Type of Award: Research Aid Award

Name of Principal Investigator: Nicole Gange

Institution: Case Western Reserve University

Title of Project: Bonding Brackets and Attachments to Non-Enamel Substrates

Period of AAOF Support: 7/1/18-6/30/19

Amount of Funding: $4,862.00

ABSTRACT

Objective: To examine the shear bond strength of brackets and attachments bonded to non-enamel substrates. **Materials and Methods:** Twenty bovine molars, eighty porcelain disks, and sixty zirconia disks were mounted in acrylic and separated into groups according to surface preparation. The methods of surface preparation were pumice, diamond-roughened, micro-etched, and HF acid etched. Each group was split into two and bonded with brackets and attachments. Shear bonded strength was tested and recorded. **Results:** In both the porcelain bracket and attachment groups, there was no significant difference found between the methods of surface preparation compared to each other. There was a significant difference between the bracket enamel control and the porcelain bracket HF acid, diamond roughening, and pumicing groups. When comparing the methods of surface preparation of zirconia to the enamel control, there was a significant difference found between both the attachments and brackets compared with enamel, respectively. In the attachment group, there was a statistically significant difference between the pumice prepared group compared to the diamond roughened, sandblasted, and enamel control groups. In the bracket group, there was a statistically significant difference between both the diamond roughened and pumiced groups compared to the enamel control. **Conclusions:** When bonding to porcelain, any method of surface preparation will deliver adequate shear bond strength values. When bonding to zirconia, the clinician must either remove the glaze completely or treat all crowns like they are porcelain and apply a silane conditioner before their universal primer.

Keywords: shear bond strength, brackets, attachments, porcelain, zirconia

Results

The samples were first compared within the groups and then compared to the enamel control. In both the porcelain bracket and attachment groups, there was no significant difference found between the methods of surface preparation compared to each other. When comparing the methods of surface preparation of porcelain to the enamel control, there was only a significant difference in the bracket groups. There was a significant difference between the enamel control and HF acid, diamond roughening, and pumicing. There was not a significant difference between the bracket groups prepared with sandblasting and the enamel control. In both the zirconia bracket and attachment groups, there was a significant difference found in all methods of surface preparation. When comparing the methods of surface preparation of zirconia to the enamel control, there was a significant difference found between both the attachments and brackets compared with enamel, respectively. In the attachment group, there was a statistically significant difference between the pumice prepared group compared to the diamond roughened, sandblasted, and enamel control groups. There was not a statistically significant difference found between the diamond roughened, sandblasted, or enamel controls. In the bracket group, there was a statistically significant difference between both the diamond roughened and pumiced groups compared to the enamel control. There was not a statistically significant difference between the sandblasted and enamel control groups. The raw data is shown in table I and the ANOVA tests are shown in table II-V.

Tables

Table I. Raw data of all samples

Shear Bond Strength and ARI Values								
		N	Mean Shear Bond Strength (Mpa)	Standard Deviation	Minimum	Maximum	95% Confidence Interval	ARI Average
Enamel Control	Brackets	10	28.38	3.53	25.13	37.11	25.86-30.91	2.5
	Attachments	10	7.28	1.96	4.24	10.47	5.87-8.68	4.3
Porcelain Brackets	Pumiced	10	14.48	3.30	9.91	19.24	12.12-16.84	3
	Diamond Roughened	10	19.98	9.31	8.33	35.14	13.32-26.64	2.1
	Sandblasted	10	21.46	6.76	12.22	32.01	16.62-26.30	2.1
	HF Acid	10	16.31	4.11	9.61	22.28	13.36-19.25	2.3
Porcelain Attachments	Pumiced	10	6.43	3.34	3.47	14.26	4.04-8.82	3.7
	Diamond Roughened	10	9.22	2.97	3.39	13.22	7.10-11.34	4.3
	Sandblasted	10	7.62	3.40	2.86	13.11	5.18-10.05	3.3
	HF Acid	10	8.83	3.87	3.47	13.14	6.14-11.68	3.7
Zirconia Brackets	Pumiced	10	8.99	2.10	6.17	12.34	7.49-10.49	4
	Diamond Roughened	10	16.66	6.40	10.15	29.92	12.08-21.24	3.7
	Sandblasted	10	25.12	7.36	17.28	35.66	19.85-30.39	1.7
Zirconia Attachments	Pumiced	10	1.39	1.33	0.29	4.92	0.43-3.34	4.3
	Diamond Roughened	10	6.90	2.88	2.47	12.32	4.84-8.96	4.7
	Sandblasted	10	8.74	2.01	5.83	11.97	7.30-10.18	1.9

Table II. ANOVA tests of porcelain brackets

Porcelain Bracket ANOVA					
	A Group	B Group	Mean Difference (A-B)	Significance	Standard Error
Bracket	Diamond Roughened	Pumiced	5.50	0.24	2.63
		Sandblasted	-1.48	0.98	2.63
		HF Acid	3.67	0.63	2.63
		Enamel	-8.40	0.02	2.63
	Pumiced	Diamond Roughened	5.50	0.24	2.63
		Sandblasted	-6.98	0.08	2.63
		HF Acid	-1.83	0.96	2.63
		Enamel	-13.90	0.00	2.63
	Sandblasted	Diamond Roughened	1.48	0.98	2.63
		Pumiced	6.98	0.08	2.63
		HF Acid	5.15	0.30	2.63
		Enamel	-6.92	0.08	2.63
	HF Acid	Diamond Roughened	-3.67	0.63	2.63
		Pumiced	1.83	0.96	2.63
		Sandblasted	-5.15	0.30	2.63
		Enamel	-12.07	0.00	2.63

Table III. ANOVA tests of porcelain attachments

Porcelain Attachment ANOVA					
	A Group	B Group	Mean Difference (A-B)	Significance	Standard Error
Attachment	Diamond Roughened	Pumiced	2.79	0.30	1.42
		Sandblasted	1.61	0.79	1.42
		HF Acid	0.31	1.00	1.42
		Enamel	1.94	0.65	1.42
	Pumice	Diamond roughened	-2.79	0.30	1.42
		Sandblasted	-1.12	0.92	1.42
		HF Acid	-2.48	0.42	1.42
		Enamel	-0.85	0.96	1.42
	Sandblasted	Diamond Roughened	-1.61	0.79	1.42
		Pumiced	1.19	0.92	1.42
		HF Acid	-1.29	0.89	1.42
		Enamel	0.34	1.00	1.42
	HF Acid	Diamond Roughened	-0.31	1.00	1.42
		Pumiced	2.48	0.42	1.42
		Sandblasted	1.29	0.89	1.42
		Enamel	1.63	0.78	1.42

Table IV. ANOVA tests of zirconia brackets

Zirconia Bracket ANOVA					
	A Group	B Group	Mean Difference (A-B)	Significance	Standard Error
Bracket	Diamond Roughened	Pumiced	7.67	0.01	2.37
		Sandblasted	-8.46	0.01	2.37
		Enamel	-11.72	0.00	2.37
	Pumiced	Diamond Roughened	-7.67	0.01	2.37
		Sandblasted	-16.13	0.00	2.37
		Enamel	-19.39	0.00	2.37
	Sandblasted	Diamond Roughened	8.46	0.01	2.37
		Pumiced	16.13	0.00	2.37
		Enamel	-3.26	0.52	2.37

Table V. ANOVA tests of zirconia attachments

Zirconia Attachment ANOVA					
	A Group	B Group	Mean Difference (A-B)	Significance	Standard Error
Attachment	Diamond Roughened	Pumiced	5.51	0.00	0.95
		Sandblasted	-1.84	0.23	0.95
		Enamel	-0.38	0.99	0.95
	Pumiced	Diamond Roughened	-5.51	0.00	0.95
		Sandblasted	-7.35	0.00	0.95
		Enamel	-5.89	0.00	0.95
	Sandblasted	Diamond Roughened	1.84	0.23	0.95
		Pumiced	7.35	0.00	0.95
		Enamel	1.47	0.42	0.95

Figures

Figure I. Shear bond strength porcelain

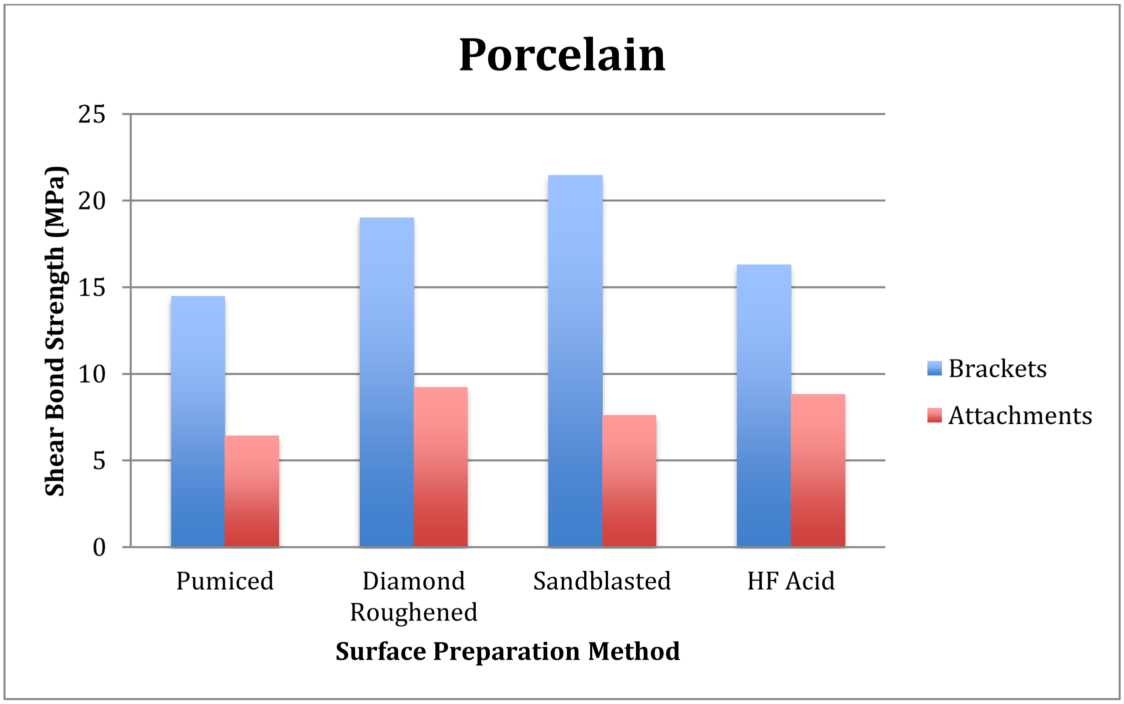


Figure II. Shear bond strength zirconia

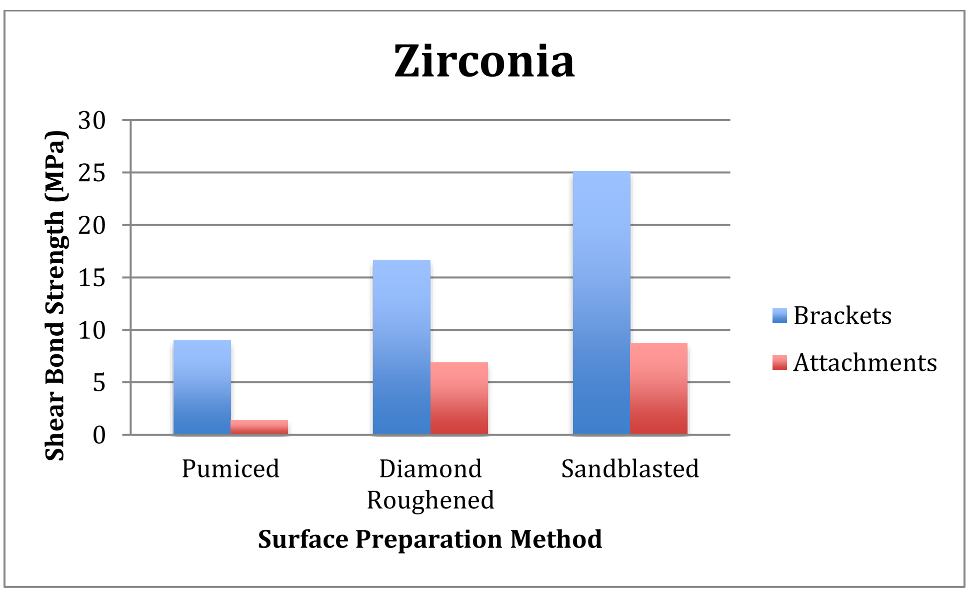


Figure III. ARI porcelain

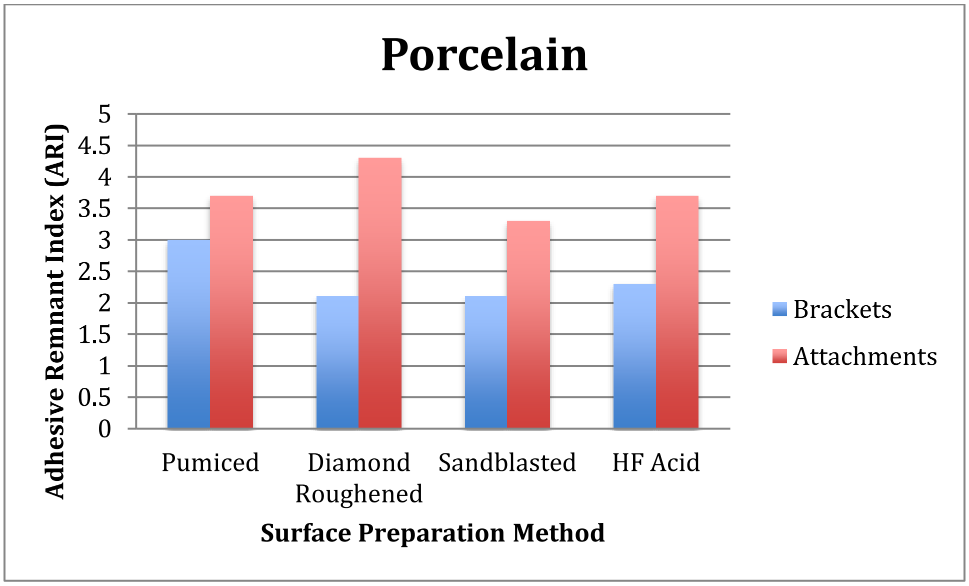
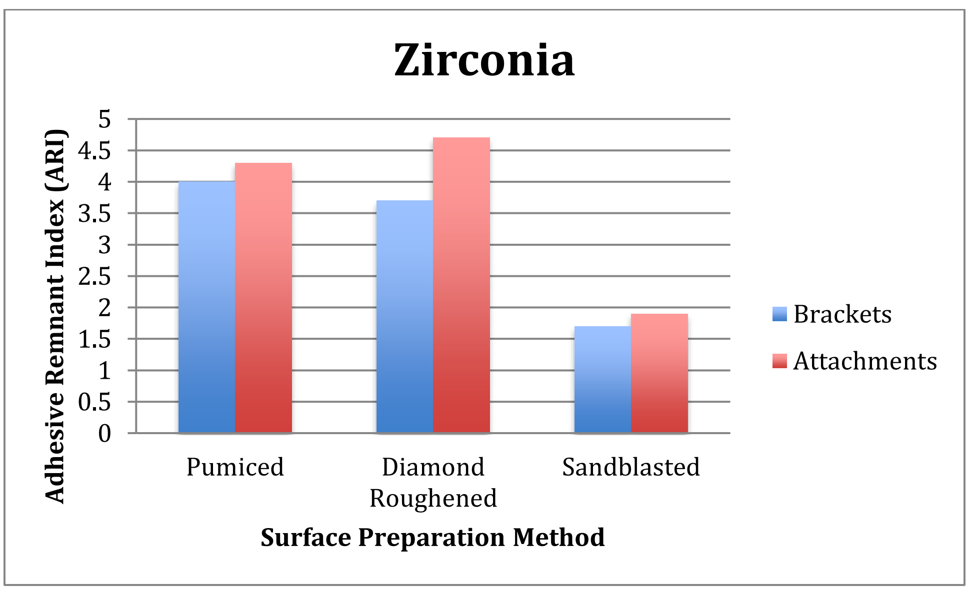


Figure IV. ARI zirconia



Discussion

This study investigated the various surface preparation techniques to determine which would exhibit the highest bond strength when orthodontic brackets and attachments were bonded onto porcelain and zirconia surfaces. The results were compared to the required bond strength values of 6-8 MPa.[4] The control group, enamel, gave us a baseline for comparison of the experimental groups, as well as allowed us to determine what method of preparation was most similar to the compared enamel control. The enamel control groups showed similar shear bond strength values compared to studies done by Uysal et al and Jassem et al. Uysal et al reported mean bracket to enamel strengths at 25.5 ±5.1 MPa[40] while Jassem et al reported attachment bonded to enamel strengths at 10.5 ±3.7 MPa.[41] It should be noted that Jassem et al is the only study found to evaluate the shear bond strength of a composite attachment bonded to enamel, and there were no studies found that tested the bond strength of attachments bonded to non-enamel surfaces.

The experimental groups used different surface preparation methods (pumice, sandblasting, diamond-bur roughening, and hydrofluoric acid for porcelain) before bonding orthodontic bracket and attachments to the non-enamel surfaces. The results in each individual group were compared to each other to determine the best surface preparation method for each material.

The results of this study showed that there is a significant difference in the surface preparation methods of the zirconia surfaces when compared to each other and compared to the enamel control. In the bracket groups, sandblasting was better than diamond roughening, which was better than pumice. The shear bond strength values for the diamond-roughened group in this study were similar to the values reported by Kwak et al, 15.48 ±3.15 MPa.[28] There was no statistically significant difference between sandblasting and enamel control; both gave equal shear bond strength values. The sandblasted bracket group showed similar results when compared to the study done by Lee et al with the shear bond strength value measured at 26.74 ± 0.94 MPa.[29] In the attachment groups, sandblasting and diamond roughening were not different from each other or from enamel, but all three were better than pumicing.

There was no significant difference found between the surface preparation methods in the attachment groups of the porcelain surfaces. There was also no difference when the porcelain surface preparation groups were compared to the enamel control, telling us that the surface preparation methods gave us similar bond strength values to the enamel control. This is consistent with the findings by Wood et al who reported that as long as a porcelain primer was used on the porcelain substrate, one can produce a shear bond strength comparable to acid-etch enamel bonding. He reported that roughening the surface increased the shear bond strength, which was also supported in this study.[33] In the bracket groups, sandblasting gave similar values to the enamel control, but there were significantly lower strengths found between when comparing HF acid, pumice, and diamond roughening to the enamel control. Our shear bond strength values in the porcelain bracket groups gave similar results to two studies done previously. Zachrisson et al reported shear bond strengths of 16.3 ± 2.6 MPa and 15.8 ± 2.6 MPa for the sandblasted and HF acid groups respectively.[42] Gillis et al reported shear bond strength values of 16.24 ±3.55 MPa for the HF acid group and 17.90± 3.65 MPa for the diamond-roughened group.[37]

Overall, the highest shear bond strength of the experimental groups was found in the sandblasted zirconia bracket group and the lowest in the pumiced zirconia attachment group. In all experimental groups, the lowest shear bond strength values were observed with the pumice preparation method. However, the only group that demonstrated a shear bond strength that was unacceptable (below the recommended 6-8 MPa), was the pumiced zirconia attachment group.

In the porcelain group, the highest average adhesive remnant index (ARI) was found in the diamond-roughened attachment group (4.3) and the lowest was found in the diamond-roughened and sandblasted bracket groups (2.1). In the zirconia group, the highest ARI was found in the diamond-roughened attachment group (4.7) and the lowest was found in the sandblasted bracket group (1.7). An ideal bond would demonstrate a cohesive fracture of the bonding material, indicating a good bond to both the substrate and the bracket. Overall, the attachment groups had higher ARI values than the bracket groups, indicating less bonding paste that was left on the substrate.

With these results, we can appreciate that all methods of surface preparation are appropriate for porcelain. All methods gave acceptable shear bond strength values that would withstand orthodontic and masticatory forces. In the zirconia groups, the highest values were demonstrated in the sandblasted groups. The lowest values were demonstrated in the pumiced groups. While the pumiced brackets were acceptable, the pumiced attachments were well below acceptable values. The low shear bond strength values can be attributed to not removing the glaze on the zirconia. The glaze that was placed on the substrate contained silica, one of the staple ingredients in many zirconia glazes. Since the glaze was not being removed in the pumice groups and there was no silane that was being used on the zirconia, there was a low chance that the bond strengths would be acceptable. Moving forward, it is important for the clinician to either determine the ingredients in the glaze or treat all crowns as if they were porcelain with a silane application.

Conclusion

When bonding to porcelain, any method of surface preparation will deliver adequate shear bond strength values. Pumice only will maintain the integrity of the crown and the glaze, but diamond roughening and sandblasting give higher strength values. When bonding to zirconia, the clinician must either remove the glaze completely or treat all crowns like they are porcelain and apply a silane conditioner before their universal primer.

Response to the following questions:

1. Were the original, specific aims of the proposal realized?
    a. Yes. The aim of the proposal was to examine the shear bond strength of brackets and attachments bonded to different substrates, and this aim was realized.
2. Were the results published?
    a. If not, are there plans to publish? If not, why not?
        a. Yes. We are in the process of continuing to submit to journals.
3. Have the results of this proposal been presented?
    a. If so, list titles, author or co-authors of these presentation/s, year and locations
        a. Bonding Brackets and Attachments to Non-Enamel Substrates
        b. Author: Nicole Gange
        c. Co-Authors: Rolando Nunez, Juan Martin Palomo, B. Douglas Amberman
        d. Case Western Reserve University, June 2018
    b. Was AAOF support acknowledged?
        a. Yes
4. To what extent have you used, or how do you intend to use, AAOF funding to further your career?
    a. I have enjoyed this research project and would be honored to use future AAOF funding to continue my research career.