded using the flash-free system compared to that of conventional adhesive. Furthermore, the minimal AF produced by the flash-free system had a smooth surface at the microscopic level.

The purpose of the current study is to compare the effects of the use of flash-free(FF) and conventional adhesives in orthodontic bonding on plaque retention and WSL development in-vivo.

MATERIALS AND METHODS

INTRODUCTION

Institutional review board approval was obtained. Subjects were randomly recruited from a pool of patients needing orthodontic treatment. The inclusion criteria were as follows: minimum age of 10 years old; fully erupted maxillary central and lateral incisors, and requiring at least 6 months of orthodontic treatment with fixed appliances. The criteria for exclusion were as follows: patients with peg maxillary lateral incisors; patients who are pregnant, currently using or have used antibiotics, corticosteroids or mouth rinses in the past 3 months; current smokers or those who have smoked in the past 3 months, and discolored, restored, presence of caries or WSLs on maxillary central and lateral incisors. Patients were randomly assigned to receive FF brackets on either the maxillary right central and lateral incisors or maxillary left central and lateral incisors. The opposing maxillary left or right central and lateral incisors along with all the remaining teeth received conventional orthodontic brackets (Clarity™ Advanced, 3M Unitek, Monrovia, CA) with conventional adhesives (Pad Lock™ no-fluoride, Reliance Orthodontic Products, Inc., Itasca, IL). All patients were provided with the same oral hygiene kit, which included an electric tooth

brush (Oral B Pro 5000 Smartseries, Oral B, Cincinnati, OH) along with a large tube of fluoridated tooth paste (Crest Prohealth Advanced, Crest Company, Cincinnati, OH) and dental floss (SuperFloss, Oral B, Cincinnati, OH). Patients were given standard oral hygiene instructions which included brushing at least twice a day for 4 minutes and flossing at least once a day. All patients were instructed not to use mouth rinse for the first 6 weeks of treatment. The patient and guardian were also instructed that the patient must refrain from brushing on the day of and also refrain from eating or drinking one hour before the patient's research appointments. Figure 1 illustrates the timeline of the study. The patients were recalled for a total of 3 appointments as described below to complete the data collection.

Figure 1: Experimental Timeline. Patients were recalled at three time points. Plaque samples were collected 2 weeks ± 2 days (T1) and 6 weeks ± 2 days (T2) after bonding. Canary scans to determine enamel decalcification were performed at T1 and 6 months ± 2 days (T3).

First Appointment (T1)
Patients presented 2 weeks ± 2 days after bonding for the first plaque collection and the first Canary scan.
Second Appointment (T2)
Patients presented 6 weeks ± 2 days after bonding for the second plaque collection.
Third Appointment (T3)
Patients presented 6 months ± 2 days after bonding for the second Canary scan.

Plaque Analysis:
At time points T1 and T2, main arch wire was removed and plaque was collected from around the orthodontic brackets of the maxillary incisors. Plaque collection for each tooth was standardized by a 4-pass technique sweep around the bracket base (Figure 2). The 4-pass technique was repeated 3 times for each tooth, and the plaque from each tooth was placed in separate sterilized 1.5 ml centrifuge tubes (VWR International, Radnor, PA) containing 0.5ml of Phosphate Buffered Saline (PBS). Tubes containing plaque were then stored at -800C until the day of analysis.

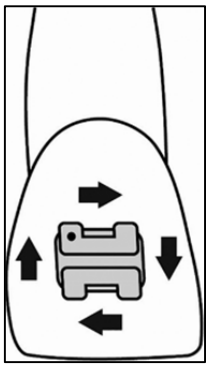


Figure 2: Plaque Collection. 4-Point Pass Technique. Initial pass starts at the incisal interface of the bracket and the tooth, followed by mesial, gingival, and finally distal surfaces. This technique was repeated 3 times for each tooth.

Plaque samples were analyzed using BacTiter-Glo™ Microbial Cell Viability Assay Kit (Promega, Madison, WI), and ATP-driven bioluminescence was measured by TD-20/20 lumionometer (Tuner Biosystems, Sunnyvale, CA). Relative light units (RLU) were calibrated using a standard curve of ATP. For each time point plaque sample was analyzed 3

times and the mean RLU value was calculated. RLU is directly related to the number of viable microbial cells in the plaque sample.

Quantitative Evaluation of Enamel Demineralization

At time points T1 and T3, maxillary incisors were scanned using the Canary System™ (Quantum Dental Technologies Inc., Toronto, Canada) to compare the extent of decalcification and development of WSLs between two time points. Intra-oral images of teeth were taken and on each tooth 8 specific segments of the facial surface, around the bracket were scanned (figure 3). Each segment of the facial surface of each tooth was scanned 3 times and mean value was calculated. Mean value obtained for each segment of each tooth was compared between T1 and T2.

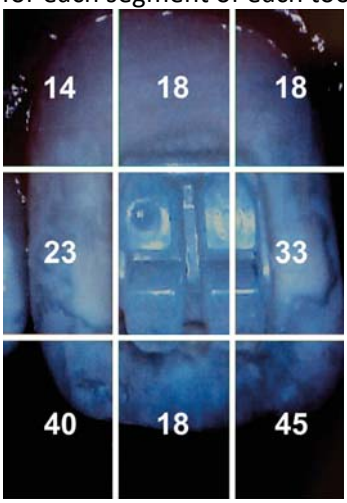


Figure 3: The Canary Scan. The Canary System™ divides the photograph of the labial surface of an incisor tooth into 9 equal segments. Each of the 8 segments around the orthodontic bracket was scanned 3 times and mean value was calculated.

Bracket Bond Failure

FF and conventional brackets on the maxillary incisors were monitored for 6 months after bracket placement to evaluate the bond failure. No other brackets/teeth were included in this evaluation.

Error of Method

To evaluate the reliability of the Canary scan measurements, two independent examiners scanned five randomly selected patients at T1 and T3. Scan measurements were used to calculate the inter-examiner reliability.

Statistical Analysis

Paired t-test was performed compare of RLU differences between FF and conventional brackets bonded to central and lateral incisors at T1 and T2. Paired t-test was performed to analyze the differences in Canary scan measurements around brackets bonded using FF and conventional adhesives at T1 and T3. The significance level was set at $p < 0.05$. The Pearson correlation coefficient was derived to establish the reliability of the Canary scan measurements. Spontaneous bond failure of FF brackets and conventional brackets were reported as a percentage.

RESULTS

Twenty-two subjects were recruited for this prospective clinical study. Two of the 22 patients were excluded from the study since they required treatment with functional appliance prior to bonding of orthodontic brackets. A total of 20 patients participated in this study. Table 1 describes the patients in this study, including randomized allocation of brackets to the maxillary incisors. Subjects were randomly assigned to received FF adhesive brackets on the maxillary left or right incisors. Incisors on the contra-lateral side were bonded using conventional adhesives.

M, male; F, female; N/A, not applicable; UR2, maxillary right lateral incisor; UR1, maxillary right central incisor; UL2, maxillary left lateral incisor; UL1, maxillary left central incisor; C, conventional technique; FF, flash-free technique.

Twenty patients completed the plaque collection at T1 and T2. Twenty patients completed the Canary scan at T1. Since a subject relocated out of state,

Table 1. Patient demographics and placement of brackets on selected teeth

Patient #	Sex	Age (y)	Orthodontic Treatment	UR 2 Bracket Type	UR 1 Bracket Type	UL 2 Bracket Type	UL 1 Bracket Type	Note
1	M	14.8	Full	C	C	FF	FF	N/A
2	M	25.6	Full	FF	FF	C	C	N/A
3	M	14.5	Full	C	C	FF	FF	N/A
4	F	12.1	Full	FF	FF	C	C	N/A
5	F	24.9	Full	C	C	FF	FF	N/A
6	F	16.5	Full	FF	FF	C	C	N/A
7	F	38.0	Full	C	C	FF	FF	N/A
8	F	15.1	Full	FF	FF	C	C	N/A
9	F	18.0	Full	C	C	FF	FF	UL 2 Bracket Failed
10	M	13.8	Full	FF	FF	C	C	N/A
11	M	11.4	Full	C	C	FF	FF	N/A
12	F	35.8	Full	FF	FF	C	C	Moved Prior to Canary Scan 2
13	F	13.1	Full	C	C	FF	FF	N/A
14	F	12.5	Full	FF	FF	C	C	N/A
15	F	26.0	Full	C	C	FF	FF	N/A
16	M	15.1	Full	FF	FF	C	C	N/A
17	F	13.1	Full	C	C	FF	FF	N/A
18	F	10.4	Full	FF	FF	C	C	N/A
19	M	12.1	Full	FF	FF	C	C	UR 2 Bracket Failed
20	M	11.6	Full	C	C	FF	FF	N/A

19 patients completed the scans at T3. Two patients had bracket failures on tooth # 7 and tooth #10 prior to scan at T2. Therefore, tooth # 10 and tooth # 7 of these two patients were not scanned.

Plaque samples were analyzed for bacterial ATP and the mean of the 3 RLU measurements were recorded for each tooth at T1 and T2. Differences in the mean RLU between the FF and conventional brackets were calculated for T1 (Table 2) and T2 (Table 3). There were no significant differences in plaque retention between conventional and FF brackets bonded to either maxillary central or lateral incisors at T1 and T2 (Figure 4 and Table 4).

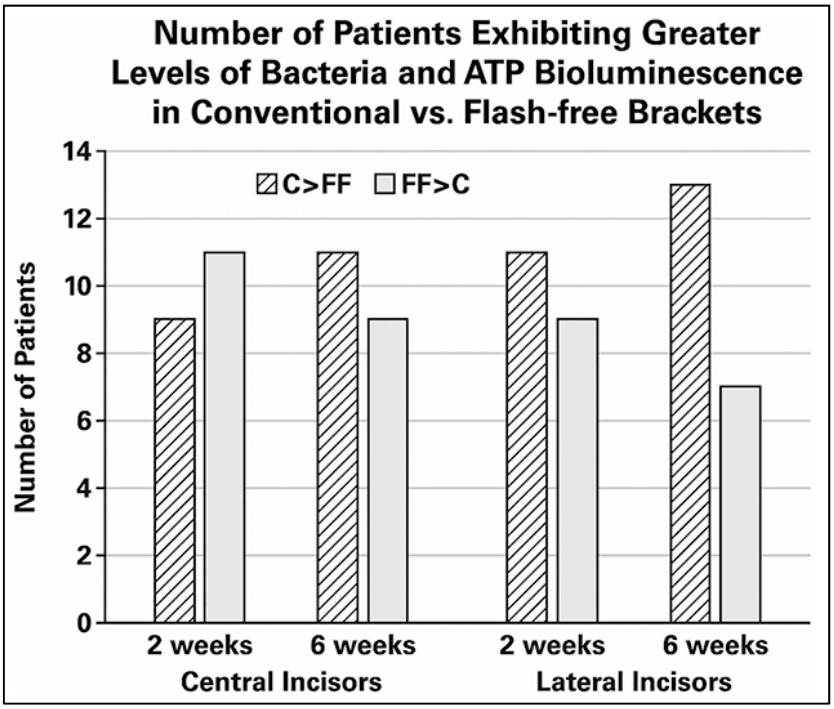


Figure 4: Comparison of ATP-bioluminescence of plaque from tooth surfaces surrounding conventional or flash-free brackets. Histograms depicts numbers of patients in whom RLU (relative light unit) values are higher on tooth surfaces surrounding conventional (C) compared with flash-free (FF) brackets(C>FF) and the reverse comparison (FF>C).

Plaque samples were collected from C1 (maxillary central incisor bonded with conventional adhesive), C2 (maxillary lateral incisor bonded with conventional adhesive), FF1 (maxillary central incisor with APC™ Flash-Free adhesive), and FF2 (maxillary lateral incisor with APC™ Flash-Free adhesive) at T1 (2 weeks ± 2 days after bonding). ATP-driven bioluminescence was determined 3 times for each sample and mean RLU (Relative light units) was calculated for each tooth. The difference in RLU was obtained by subtracting RLUs of Flash-Free bracket from that of conventional. RLU is directly related to the number of viable microbial cells in the plaque sample.

Table 2. Differences in plaque accumulation around brackets at T1							
Time	Patient Number	C1	C2	FF1	FF2	C1-FF1	C2-FF2
T1	1	624.8	1465	744.1	776.9	-119.3	688.1
T1	2	755.1	727.5	624.1	1307	131	-579.5
T1	3	103.9	180.2	134.2	95.19	-30.3	85.01
T1	4	96.82	148.6	210.7	235.8	-113.88	-87.2
T1	5	34.99	63.96	119.5	150.7	-84.51	-86.74
T1	6	106.6	28.25	40.65	46.65	65.95	-18.4
T1	7	44.65	98.96	59.99	49.28	-15.34	49.68
T1	8	427.7	618.2	205.2	258.2	222.5	360
T1	9	470.1	922.8	624.4	237.6	-154.3	685.2
T1	10	904.8	1218	117.1	1564	787.7	-346
T1	11	384	246.3	492.6	472.7	-108.6	-226.4
T1	12	198.2	488.9	383.3	578	-185.1	-89.1
T1	13	403.1	512.8	314.8	501.1	88.3	11.7
T1	14	112.6	334.8	408.3	203.6	-295.7	131.2
T1	15	36.63	95.23	45.58	39.81	-8.95	55.42
T1	16	65.35	152.7	58.32	45.19	7.03	107.51
T1	17	688.9	554.2	381.8	645.3	307.1	-91.1
T1	18	4.757	35.83	5.801	35.66	-1.044	0.17
T1	19	238.3	523	62.52	800.7	175.78	-277.7
T1	20	225.7	360.8	110.8	162.3	114.9	198.5

Table 3. Differences in plaque accumulation around brackets at T2							
Time	Patient Number	C1	C2	FF1	FF2	C1-FF1	C2-FF2
T2	1	1565	2897	2298	4031	-733	-1134
T2	2	1060	1185	1038	2200	22	-1015
T2	3	207.4	1370	134.4	1029	73	341
T2	4	598	573.7	319	812.9	279	-239.2
T2	5	189.8	397.6	278.2	358.6	-88.4	39
T2	6	1706	2200	1941	4425	-235	-2225
T2	7	160.3	1590	408.3	2049	-248	-459
T2	8	2200	2588	1725	1912	475	676
T2	9	1663	2422	2421	750.9	-758	1671.1
T2	10	2366	5398	1285	4556	1081	842
T2	11	1011	2667	789.2	1440	221.8	1227
T2	12	623.3	1072	557.2	1015	66.1	57
T2	13	2788	3870	4086	3414	-1298	456
T2	14	763.5	1260	442.1	821.8	321.4	438.2
T2	15	165.5	500.9	180	149.3	-14.5	351.6
T2	16	943.7	2022	2013	2707	-1069.3	-685
T2	17	400.8	580.9	647.1	991.3	-246.3	-410.4
T2	18	389.9	1873	195.6	1271	194.3	602
T2	19	38.28	377.9	32.52	231.4	5.76	146.5
T2	20	160.6	353.6	121.5	178.4	39.1	175.2

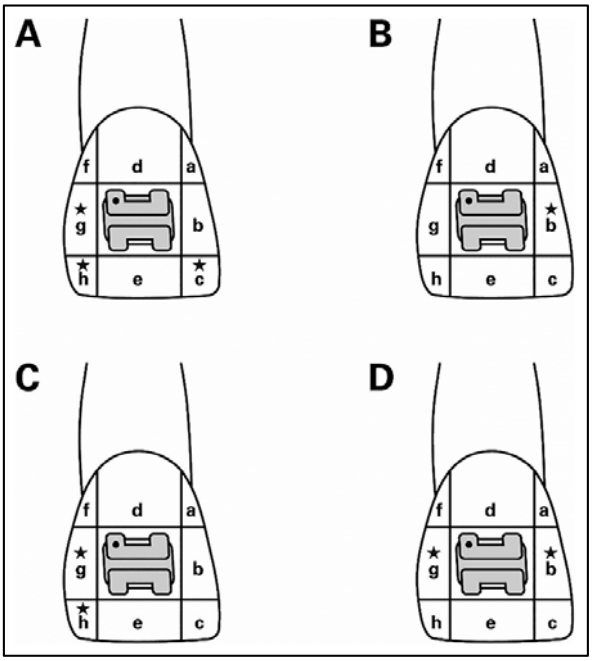
Table 4. Total bacteria (as measured by ATP bioluminescence) on tooth surfaces with conventional and Flash-free brackets.							
		plaque T1				Plaque T2	
	Mean Difference (C-FF)	SD	P		Mean Difference (C-FF)	SD	P
Maxillary Central Incisors	39.16	229.4	0.4546		-95.60	573.7	0.4414
Maxillary Lateral Incisors	28.52	303.7	0.6793		42.75	878.4	0.8300

Plaque samples were collected from C1 (maxillary central incisor bonded with conventional adhesive), C2 (maxillary lateral incisor bonded with conventional adhesive), FF1 (maxillary central incisor with APC™ Flash-Free adhesive), and FF2 (maxillary lateral incisor with APC™ Flash-Free adhesive) at T1 (6 weeks ± 2 days after bonding). ATP-driven bioluminescence was determined 3 times for each sample and mean RLU (Relative light units) was calculated for each tooth. The difference in RLU was obtained by subtracting RLUs of Flash-Free bracket from that of conventional. RLU is directly related to the number of viable microbial cells in the plaque sample.

Mean relative light unit (RLU) values of plaque from tooth surfaces surrounding brackets bonded using flash-free technique(FF) was subtracted from that of brackets bonded using conventional adhesive (C). Paired t-test was performed to calculate the statistical significance at T1 and T2 ($p<0.05$).

Using the Canary System™, each of the 8 segments of maxillary incisor surface was scanned 3 times at T1 and T3. Mean of the 3 scans for each segment was calculated and compared between T1 and T3. There were no significant differences in enamel decalcification around conventional or FF brackets on either maxillary central or lateral incisors. However, the process of demineralization did take place in the sample during the study period (Figure 5).

Five randomly selected patients were scanned by two operators at T1 and T3. Pearson correlation coefficients were calculated to establish inter-examiner reliability of scans. A correlation coefficient of 0.8924 was obtained for combined T1 and T3 scans. A total of 19 patients were included in the bond failure portion of the study with 38 conventional and 38 FF brackets. Two FF brackets bonded to lateral incisors in two different patients failed within the first 6 months of treatment. Failure rate for the FF brackets is 5.26% in the 6-month study period. None of the conventional brackets failed during the study.



Effects of Flash

Figure 5: Development of white spot lesions in maxillary incisors between T1 and T3. Star indicates a statistically significant increase in enamel decalcification between time points as measured by Canary scan. A. Central incisor with conventional bracket (C1) B. Lateral incisor with conventional bracket (C2) C. Central Incisor with APC™ Flash-Free Bracket (FF1) D. Lateral Incisor with APC™ Flash-Free Bracket (FF2)

DISCUSSION

The ability to minimize plaque accumulation and prevent WSL development around fixed appliances is of great interest to orthodontists. In this prospective, randomized clinical study, plaque accumulation and WSL development around the brackets bonded with conventional adhesives were compared to that of brackets bonded using FF adhesives. Hitherto, no clinical study has investigated the effect of minimizing adhesive flash around orthodontic brackets on plaque retention and enamel demineralization.

The amount of plaque accumulated around the brackets bonded using conventional or FF technique was measured indirectly by determining the amount of bacterial ATP activity presence in the plaque.

Plaque samples were collected at two different time points. Results demonstrated that there were no significant differences in the amount of plaque accumulated around brackets bonded with conventional adhesives compared to that of FF adhesives at both time points.

Development of WSL is accelerated during the first 6 months of orthodontic treatment and continued to increase at a slower pace approaching 12 months of treatment [1-6]. In the present study, enamel demineralization was determined using Canary scans at two time points which were 6 months apart. There was no significant difference between conventional and FF brackets in the initiation and development of WSL during the first 6 months of treatment. Prolonged accumulation of plaque around orthodontic brackets can lead to development of WSLs [1, 2, 4, 6].

In the present study, the lack of significant difference in WSL development is consistent with the lack of significant difference in plaque accumulation between bracket groups.

In addition to adhesive flash, microleakage underneath orthodontic brackets play a role in the development of WSL[6-17]. In laboratory settings, there was no significant difference between the extent of microleakage under the brackets bonded using FF or conventional adhesive technique [18, 19]. This finding may explain the lack of difference between FF and conventional techniques in the amount of plaque accumulation and WSL development , even though there was a significant difference in the adhesive flash around the brackets[15]. In addition, oral hygiene, diet, bracket shape or type of ligation play a role in plaque accumulation and development of WSL [8-12].

In this study, operators who placed the brackets knew that these patients were participants of a research project. The operators were given as much time as they needed for bonding. This combined with the ease of access to the maxillary anterior teeth may have led to adequate cleaning of adhesive flash around the brackets bonded using conventional technique, and therefore lack of significant difference between conventional versus FF adhesives in this study. In addition, the operators who bonded the brackets in this study observed that the FF brackets would slide on the enamel surface soon after the placement but prior to light curing of the adhesive. This could be due to the fact that the FF adhesive is less viscous than the conventional adhesive used in this study. The movement of the FF brackets on the enamel surface before curing may lead to accumulation of adhesive around the edges of the FF bracket and act as adhesive flash. This could be another reason for the lack of difference in the plaque retention and WSL development. In this study, no effort was made to remove flash around FF brackets.

Inter-examiner reliability for Canary scans were determined for T1 and T3. Pearson correlation coefficient calculated for T3 was better than T1. This could be due to better accuracy and improved scanning skills of the operators.

Despite the lack of significant differences in WSL development between brackets with conventional versus FF adhesives, enamel demineralization process did happen in the study sample. It was found that multiple segments of the maxillary incisors did exhibit significant increase in Canary scan values which indicate demineralization of enamel. In the present study, mesiofacial and distofacial surfaces of the maxillary incisors are more frequently affected compared to other areas. The mesial and distal surfaces of a tooth are more challenging for plaque removal due to the presence of a continuous arch wire and common use of elastic chains.

Findings of the in-vitro studies which compared the shear bond strength of the brackets bonded with FF and conventional adhesives are equivocal [20, 21]. Failure rate of brackets bonded with FF adhesives has not been studied in-vivo, previously. In the present study, 5.26% of FF brackets failed within the first 6 months of treatment, whereas 0% of conventional brackets failed during the same period of time. The two failed FF brackets were both on maxillary lateral incisors in two different patients.

CONCLUSION

Brackets bonded with conventional and FF adhesives were compared for plaque accumulation, WSL development and failure rate during the first 6 months of orthodontic treatment. There were no significant differences in plaque accumulation or WSL development between brackets with conventional adhesives and brackets with FF adhesives. The process of demineralization does take place during the first 6 months of orthodontic treatment with the mesiofacial and distofacial segments of the maxillary incisors being more commonly affected. FF adhesive demonstrated a 5.26% failure rate, whereas conventional adhesive had a 0% failure rate. Overall, minimizing adhesive flash around the brackets with the use of FF adhesive did not reduce plaque accumulation and enamel demineralization.

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