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Shear bond strength of flowable composite posts on 0.019" x 0.025" stainless steel wires

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Abstract:
Excessive force during crimping can cause gabling of the wire. 30 samples each with 0.019'' x 0.025'' stainless steel wire were surface treated: sandblasted only; metal primed only; and both sandblasted and metal primed. Flowable composite posts were prepared on it. A universal mechanical testing machine was used to measure debond force. The mean shear bond strength for flowable composite posts on 0.019″ x 0.025″ stainless steel wires in this study was 16.29 MPa. It was 11.33 MPa with sandblasted wires and 8.51 MPa with metal primed wires. Sandblasting or metal priming increases the bond strength of flowable composites to stainless steel wires.

Keywords: Flowable composite posts, Archwire, sandblasting, metal priming, orthodontic bracket

Background:
Archwire fabrication has been considerably simplified with the advent of pre-adjusted edgewise orthodontic bracket systems **[1].** However, fabricated tie-back loops, soldered brass hooks, pre-posted archwires and crimpablearchwire hooks are still commonly used in certain situations. Soldering requires chairside or laboratory equipment, is time consuming and may lead to annealing of the archwire **[2, 3]**. However, excessive force during crimping can cause both gabling of the wire and the introduction of unwanted force into the wire **[4].** Griffin and Ferracane examined the effect of sandblasting and/or adhesives on the stability of crimpable hooks when positioned and crimped onto surgical archwires **[5].** The combination of sandblasting and dental adhesive increased the force required to dislodge the hook by a factor of 10.Since the advent of bonding, clinicians and researchers have worked to improve the qualities of bonding agents **[6].** Composite resins form the basis of most orthodontic adhesives and among the composite resins that could be used in orthodontics as bonding agents, flowable composite merits great attention because of its clinical handling characteristics. Flowable composites show two desirable clinical handling characteristics that have not existed for composites until very recently: (1) non-stickiness and (2) fluid inject ability **[7].**Therefore, it is of interest to evaluate the shear bond strength of flowable composite posts on 0.019'' x 0.025'' stainless steel wires in order to establish how strong that bond is; to comparatively evaluate the shear bond strength of flowable composite posts to sandblasted; primed or both sandblasted and primed rectangular 0.019″ x 0.025″ stainless steel wires; and to evaluate whether the flowable composite posts have sufficient shear bond strength to be put into various orthodontic uses on rectangular 0.019″ x 0.025″ stainless steel wires.

Materials and Methods:
In this study, straight length 0.019'' x 0.025'' stainless steel wires from Ortho Organizers was taken. The wire was given right angle bends on both ends so that 4 mm of wire is there between the bends. Both ends of the wire are embedded in acrylic blocks **(Figure 1)**. Cold cure acrylic resin (DPI-RR cold cure) was used to make the acrylic blocks. The acrylic blocks were color-coded to differentiate between three different groups. 30 samples were prepared in each group. The wires were cleaned with isopropyl alcohol so that impurities on the wire that could interfere with bonding were removed.

Group 1: The wires in this group were sandblasted with aluminium oxide powder (50 microns) directed from the sandblaster (Mini sandblaster^{R} from Deldent Ltd.) under 80 psi of air pressure for 15 to 20 seconds. It was then rinsed with water and dried in a stream of oil-free compressed air. A thin layer of metal primer (Ivoclar Vivadent) was applied to the sand blasted wire surface with an applicator tip **(Figure 1)**. The primer was gently dried and thinned with air from a chip syringe and light cured for 10 seconds. Poly vinyl siloxane tubing with an internal diameter of 3.5 mm and height of 4 mm were held on the broader side of the wire with tweezers. Flowable composite (Tetric R N-Flow) through the syringe was injected in the well of the tubing and light cured for 10 seconds. The Light Emitting Diode used was blue phase (Ivoclar Vivadent) with a wavelength of 380-515nm. Thereafter the tubing was cut at two opposite ends with a BP blade and removed with tweezers**.** In this way flowable composite posts on the 0.019'' x 0.025'' stainless steel wire were prepared**.**

Group 3: A thin layer of metal primer (Ivoclar Vivadent) was applied to the wires in this group with an applicator tip. The primer was gently dried and thinned with air from a chip syringe and light cured for 10 seconds. The rest of the bonding protocols to prepare the flowable composite posts were the same. All the 30 samples were prepared in the same way**.** A universal mechanical testing machine (Instron, Model 3366, USA) was used to measure the debond force of the flowable composite posts on 0.019'' x 0.025'' stainless steel wire **(Figure 2)**.The Instron machine was connected to a computer to record the data. A crosshead speed of 0.5 mm/minute was used and the force required to dislodge the flowable composite posts was measured Data entry template was generated on MS-excel. Data analysis was done by SPSS (16 Version). One way Analysis of Variance (ANOVA) test was used to see the significant difference between the groups. Pairwise comparison was done through post Hoc Tukey test.

Results:

The mean shear bond strength obtained from sandblasted and metal primed wires (Group 1) was 16.29 MPa. Standard Deviation was 6.08 MPa. The mean shear bond strength obtained from sandblasted only wires (Group 2) was 11.33 MPa. Standard Deviation was 3.64 MPa. The mean shear bond strength obtained from metal primed only wires (Group 3) was 8.51 MPa. Standard Deviation was 3.18 MPa **(Table 1)**. One way ANOVA shows that a significant difference exists between the three methods at 95% (i.e., α = 0.05) level of significance **(Table 2).** Pairwise tests were performed to compare different groups. Tukey's post Hoc Significance Test shows that significant difference exists between Group-1 & Group-2 , Group-1 & Group-3, and Group-2 & Group-3 at 95% (i.e., α = 0.05) significant level. So, sandblasting and metal priming (Group-1) significantly improves the bond strength (16.29 ± 6.08 MPa) compared to sandblasted only (Group 2) and metal priming only (Group 3) **(Table 3).** The colour coding of acrylic block is given in **Table 4**.

Table 1: Mean and standard deviation of shear bond (in MPa) in different groups

Groups	Shear Bond (in MPa)	
	Average (in MPa)	Standard deviation (in MPa)
Sandblasted and metal primed (Group-1)(n=30)	16.2851	6.07753
Sandblasted only (Group-2)(n=30)	11.3314	3.64560
Metal primed only (Group-3)(n=30)	8.5115	3.18092

Table 2: The ANOVA comparing the means of shear bond in different groups

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	929.184	2	464.592	23.097	.000
Within Groups	1750.006	87	20.115		
Total	2679.190	89			

Table 3: Tukey Post Hoc Significant Test

Comparison	Mean difference	Standard error	P value
Group-1 vs Group-2	4.95370*	1.15802	.000
Group-1 vs Group-3	7.77353*	1.15802	.000
Group-2 vs Group-3	2.81983*	1.15802	.044

**The mean difference is significant at the 0.05 level*

Table 4: Color coding of acrylic block

Groups	Color coding of Acrylic blocks	Wire surface treatment	Sample size
1	Pink group	Sandblasting followed by metal priming	30
2	White group	Sandblasting only	30
3	White and pink group	Metal priming only	30

Figure 1: Ivoclar Vivadent

Figure 2: Universal mechanical testing machine (Instron, Model 3366, USA)

Discussion:

Since the bis-phenol Aglycidyl methacrylate (BISGMA) resins were first applied in clinical orthodontic practice as adhesives the acid etched/composite technique has become the most widely adopted bonding system in contemporary orthodontic practice **[8].** Clinicians and researchers have worked to improve the qualities of bonding agents. They have always searched for an adhesive that could simplify the procedures involved in bonding at the same time have sufficient bond strength, adequate working time, shorter curing time and improved ease of use. In this quest, flowable composite resins merit great attention because of two of their clinical handling characteristics, *i.e.* (1) non stickiness and (2) fluid injectability **[7].** These characteristics are associated with the low viscosity of the mixture. Generally, all mechanical properties of a composite resin improve with filler loading. Traditional dental composite resins are densely loaded with reinforcing filler particles for strength and wear resistance. Wear resistance increases when small filler particles are highly packed to protect the polymer matrix in the composite **[9].** Flowable composites were created by retaining the same small particle size of traditional hybrid composites but reducing the filler content and allowing the increased resin to reduce the viscosity of the mixture. In the present study Tetric N-Flow (flowable composite) has been used. It contains 36 wt % dimethacrylates (including TEGDME), 63 weight % fillers (barium glass, ytterbium trifluoride, highly dispersed silica and mixed oxide). The total content of inorganic fillers is 39 vol%. The particle size of inorganic fillers is between 40 and 3000 nm. This enables the filler particles to be highly packed. This is in accordance with study by Attilio *et al.* in which they used Denfil Flow (flowable composite) and concluded that since the content of inorganic filler is 60% by weight with very small size of particles (mean particle size is 0.01 ~2.5μm), the filler particles can be more highly packed than other flowable composites, even maintaining the same low viscosity **[10].** This increases their wear resistance. The purpose of the present study was to measure the shear bond strength of flowable composite posts on rectangular 0.019" x 0.025" stainless steel wires using 3 surface treatments prior to application of flowable composite- sandblasting only, metal priming only and both sandblasting and metal priming. The comparison of the shear bond strength was done using Analysis Of Variance (ANOVA).The mean shear bond strength in this study was 16.29 MPa with sandblasted and metal primed group, 11.33 MPa with sandblasted only group and 8.51 MPa with metal primed only group. The bond strength of flowable composite posts with all three surface treatments was quite above the clinically acceptable level of 5.9-7.8 MPa as suggested by Reynolds **[11].** Lopez recommended a value of 7 MPa as minimum bond strength for successful clinical bonding **[12].** The goal of current orthodontic research is to improve the bonding procedure by reducing chairside time without jeopardizing the ability to maintain clinically acceptable bonds strength. Clinicians are interested in determining the level at which the bond failure will take place with force application **[13].** However, flow property is another special feature and is an important clinical consideration that influences both the penetration of the adhesive into the retentive metal bases and the ability of composite to resist drift **[14].** Flowable composites were created by retaining the same small particle size of traditional hybrid composites but reducing the filler content and allowing the increased resin to reduce the viscosity of the mixture **[9].** With additional merits of non-stickiness and fluid injectability, composite posts of flowable composites were used in the present study. D'Attilio and Tecco have reported very high values 34.80 MPa and 24.98 MPa for flowable composites **[10, 15].** They suggested that flowable composites can be used for orthodontic bonding. Dong-Bum-Ryou reported that flowable composites demonstrated a significantly superior flowability and the shear bond strength for the flowable composites ranged between 7.2 and 8.3 MPa and they concluded that flowable composites with no intermediate bonding resin could be conveniently applied for orthodontic bracket **[16].** Pickett *et al.* indicated that mean bond strengths recorded *in vivo* following comprehensive orthodontic treatment are significantly lower than bond strengths recorded *in vitro* **[17].** In the present study, the *in vitro* values need to be correlated with further *in vivo* studies. Moreover, all the above studies have been done on tooth enamel and that also without surface treatment whereas the present study evaluates bond strength of flowable composites on stainless steel wires with various surface treatments. Different surface treatment has been tested on metals to enhance the bond strength of the composite to metals **[18, 19].** Studies have proven that sandblasting enhanced the bond strength between metals and composite resin by at least 300% **[20].** Claims have also been made that adhesion promoters (metal primers) can also increase the metal composite bond strength **[18, 19].** Nawrocka *et al.* stated that sandblasting was more effective in preparing the amalgam surface for bonding than roughening with a diamond bur, but the difference was not statistically significant **[21].** Griffin and Ferracane stated that when sandblasting and adhesives were used the force required dislodging crimpable hooks increased by a factor of 10 **[5].** In the present study also sandblasting stainless steel wires alone or in combination with metal primer application increased the shear bond strength to around one and half times and two times respectively as compared to metal priming alone which also produced clinically acceptable shear bond strength of flowable composite posts on stainless steel wires. Tjan *et al.* conducted a study on the bond strength of composite to metal, mediated by metal adhesive promoters (Primet, Fusion, ABC Bond) and indicated that the bond strength attained with the metal primers were not high and further research is needed for the development of a metal primer with an improved adhesive strength **[18].** In the present study, metal priming when used alone for surface treatment of stainless steel wires produces bond strength values less than sandblasting alone or sandblasting with metal priming but the values, however, approach clinically acceptable values. The high fluidity of flowable composites could be an advantage for bonding for allowing a better adaptation in areas of anchorage **[22, 23].** In the present study, sandblasting and metal priming (Group-1) significantly improves the bond strength (16.29±6.08 MPa) compared to sandblasting only and metal priming only groups. However, further studies are needed to check for strength of flowable composite posts of smaller diameter in vitro and co-relate the same *in vivo*.

Conclusion:

The combination of both sandblasting and metal priming produces the high shear bond strength. Thus, all three wire surface treatments can be effectively used in orthodontics for use of composite posts on 0.019″ x 0.025″ stainless steel wires depending upon the clinical situations.

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