Evaluation and comparison of the shear bond strength between different types of brackets bonded on composite surface using different surface treatments: An in-vitro study

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Abstract: **Orthodontists are more likely to face the difficulty of bonding orthodontic attachments to anterior restored teeth. 180 photoactivated composite resin discs were divided into different groups and subjected to different surface treatments. Different types of brackets were bonded onto the composite surface and shear bond strength was evaluated and compared. Metal brackets gave highest bond strength with silane conditioning agent followed by ceramic bracket gave highest value with diamond bur and least bond strength by composite bracket with monomer.**

Keywords: Composite restoration, surface treatment, shear bond strength.

I. Introduction

In present life, the demand for orthodontic treatment has been gradually increasing among the adult population[1]. Orthodontic treatment may also serve as a pre-prosthetic activity as it is confronted not only with natural teeth but also extensive composite resin restorations, implants, metal crowns, ceramics and provisional restorations. In adult patient, given the fact that archwires and brackets are still needed to achieve orthodontic movements, a wide range of surfaces exists where brackets need to be bonded [2]. To be accepted, a bracket bond system must be able to withstand the forces of orthodontic wires as well as those of the oral environment[3]. Things get even complicated when the bracket has to be bonded to the restoration surface rather than enamel. Some research has been carried out on the results of various surface preparation methods, such as diamond milling, sandblasting or etching with phosphoric acid and hydrofluoric acid[4]. A weak bond of the brackets to provisional materials will lead to a high failure rate, with adverse consequences on the cost and efficiency of orthodontic therapy as well as on patient comfort. Many factors influence the strength of the bond between the bracket and provisional materials, including the type of provisional material, the adhesive material, the time of storage following bonding, and thermocycling[5] . The bond strength of composite resin to an aged composite restoration is frequently reduced, leading to early failure of the resin addition. Because the usual method of 'etching' the surface of the aged restoration with phosphoric acid does not result in satisfactory bond strength, mechanical and chemical methods of surface treatment have been tried. The mechanical methods include sandblasting or roughening the surface of the restoration with rotating tungsten carbide or diamond burs[6]. Since clinical failure of brackets bonded to composite resin restorations using conventional bonding procedures have frequently been encountered, the purpose of this *in vitro* study was to investigate the shear bond strength (SBS) of orthodontic brackets bonded to artificially aged restorative composite resin surfaces treated with various surface roughening methods.

II. Material and methods

The materials used were 180 light cured discs of composite restorations. Three different types of brackets used were Maxillary central incisor laser- cut stainless steel brackets (MBT, 0.022 inches slot, Gemini series, 3M Unitek, USA). Maxillary central incisor laser- cut ceramic brackets (MBT, 0.022 inches slot, Gemini series, 3M Unitek, USA). Maxillary central incisors laser-cut composite brackets (MBT, 0.022 inches slot, Elgant Composite brackets, Modern traders). The materials used for surface treatment were 4mm width double sided coarse grit abrasive strip, S S White diamond bur, Methylmethacrylate monomer and a plastic conditioner. The bonding materials used were 3M unitek bonding agent, Transbond XT adhesive primer and Transbond XT adhesive paste. Bonding procedure was done after the discs were mounted onto the acrylic block. The sample was arbitrarily divided into three main groups and four equal subgroups of 15 specimens each. Before bonding the brackets the surface treatment over the restoration was done in following manner:

Sub-Group I: The surface was roughened with an abrasive strips, rinsed for 60 seconds with water and dried.

Sub-Group II: The surface was roughened with a coarse diamond bur with grit sizes 125-150 micrometer rotating at high speed with a constant water spray. The rotating bur was passed over the composite surface three times, rinsed for 60 seconds with water and dried.

Sub-Group III: The surface was etched with 1 layer methylmethaacrylate monomer at room temperature with brush, air dried.

Sub-Group IV: The surface was etched with 1 layer of plastic appliance conditioner with brush, and air dried.

The bonding of brackets was done by applying adhesive paste and light curing it for 20 seconds. The specimens were stored in distilled water in an oven for 1 week at 37 °C.

Debonding procedure: The samples were positioned in the universal testing machine with the long axis parallel to the direction of the load application. A stainless steel wire 0.009" diameter in the shape of a loop was fixed to the upper cross head at one end and was adjusted to engage the bracket at the other end. A crosshead speed of 10 mm/minute was used and the maximum load necessary to debond the brackets was recorded. The force required to shear the bracket was recorded and the shear bond strength was calculated.

III. Results

Descriptive statistics, including the mean, standard deviation (SD), and minimum and maximum values were calculated for all the groups of specimen tested. Comparisons of the means of SBS values were made with factorial analysis of variance (ANOVA). 95% Confidence interval has been computed to find the significant association. The level of significance for all tests was set at $p < 0.05$. The results of the shear bond strength were subjected to Weibull analysis (survival analysis) which facilitated comparison between the groups. This statistical analysis had the ability to predict the number of bonds likely to fail at particular bond strength.

Table – I: Bond strength values (in MPa) of different groups

METAL BRACKETS				CERAMIC BRACKETS				COMPOSITE BRACKETS			
Abrasive strip	**Diamond bur**	**Monomer**	**Primer**	**Abrasive strip**	**Diamond bur**	**Monomer**	**Primer**	**Abrasive strip**	**Diamond bur**	**Monomer primer**	
24.938	19.962	26.896	25.343	17.294	23.026	22.702	18.456	17.668	15.83	5.706	14.637
24.83	28.723	16.718	25.394	17.249	16.765	23.448	17.993	11.83	6.93	4.968	8.788
23.382	20.508	16.718	25.394	16.404	16.698	17.206	18.073	19.08	8.108	8.179	7.003
22.841	19.796	23.23	26.343	7.63	19.11	19.031	15.152	16.846	6.172	15.628	11.886
22.316	20.159	26.923	24.508	16.294	20.369	14.501	7.98	13.085	12.89	9.321	9.05
6.9	18.077	24.549	29.056	17.092	21.544	16.864	16.504	8.908	12.073	8.162	10.78
25.19	15.305	18.647	26.357	14.987	20.609	24.795	6.98	16.484	9.462	7.041	7.85
23.065	27.864	25.032	25.384	15.82	19.374	18.045	16.598	6.19	13.955	10.273	13.245
22.381	7.46	22.605	28.745	7.74	22.923	7.83	17.532	7.94	11.392	6.219	9.656
22.766	24.93	24.976	24.039	17.436	17.58	20.549	18.364	12.73	16.328	14.294	12.976
21.73	5.05	20.395	23.498	17.475	19.256	21.754	16.384	13.984	14.883	15.238	6.39
23.048	24.837	6.04	25.793	6.524	22.486	21.674	16.483	15.839	7.729	10.47	12.238
22.789	20.387	24.094	27.84	15.86	21.978	7.82	17.932	17.087	11.649	3.744	6.39
25.08	19.483	21.24	26.385	16.865	23.865	16.357	18.753	16.754	7.64	14.086	5.23
24.048	26.98	22.387	7.45	17.643	5.83	18.075	18.954	14.245	16.27	5.432	14.476

TABLE –II: Shear bond strength (Mpa) for brackets with different surface treatements

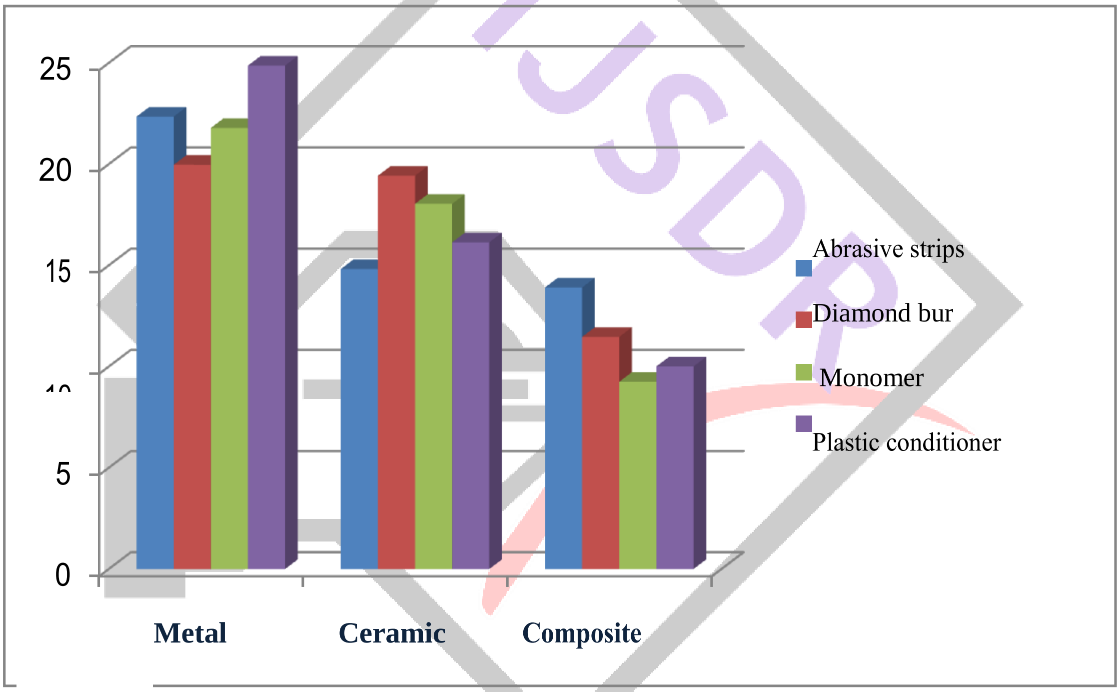
Bracket	Surface treatment	NMinimum	Maximum	Mean	Standard Deviation
Metal	Abrasive Strips	156.90	25.19	22.36	4.42
	Diamond Bur	155.05	28.72	19.97	6.77
	Monomer	156.04	26.92	21.79	5.19
	Reliance	157.45	29.06	24.87	5.07
Ceramic	Abrasive Strips	156.52	17.64	14.82	3.97
	Diamond Bur	157.82	24.80	18.04	5.05
	Monomer	156.98	18.95	16.14	3.68
	Reliance	156.17	16.33	11.42	3.57

Composite	Abrasive Strips	156.19	19.08	13.91	3.83
	Diamond Bur	155.43	15.63	11.43	3.57
	Monomer	156.63	14.64	9.25	3.97
	Reliance	156.90	25.19	10.01	3.01

TABLE III: Associations between brackets types and surface treatments using general linear model

	Abrasive strips	**Diamond bur**	**Monomer**	**Reliance silane**
Metal Brackets	22.35	19.97	21.79	24.87
Ceramic Brackets	14.82	19.43	18.04	16.14
Composite Brackets	13.91	11.47	9.25	10.01

GRAPH I: Association between brackets types and surface treatments using general linear model



Metal brackets showed the highest bond strength (24.87 MPa) than the other brackets in all sub groups. The highest bond strength of metal bracket was found with Reliance conditioner (24.87 MPa) and the least bond strength (19.97 MPa) was found with diamond bur surface treatment. Ceramic bracket showed the highest bond strength (19.43 MPa) with diamond bur surface treatment and the least bond strength (14.82 MPa) was found with abrasive strip surface treatment. Composite bracket showed highest bond strength (13.91 MPa) with abrasive strip surface treatment and the least bond strength (9.25 MPa) with monomer surface treatment.

GRAPH II: Estimated Marginal mean values of all the sub groups

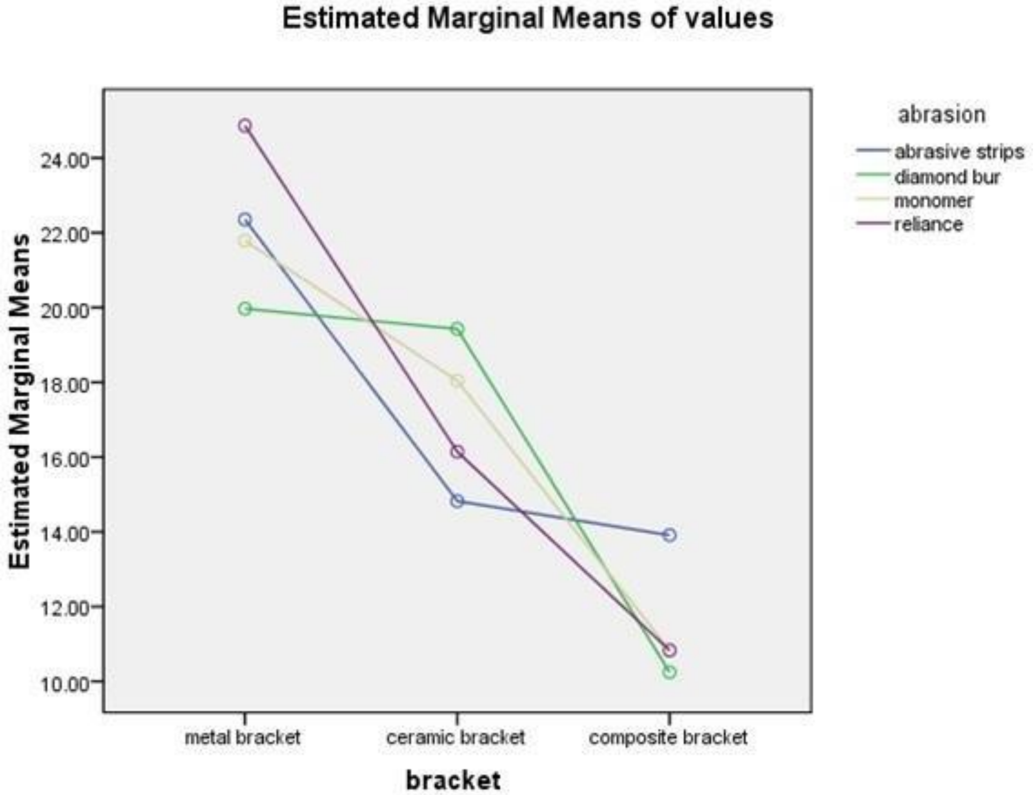


TABLE IV: ANOVA TABLE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
bracket	3495.108	21747.554		92.300	.000
abrasion	12.600	3	4.200	.222	.881
bracket * abrasion	481.870	6	80.312	4.242	.001

Statistical analysis using ANOVA showed statistically significant difference in the bond strength among three brackets (F = 92.300, *P* = 0.00). There was no statistically significant difference in bond strength on comparing the four surface treatments (F = 0.222, P = 0.881).

TABLE V: Post hoc Schiffe's test within the bracket

Standard error			Mean difference	p value
metal bracket	ceramic bracket	5.1351*	.79443	.000
	composite bracket	10.7895*	.79443	.000
ceramic bracket	metal bracket	-5.1351*	.79443	.000
	composite bracket	5.6545*	.79443	.000
composite bracket	metal bracket	-10.7895*	.79443	.000
	ceramic bracket			

Following ANOVA, Pair wise multiple comparisons between the groups was done using Tukey's Post Hoc Test which showed significant values with different brackets but non significant values with different surface treatments.

TABLE VI: Post hoc Schiffe's test within the surface treatment

Standard error			Mean difference	p value
abrasive strips	monomer	.4816	.91732	.964
diamond bur	abrasive strips	.1414	.91732	.999
	Monomer	-.2505	.91732	.995
monomer	reliance	-.4816	.91732	.964
	abrasive strips	-.3402	.91732	.987
abrasive strips	diamond bur	-.7321	.91732	.888
diamond bur	monomer	-.1414	.91732	.999
monomer	monomer	.3402	.91732	.987
	abrasive strips			

IV. Discussion

The success of the bonding of polymeric materials in orthodontics involves combination of three basic factors, that is the mechanical conditioning (mechanical retention) or chemical conditioning of a surface, or a combination of both, along with the appropriate choice and proper handling of bonding materials and the retentive potential of accessories or brackets to be used[7]. The substrate type (enamel, ceramic, composite, amalgam or metal alloys) and the clinical need (type of movement to be used) are other important aspects to be considered for determining the necessary procedures in order to perform the conditioning of the adherent surface and select the type of adhesive system to be used in the bonding technique. One of the challenges for the professional in terms of technique and materials is the union of orthodontic attachments to teeth with esthetic restorations, either composite resin or ceramic. When an orthodontic attachment is bonded to a composite restoration in the oral cavity, it is likely that the restoration has been ageing for a long time in a humid environment[8]. The bond strength between an orthodontic bracket and a composite restoration should be sufficient to withstand the forces generated by mastication, last the duration of orthodontic treatment but allow straight forward removal at the end of treatment without damage to the underlying restoration. The minimum bond strength for orthodontic purposes falls within the range of 6 to 8 MPa[9]. A previous study reported that forces generated on brackets in the posterior quadrants exceeded 20 MPa[10]. Several techniques have been suggested to improve the composite–composite bond. One technique is roughening the surface and the others are based on attempts to improve adhesion of new resin to cross-linked polymer matrix or filler particles of the Composite[11]. Improving the bond strength between new and old composite usually requires increased surface roughness to promote mechanical interlocking and coating of old composite with unfilled resin bonding agents to advance surface wetting and chemical bonding [12]. It was found that the increase in mechanical interlocking is the most significant factor that contributed to bond strength between composite resins. The surface treatments used in this study are abrasive strip, diamond bur, monomer and silane conditioning agent. Abrasive strip and diamond bur increased surface roughness to promote mechanical interlocking and coating of old composite with unfilled resin bonding agents to advance surface wetting and chemical bonding. Increase in shear bond strength values was expected from the particle abrasion and diamond bur groups.

In the present study highest bond strength values were obtained with metal brackets with Reliance conditioner as it is metal primer which creates a chemical bond between precious and non precious metals and an adhesive. Metal brackets showed highest bond strength (24.87 MPa) with plastic coupling agent and showed lower shear bond strength values of 22.35MPa , 21.79 MPa and 19.97 MPa with abrasive strip , monomer and diamond bur surface conditioning respectively. Ceramic brackets showed highest bond strength (19.43 MPa) with diamond bur surface treatment and lower shear bond strength of 18.04 MPa, 16.14 MPa and 14.82 MPa with monomer, plastic conditioner and abrasive strip respectively. Composite brackets showed least bond strength (13.91 MPa) with abrasive strip surface treatments followed by 11.47 MPa, 10.01 MPa and 9.25 MPa with diamond bur, Reliance and monomer respectively. The mean shear bond strength values of all surface conditioning groups exceeded the limits required for clinically satisfactory shear bond strength and therefore could be considered sufficient for clinical applications.

Results showed maximum failure probability (28%) with composite brackets followed by ceramic brackets with failure probability of (13.3 %) and the least with metal brackets (8.3%). This indicates that although the shear bond strength values of all the brackets were within the clinically acceptable range, the probability of failure is higher for composite brackets which may be due to less mesh network at the base of composite bracket. Less failure was found with the metal brackets, the reason for which could be attributed to the good mesh network at the bracket base.

V. Conclusion

Orthodontic bonding to aged restorative resin composite was evaluated *in vitro* with four different surface conditioning methods. Within the limitations of this study, the conclusions are as follows:

1. Surface roughening is effective in bonding an orthodontic attachment to aged resin composite surfaces.
2. Clinically, adequate SBS values can be obtained with the application of diamond bur, abrasive strip, monomer and silane coupling agent.
3. The failure patterns of brackets were at the resin – bracket interface for abrasive strip and diamond bur application and at the resin – adhesive interface for monomer and silane agent.
4. The failure probability of composite brackets is maximum and minimum failure probability with ceramic brackets followed by metal brackets.

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