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Comparison of shear bond strength of four different commercially available ceramic brackets: An *in-vitro* study

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Abstract
The aim of this study is to determine bond strength of different ceramic brackets with acceptable bond strength. The materials used for the study included 60 mechanically retentive ceramic brackets (Ormco, Koden, 3M Clarity advance, Modern).The SBS was measured using a Universal Testing Machine with crosshead speed of 5mm/min. ARI index was assessed on the enamel surfaces. The test results demonstrate the mean shear bond strength for group1 (ormco) was 11.94 ± 3.50, group 2 (koden) was 16.09 ± 4.54, group 3 (3M) was 19.42 ± 2.15 and for group 4(Metro) was 6.73 ±2.1. Group 3 showed the highest mean shear bond strength among all the groups. The present study concluded that there was statistically significant difference in the shear bond strength among the four groups and 3M group being more than the other three groups.

Keywords: Brackets, ceramic, bond strength, universal testing machine

1. Introduction
As the number of adults seeking orthodontic care increased, orthodontists felt the need to provide their patients with more esthetically "appealing" appliances. This perceived need motivated manufacturers to provide acceptable esthetic brackets, including the ceramic brackets. Ceramics are materials that are both very rigid and brittle, that is, non-ductile.
An understanding of the characteristics of ceramic brackets that influence bond strength and bracket removal should assist the clinician in the use of these brackets.
Although the term *ceramics* encompasses different compounds, most currently available ceramic brackets are composed of aluminum oxide. Two basic types of brackets exist, based on two different manufacturing processes [1].
The polycrystalline brackets are made of sintered or fused aluminum oxide particles. The process begins by blending the particles with a binder. This mixture is then molded into a shape from which the critical parts of the brackets can be cut. The molded part is then fired at a temperature that allows the binder to be burnt out and the aluminum oxide particles to fuse but not melt. This firing process is called sintering. This molding/sintering process is relatively inexpensive, making it a popular manufacturing technique. Unfortunately, the process results in both structural imperfections at grain boundaries and the incorporation of trace amounts of impurities. These slight imperfections and impurities, even in quantities as low as 0.001%, can serve as foci for crack propagation under stress. This could lead to fracturing of the bracket [1].
Mono crystalline ceramic brackets also are manufactured from aluminum oxide. In this process, the oxide particles are melted and then cooled slowly, permitting complete crystallization. This process minimizes the stress-inducing impurities and imperfections found in the polycrystalline brackets. The orthodontic bracket is then milled into shape from the single crystal of aluminum oxide. This is a more difficult and expensive manufacturing process, because of the hardness of the ceramic material? Milling and the presence of sharp corners introduce their own stresses on the material and also pre-dispose the brackets to fracture provide the only advantage over stainless steel brackets [2, 3].
The larger the ceramic grains, the greater the clarity becomes. However, when the grain size reaches about 30 lam, the ceramic material becomes weaker.

The grain boundaries and impurities that are present in polycrystalline ceramics reflect light, resulting in some degree of opacity. The mono crystalline brackets, however, are essentially clear. The clear appearance is the result of two factors: reduction of grain boundaries and having fewer impurities introduced during the manufacturing process [4] .Whether the difference between the optical properties of the opaque and clear ceramics is significant from an esthetic point of view is based on the personal preference of the clinician. This is particularly true because ceramic brackets in the oral environment can be affected by color pigments for example, in tea, coffee, and wine.

The currently available ceramic brackets are composed of aluminum oxide, being either mono crystalline or polycrystalline.

The physical properties of ceramic brackets differ from brackets previously used in orthodontics. The fracture toughness (ability of the material to resist breakage) is the mechanical

Property which most distinguishes ceramic from conventional metal brackets (Scott, 1988).

Ceramics are extremely brittle and even the smallest surface cracks can dramatically reduce The load required for fracture [2].

The purpose of this study was, therefore, to determine the bond strengths of various ceramic brackets available commercially.

2. Materials and Methods

2.1 Study Design: Four different types of premolar ceramic brackets (commercially available) were investigated (Table 1). Sixty sound human premolars, extracted for orthodontic reasons were collected and immediately stored in water. Teeth were divided into groups of four, with 15 samples in each group.

Brackets were bonded using the following regimen. Prophylaxis of the buccal surface of each tooth was carried out using a pumice and water slurry in a rubber cup, following which the teeth were washed, dried, and etched for 30 seconds using a 37 per cent phosphoric acid gel (Scotchbond-3M). Final rinsing was undertaken using copious amounts of water and the teeth were dried with an oil-free stream of air. The enamel should exhibit a frosty, white appearance. Transbond primer will be applied to tooth surface and light cured (3M ESPE ELIPAR S10) for 10 seconds. Transbond XT adhesive will be placed on the ceramic bracket base with a plastic instrument, and the bracket will be placed on the tooth at the ideal occluso-gingival and mesio-distal position. Excess adhesive resin will be removed with an explorer, and the adhesive will be light cured from the mesial and distal sides for 30 seconds.

Each of the commercially available brackets was tested, an occluso-gingival load was applied to produce a shear force at the bracket-tooth interface. This was accomplished with the flattened end of a steel rod attached to the crosshead of a Universal Testing Machine. The bond strengths were measured at a crosshead speed of 5 mm/min, and the load applied at the time of fracture was recorded in Mega Pascal (MPa) as a unit.

Brackets used in study.

Samples	Manufacturer
Group I	Ormco
Group II	Koden
Group III	3M clarity advance
Group IV	Metro

The sheared surfaces and base of the bracket was further investigated with a stereomicroscope (LYNX) at 10X magnification to assess the adhesive remnants on the specimen surface.

ARI scores was used as a means of defining the sites of bond failure between the composite surface, resin (adhesive), and the bracket base. The data were analysed statistically using the It includes expression of the shear bond strength in terms of Mean & SD. One-way ANOVA test followed by Tukey's HSD post hoc Analysis will be used to compare the mean shear bond strength between different study groups. The level of significance [P-Value] will be set at $P<0.05$

3. Results

The test results demonstrate that the comparison of mean shear bond strength between different groups. The mean shear bond strength for group 1 was 11.94 ±3.50, group 2 was 16.09 ±4.54, group 3 was 19.42 ±2.15 and for group 4 was 6.73 ±2.17. This difference in the mean shear bond strength between 04 groups was statistically significant at $P<0.001$.

Table 1: Comparison of mean Shear Bond Strength

Comparison of mean Shear Bond Strength (in Mpa) between different groups using One-way ANOVA Test						
Groups	**N**	**Mean**	**SD**	**Min**	**Max**	**P-Value**
Group 1	15	11.94	3.50	6.28	18.78	<0.001*
Group 2	15	16.09	4.54	8.89	28.18	
Group 3	15	19.42	2.15	16.77	24.77	
Group 4	15	6.73	2.17	2.09	10.38	

*-Statistically Significant

Table 2: Multiple comparison of mean difference in Shear Bond Strength

Multiple comparison of mean difference in Shear Bond Strength (in Mpa) between different groups using Tukey's Post hoc Analysis					
(I) Groups	**(J) Groups**	**Mean Diff. (I-J)**	**95% CI for the Diff.**		**P-value**
			Lower	**Upper**	
Group 1	Group 2	-4.15	-7.29	-1.01	0.005*
	Group 3	-7.48	-10.62	-4.34	<0.001*
	Group 4	5.20	2.06	8.34	<0.001*
Group 2	Group 3	-3.33	-6.47	-0.19	0.03*
	Group 4	9.35	6.21	12.49	<0.001*
Group 3	Group 4	12.68	9.54	15.82	<0.001*

* - Statistically Significant

Multiple comparison of mean difference in the shear bond strength between groups revealed that Group 3 showed significantly highest mean shear bond strength as compared to group 4 and group 1 at $P<0.001$, whereas group 2 at P=0.02. And this was followed by group 2 showing significantly higher mean shear bond strength as compared to group 1 at

P=0.002 and group 4 at $P<0.001$. Finally, group 1 showed significantly higher mean shear bond strength as compare to group 4 at P=0.02. The results infer that Group 3 had highest significant mean shear bond strength, followed by Group 2 & 1 and the least with Group 4.

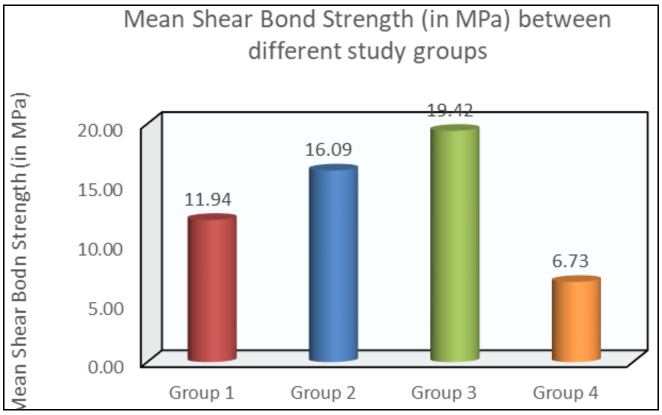

Fig 1: Comparision Mean Shear Bond Strength (in MPa) between different study groups

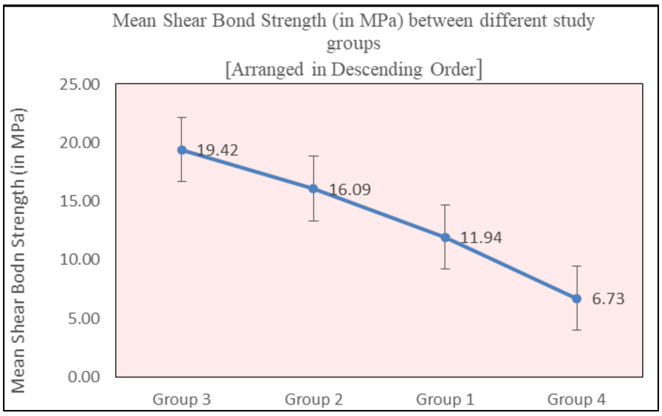

Fig 2: Mean Shear Bond Strength (in MPa) between different studies groups [Arranged in Descending Order]

Table 3: Comparison of Adhesive Remnant Index (ARI) scores between different adhesives for Ceramic Brackets using Chi Square Test

ARI	Ormco n %	Koden n %	Clarity Advance n %	Metro n %	P-Value
Score	8	10	7	5	
0	53.3%	66.7%	46.7%	33.3%	
Score	7	5	7	10	0.56
1	46.7%	33.3%	46.7%	66.7%	
Score	0	0	1	0	
2	0.0%	0.0%	6.7%	0.0%	
Score	0	0	0	0	
3	0.0%	0.0%	0.0%	0.0%	

4. Discussion

In modern society, the esthetic aspect of orthodontic therapy is important since the numbers of adults undergoing orthodontic therapy are increasing. Therefore, the development of an appliance that combines both esthetic and adequate technical performance is an important goal. Ceramic brackets were developed to improve the esthetics during orthodontic treatment[5].

Longevity of brackets is predicted to some extent by their adhesive ability and their adhesive bond strength, which can be measured by bond strength testing. An ideal bond strength test should be accurate, clinically reliable, and not technique-sensitive.

The bond strength of bracket - adhesive - enamel system in orthodontic bonding varies and depends on factors such as the type of adhesive, bracket base design, enamel morphology, appliance force systems and the clinician's technique. Bracket bonding technique is based on the formation of a mechanical lock between the adhesive and the irregularities in the enamel surface of the tooth, and to the mechanical locks that is formed at the base of the orthodontic bracket.[6]

Hence the present study was conducted to test and evelauate shear bond strength of ceramic brackets available commercially.

The present study results indicate significant differences between various ceramic brackets with respect to bond strengths. The test results demonstrate that the comparison of mean shear bond strength between different groups. The mean shear bond strength for group 1(Ormco) was 15.89 ±2.06, group 2 (Koden) was 20.02 ±3.91, group 3 (Clarity advance) was 23.49 ±3.71 and for group 4 (Metro) was 12.61 ±1.34. This difference in the mean shear bond strength between 4 groups was statistically significant at $P<0.001$.

Multiple comparison of mean difference in the shear bond strength between groups revealed that group 3 showed significantly highest mean shear bond strength as compared to group 4 and group 1 at $P<0.001$, whereas group 2 at P=0.02. And this was followed by group 2 showing significantly higher mean shear bond strength as compared to group 1 at P=0.002 and group 4 at $P<0.001$. Finally, group 1 showed significantly higher mean shear bond strength as compare to group 4 at p=0.02. The results infer that group 3 had highest significant mean shear bond strength, followed by group 2 & 1 and the least with group 4.

In the present study, when comparing the mean SBS of different bracket systems, it was observed that the mean SBS of Clarity Advanced (microcrystalline) base was the highest followed by Koden, Ormco (bead ball base), while the bracket system with the least mean SBS was of mechanical mesh base (Gemini Metal). The Clarity Advanced ceramic bracket with microcrystalline base is composed of small glass particles fused to a polycrystalline alumina, which increases the surface area available for adequate bonding and thus, the bond strength. These results were in accordance with studies conducted by Park MG and Kang DY *et al.*, [7, 8].

The bead base surface Ormco has many round beads as completely distributed over the base surface as possible. These small beads have undercuts for mechanical interlocking of the adhesive resin resulting in the statistically higher SBS than Koden brackets. These results were in accordance with studies conducted by Park MG, Kukiattrakoon B and Samruajbenjakul B [7, 9, 10]

Results also showed that the mean SBS of Metro was lowest among all ceramic brackets [Table1], but SBS of Metro was clinically aceppeted Reynolds stated that 5.9-7.8 MPa resistances are sufficient to withstand masticatory forces [13]. Since the Metro brackets were the largest (whole bracket base surface area) as compared with the other ceramic brackets, the greater bonding area reduced the bond strength.

A study conducted using finite element analysis which stated that bond strength is inversely proportional to the bonding area of the bracket. The larger the bonding area, the higher is the probability that a flaw of critical 11size is present. Thus, a specific base design which provides a favourable stress distribution should be preferred rather than increasing the bracket dimensions. Irregular surface base of Clarity Advanced and bead ball base of Ormco used in this study may decrease bracket base dimension without affecting SBS. These results were in accordance with studies conducted by Kang DY *et al.* [8].

Shear bond strength (SBS) is the main factor, which has to be concerned in the evolution of bonding materials. The bond strength of the orthodontic bracket must be able to withstand the forces applied during the orthodontic treatment.. An ideal orthodontic adhesive should have adequate bond strength while maintaining unblemished enamel after debonding. Bracket bonding technique is based on the formation of a mechanical lock between the adhesive and the irregularities in the enamel surface of the tooth, and to the mechanical locks that is formed at the base of the orthodontic bracket. Transbond XT (3M ESPE St. Paul, Minnesota, USA) bonding system has become a gold standard for bonding of brackets and buttons in orthodontic practice because of its ideal consistency, light curing ability,superior tooth/bracket adhesion and availability [14]. Transbond XT has greater control of working time by orthodontists, which facilitates the proper placement of brackets on the teeth [6].

When the bond is tested for failure, there are three main failure sites [12]. These are the bracket base/adhesive interface, the enamel/adhesive interface and cohesive failure .Higher ARI scores mean that the mode of failure is closer to the bracket/adhesive interface, and the risk of enamel fracture is decreased. [16]

On comparing the ARI scores on the tooth surface for the three adhesives bonded with ceramic brackets in the present study it was revealed that there is no statistical significance among the groups. Higher ARI 2 was found only in group Clarity Advance i.e only one in 15 samples. ARI score 1 was recorded in almost 50% of the total ceramic group, with the highest samples seen in Clarity Advance group 3(7) and group 1(7), followed by Koden group, Metro group brackets (5) revealing that less than half of the adhesive remaining on the tooth surface (enamel -adhesive interface failure) in the respective samples. The remaining 50% of the ceramic group fall under the criteria of score 0, with the Koden, Metro group (10) having the highest samples, followed by Ormco (8) and least in Clarity Advance (7) indicating that the bond strength at the enamel adhesive interface is higher than that of at the bracket adhesive interface with no adhesive left on the tooth.

In an study it 15was found that the failure mode after debonding either during shear bond strength testing or with pliers was predominantly at the bracket/adhesive interface for the ceramic brackets. There was no statistical significance in the ARI scores between the Enlight and Transbond XT group in the ceramic group. In and another study [13] the highest ARI score 3 was found for Clarity Advanced (80%). This means that debonded brackets had no adhesive remaining on the bracket base and all adhesive remaining on tooth surface resulting in a reduced enamel fracture risk and ultimate bracket bond strength.

5. Conclusion

Bonding of orthodontic brackets to the tooth surface is a necessary procedure in clinical treatment. The bond strength between a bracket and the tooth surface must be highly reliable and is the key to therapeutic success. The present study determined the SBS of different ceramic bracket by different manufactures, bonded with Transbond XT. It was concluded that the mean SBS of Clarity Advanced was significantly higher than Ormco, Koden, Metro. Further studies need to be conducted on Koden and Metro ceramic brackets as few and no literature is available at present. Comparison of the ARI scores among different groups led to the conclusion that there were no statistically significant differences in the ARI score for the four ceramic bracket group.

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